Modelling the Economic Impact of Transport Projects in Sparse Networks and Peripheral Regions

James Jeremy Laird

Submitted in accordance with the requirements for the degree of Doctor of Philosophy (PhD)

University of Leeds
Institute for Transport Studies

September 2008

The candidate confirms that the work submitted is his own, and that appropriate credit has been given where reference has been made to the work of others.

ACKNOWLEDGEMENTS

I would like to pay special thanks to my supervisors, Professor Peter Mackie and Dr Richard Batley. Their support, encouragement, and advice has been invaluable. I am also grateful to a long list of people for the discussions and comments that have shaped different aspects of the research. These include Dirck Van Vliet, Kevin Reilly, Chris Nash, Karst Geurs, Gerard de Jong, Tony Fowkes, Andrew Daly, Lars Rognlien, Gerard Whelan, Stephane Hess and David Watling.

The case studies are one of the key elements of the thesis. Data for these were kindly provided by Tom Worsley and Hadi Zamani of the Department for Transport, Frank Roach of the Highland Rail Partnership, Alan MacMillan of Network Rail and my colleague John Nellthorp.

Funding my doctoral studies would not have been possible without my Engineering and Physical Sciences Research Council studentship, whilst the breadth of the empirical work undertaken was only made achievable through the generous support of a number of external bodies. The Scottish Executive provided funding for the surveys in the Outer Hebrides, Caledonian MacBrayne provided free ferry travel for the survey enumerators, the Department for Transport funded the study upon which Chapter 3 is based and the government Whitehall Placement Scheme provided support for the study upon which Chapter 8 is based.

A part-time PhD is a long undertaking when combined with work and family life. Its completion owes as much to the support and understanding of my wife Jacquie as to my own efforts.

ABSTRACT

The lack of alternatives and choices make sparse networks and peripheral regions distinct. Travel choices are limited, as are employment and supplier choices. This thesis is therefore concerned with whether cost benefit analysis techniques need to be adapted so as to adequately deal with the appraisal of transport projects in these areas. Specifically, improved treatment of scheduling costs, uncertainty and wider economic impacts is proposed. A theoretical case is made for the inclusion of scheduling costs and the cost of risk bearing by drawing on the literature on time use, departure time choice, activity scheduling, risk premia and option values. Similarly a theoretical case is made for the inclusion of efficiency gains from an expansion in output in imperfectly competitive markets, an expansion of employment in the presence of a labour market failure, and an increase in productivity in industry clusters.

A survey of ferry users and island residents in the Outer Hebrides finds evidence of statistically significant costs associated with transport related constraints on activity scheduling. These costs decrease non-linearly in the transport constraints - headway and operating hours. A difficulty faced when estimating discrete choice models with taste variation is a lack of knowledge of the distribution of willingness to pay. This difficulty can be overcome through a mix of contingent valuation questions and stated preference questions with fixed boundary values. Significant differences are found in willingness to pay depending on whether the stated choice question is framed as per trip or per year. In contrast to what might be expected from the options value literature, no difference in the cost of risk bearing is found between a fixed link and a high quality ferry service. Further empirical work identifies less than complete wage compensation for commuting costs of workers in peripheral areas of Scotland. This indicates the presence of a labour market failure arising through high job search costs in a thin labour market.

The main conclusion of the thesis is that the scope of a cost benefit analysis should be widened to include the studied effects. The case studies undertaken show that for public transport projects the effects, in totality, can be a similar order of magnitude to user benefits. Importantly, the large potential benefits from fixed links and the low incomes evident in peripheral regions combine to make income effects important, when calculating total economic welfare in these areas. Further research opportunities on scheduling costs, risk premia and thin labour markets are identified.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

BHPS	British Household Panel Survey
CC	cultural constraints
COBA	cost benefit analysis (software)
CV	contingent valuation
DETR	Department of the Environment, Transport and the Regions (transport role superseded by the DfT)
DfT	Department for Transport (formerly part of the DETR)
HIE	Highlands and Islands Enterprise
IC	institutional constraints
IV	instrumental variables
LFS	Labour Force Survey
MNL	multinomial logit
MVA	MVA Consultancy
MXL	mixed logit
NATA	New Approach To Appraisal
NESA	Network Evaluation from Survey and Assignment (software)
NUV	non-use value
OLS	ordinary least squares
OV	option value
PAT	preferred arrival time
PVB	present value of benefits
RP	revealed preference
SACTRA	Standing Advisory Committee on Trunk Road Assessment
SCGE	spatial computable general equilibrium (model)
SDE	schedule delay early
SDG	Steer Davies Gleave
SDL	schedule delay late
SE	Scottish Executive
SHS	Scottish Household Survey
SP	stated preference
STAG	Scottish Transport Appraisal Guidance
TC	transport constraints
TEV	total economic value
TSO	The Stationery Office (formerly Her Majesty's Stationery Office)
WTP	willingness to pay

1 INTRODUCTION

1.1 Background

Sparse transport networks and peripheral regions go hand in hand. Peripheral regions typically have small populations, low economic power and a sparse transport network characterised by limited alternatives or choices. These attributes in isolation and in combination lead to particular set of issues. Long distances of travel, the reliance of communities on what is often a single 'lifeline' link, and the vulnerability of these links to inclement weather and subsidence, places a burden on businesses and residents in remote communities. This together with the limited choices that residents and businesses face in finding employment, filling vacancies and purchasing goods and services set sparse networks and peripheral regions apart. Government economic and transport policies explicitly reflect the nature of these regions recognising both the role of lifeline transport links in sustaining remote and fragile communities (Scottish Executive, 2006 p.19) and the need to achieve a better regional balance in wealth (Scottish Government, 2007 pp.36-39).

Networks can be sparse in any of several dimensions: geographically, modally or temporally. Sparse networks therefore lack either route choice options, mode choice options or departure time choices. Furthermore in sparse networks, alternatives - where they exist - typically have a high cost compared to the preferred route, mode or travel time. The sparsest network is, of course, that in which no alternative exists, such as an island's only link to the outside world –the lifeline link. Peripheral regions are, in a geographic sense, those located along the boundary of a nation. In an economic sense a peripheral region has minor economic importance relative to other regions (the core). They are typically characterised by low population densities and low incomes. Invariably these regions are also distant from the core (in that transport costs are high) and therefore experience a degree of isolation.

These characteristics are clearly distinct from those of cities and busy inter-urban networks. This raises the question as to whether existing cost benefit analysis methods are applicable in their current form to sparse networks and peripheral regions. Such methods are exemplified by COBA (DfT, 2006a) and NESA (Scottish Executive, 2005) and embedded into the respective appraisal frameworks New Approach To

Appraisal (NATA) (DETR, 1998) in England and Wales, and the Scottish Transport Appraisal Guidance (STAG) (Scottish Executive, 2003) in Scotland. The applicability of these methods is questioned as they were pioneered on busy inter-urban routes and further developed to encapsulate the economic impact of transport projects in cities, including that of generated traffic and productivity growth (e.g. SACTRA, 1986; 1994; 1999). Whether cost benefit analysis methods need to be adapted to adequately deal with the special case of sparse networks and peripheral regions is the central research question this thesis therefore sets out to address. The research uses a mixture of existing evidence and new evidence from the Highlands and Islands of Scotland to model the economic impact of transport projects in this geography.

1.2 Measuring economic impact in the transport market

The economic identity set out in Figure 1.1 encapsulates the method by which the economic benefits of a transport project in a sparse network and peripheral region are modelled using existing transport cost benefit analysis methods. This identity focuses on the transport market not because transport projects are only expected to impact on the transport market, but because, in the first instance measuring the economic impact of a transport project as the sum of all impacts across all markets affected would result in serious double counting (Mohring, 1961; Dodgson, 1973; Nash and Mackie, 1990). Secondly it can be shown that if the economy operates under conditions of perfect competition and zero externalities (or all externalities are appropriately charged for) – that is price equals marginal social cost everywhere in the economy outside of the transport market – then an exact measure of the economic impact of a transport project can be obtained by analysing the transport market alone (Dodgson, 1973; Jara-Diaz, 1986). Additionally the transport market is the preferred place to measure the economic impact of a transport project as basing the analysis in any other market (e.g. the labour market or land market) would result in an underestimate of the economic benefit with an elastic supply of any factor input (e.g. labour, capital, land, etc.) (Nash and Mackie, 1990).

Figure 1.1: Economic benefit of a transport project

Economic Benefit	=	Transport Users' Benefit (Consumers' Surplus)	+	Change in Transport Operators' Profits (Producers' Surplus)	+	Changes in Government grants and indirect tax revenue	+	Change in external costs (e.g. accidents, pollution, etc.)

The identity in Figure 1.1 therefore acts as the starting point for this research. The lack of choices and alternatives in sparse networks and/or peripheral regions leads to a focus on three economic issues in understanding whether the scope of this identity needs to be expanded. These are:

1. **Scheduling costs.** Sparse networks differ from the denser urban networks and inter-urban networks in the availability and frequency of public transport services (bus, rail, ferry and plane). Communities in sparse networks served by only two or three services a day face tremendous scheduling restrictions in accessing employment, services and leisure activities. Within the current cost benefit analysis framework such costs do not feature[1]. Whether there is a theoretical justification for including them and what their scale is relative to traditional components of economic impact is an important question, and forms the first research issue addressed in this thesis.

2. **Uncertainty.** There is a large literature that indicates risk imposes a cost on economic decision makers. All activities are affected by uncertainty, but the vulnerability caused by reliance on a single option with limited, if any, alternatives it is argued imposes a higher burden than if alternatives exist. A rockfall or landslip on a road, or the cancellation of a ferry due to high winds may have severe consequences in a sparse network where there are no alternatives of route or mode (e.g. for access to healthcare). Uncertainty is not just restricted to the supply of transport services, as uncertainty regarding locations of future workplaces (if made redundant) and how to access those workplaces are important factors in economic decision making. How and to what extent uncertainty affects economic welfare in a sparse network and peripheral region forms the second research issue.

3. **Wider economic impacts.** If market failures occur in markets outside of transport the economic identity in Figure 1.1 does not hold. Extensions to appraisal practice to incorporate the changes in economic efficiency with such failures have focused on agglomeration externalities arising through urbanisation and imperfect competition (e.g. DfT, 2005). Economic benefits

[1] It is noted that in the rail demand forecasting literature scheduling costs arising through transport constraints feature. In contrast appraisal guidance, including UK rail appraisal guidance, still places the full economic emphasis on user benefits when calculating the total economic impact (e.g. DfT, 2007a Table 3).

attributed to wider economic impacts are therefore mainly associated with large projects in big cities (e.g. Eddington, 2006). There is good reason to expect wider economic impacts to also occur in peripheral areas as the nature of the economy in these areas leads to the presence of industrial clusters, isolated markets and thin labour markets. However, whether significant gains in economic efficiency can be made in the wider economy in peripheral areas has received limited attention in the literature, and the potential importance of wider economic impacts is therefore unknown. This is the third issue examined in the thesis.

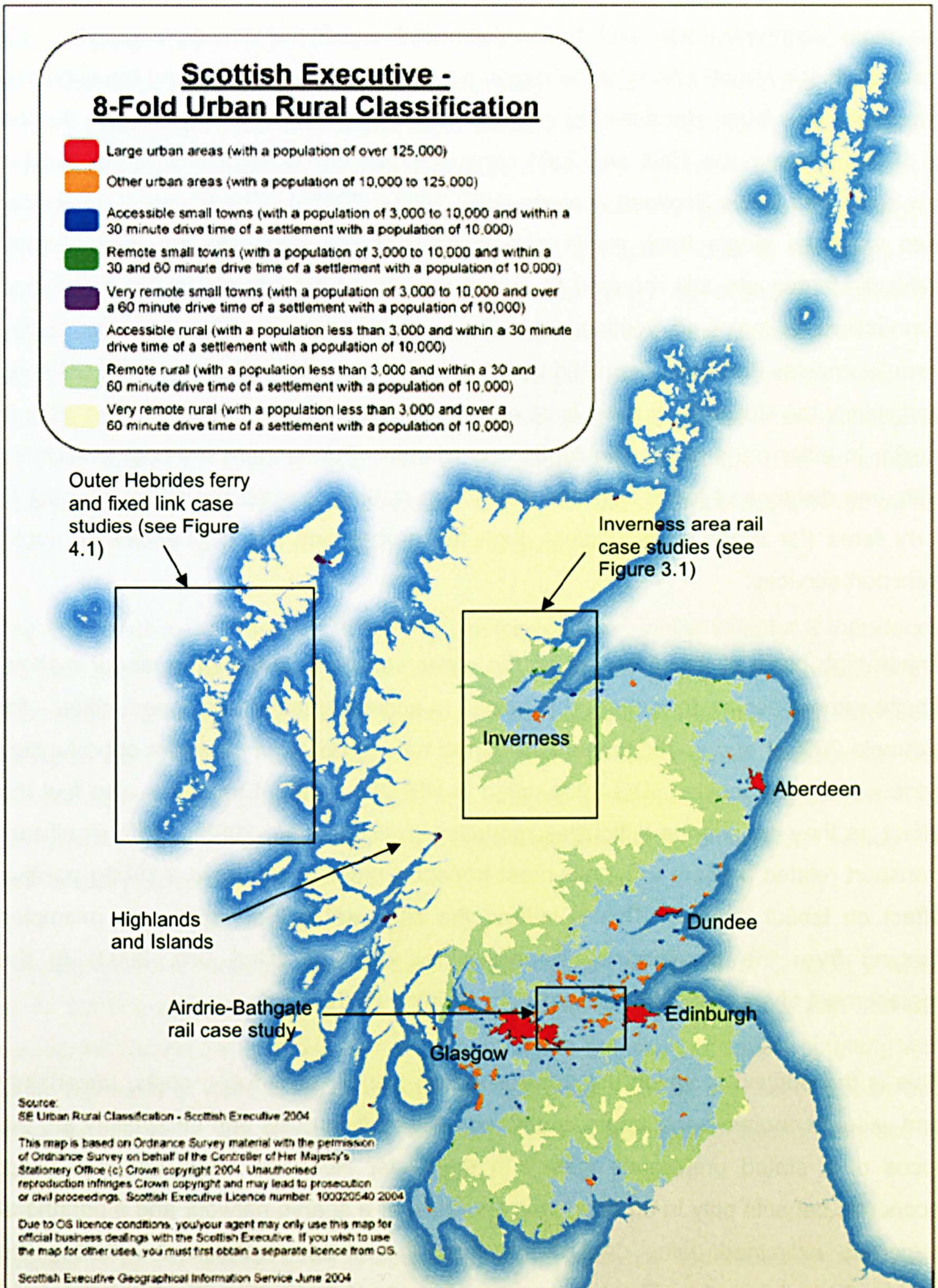
For each of these issues the research looks at:

- Whether there is a theoretical argument to expand the scope of a cost benefit analysis to encompass the issue;
- Whether there is empirical evidence demonstrating that a statistically significant economic effect can be identified; and
- Whether the inclusion of the additional economic impact makes a material or practical difference to the estimate of total economic impact. That is whether the additional economic impact is small or large relative to the impacts already included in a cost benefit analysis.

1.3 Highlands and Islands as a case study area

The Highlands and Islands region in Scotland is sparsely populated, being home to approximately 1% of the UK's population but accounting for one sixth of the UK's land mass. Within the region there are also more than ninety inhabited islands. Journey times to the economic centres of Scotland and the UK are longer than from any other location in the UK and the transport network contains many sections of poor quality – single carriageway trunk roads and infrequent train and ferry services (SDG, 2007). As can also be seen from Figure 1.2 the majority of the region is classified as very remote – that is drive time to a settlement with a population of 10,000 or more is in excess of 60 minutes. Average income levels in the region are about 12% below the Scotland average (HIE, 2007a), which are in themselves below the UK average. With such geographic, economic and transport characteristics the area lends itself as an ideal case study for this research.

Figure 1.2: Urban-rural classification of Scotland and location of case studies



Source: Scottish Executive Urban Rural Classification
http://www.scotland.gov.uk/library5/rural/seurc-03.asp [accessed 4th January 2008]

The size of the Highlands and Islands leads to many diversities within it. Inverness is the main economic force and has experienced significant economic growth. By contrast, in the remoter parts of the region populations are in decline and the economy struggles. The Outer Hebrides, for example, experienced a marked population decline of 10.5% between the 1991 and 2001 censuses, and Gross Value Added per head is low compared to the Scotland average (HIE, 2003a; 2007b). The transport network is also weak as single track roads with passing places dominate the internal road network, ferries are still required to connect some of the islands in the group and connections to mainland Scotland are infrequent (there are two ferry services a day from Stornoway, the main population centre, to the mainland). The transport network, particularly the lifeline ferry links, is also vulnerable to inclement weather. The story is similar in other parts of the Highlands and Islands. Furthermore the cost associated with long distance of travel between population centres is exacerbated by the cost of ferry fares (for island communities), high fuel prices and low frequencies of public transport services.

These high costs of travel impact on the wider economy, notably the labour market. Those without access to a car find it difficult to access employment opportunities – for example 20% of survey respondents reported turning down employment opportunities because of travel costs (SDG 2004, cited in HIE 2006 p.6). Employers also feel the effect as they experience difficulties recruiting (Nelson *et al.*, 2008). With significant transport related barriers to employment transport projects can have a strong positive effect on labour supply. This is indeed the case within the region with examples ranging from the provision of commuter rail services (Carl Bro, 2003) to the replacement of short sea crossings with fixed links (SQW, 2004).

This is the context in which the three research issues: scheduling costs, uncertainty and wider economic benefits are examined. Scheduling costs and uncertainty are the focus of a stated preference survey in the Outer Hebrides. The role that wider economic benefits play in an economic appraisal of a sparse network and a peripheral region is examined using data drawn from the whole of Scotland including the Highlands and Islands. The two case studies presented within this thesis are also located within the region. The first relates to train services linking isolated communities with Inverness, and the second relates to the replacement of a short sea ferry crossing with a fixed link (causeway) in the Outer Hebrides.

1.4 Thesis structure

Figure 1.3 illustrates the thesis' structure. As can be seen from this figure Chapters 2 and 7 consider the theoretical case for extending the scope of cost benefit analysis, whilst the empirical case is considered in Chapters 3, 4, 5, 6 and 8. Whether the inclusion of additional economic impacts makes a practical difference to an appraisal is considered in Chapters 3 and 9. As can also be seen from the figure the main body of the thesis comprises of two parts. The first part (Chapters 2 to 6) considers the theoretical justification for and evidence of including, in an economic appraisal, scheduling costs and uncertainty. Like user costs, these costs are associated with the economic behaviour of individuals. The second part (Chapters 7 and 8) considers whether the economic conditions prevalent in peripheral regions lead to the occurrence of wider economic impacts additional to transport user benefits. The concluding chapter, and the case study that precedes it, bring all the different facets of the thesis together. A fuller description of each chapter is given below.

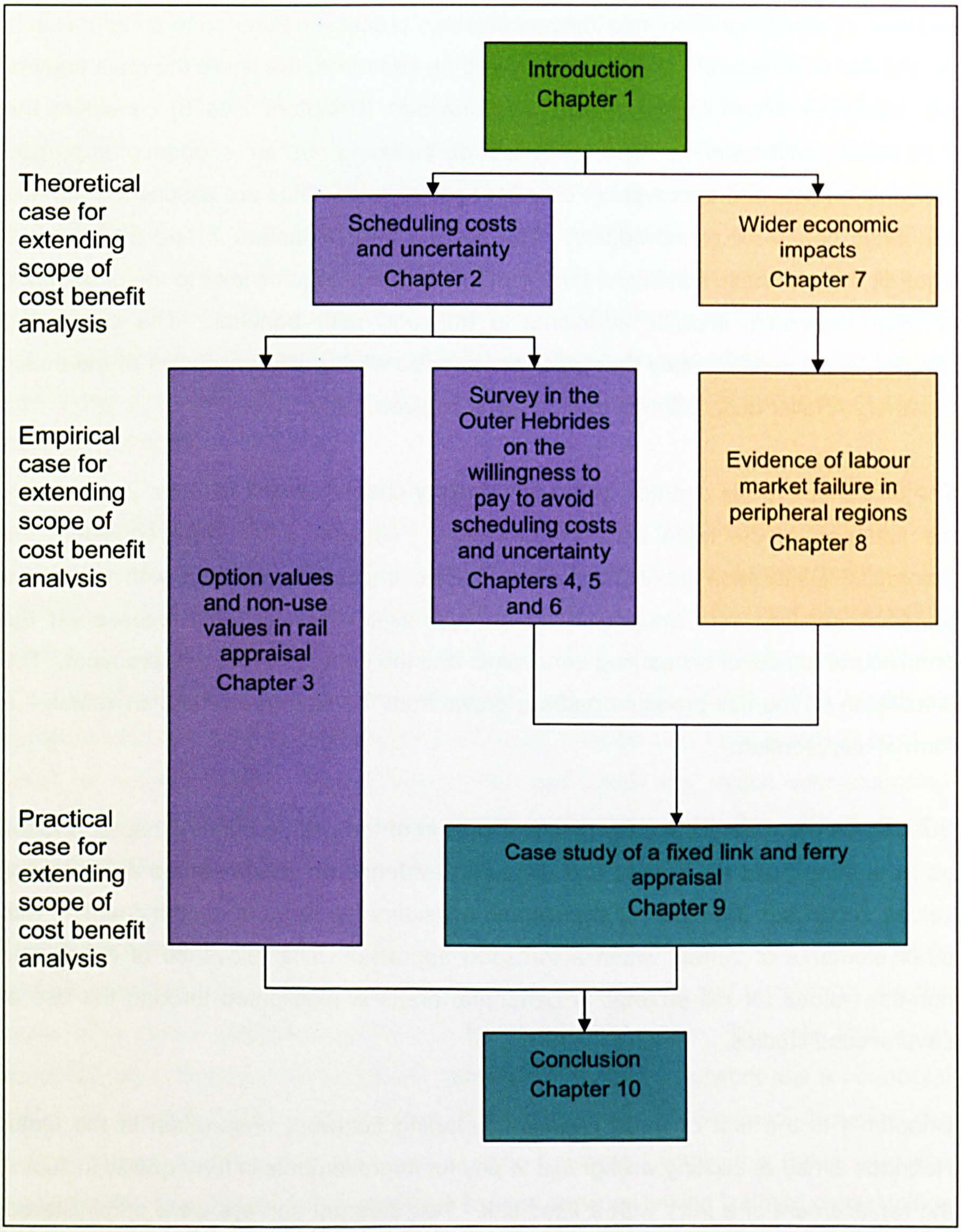
The first chapter, this chapter, is the introductory chapter, whilst Chapter 2 introduces the first part of the main body of the thesis. Chapter 2 therefore considers the theoretical justification for including the welfare impacts associated with infrequent transport services and uncertainty in an appraisal. The chapter focuses on the behavioural effects of scheduling constraints and the concept of the risk premium. The discussion on the risk premium partially draws from the literature on option values – a form of risk premium.

Building on the theoretical case for the inclusion of the risk premium, Chapter 3 takes as its starting point the limited and disparate evidence on option values and non-use values, reconciles the different studies and considers the issue of double counting with other elements of benefit within a transport appraisal. The relevance of option and non-use values for rail projects in peripheral areas is highlighted through the use of several case studies.

Chapter 4 is the first of three chapters reporting fieldwork undertaken in the Outer Hebrides aimed at eliciting willingness to pay for improvements in ferry quality including the replacement of a ferry with a fixed link. Two different surveys were administered. The first focused on users of a 'long-distance' inter-island ferry, whilst the second focused on households recently affected by the replacement of a 'short' ferry service with a fixed link. The design of the survey is discussed and presented in this chapter.

Chapters 5 and 6 describe the results of the two surveys respectively, the econometric models developed and the economic implications of the results. These chapters conclude the first part of the thesis.

Figure 1.3: Thesis structure



Chapter 7 introduces the second theme of the thesis, that of the wider economy. The chapter reviews the justification for and evidence of economic efficiency impacts additional to transport user benefits, with a particular emphasis on peripheral areas.

Chapter 8 presents econometric work analysing the relationship between commuting costs and wages in peripheral labour markets. This is of interest as job search models suggest that in thin labour markets workers will not be compensated for their commuting costs and the marginal product of labour will differ from the wage – that is a labour market failure occurs. In such conditions a change in levels of employment will result in a wider economic impact additional to transport user benefits occurring in the labour market of a peripheral region. This work is undertaken using the Scottish Household Survey.

Chapter 9 brings the different strands of the theoretical and empirical research presented in Chapters 2 to 8 together through the use of a case study of the Berneray causeway and the Sound of Harris ferry.

Chapter 10 presents the conclusions of the research and makes suggestions for further research.

2 SCHEDULING COSTS AND UNCERTAINTY

2.1 Introduction

This chapter introduces the first part of the thesis which considers the issues of scheduling costs and uncertainty. The chapter itself considers the theoretical basis for extending the economic impact identity (as set out in Figure 1.1) to include costs and benefits associated with these issues. Such benefits are felt by users and potential users of the transport system, but as the benefits are not directly associated with transport use, they do not feature in the existing appraisal framework. The hypothesis pursued in this chapter and developed further with empirical research in chapters 3, 4, 5 and 6 and the case study in chapter 9 is that these benefits are important contributors to overall economic impact in sparse networks. Such benefits should therefore appear in the appraisal of a transport scheme.

This assertion is based on the fact that the need for effective activity scheduling is never more pertinent than in sparse networks, where transport constrains activity schedules both geographically and temporally, and a lack of alternatives within such networks creates economic uncertainty. Uncertainty arises through network availability (supply side uncertainty) and uncertainty in future preferences including future travel demands (e.g. access to future employment if a person is made redundant). This is demand side uncertainty. There is a large literature on the role of transport costs on residential location and travel demand (see for example Lerman, 1976 for an early model), whilst uncertainty plays a role in household and business location decisions in regional economic models - for example the new economic geography literature (Krugman, 1991 pp.38-49). As such, scheduling costs and uncertainty form part of both trip-making and household location decisions in a sparse network. Consequently to understand the welfare benefits from a change in the transport network an economic model that incorporates activity scheduling and uncertainty is needed. Such a model is proposed in this chapter.

There is consensus on the theoretical identification of the economic value of time spent in work and non-work activities (Becker, 1965; Oort, 1969; De Serpa, 1971; and Evans, 1972). The work of De Serpa is most applicable to travel research and, following the work of Truong and Hensher (1985) and MVA, ITS and TSU (1987), forms the basis for describing the economic value of travel time savings in the literature. Similar agreement is evident regarding the means of analysing trip scheduling - deferring to Small's (1982) analysis for a 'car-available' household. Utility derived from undertaking an activity also varies with time of day and activity duration (Winston, 1982; Wilson, 1989; Wang, 1996). The distinguishing aspect of a sparse network - an infrequent ferry to an island, for example – is that a number of scheduling constraints exist that are not applicable in the environments for which the literature has been developed. These constraints include:

(i) The maximum duration of an activity, as for example it will be necessary to return home on the last ferry of the day at the very latest;
(ii) The minimum amount of time required for an activity. Whilst, for example, a four hour gap between arriving by ferry and first available ferry departure ferry will impose a minimum time at the destination on a business trip of four hours despite only two hours being needed; and
(iii) The start time of an activity. For example an activity on the mainland can only commence once ferry or air services have begun to operate and have arrived at the destimation.

The main thrust of travel research into the impact of uncertainty on behaviour utilises the concept of maximisation of expected utility. Both Noland and Small (1995) and Bates *et al.* (2001) utilise this approach in the treatment of trip scheduling under uncertainty. This approach is most suited to that of travel time variability. In sparse networks the consequences of uncertainty can be severe and potentially irreversible - missing the last ferry, needing emergency medical treatment after ferry operations have ceased for the day, losing one's job and not being able to access another one due to geographic or temporal constraints. In such situations it is hypothesised that the full costs of uncertainty are not captured within the expected utility function.

The contribution of this chapter is to formalise two extensions to the existing literature and to identify empirical gaps in the economic valuation of scheduling and uncertainty. First, the concept of schedule constrained activities is developed by combining Small's analysis with De Serpa's. The existence of schedule constrained activities gives economic justification for including benefits of alleviating travel constraints in the welfare function when modelling the economic impacts of transport services. Second, a measure of the value (or cost) of uncertainty is developed by reconciling the literature of travel behaviour under uncertainty with the concepts of the 'risk premium' and 'option value'. This demonstrates that the full economic value of a transport good is given by the sum of expected use value and the risk premium (equivalent to the option value for the situations where option values exist). In the third section, a review of the existing empirical evidence in this field identifies several gaps. There is limited evidence on the costs associated with infrequent services, little information on the costs of moving from discrete departure time choices to continuous (infinite) choice of departure time – as occurs with the construction of a fixed link in replacement of a ferry service – and what evidence there is on risk premia is confined to the handful studies on transport option values. The final section draws the different elements of the chapter together, proposes a revision to the economic identity set out in Chapter 1 and sets the scene for the empirical work contained in the following chapters.

2.2 Scheduling under certainty

Classical economic theory assumes that consumers derive utility from the consumption of commodities. Such theory does not have space for time spent in different non-work activities, and yet consumers are constrained by a time budget (the number of hours in the day, week, month, etc.) and have to split their time between different activities including work, leisure, household tasks and sleeping. Time therefore impacts on consumer decisions in that it affects the consumption choice set that is available to any consumer. The pioneering work of Becker (1965), Oort (1969), De Serpa (1971) and Evans (1972) considered these issues and has since led to a degree of consensus being developed. In essence individuals derive utility from what they do (activities) and what they consume (goods). They are restricted by a money budget of earned income, related to time spent at work, and unearned income. They are also subject to a time budget constraint that has to account for social and biological activities (e.g. sleeping). Finally, the consumption of activities and goods requires that a minimum amount of time is spent on the production of these goods (e.g. the preparation of a meal).

Following De Serpa a simple, but rich, framework regarding the social value of a saving in travel time can be developed (Truong and Hensher, 1985; MVA, ITS and TSU, 1987). Utility (U) is a function of goods consumed, represented by a single numeraire good X, time spent undertaking non-work activities t_j , for j=1...J, and time spent undertaking work related activities (t_w).

$$U = f(X, t_1, t_2, ..., t_J, t_w) \qquad (2.1)$$

Individuals maximise utility subject to:

Money budget constraint $wt_w + y \geq \sum_{i=1}^{m} pX$

Time resource constraint: $T \geq t_w + \sum_{j=1}^{n} t_j$

Time consumption constraint: $t_j \geq t_j^*$

where w = wage rate,

y = unearned income;

X = a single numeraire good

p = price of good X

T = total time

t_j = time spent in activity j

t_w = time spent at work

t_j^* = minimum amount of time for activity j (can be zero)

De Serpa terms all activities where the time consumption constraint is ineffective (i.e. t_j^* > t_j^*) as pure-leisure goods whilst those for which the constraint is binding as intermediate goods.

This is a constrained maximisation problem that can be solved by forming the Lagrangian and obtaining the first order conditions for a maximum. The relationship in equation (2.2) can therefore be derived. Here μ is the marginal utility of having an extra unit of time available, λ is the marginal utility of an additional unit of income and η is the marginal utility of decreasing the minimum time requirements of an intermediate activity.

$$\frac{\eta_j}{\lambda} = \frac{\mu}{\lambda} - \frac{\partial U / \partial t_j}{\lambda} \qquad (2.2)$$

Marginal social value of saving time in activity j (e.g. travel) and transferring it to leisure	Resource value of time (The value to have the total time budget increased)	The marginal valuation of time spent in activity j (e.g. travel)

Equation (2.2), which describes the social value of transferring time in one activity to a leisure activity, demonstrates that the marginal value of transferring time from one leisure activity to another is zero. This is because the terms on the right hand side of Equation (2.2) cancel out. It does not mean that the value of leisure is zero (as the value of leisure equals the resource value of time $\frac{\mu}{\lambda}$), rather it means that a saving in leisure time has no value as that time saving is transferred to another leisure activity. A time saving can only bring about a change in utility if the time is transferred from an activity with a minimum time constraint (an intermediate activity) to a leisure activity (a final activity). As travel is an intermediate activity this model clearly demonstrates that a saving in travel time has value. The value is given by the marginal valuation of time spent travelling and it is this concept that is conventionally referred to as the value of travel time savings, rather than the $\frac{\mu}{\lambda}$ term (the resource value of time).

Small's seminal work on consumers' work trip scheduling (Small, 1982) sets out a framework that has since formed a starting point for the economic analysis of departure time choice and uncertainty of travel times. Small exploits Becker (1965) and Vickrey (1969) to present a scheduling model in which individuals try to optimise their time of arrival at work to balance both their dislike for travelling and for arriving late or early. Small's model is relatively simple in that it includes only two activities (work, t_w, and leisure, t_l) with a single scheduling decision, s - the time of arrival at work – and a single numeraire good x. The utility function in Small's model is set out in (2.3)

$$U = \mathrm{f}(x, t_l, t_w, s) \qquad (2.3)$$

Small adjusted the Becker budget constraint and the time resource constraint to reflect that the cost of consumption of the good, $c(s)$, and the consumption time associated with an activity, $t(s)$, varies with the time that the good is consumed. A further technical constraint, a work hours constraint, $F(s, t_w, w)$, was also added. The latter constraint reflects the fact the wage rate effectively depends through promotions or merit pay increases on arrival time as well as work hours. Small did not include De Serpa's time consumption constraint within his model. Small's model allows a description of the dependency that utility has on the start time, s, (see equation 2.4) to be made and it is from this that Small developed the now classic formulation of schedule delay (equation 2.5).

$$\frac{\partial U}{\partial s_j} = \lambda \frac{dc_j}{ds_j} + \mu \frac{dt_j}{ds_j} + v_j \frac{\partial F}{\partial s_j} \tag{2.4}$$

$$U_{trip} = \alpha T + \beta SDE + \gamma SDL + \delta L \tag{2.5}$$

where: T is travel time
SDE is schedule delay early
SDL is schedule delay late
L is a penalty for late arrival
$\alpha, \beta, \gamma, \delta$ are constants

The above formulation is conditioned by the preferred arrival time (PAT) of the traveller as follows:

$$\begin{aligned} &SDE = \max[(PAT - a), 0] \\ &SDL = \max[(a - PAT), 0] \\ &L = 1 \text{ if } (a - PAT) > 0, \\ &L = 0 \text{ otherwise} \end{aligned} \tag{2.6}$$

where: PAT is preferred arrival time
a is actual arrival time

In Small's original analysis on work trips the PAT is taken as given. This is not an unrealistic assumption in that for the majority of workers this situation will apply. This scheduling framework has formed a popular starting point for models of departure time choice (see De Jong *et al.*, 2003 for a review). The model has also been used to model departure time choice for trips other than the journey-to-work – De Jong *et al.*, for example, applied the model to commute trips, business trips, education trips and 'other' trips. Bates *et al.* (2001) and Batley (2007) extend this framework to model departures at fixed service intervals.

The previous interests have been concerned with choice of travel departure time, both under certain and uncertain conditions of supply, so as to commence an activity at a given time. The choice of activity schedule is therefore external to the framework considered. Winston (1982) emphasises that the utility derived from undertaking an activity varies according to when that activity takes place (i.e. the timing of it) and its duration. In Winston's household consumption model the household optimally chooses, at each moment, to do the activity in which time has the greatest value. It is therefore expected that if transport constraints prevent a household optimising its activity schedule, the alleviation of those constraints will generate a welfare impact additional to transport use impacts. In a slight variation on this theme Wilson (1989) shows that for the majority of people utility is maximised if leisure time can be taken at the same time as others within the friendship and family group and at a time in which leisure and social facilities are also available/open. The corollary is that utility can be improved through better co-ordination of work start times. Similarly it can also be beneficial for businesses to co-ordinate the work activities of their employees and to have opening hours similar to suppliers and clients. Scheduling costs are therefore more associated with the inconvenience of having to undertake activities at particular times, rather than the problem of alternative uses of time as in Small's model. The constraints on schedules that give rise to these scheduling costs can be institutional (e.g. limits on shop and leisure facility opening hours), cultural (e.g. work begins at 9am and ends at 5pm) or transport related (e.g. a public transport timetable).

By interpreting the Small concept of schedule delay as conditional on institutional and cultural constraints (IC) it is easily reconciled against the Wilson concept of scheduling costs. The PAT is also conditional on transport related constraints (TC), particularly for trips other than the commute. This is because, for example, appointments and meetings are arranged to fit in with the given transport network and/or public transport schedule. The PAT, in this case the appointment/meeting time, is determined in advance and travellers then experience schedule delay early or late as part of the decision process in determining, for example, their departure time. Equation 2.7 therefore generalises the Small definition of schedule delay to be consistent with the Wilson and Wang concept of scheduling costs.

$$\begin{aligned} SDE &= \max[(PAT \mid (\mathrm{IC},\mathrm{TC}) - a), 0] \\ SDL &= \max[(a - PAT \mid (\mathrm{IC},\mathrm{TC})), 0] \\ L &= 1 \text{ if } (a - PAT \mid (\mathrm{IC},\mathrm{TC})) > 0 \\ L &= 0 \text{ otherwise} \end{aligned} \tag{2.7}$$

where: $PAT\,|\,(IC,TC)$ is preferred arrival time conditional on institutional/cultural and transport constraints

a is actual arrival time

To develop the concept of schedule constrained leisure activities a model is now proposed that can be viewed as a synthesis of, and extension to, the models of De Serpa (1971) and Small (1982). Utility, U, is a function of a numeraire good X, time spent at work t_w, time spent in non-work activities t_j, for j=1....J, and the associated start times of those activities s_j. Individuals maximise utility subject to a number of constraints: the money budget constraint, the time resource constraint, the time consumption constraint and a scheduling constraint. The money budget and time resource constraints are those of Small's generalised to J non-work activities. De Serpa's time consumption constraint has been adjusted by making t_j and t_j^* a function of the start time s_j. This accommodates the possibility that, in sparse networks, the minimum and maximum duration of an activity is dictated by the start time of that activity. The final constraint is a scheduling constraint and is an extension of Small's work hours constraint. The scheduling constraint reflects the fact that activity start time, hours at work and hours spent in different non-work activities are dependent on the wage rate as well as institutional/cultural scheduling constraints (IC) and transport scheduling constraints (TC). The model is as set out below:

$$U = f(X, t_1, t_2, \ldots, t_J, t_w) \qquad (2.8)$$

Individuals maximise utility subject to:

Money budget constraint: $wt_w + y \geq \sum_j c(s_j) + pX$

Time resource constraint: $T \geq t_w + \sum_j t_j(s_j)$

Time consumption constraint: $t_j(s_j) \geq t_j^*(s_j)$

Scheduling constraint: $F(s_j, t_w, t_j(s_j); w, IC, TC) = 0$

where: w = wage rate,

y = unearned income; and

X = a single numeraire good

p = price of numeraire good X

T = total time

t_j = time spent in activity j

t_w = time spent at work

t_j^* = minimum amount of time for activity *j*, where $t_j^* \geq 0$

s_j = start time of activity *j*

TC = transport scheduling constraints (e.g. operating hours)

IC = institutional/cultural constraints (e.g. work hours, shop opening hours)

It is possible from this model to derive a relationship for the marginal value of time spent in activity *j* with all constraints binding, as given by (2.9). The full working for this derivation is contained in Appendix A. The term $\frac{\nu_j}{\lambda}\frac{\partial F}{\partial t_j}$ represents the marginal value of the scheduling difficulties incurred if the time spent in activity *j* is altered.

$$\frac{\partial U}{\partial t_j}\Big/\lambda = \frac{\mu}{\lambda} - \frac{\eta_j}{\lambda} - \frac{\nu_j}{\lambda}\frac{\partial F}{\partial t_j} \tag{2.9}$$

It should be noted that the Lagrangian multipliers λ, μ, η and ν have economic meaning. Specifically, they are the marginal utilities of income, a change in the time resource constraint, a change in the time consumption constraints, and a change in the scheduling constraints, respectively.

If the scheduling constraints do not bind then the marginal value of time spent in activity *j* is given by (2.10). The term $\frac{\eta_j}{\lambda}$ represents the value of a reduction in the time consumption constraint. This gives a result equivalent to the De Serpa model for the marginal value of time spent in an 'intermediate' activity if the time spent in an activity is independent of the activity start time.

$$\frac{\partial U}{\partial t_j}\Big/\lambda = \frac{\mu}{\lambda} - \frac{\eta_j}{\lambda} \tag{2.10}$$

If the scheduling constraints bind but the time consumption constraints do not then the marginal value of time spent in activity *j* is given by (2.11). This is equivalent to the original Small model for the particular circumstance that there is only one non-work activity (aside from the commute) and arrival time at work is inflexible.

$$\frac{\partial U}{\partial t_j}\Big/\lambda = \frac{\mu}{\lambda} - \frac{v_j}{\lambda}\frac{\partial F}{\partial t_j} \tag{2.11}$$

If neither the time consumption nor the scheduling constraints bind then the marginal value of time spent in activity j is equivalent to the resource value of time, $\frac{\mu}{\lambda}$; i.e. the Becker model of time allocation (2.12).

$$\frac{\partial U}{\partial t_j}\Big/\lambda = \frac{\mu}{\lambda} \tag{2.12}$$

Three types of activity therefore exist: those for which no constraints bind, which De Serpa termed 'pure leisure' activities; those for which the time consumption constraint binds, which De Serpa termed 'intermediate' activities; and a new group of activities for which the scheduling constraint binds. This group of activities are '*schedule-constrained'* activities, and can be either intermediate activities (i.e. the time consumption constraint is also binding) or leisure activities. The existence of *schedule-constrained* activities means that transport scheduling constraints impose costs on activities other than travel. Any analysis of economic welfare in the presence of transport scheduling constraints should, therefore, have a broader focus than the 'use' costs associated with travel.

The utility function (2.8) and associated constraints suggest a relationship between utility and time spent in an activity and the start time of an activity. These are given by equations (2.13) and (2.14) respectively. Transport constraints can therefore be seen to impact on utility in three ways: through the marginal utility of a change in the time consumption constraint (η) as the presence of transport constraints can determine whether this constraint binds; the marginal utility of a change in the scheduling constraint (v); and the scheduling function (F) itself.

$$\frac{\partial U}{\partial t_j} = \mu - \eta_j - v_j\frac{\partial F}{\partial t_j} \tag{2.13}$$

$$\frac{\partial U}{\partial s_j} = \lambda\frac{dc_j}{ds_j} + \left[\mu - \eta_j - v_j\frac{\partial F}{\partial t_j}\right]\frac{dt_j}{ds_j} - \eta_j\frac{dt_j^*}{ds_j} - v_j\frac{\partial F}{\partial s_j} \tag{2.14}$$

Two methods present themselves for the estimation of the marginal value of alleviating transport constraints on activity scheduling: activity based travel analysis and a direct elicitation of willingness to pay. The emphasis of activity-based travel analysis is the role of temporal-spatial constraints (Hägerstrand, 1970) in determining behaviour, including travel behaviour (for a review see Kitamura, 1998; Axhausen and Gärling, 1992). Whilst there have been many practical applications of activity-based travel analysis models the approach is very data and resource intensive. Typically data on a population's activity schedules are required, the location of activities and the transport costs between different locations at different times of the day. The advantage of such a method however is that it can give a direct estimate of the marginal utility derived from changing the start time of an activity ($\partial U/\partial s_j$) and changing an activity's duration ($\partial U/\partial t_j$). The change in utility from a change in transport constraints then has to be calculated through a comparison in activity schedules before and after the transport intervention in combination with the marginal utilities of money, activity duration and activity start time.

An alternative approach to eliciting the marginal value of a change in transport constraints is a direct survey of willingness-to-pay. In the context of public transport services, transport constraints include frequency and hours of operation. One would therefore survey the willingness to pay for changes in headway and operating hours to obtain an estimate of the cost that transport constraints place on activity schedules. A drawback with a direct elicitation of willingness-to-pay is that it does not uniquely identify either the marginal value of undertaking activities at a more appropriate time or the marginal value of activity duration. The value derived is also confounded with use values (such as changes in waiting or interchange time and possibly travel time in the context of journey time as a transport scheduling constraint). Bråthen and Hervik (1997) term the confounded value of use values and activity re-scheduling values 'inconvenience costs'. The principal advantage of a direct survey of willingness to pay is that it does not require a large amount of data nor the development of complex activity based models. For this reason it is the basis of the method used to derive estimates of scheduling costs in this thesis.

2.3 Uncertainty in sparse networks

Over the last 150 years, twenty two Outer Hebridean islands have lost their populations (Comhairle nan Eilean Siar, 2008). The most recent two are Scarp (abandoned in

1971) and Taransay (abandoned in 1994). The reasons for abandonment vary, but isolation, inability to cope after disasters at sea and the unexpected effects of illness are common themes. Clearly resilience of population to random shocks is important in maintaining island populations.

Sparse transport networks differ from dense networks in the relevance of uncertainty and the severity of the consequences of uncertainty. The lack of alternatives in a sparse network means that a loss of supply can mean a community is severed from access to a large part of the country. For example cancellation of ferry or air services, bridge collapse or land slip all can result in a complete loss of transport supply to a remote community or region. In more extreme environments than the UK, uncertainty in transport supply is also created by earthquakes, volcanic activity and floods. Supply side uncertainty can also be created by terrorist activity (e.g. targeting of mainline train stations and hub airports). Demand side uncertainty exists in sparse networks, particularly when combined with the low population and employment densities of peripheral regions, as future demand needs are unknown For example a lack of alternative employment opportunities or a lack of specialist healthcare facilities within a locality may necessitate travel at some point in the future. But the need for such trips is unknown, as for example it is not known if a person will be made redundant or if specialist healthcare will be needed.

Whilst the probabilities of events such as bridge collapse, need for specialist medical care, need for a new job, terrorism, etc. are naturally low, this does not detract from the impact of the event - which can be severe and long lasting. Nor does it detract from the desire by economic agents to behave so as to avoid experiencing such events. For example, as the severity of job loss in a small economy is high, it forms one of the reasons that labour has historically been observed to migrate to large labour markets. Businesses also locate in clusters for similar reasons. Migration of workers and clustering of businesses occurs as when the economy is subject to random shocks expected wages and expected business profits are higher in large labour markets than in small labour markets all else being equal (e.g. productivity) (Krugman, 1991 pp.38-49); Duranton and Puga, 2003 p.18).

The issue of uncertainty in transport networks is closely related to the concept of reliability in networks, of which there is a well-established engineering based literature. Reliability engineering focuses on the probabilities of events and the identification and ranking of unreliable parts of a network. An extension to this field is the emerging literature on transport network vulnerability (Berdica, 2002; Husdal, 2005; Jenelius, Petersen and Mattsson, 2006). This literature specifically addresses the issue that whilst events are random the consequences of an event can vary. This distinction is important as events with a low probability but very severe consequences can be more important from a policy perspective than events with a high probability but hardly any consequence. Again the emphasis within the field is on the identification of the most vulnerable points in the network (e.g. Jenelius, Petersen and Mattsson, 2006). This literature whilst illuminating the inter-relationship between probability and consequences does not inform us as to the economic costs of uncertainty. Husdal (2005) therefore develops the vulnerability literature by proposing a multi-criteria framework as mechanism for incorporating vulnerability into a cost-benefit analysis. Other research efforts have estimated use costs during a network degrading event (e.g. Nicholson and Du, 1997) and calculated expected use costs from an analysis of historic event data (e.g. Dalziell and Nicholson, 2001). Whilst going part way to enhancing a cost benefit analysis to include the economic costs of uncertainty in sparse networks neither of these extensions addresses the issue fully.

The literature on transport economic decision-making under uncertainty has a different perspective on the economic costs of uncertainty compared to the reliability engineering and vulnerability literature. To date this literature has been developed within the context of the costs of travel time variability (Noland and Small, 1995; Bates *et al.*, 2001; Batley, 2007). It has therefore focused exclusively on supply side uncertainty[2] and is caged within the context of a single trip. Both Noland and Small, for car-based continuous departures, and Bates *et al.* for public transport based discrete departures exploit the concept of maximum expected utility (von Neumann and Morgenstern, 1947) as a means of including travel time variability into the utility function. Travel time variability is modelled by adding a random parameter with an exponential distribution to Small's scheduling model (Equation 2.5). This approach has achieved a degree of consensus within the relevant literature (Noland and Polak, 2002; De Jong *et al.*, 2004). Batley (2007) extends Bates *et al.*'s approach by marrying the concept of travel time unreliability with the microeconomist's notion of risk through the introduction of a reliability premium. Batley's reliability premium is the "delay to arrival time the individual would be willing-to-pay in exchange for eliminating unreliability in arrival time". This is analogous to the microeconomist's risk premium (Pratt, 1964) but the pay-off is arrival time rather than income. Whilst these approaches are applicable

[2] In this strand of the literature the decision maker's preferences are known. There is therefore no demand side uncertainty within these authors' work.

to the concept of travel time variability within a sparse network, they do not account for all of the burden that uncertainty places on individuals' and firms within a sparse network. This is because the problem is set within the context of a single trip and is therefore purely associated with supply side uncertainty. Furthermore the approach cannot accommodate a complete loss of supply, such as when a lifeline link is blocked or a network is severed in two. To capture the costs that uncertainty in sparse networks places on economic decision-makers it is necessary to extend the existing literature. The extension proposed below does this by marrying the literature on the economic costs of uncertainty in transport networks with that of option values.

One of the principal consequences of the existence of a risk premium for risk averse individuals or firms is that under conditions of uncertainty the expected utility from an income is less than if that income was available with certainty (Pratt, 1964). As already mentioned this principle is exploited by Batley (2007) in his definition of the reliability premium - within the context of travel time variability. It is also appropriate to the problem of the full economic cost of uncertainty in sparse networks. Following Pearce and Nash (1981), let U(Y) be the utility function of money which is upward sloping at a decreasing rate – thereby reflecting a diminishing marginal utility of income. Furthermore let two potential income levels, Y_1 and Y_2, exist. If each of the two income levels have an associated probability p_1 and p_2 then expected utility E(U) is:

$$E(U) = p_1.U_1 + p_2.U_2 \qquad (2.15)$$

The line AB, in Figure 2.1, represents the locus of expected utility given different probabilities of the two outcomes. The expected utility E(U) in (2.14) is associated with an expected 'risky' income of Y_3. The same utility level, however, could have been obtained from a certain income of Y_4. Here Y_4 is the certainty equivalent of Y_3. The risk premium is given by the difference between Y_3 and Y_4. It is also clear that a certain income of Y_3 gives rise to more utility than a 'risky' income of Y_3. Using superscripts C and R to represent certainty and risky this can be expressed:

$$U(Y_3^C) > EU(Y_3^R)$$

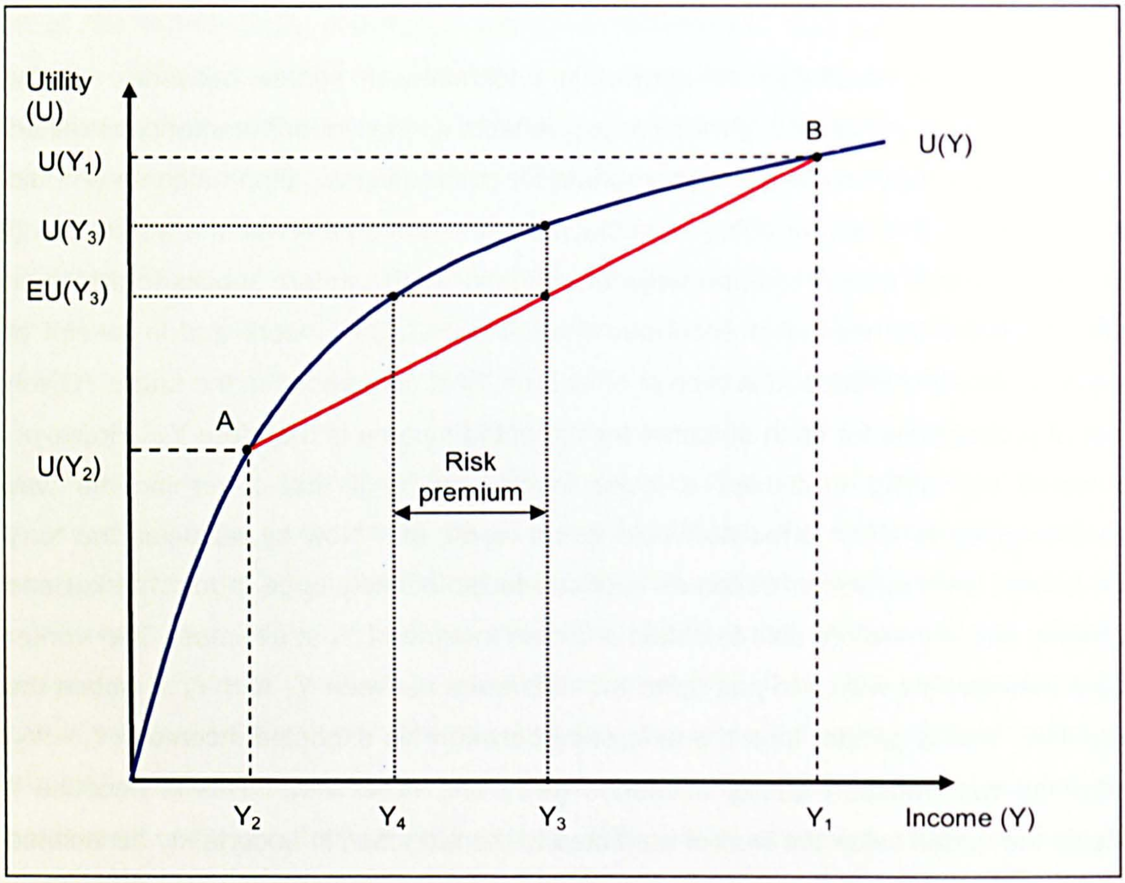
As the risk premium, $Y_3 - Y_4$, represents what the decision-taker will accept by a way of reduction in income to obtain a secure income, this value should be deducted from the net expected benefits (in monetary terms) to determine the net welfare value to the decision-taker of facing an uncertain income level (which could be either Y_1, or Y_2)

(Pearce and Nash, 1981 p.69).

This concept and result can be applied to uncertainty in sparse networks. If the scenario depicted in Figure 2.1, for example, reflects a small labour market constrained in size by say a ferry link that is inappropriate for commuting on; then outcome B could be associated with a worker being in employment and outcome A with the worker being out of work and in receipt of unemployment benefit. With random shocks to the small island economy the worker is uncertain whether he will be in work and in receipt of income Y_1 or out of work and in receipt of income Y_2 at some point in the future. Given a set of probabilities for each outcome his expected income is therefore Y_3. However, he would be willing to accept a lower income of Y_4 if that lower income was guaranteed, as in utility terms he would be no worse off. Now by replacing the ferry with a fixed link the worker becomes exposed to an infinitely large labour market and economy and is therefore able to obtain a certain income of Y_1 at all times. The worker would therefore be willing-to-pay up to the difference between Y_1 and Y_4 to obtain the fixed link. This is greater than the difference between his expected incomes ($Y_1 - Y_3$) under the two transport quality scenarios (ferry and fixed link). This is because it reflects the added value the worker attributes to the reduction in uncertainty associated with his income.

Two observations can now be made. Firstly, a survey of expected *use* values of island residents (e.g. travel time saving values) would obtain values leading to an estimate of transport user benefits equivalent to $Y_1 - Y_3$ (for the fixed link compared to the ferry). A conventional transport appraisal (Figure 1.1) therefore, by excluding the risk premium, underestimates the economic impact on the worker. Secondly, the difference between the pay-offs under each outcome (employed and unemployed in this instance) can be interpreted as the consequence of an event happening (becoming unemployed in this instance). As can be seen in Figure 2.1 the size of the risk premium is a function of this difference. This is consistent with the *a priori* view that vulnerability increases with the severity of event. As the risk premium is also a function of the diminishing marginal income utility function, U(Y), the risk premium is at its smallest when the likelihood of an event is large, though it is non-symmetrical in the probability of an event. That is the risk premium associated with a high probability of event B (e.g. p_B=0.999) and low probability of event A (e.g. p_A=0.001) is greater than the risk premium associated low probability of B (e.g. p_B=0.001) and high probability of A (p_A=0.999). This is again consistent with the concept of network vulnerability.

Figure 2.1: The risk premium



It must be stated that the existence of the risk premium in a measurable form is dependent upon a number of stringent conditions. Firstly an income-utility function has to be specified and estimable. Secondly the income-utility function needs to exhibit diminishing marginal returns – i.e. individuals need to be risk averse. Whilst these conditions appear in general sensible, they are necessary conditions and under certain circumstances may not hold. Without being drawn into the debate on these issues and given the analogy between the risk premium and the option value (Pearce and Nash, 1981 p.78; Wilman, 1987) it is useful to defer to the option value literature on this issue.

The option value of a good was first identified by Weisbrod (1964) and is the "price people are willing to pay for an assurance (an option) that the good in question will be available (at a predetermined price) if they want it" (Pearce and Nash, 1981 p.79). The term option value in transport is typically used to relate an alternative transport good to the one that is being used – e.g. a rail service for car users. The reason why the transport good holds an option value is that an individual's existing mode of transport may become unavailable or their personal circumstances may alter (e.g. changing job). The alternative transport mode is therefore needed to continue to access existing activities and potentially new activities at some point in the future. There are therefore many analogies within a transport context between the risk premium associated with a single piece of infrastructure with no alternatives (e.g. ferry or fixed link to an island) and a piece of infrastructure to which there are alternatives (e.g. car, bus and rail links between a city and a distant settlement).

Option values can be both positive and negative and will only exist if there is uncertainty, individuals are risk averse and consumer surplus exists in at least one of the uncertain future states (Schmalensee, 1972; Bishop, 1982). Uncertainty in the supply of the good will typically lead to positive option values (Bishop, 1982; Wilman, 1987), however, once the uncertainty is extended to the demand side there is ambiguity over the sign of the option value (Schmalensee, 1972). Option values may also exist in situations of risk neutrality particularly where decisions are irreversible or are possibly very costly to reverse (Arrow and Fisher, 1974). There is a well established empirical evidence base on option values - Carson *et al.* (1995, cited in Humphreys and Fowkes, 2006) noted some 2,000 papers or studies where empirical estimates of option values have been made. This empirical evidence lends credence to the existence of the conditions necessary for risk premia to exist. Option values are also expected to exist in transport, in fact Weisbrod in his seminal paper identified public transport services as a likely good for which individuals would hold option values.

There are good grounds to expect risk premia and option values to be significant in sparse transport networks in contrast to dense networks. This is because in sparse networks the risk of a service or infrastructure no longer being available is real (due to closure due to weather for example) and substitutes are poor. This is set against a background, equally applicable to those residing in either a sparse or a dense network, in which individuals' own circumstances are vulnerable to change (e.g. loss of employment or good health) and the consequences of the lack of availability of transport are irreversible or severe.

2.4 The empirical evidence

The previous sections have argued that there is a theoretical justification for including scheduling costs, the costs that travel constraints have on activity schedules, and the risk premium (the burden of uncertainty) in a cost benefit analysis. This section now examines what evidence there is for each of these benefit categories. In the first instance the literature on scheduling costs is discussed and then that on the risk premium is presented.

Scheduling costs

As discussed earlier, scheduling costs influence willingness to pay for changes in departure time, headway and operating hours. On this basis Table 2.1 summarises some of the key studies from the literature on these attributes. For presentational and comparability purposes the valuations in these studies have all been converted to equivalent in-vehicle time minutes (IVT-mins), except for the two air studies where values of time are not available (Scott Wilson Kirkpatrick, 2004; McGregor and Laird, 2005). The valuations presented relate specifically to scheduling costs or the costs of not having complete travel flexibility.

There have been a substantial number of studies on the value of headway (for a review see Wardman, 2004). At low frequencies (large headways) the valuation of a change in headway is driven principally by a change in scheduling costs, though because elements of use costs (e.g. wait time) will always be present in headway valuations, headway values do not offer a precise measure of scheduling costs. On the other hand headway valuations at high frequencies are driven by use costs. Empirical studies on the values of long headways are therefore useful to the interest of this thesis. There are also a substantial number of studies associated with departure time choice (for a review see De Jong *et al.*, 2003). Where these models use the Small formulation of schedule delay they are also useful to the interests of this thesis. This is because schedule delay estimates are equivalent to scheduling costs when the time consumption constraint does not bind and the PAT is fixed by institutional and or cultural constraints (e.g. the start of the working day). Studies on the value of replacing ferries with fixed links are also of interest as a fixed link removes all transport related constraints on activities.

As can be seen from Table 2.1 there is substantial variation in the values. Values vary by whether the trip is work related or non-work related and importantly also with distance. The longer the distance travelled the lower the value that a traveller places on improvements in frequency (or reductions in headway). Wardman (2001) and ASEK (2000) explicitly separate values by distance, but the results from Bates *et al.* (2000 cited in ATOC 2002 Table C4.1) can also be considered to exhibit some variation by distance. This is because train operators such as Virgin cater for the long

Table 2.1: Literature survey: value of headway reductions

Study/Guidance		Units	Equivalent In-Vehicle Time (mins)	
			Work Trips	Non-work Trips
Periodic departures to continuous departures (ferry to fixed link)				
Bråthen and Lych (2004) (derived from Bråthen and Hervik, 1997)	Proposed guidance for Norwegian ferry and fixed link appraisal	Car veh-mins	Ferry to city centre: 2.2 Other ferry: 6.9	Ferry to city centre: 4.4 Other ferry: 13.8
Equivalent in-vehicle time for a change in frequency per day (low frequency)				
Scott Wilson Kirkpatrick (2004 p55)	SPASM - UK air demand forecasting and evaluation model	£ (1998 behavioural values)	From 1 to 2 departures/day: £10.80 From 1 to 3 departures/day: £19.80 From 1 to 4 departures/day: £27.30 From 1 to 5 departures/day: £33.60	
McGregor and Laird (2005)	Air services in the Highlands and Islands, Scotland	£ (2004 behavioural values)	1 to 2 flights per day £69 Day return trips (8 hrs at destination) £83	1 to 2 flights per day £38 Day return trips (8 hrs at destination) £29
Equivalent in-vehicle time for a 1 hour reduction in headway				
Daly *et al.* (1998)	Great Belt Bridge, Denmark	Person-mins	16	No data - Frequency model
COWI *et al.* (1999)	Oresund Bridge, Denmark	Person-mins	Short distance trips (p16) 34 Long distance trips (p67 Table 11.3) 2	
FTC (1998)	Fehrman Belt Bridge, Denmark	Person-mins	19	15
Wardman (2004 Table 12)	Meta-analysis of public transport values of time from 171 British studies	Car person-mins	Trips 2km length: 53 Trips 200km length: 15	Trips 2km length: 43 Trips 200km length: 12
ATOC (August 2002 Table B3.4)	UK rail guidance (PDFH): Penalty costs with headways	Person-mins	90 mins to 30 mins Full fare: 25 120 mins to 60 mins Full fare: 24 180 mins to 120 mins Full fare: 24	Reduced fare: 12 Reduced fare: 12 Reduced fare: 12
ASEK (2000)	Swedish appraisal guidance	Person-mins	Regional: 37 Inter-regional: 29	Regional: 17 Inter-regional: 13
Equivalent in-vehicle time for a 30 minute reduction in schedule delay (equivalent to a 1 hour reduction in headway)				
De Jong *et al.* (2003)	Departure time choice study (Netherlands)	Person-mins	30 - 45	
Bates *et al.* (2000, cited in ATOC 2002 Table C4.1)	Punctuality and reliability study for UK rail services	Person-mins	7 (Central) to 29 (Connex)	2 (Virgin) to 19 (Central)

distance market, whilst train operators such as Connex cater for the short distance market.

Looking at the Danish fixed link studies (Daly *et al.*, 1998; COWI *et al.*, 1999; FTC, 1998) variation by trip distance also exists, with values associated with a 1 hour reduction in ferry headway ranging from 2 equivalent in-vehicle time minutes to 34 minutes. The Norwegian fixed link studies (Bråthen and Hervik, 1997, Bråthen and Lych, 2004) differ from the other fixed link studies as the values relate to vehicle trips not passenger trips. This makes comparisons difficult. However, given that most crossings analysed had 15 minute or 30 minute ferry headways it can be seen that similar valuations to those obtained in Denmark are observed. No evidence on the cost of limited operational hours has been found. The Norwegian and Danish fixed link studies, for example, all relate to crossings with either a long operating day (6am to 11pm) or to a 24 hour service. There have been no published fixed link valuations or ferry headway studies in Britain to date. Indirect evidence however exists in that traffic growth across recently constructed fixed links has been substantial (Laird, Nellthorp and Mackie, 2004; DHC, 2007). Such growth has occurred due to the significant change in the generalised cost of travel following the construction of the fixed link.

The studies discussed above, whilst valuing scheduling costs indirectly, do not specifically focus on the costs or benefits of activity re-scheduling, that is the specific costs or benefits of altering the time when an activity is undertaken, the duration of that activity or even the replacement of that activity with another activity. Wilson (1989) analysed the costs to workers who started work in the off-peak and found that allowing them to adjust the time they start work towards the peak had a similar value to that of travel time savings. Thus a shift of say 30 minutes earlier in their work activity schedule was comparable to a 30 minute travel time saving. Thus transport projects that allow an adjustment of activity schedules can give rise to significant benefits, other than pure use costs.

Another feature regarding the empirical data available is that there is very little data on low frequency services. This can be illustrated by Wardman's review. He reviewed 171 value of time studies from the UK and identified 49 studies that considered headway - giving rise to 159 valuations of headway. However only 5 of these valuations were associated with headways of 1 hour and none were associated with headways over 2 hours. The ATOC (2002) guidance also provides no advice on headways over 3 hours duration, whilst the Danish and Norwegian fixed link work

Table 2.2: Literature survey: option and non-use values (average values, converted to yearly WTP values)

	UK case studies			Non-UK case studies	
	Bristow *et al.* (1991)	Crockett (1992)	Humphreys & Fowkes (2006)	Painter *et al.* (2002)	Geurs, Haaijer and van Wee (2006)
Mode	Bus	Rail	Rail	Bus	Rail
Study area	Hawksworth, Leeds; Rainow, Cheshire	Settle	Edinburgh to North Berwick, Scotland	Chelan County; Clallam County, both Washington State, USA	Arnhem to Winterswijk and Leiden to Gouda, the Netherlands
Base year	1990	1992	2002	1999	2004
Currency	UK pound	UK pound	UK pound	US dollar	Euro
Unit of analysis	Possibly household WTP, but not specified in CV questions, so could be individual WTP	Possibly household WTP, but not specified in CV questions, so could be individual WTP	Household	Not specified in the survey. A follow-up survey identified it to be a mixture of individual and household values	individual (4)
Consumer surplus	user: £102 (year)	not estimated	user: £46 (year)	not estimated	user: €86 (year)
Option value (OV)	not estimated	not estimated	user: £150 (year) non-user: £172 (year) average(2): £154 (year)	not estimated	user: €112 (year) non-user: €96 - €132 (year) average (3): €94
Non-use value (NUV)	not estimated	not estimated	*total indirect use value:* user: £28 (year) non-user: £22 (year) average(2): £27 (year) *altruistic value:* user: £17 (year) non-user: -£27 (year) average(2): £9 (year)	not estimated	user: €196 (year) (4) non-user: €97 (year) (4) average: €148 (4)
OV + NUV	user: £22 to £30 (year) non-user: £78 to £84 (year) average(1): £58 (year)	user: £43 (year) non-user: £24 (year) average: £36 (year)	user: £195 (year) non-user: £167 (year) average(2): £190 (year)	user: not estimated non-user: $56 (year)	user: €308 (year) (4) non-user: €193 - €229 (year (4) average: €242 (4)
Basis of OV + NUV valuation	No alternative PT service	Existing bus service and alternative rail line/train station	Existing bus service	No alternative PT service	No alternative PT service

Notes: (1) Average values calculated using user/non-user proportions in Bristow *et al.* (1991 Tables 3.13), (2) Average values calculated using proportions: 81% users and 19% non-users (Humphreys and Fowkes, 2006), (3) Average option value calculated assuming that those who indicated that they would never catch the train have an option value of zero, (4) Geurs (2006): non-use values may reflect household WTP. Furthermore user non-use values may also be biased upwards by use motives. The OV+NUV total is therefore likely to be biased upwards compared to the true total for an individual.

relates to crossings which previously had high frequency ferries (a minimum of 2 ferries an hour). There is therefore a clear evidence gap for public transport services, and ferries in particular, with low frequencies and limited hours of operation.

Risk premium

Turning now to evidence on the existence of a risk premium in transport. It appears that there are no specific studies on transport related risk premia aside from the limited number of studies on option values for public transport services. In a recent review of the literature Laird, Geurs and Nash (2007) identify six studies on option and non-use values of which only the results from five are published (see Table 2.2). Two of these studies have focused on values associated with bus services and three on rail services. All have focused exclusively on passenger transport by households. However, as can be seen from the penultimate row in the table a wide range of values regarding the willingness-to-pay (WTP) for transport services, above and beyond pure use costs, appear to exist. These range from £36 per year (Crockett, 1992) to £190 per year (Humphreys and Fowkes, 2006)[3]. With only five reported studies and with all the studies aside from Geurs, Haaijer and van Wee (2006) having small to modest sample sizes it is apparent that the field of measuring transport option values is in its infancy. Whilst Chapter 3 considers the source of the variation between the studies and the implications for transport appraisal, it is clear from Table 2.2 that there is a need for the option value evidence base to be expanded to include ferry, air and road links, and for a parallel evidence base on risk premia for transport links with no alternatives to be developed.

2.5 A revised economic identity

Drawing the different strands of this chapter together, it is clear there is a strong theoretical basis for extending the economic identity presented in Chapter 1 (Figure 1.1) to include costs associated with:

- activity scheduling arising from a change in travel constraints – that is scheduling costs; and
- the risk premium arising from the cost of uncertainty.

[3] These values are the sum of option and non-use values. Non-use values represent the willingness to pay for continued existence of transport service regardless of future use. Non-use values are discussed in more detail in Chapter 3, both in relation to option values, the motives that give rise to them and transport appraisal.

These costs are not directly associated with transport use and, importantly, have welfare impacts additional to transport user benefits, transport provider and government impacts and external costs as set out in the identity in Figure 1.1.

Whether economic appraisals of transport projects in sparse networks and peripheral regions should include these additional benefit categories now becomes an empirical question. This is because the inclusion of additional benefit categories requires additional effort by the analyst, and is only justified if these benefit categories form a significant element of the total economic impact of a transport project. The current evidence base is too limited to permit this question to be answered. Chapters 3, 4, 5 and 6 therefore attempt to fill some of the evidence gaps and go someway to addressing this question.

The limited evidence on option values (a form of risk premium) is therefore reviewed in Chapter 3 and adapted for use in a transport cost-benefit analysis. Five case studies are used to illustrate the importance of option values to rail scheme appraisal by type and location of scheme.

As discussed in the previous section there is a paucity of evidence on the scheduling costs associated with ferries and the relative values of the risk premia attached to ferries and fixed links. Chapters 4, 5 and 6 therefore present the results of a stated preference survey aimed at eliciting such values. The approach adopted is a direct survey of willingness to pay for changes in hours of operation and frequency. Hours of operation and frequency are the aspects of a ferry service that impose scheduling constraints. As discussed earlier this gives a confounded value of use and scheduling costs. The final element in determining whether scheduling costs and risk premia are important benefit categories in a cost benefit analysis is to consider the size of the benefits they produce relative to user benefits. This is considered through the medium of a fixed link case study presented in Chapter 9.

3 OPTION AND NON-USE VALUES AND RAIL PROJECT APPRAISAL

3.1 Introduction

In Chapter 2 a theoretical case was made for extending the economic identity underpinning cost benefit analysis to include the risk premium. Option values are a type of risk premium. This chapter therefore looks at evidence on option values and their relevance to appraisal in more detail – particularly to rail schemes in sparse networks. Despite the possibility that option values exist for transport related goods as well as for environmental goods (Weisbrod, 1964; DfT, 2003), as far as it can be ascertained there have been no incidences of option and non-use values being included in transport efficiency calculations (i.e. the cost-benefit analysis). Given the potential importance of option values to developing the economic case for transport projects in sparse networks this seems unusual. Why is it the case? In part because the evidence base is not only small and fragmented but has, at first glance, a very large range. In part it is also because of the problem of double counting. Double counting arises as estimates of option values often include elements of non-use values. The contribution of this chapter therefore is in setting out the role of option and non-use values within the context of a transport cost benefit analysis and, through a review of recent international empirical studies, demonstrating that there is consistency, at least at a qualitative level in the evidence base. Drawing from five rail case studies the importance of option and non-use values to the total economic impact of projects in sparse low trafficked networks is demonstrated. The case studies also highlight some of the difficulties in applying option and non-use values in a transport cost-benefit analysis, particularly with the existing evidence base.

The structure of this chapter is as follows. In the next section the principles behind the identification of option and non use values and their use in transport appraisals is described. The empirical evidence is then reviewed and synthesised. In the fourth section the results of introducing option and non use values into five case studies is presented, before the final section presents some conclusions.

3.2 Option and non-use values in a transport cost-benefit analysis

In a transport cost benefit analysis the focus is on measuring the total economic change caused by a transport intervention. As discussed earlier under partial equilibrium conditions, with perfect competition everywhere except the transport sector, this is equivalent to measuring the change in the value of consumption plus any impacts felt by transport operators, the government and society – the latter as a consequence of a change in external costs. The implication of this summation (see Figure 1.1) is that the value of consumption (user benefits) is the value of the transport good or service. However, and as set out in chapter 2, under conditions of uncertainty the welfare cost borne by the decision-taker also includes a component unrelated to use - the risk premium. To reflect both this and other non-use values that decision-takers may attribute to a good the environmental economics literature uses a concept known as total economic value (TEV). TEV therefore includes both use and non-use attributes. In a transport cost-benefit analysis the change in user benefits cannot simply be replaced with the change in TEV without double counting some of the economic impacts, such as those associated with noise, pollution and de-congestion benefits to non-public transport users (for a public transport scheme). Some adjustments to the change in TEV are therefore needed before it can be included in a transport cost-benefit analysis. To understand these adjustments it is necessary to be clear as to the components of TEV within a transport context.

Whilst the concept of TEV is accepted its precise definition is still subject to some debate. Aside from option values concepts such as passive non-use values, existence values, bequest values, altruistic values, stewardship and intrinsic values have been defined by various authors (see Pearce and Turner, 1990, for a discussion), as have the concepts of vicarious-indirect-use and functional-indirect-use (see Humphreys and Fowkes, 2006, for a discussion). Ultimately the boundaries between the different components of TEV are unclear and tend to overlap. Without being drawn into the debate regarding the nomenclature of the components of TEV, there is a consensus that such a concept exists and that it will differ from the value of consumption if individuals are willing-to-pay for:

(1) The option of consuming the good at some point in the future, even if they may never actually take up that option - i.e. the option value (OV); or

(2) The continued existence of a good which they themselves do not directly consume or ever intend to consume. Following Bateman *et al.* (2002 p.29) this

is referred to as the non-use value (NUV)[4].

An option value, in the transport context, is the willingness-to-pay over and above the expected value of future use to preserve the option of using a transport service for future trips not yet anticipated, anticipated but with some uncertainty, or currently undertaken by other modes[5]. As discussed in chapter 2 it exists only if there is uncertainty, individuals are risk averse and individuals value consuming the good. It is analogous to the risk premium, can be either positive or negative depending on circumstance, is additional to the change in the value of consumption (i.e. change in consumer surplus) and can always be included in a cost-benefit analysis without double counting other economic impacts.

Non-use values on the other hand differ from use values and option values in that a value may be placed on the continued existence of a good regardless of any possibility of future use by the individual in question. The motivation for the desire for the good to continue to exist may, however, vary from one circumstance to another. For example, individuals may value a good for altruistic reasons, reasons of indirect use or because the good has some existence, bequest or intrinsic value. Examples of situations where non-use values may exist in a transport environment include:

- A resident in a village deriving benefit from the knowledge that the elderly can use public transport to access the facilities they need;
- A householder living on a busy road experiencing less noise, and a car commuter experiencing less congestion as a consequence of other commuters using a rail service;
- Where the vitality of a community may depend on the transport link – for example where a substantial proportion of the economic activity in the

[4] Whilst such a categorisation of option values and non-use values is consistent with that adopted by one of the strands of the literature (e.g. Bateman *et al.*, 2002; Geurs, Haaijer and van Wee, 2006), Humphreys and Fowkes (2006) define option values as a non-use benefit. The primary motivation for using the Bateman *et al.* nomenclature is twofold. Firstly the interst of this thesis is in the risk premium and the option value, and secondly this categorisation more easily dovetails into transport appraisal practice. The latter is because the option value is always additional to user benefits, whilst some or all of the non-use value will double count user benefits.

[5] The literature also identifies a concept referred to as a quasi-option value, which represents the value of maintaining a facility until better knowledge is available as to its future demand (Arrow and Fisher, 1974). Its estimation involves estimating the probability distribution of future demand and how this may change in future with better information; it is not considered further, although to the extent that such a benefit exists at the individual level, it may be indistinguishable from option values as defined here.

community stems from either passing trade or from business associated with the provision of transport services.

- Where the cultural heritage value of transport infrastructure is large.

Clearly there may be other context specific circumstances in which non-use values may exist - see Table 3.1. Importantly from the perspective of a transport cost benefit analysis some double counting may occur with the inclusion of non-use values, particularly when the motives are associated with personal gain/loss – such as de-congestion benefits for road users, noise and pollution benefits for householders and loss or gain in income or house values. Where the motives that give rise to non-use values are purely altruistic, non-use values can be included in a cost-benefit analysis without double counting (McConnell, 1997)[6]. Given the potential for double counting benefits when including non-use values it is important that any surveyed non-use values are adjusted for double counting prior to inclusion. This is a non-trivial task as it requires the survey methodology to be able to distinguish between the different motives underlying non-use values. Ideally the survey method should also account for the bias introduced by those households who are willing to pay to maintain a transport service, not because they hold use, option and non-use values for it, but because they believe its presence influences the value of their property.

Situations in which people might become highly dependent on rail in the future would be expected to generate high option values. The most likely of these cases would be the need to change employment in circumstances in which rail offers a substantially better service than the alternatives. Thus the combination of lack of car availability and a poor bus service, or of severe road congestion and parking difficulties might raise such an issue. Other regular journey purposes such as shopping, visiting or medical related trips might also create significant option values, although given that these trips are generally less frequent than commuting trips, these are unlikely to be as large as for commuting trips. For similar reasons significant option values would be expected to be associated with stations upon which people become dependent. Origin stations and major destination stations – where they are major attractors e.g. in cities – would form

[6] McConnell (1997) shows that the motive for the altruism is also important in determining whether the non-use value is additional to consumer surplus. Where the motive is paternalistic altruism, which will prevail in a transport context, the non-use value is always additional to consumer surplus in the cost benefit analysis. Paternalistic altruism, in a transport context, is when the altruist cares about the consumer surplus of or the quantity of services available to a particular group in society (the poor, children, the elderly).

the primary candidates, as would stations that primarily serve the commuter market.

Table 3.1 Motives for willingness-to-pay for the provision of transport services

	Use value (as generally measured)	Option value	Non-use value
User	Expected value of future actual use.	Value of preserving the option of using it in the future for trips not yet anticipated or currently undertaken by other modes over and above expected value of future use.	Use by other members of the household; Use by friends, family; Concern for other people in society in general; Concern for particular groups, poor, elderly, children; Concern for future generations; Reduced congestion; Reduced environmental problems; Cohesion effects, link to larger communities
Non-user	N/A	As user.	The same as above

Source: Laird, Geurs and Nash (2007)

Contrastingly the motives that give rise to non-use values are quite varied and as a consequence the situations in which high non-use values exist are also varied. Given that non-use values arise through either altruism (e.g. concern for the poor or children) or personal loss/gain (e.g. reduced congestion, vitality of community) the largest non-use values would be expected to be found where personal losses/gains are large[7]. Such a situation occurs where businesses rely on transport infrastructure to bring in customers (e.g. retailers or tourist attractions which are fixed in location). The minimum bound on the non-use value held by a firm is the fall in profit from a loss of the transport infrastructure availability. For individuals on the other hand the minimum bound is the drop in income. Such an income drop could occur if individuals had to change job or reduce work hours as a consequence of the loss of availability of transport infrastructure.

[7] As set out earlier non-use values arising through personal loss/gain either double count benefits already included in a transport appraisal (e.g. environmental benefits for householders) or do not represent a net welfare loss/gain to society (e.g. a change in business profitability). It is only when the non-use value arises through altruism that it is additional to benefits already included in a transport appraisal.

3.3 Rationalising the evidence

To facilitate a comparison between the five studies for which option and non-use values are available (see Table 2.2) it is necessary that each of the values found in the literature are converted to the same base. This is done by:

(i) combining the user and non-user values into an average value, as each of the studies uses a different user/non-user definition (see Table 3.2);

(ii) summing the option and non-use value, as three of the studies have not separately identified these components of TEV.; and

(iii) converting the study values to a common price, value and currency base.

Table 3.2: Definition of users and non-users by study

Study	Definition of users	Definition of non-users
Bristow *et al.* (1991)	Use the bus service in a normal week	Rest of sample
Crockett (1992)	Use the train service	Rest of sample
Painter *et al.* (2002)	Households where at least one household member uses the transit system regardless of frequency.	Rest of sample
Humphreys and Fowkes (2006)	Households in which the survey respondent indicated that they were 'likely' or 'very likely' to use the North Berwick to Edinburgh train service in the following 6 months [from date of survey].	Rest of sample
Geurs, Haaijer and van Wee (2006)	Individuals who (a) used the selected train service in the previous year, or (b) are car-owners and might have used the train service had the car suddenly become unavailable in the previous year.	Rest of sample

As can be seen from Table 3.3 despite converting the evidence on option and non-use values to a common base a large range remains – from £41 to £190 (2002 prices and values). The next step in explaining this range is to understand to whom the valuations relate to – households or individuals. In fact it appears that some of the studies are unclear as to whether the values surveyed apply to individuals or households, particularly with respect to the earliest three studies. Painter *et al.* for example with follow-up questionnaire discovered that some of the respondents had answered for the household and others had responded as individuals. In Table 3.3 it can be seen that studies reflecting individual valuations give rise to values that are significantly lower than studies reflecting household values. Consequently, an adjustment for individual or

Table 3.3: Estimates of the sum of option values and non-use values at a common price and value base

Sum of option and non-use values (average over users and non-users)	Painter et al. (2002)	Bristow et al. (1991)	Crockett (1992)	Geurs, Haaijer and van Wee (2006)	Humphreys and Fowkes (2006)
Survey year (study base year)	1999	1990	1992	2004	2002
Population unit	Mixture of household and individual values	Probably household values	Probably household values	Individual values	Household values
Mode	Bus	Bus	Rail	Rail	Rail
Alternative public transport service available	No	No	Existing bus service and alternative rail line/train station	No	Half hourly bus service
1. Study values	USD 56	£58	£36	EUR 242	£190
2. (1) converted to GBP with PPP currency exchange rates for study year	£36	£58	£36	£139	£190
3. (2) converted to 2002 price base with elasticity to GDP/capita growth = 1	£41	£104	£59	£125	£190

Notes: (1) USD to GBP currency conversion with PPP (1999) is 0.644; EUR to GBP currency conversion with PPP (2004) is 0.575 (OECD, 2006). (2) RPI Multipliers to 2002: from 1990 1.40, from 1992 1.27, from 1999 1.07, from 2004 0.94 (ONS, 2006a). (3) GDP/capita multipliers to 2002: from 1990 1.28, from 1992 1.31, from 1999 1.07, from 2004 0.95 (ONS, 2006b) household valuations would be expected to significantly narrow the gap between, for example, the values observed by Geurs, Haaijer and van Wee and those obtained by Humphreys and Fowkes – for what are otherwise similar train services.

Some of the differences between the study values are expected to arise as a consequence of the availability or lack of availability of alternative transport services. The existence of a rail alternative in Crockett's study therefore goes some way to explaining the difference in values between his study and those in both the Geurs, Haaijer and van Wee study and the Humphreys and Fowkes study. Importantly from the perspective of a transport cost-benefit analysis Humphreys and Fowkes also find that the contribution of a bus service to a public transport package including both a bus and train service is small (a weighted average between users and non-users of £11). Thus the value of a package of train and bus services is similar in magnitude to the value of just a train service.

Given that it is expected that option and non-use values will be greater for services on which one is or could become dependent, variation by quality of the service and whether the service serves a commuting or other function is expected to occur. Table 3.3 demonstrates such a variation in that bus services have lower valuations than train services and the services that offer good commuting opportunities (Bristow *et al.*, and Humphreys and Fowkes) have higher valuations than those which do not (Crockett, 1992; Painter *et al.*, 1999)[8]. This is in line with expectations and along with the issue of the availability of public transport alternatives and individual or household valuations indicates that the studies can be qualitatively reconciled against one another. Albeit this is not a formal validation, but it does suggest that the large range in surveyed values is due to differences between the studies, both in terms of definitions used and the characteristics of the service surveyed and its alternatives, rather than a lack of precision in the estimates.

Thus the large range of values observed in the literature can be largely explained by differences in services valued in each study and the characteristics of the study areas. The upper end of the range reflects a high quality train service linking a community to a large employment and service centre and for which there already exists a strong commuter demand. In the middle of the range we find values associated with high

[8] Crockett (1992) found that the only function of the line surveyed was for shopping purposes, whilst Painter *et al.* (1999) surveyed a rural bus network but included people in the sample for whom the bus network provided no opportunities for travel.

quality bus services (3 or 4 buses an hour with good evening and weekend services). Such services have a strong existing demand base reflecting their existing and potentially future usefulness to the community. At the lower end of the range we find lower quality bus services and potentially lower quality rail services, neither of which may necessarily serve the community's needs particularly well. The evidence also suggests that it is perfectly possible that a poor rail service (with an alternative) can have a lower option and non-use values than a high quality bus service (with no alternative).

3.4 Option and non-use values in practice

To apply this evidence base in a transport cost benefit analysis a number of considerations need to be borne in mind. Firstly, the evidence is restricted to household values for personal travel and does not include the values businesses may hold for employees travelling on company business or for the transportation of freight. It is also restricted to local services and not national or long distance services[9], and values are only available for bus and rail services. Furthermore, the values relate to origin stations and to households within the catchment area of that station. It is possible that option and non-user values may be held by households outwith a station's catchment area - for example Deberezion *et al.* (2006) find that stations influence house prices up to 10km from a station. The evidence also relates to the complete loss of a service. Thus it cannot be applied to communities which experience an incremental loss (or improvement) in terms of access to employment and service opportunities. Furthermore the evidence suggests that the option and non-use value is very much dependent on the transport alternatives available. Thus it seems that the option and non-use value of a bus service to a locality already served by a train is small compared to both the option and non-use value of the train service and the value of such a bus service to a locality with no other public transport.

Finally, and as discussed earlier, the non-use value may double count benefits already included in a transport cost-benefit analysis. To avoid double counting one ideally just excludes the element of the non-use value that is not altruistic. Drawing from Humphreys and Fowkes this would appear to be approximately 14% of the sum of the

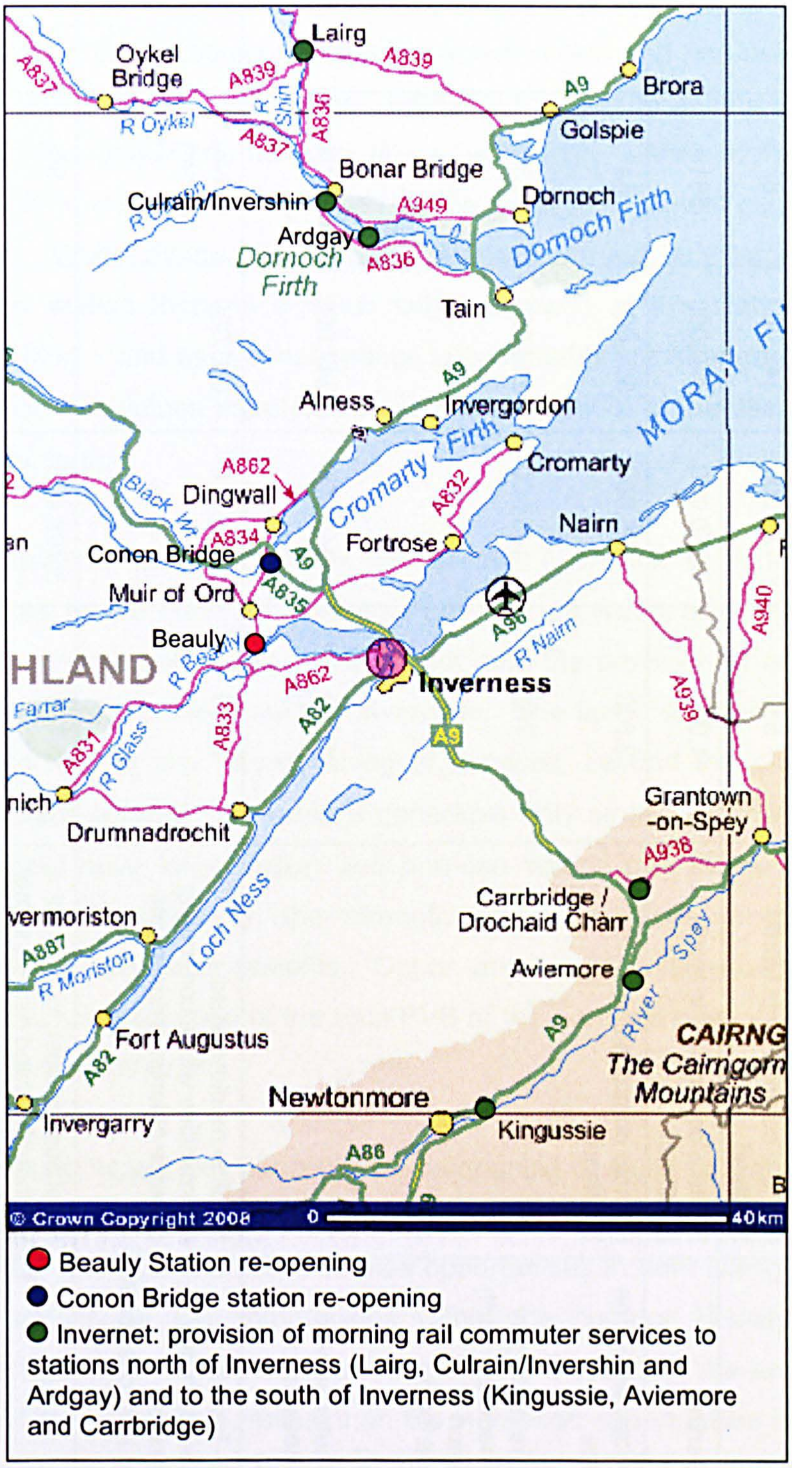
---

[9] The surveyed values in the evidence base are associated with the loss of a local rail service and not the loss of mainline services. Some of the willingness to pay values associated with the local services are however associated with long distance trips that would utilise both the local rail service and mainline rail services.

option and non-use value. A much more conservative approach to avoid double counting would be to exclude all the non-use value from the appraisal. Unfortunately, the two studies that separately examined option and non-use values (Humphreys and Fowkes and Geurs, Haaijer and van Wee) suggest very different levels of importance for the non-use element of TEV compared to the option value element. Humphreys and Fowkes found that the non-use element comprised 25% of the sum of the option and non-use value whilst Geurs, Haaijer and van Wee found that it comprised between 40 and 60% (depending on the category of user). Both studies were exploratory and the results may in fact be artefacts of the survey design. Humphreys and Fowkes treated option values as a 'residual' category and used proxies for the different non-use motives to estimate the non-use value. As their proxies may have been insufficient to capture all the non-use benefits it is likely that they underestimate non-use values and overestimate option values. Geurs, Haaijer and van Wee on the other hand estimated option values for individuals but the phrasing of the questionnaire means that the non-use values estimated may reflect household values and should therefore be interpreted as an upper bound for individual non-use values. Some sensitivity testing of the results to the inclusion of non-use values is therefore prudent when undertaking a cost-benefit analysis.

From the case studies undertaken the importance of option and non-use values varies with the characteristics of the rail service and the type of proposal (see Table 3.4). Three of the case studies are in the Inverness area of the Highlands and Islands in Scotland (Highland Rail Developments, 2000; Highland Rail Partnership, 2003; Halcrow, 2006). Historically, the rail network in the Inverness area served a long distance function and therefore did not serve the immediate needs of the local communities particularly well – frequencies were low and service timings did not facilitate access to employment and social opportunities. This combined with the fact that the area is sparsely populated, aside from Inverness, means that the rail network is lightly trafficked. In contrast the fourth and fifth case studies are situated near much larger conurbations. The fourth scheme is in central Scotland (Jacobs, 2006) and the fifth in the south of England (DfT, 2006c). Importantly from the perspective of these case studies both have a reasonably frequent rail service and consequently are much more heavily trafficked than the north of Scotland lines. The location of the four Scottish case studies is detailed in Figure 1.2 and, in more detail for the three Inverness area case studies, in Figure 3.1.

Figure 3.1: Location of rail stations considered in Inverness area case studies



Source: Ordnance Survey website (http://www.ordnancesurvey.co.uk/oswebsite/) [accessed 1st November 2008]

Table 3.4: Size of option and non-use values relative to user benefits and the present value of benefits

Scheme	Area type	No. of households affected (opening year)	Annual patronage on line (single trips in opening year)		Option and non-use values as percentage of:	
			Do Minimum	Do Something	Transport user benefits	Present Value of Benefits (PVB)
Beauly station re-opening (opened 2002)	Remote community in North Scotland	550	125,000	148,000	87%	84%
Conon Bridge station re-opening (proposal)	Remote community in North Scotland	1,000	250,000	270,000	561%	117%
Invernet – provision of services within the Inverness travel to work area (opened 2005)	Remote communities in North Scotland	2,600	485,000	557,000	64%	57%
(a) Increase in service frequency by approximately 50% immediately north of Inverness plus provision of commuting opportunities for 3 communities (Ardgay, Culrain/Invershin, Lairg)		700	145,000	210,000	23%	20%
(b) Provision of a commuter service from the south to Inverness (from Kingussie to Inverness)		1,900	340,000	347,000	197%	178%
Airdrie-Bathgate proposal – line re-opening between Airdrie and Bathgate providing travel opportunities for communities in the corridor to access both Glasgow and Edinburgh	Small to medium sized communities within commuting distance of large conurbations	7,400	0	4,000,000	Not known	4%
Anonymised example (rail closure)	Rural communities in a part of southern England near to some moderately sized conurbations	3,700	3,798,000	0	9%	9%

Note: Transport appraisals have been undertaken in accordance with UK standard practice (www.webtag.org.uk). The option and non-use values used are £170 for rail and £90 for bus (2002 prices and values). These have been derived from Humphreys and Fowkes (2006) for rail and Bristow *et al.* (1991) for bus converted to a 2002 price base (as per Table 3.3) and deflated by 14% (and rounded to nearest £10) to account for double counting in the non-use value.

The large variation in the relationship between user benefits and option and non-use value benefits reflects the different characteristics of the schemes. At one extreme is the Conon Bridge station re-opening where option and non-use values are almost six times the level of user benefits. Primarily this occurs because user benefits are low, rather than option and non-use values being high. User benefits are low because dis-benefits to existing users (caused by the extra stop) almost cancel out benefits to new users. Whilst dis-benefits to existing users are similarly large for the reopening of Beauly station there is a much larger demand at this station – despite the lower population – and as a consequence user benefits are stronger. This results in option and non-use values therefore forming just over 80% of the user benefits of re-opening Beauly station.

The Invernet project contains two distinct elements: a significant strengthening of services to the north of Inverness plus the provision of commuting opportunities to three communities (north of Inverness); and the provision of commuting opportunities to three communities south of Inverness. The latter 'southern' element of the project occurs without any strengthening of services, beyond the provision of the morning commuter service. It therefore generates only small amounts of user benefit, whilst providing quite large option and non-use values due to the size of the population served. Contrastingly, the strengthening of services to the north of Inverness generates large user benefits. Option and non-use value benefits therefore forms a much lower proportion of the total PVB of the northern element of the scheme than for the southern element.

The fourth case study concerns the re-opening of a line between Airdrie and Bathgate. The primary function of the line is to provide access for the communities within the corridor to employment and service opportunities in both Glasgow and Edinburgh. As the majority of the communities within the corridor already have access to the opportunities in one of the conurbations the benefits of the service are driven by the use of the rail service, rather than the increased opportunities it creates[10]. Option and non-use value benefits only form 4% of the PVB. The final case study, a line closure appraisal, combines both station closures and the loss of a well used fairly good rail service. Here even though several communities lose their rail service the scale of the user costs dominates the option and non-use values – which form 9% of the total PVB.

---

[10] The evidence base on option and non-use values is too limited to identify the difference between a community being connected to two large employment and service centres rather than just one.

A pattern therefore emerges: the importance of option and non-use values is high for lines where user benefits are low – typically lines with relatively infrequent levels of service and low levels of demand - and for projects that involve the provision (or loss) of commuting opportunities (including station openings/closures). Such projects occur in areas where rail performs a strong social function, such as providing accessibility for isolated communities to employment opportunities and other social needs necessary to sustain the community's vitality. Clearly therefore option and non-use values are an important element of the total economic impact of a rail project in a sparse network, and their inclusion in the cost-benefit analysis would be expected to significantly improve the case for investment.

It is interesting to note that the impact of option and non-use values on the PVB (increasing the PVB by between 4% and 178%) differs significantly from the contribution to TEV as reported in the empirical studies. Humphreys and Fowkes for example find that option and non-use values for rail users form 51% of the TEV of rail, Geurs, Haaijer and van Wee find that they form 40-45% on average and Bristow *et al.* find they form around 20% of the TEV of bus for bus users. The difference between the TEV and PVB proportions occurs because a transport appraisal considers an incremental adjustment to the existing transport system and is therefore concerned about the change in option and non-use values rather than their absolute level. Furthermore a transport appraisal considers all users and non-users and therefore considers the benefits/costs to through traffic in addition to local traffic as well as the full cost of any safety or environmental externality – all of which, but particularly the benefits/costs to through traffic, can be substantial relative to the change in the option and non-use value for the households affected.

A consequence of the lack of development in the field of transport related option and non-use values means a number of difficulties arose in applying them in the case studies. Uncertainties in the catchment area of stations and whether option and non-use values are held by households outside those catchment areas; the real growth in values over time; the potential for double counting in the non-use value; and the option and non-use value of a mixed mode (bus and train) package all can significantly affect the present value of option and non-use values in an appraisal. Furthermore the limited data on option and non-use values means that variations in frequency of service and connectivity to different sized employment centres are not reflected in the appraisal. For example, one might expect the option and non-use values associated with the new stations and train services in the north of Scotland case studies to be less than those derived by Humphreys and Fowkes. This is because the frequency of train services is lower in the north of Scotland compared to the North Berwick to Edinburgh service and Inverness does not offer as many employment and social opportunities as does Edinburgh.

3.5 Conclusions

The field of measuring transport option and non-use values is far from developed. To date only values from five studies, which in the main have small sample sizes, are available giving a potentially large range of between £41 and £190 (2002 prices). Despite this it is possible to reconcile, in a mainly qualitative manner, the results from these studies against each other. The upper end of the range reflects a high quality train service linking a community to a large employment and service centre and for which there already exists a strong commuter demand. Values associated with high quality bus services (3 or 4 buses an hour with good evening and weekend services) lie in the middle of the range. The lower end of the range reflects lower quality bus services and lower quality rail services, neither of which may necessarily serve the community's needs particularly well. The evidence base is too small to indicate how values vary with: quality of service; the mix of public transport services that may be available in the study area; socio-economic factors such as car ownership; or to communities adjacent to mainline stations or 'hub' stations. It reasonable to think that services offering little or no value for commuting will have much lower values than services that do. Additionally there is no evidence on the values that business may attribute to the rail network either for the carriage of freight or for employees travelling on company business.

The main purpose of this chapter was to examine the inclusion of option and non-use values in transport appraisal. This has never been done before. The case studies presented clearly demonstrate the importance of option and non-use values to a scheme appraisal is very varied. Their importance increases for lines where user benefits are low – typically lines with relatively infrequent levels of service and low levels of demand - and for projects that involve the provision (or loss) of commuting opportunities (including station openings/closures). Such areas are associated with station openings/closures in sparse networks.

The lack of evidence on option and non-use values poses some problems regarding their implementation within an appraisal. This particularly relates to the treatment of which households hold the option and non-use value, the potential of double counting of the non-use value with other elements in the appraisal and how the values vary with transport quality and quality or size of the employment/service centre. This combined with the need to build up the existing evidence base forms the future research agenda for this field. As discussed above, option values are just one form of risk premium. Risk premia are also expected to exist for other types of infrastructure. Chapters 4, 5 and 6 present a stated preference study conducted in the Outer Hebrides with one of its aims to elucidate the difference in risk premia between a fixed link and a ferry.

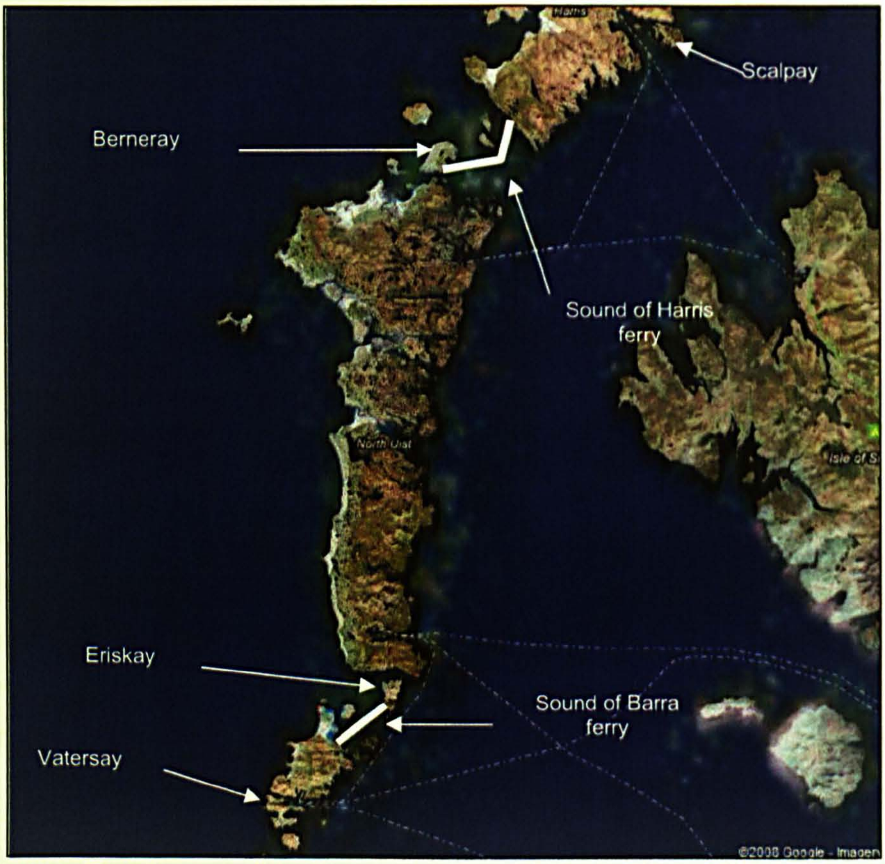
4 ISLAND SURVEY DESIGN

4.1 Introduction

The focus of this chapter and Chapters 5 and 6 is in researching whether risk premia exist for ferries and fixed links and whether evidence for significant scheduling costs for ferries can be found. These were two of the evidence gaps identified in Chapter 2, which also presented a theoretical justification for the inclusion of scheduling costs and risk premia in a cost benefit analysis. It has already been seen in Chapter 3, that option values, one of the forms of risk premia, are important to the economic benefit of rail projects in sparse networks in peripheral regions. This chapter and chapters 5 and 6 are therefore interested in whether risk premia are important for the appraisal of other types of infrastructure and whether scheduling costs are also important. The role of this chapter in that analysis is to describe the design of a stated preference survey that goes part way to filling this evidence gap. The results and analysis of the survey are presented in Chapters 5 and 6. A stated preference survey of willingness to pay is used as it allows both values for risk premia and scheduling costs to be derived. The two alternative methods – activity based travel analysis, as discussed in Chapter 2, and an ex-post analysis of traffic flows (e.g. Bråthen and Hervik, 1997) – would only allow an estimate of scheduling costs to be derived and not that of risk premia. Furthermore the data requirements for both alternative methods, particularly the need for good quality origin-destination data, are beyond the scope of this research to collect.

Two stated preference surveys were administered: one to makers of long distance trips and one to makers of short distance trips. This is because there is an *a priori* expectation that long and short distance trips will have different attitudes to scheduling costs. For example, the requirement for evening and night time services on a strategic route is probably limited. This contrasts with a route that serves as a link between a small island community with limited services and employment opportunities where evening and night time services could well be highly valued. One survey therefore focused on longer distance trips between the larger islands in the Outer Hebrides and examines scheduling costs only. This involved a self completion questionnaire which travellers on the Sound of Harris and Sound of Barra ferry services completed. The second survey focused on local trips to/from islands in the Outer Hebrides recently connected with a fixed link to a neighbouring island and examines both scheduling costs and the difference in risk premium between a fixed link and a ferry. This was a face-to-face household survey administered to residents of the islands of Berneray, Eriskay, Scalpay and Vatersay. The questionnaires were piloted as part of the design process. Figure 1.2 and Figure 4.1 illustrate the location of the islands and ferry services surveyed.

Figure 4.1: Location of fixed link and ferry case studies



Source: Google maps (http://maps.google.co.uk/maps?hl=en&tab=wl) [accessed 5th June 2008]

The surveys were financially supported by the Scottish Executive. Caledonian MacBrayne, the ferry operator, also supported the surveys by permitting free travel for survey enumerators. This support enabled a far larger survey than could otherwise have been undertaken. Despite this support the survey budget was still relatively small. Consequently the face-to-face interview element of the survey focussed exclusively on households and did not include business interviews, whilst the survey length was deliberately kept short to maximise the number of interviews that could be undertaken in a day.

The design of the inter-island ferry survey is discussed next, followed by the household survey. The final section of the chapter sets out some of the administrative details of the survey. Example questionnaires are contained in Appendices B and C.

4.2 Inter-island ferry survey methodology and design

The inter-island ferry survey focused exclusively on scheduling costs as reflected by operating hours and frequency of service. It was also set within the context of the journey in which the respondents are intercepted – either the Sound of Harris crossing (duration 1 hour) or the Sound of Barra crossing (duration 40 minutes). Both ferries provided a comfortable environment in which travellers could be intercepted and issued a self-completion questionnaire.

The survey consisted of four parts. The first part obtained background information on the journey: origin, destination, journey purpose, group size, ticket type, ticket price, who paid for the ticket, nights away from home and vehicle type. The second part obtained information about the planning of the journey including decision-making and departure times, whilst the third part contained eight stated preference questions. The final part of the questionnaire requested data on the respondent including gender, age and income. The survey could be completed in approximately 10 minutes.

Methodology and model

The approach adopted to surveying the value of a marginal change in transport related scheduling constraints was a direct survey of willingness to pay. As discussed in chapter 2 such a survey does not uniquely identify the marginal value to the individual of undertaking activities at a more appropriate time or of transferring time between activities. This is because neither the scheduling of activities, the duration of activities or the activities themselves is modelled. Instead the approach values the costs of the transport imposed constraints on activities. In the context of the Sound of Harris and Sound of Barra ferry services such constraints are frequency and operating hours (Grangeston Economics, 2003 p.46). It is therefore hypothesised that utility associated with a ferry trip can be expressed as in equation 4.1.

$$U_{qj}^{ferry} = \alpha_k^{ferry} + \beta_k^{ferry} f(H) + \chi_k^{ferry} g(OH) + \phi_k^{ferry} h(P) + \varepsilon_{qj} \quad (4.1)$$

where U_{qj}^{ferry} is the utility that individual q (belonging to population segment k) receives from the ferry service j. $f(H)$ is a function in headway, $g(OH)$ is a function in operating hours and $h(P)$ is a function in price (fares). α_k is the population segment specific intercept for the ferry service, arising from its unobserved attributes. In this model specification this includes journey time and comfort. β_k, χ_k and ϕ_k are population segment specific utility parameters associated with headway, operating hours and price respectively. ε_{qj} is a random term that is independently and identically distributed (IID) over individuals (q) and alternatives (j) and can be thought of as representing taste variation between individuals.

As mentioned in section 2.4 there is limited evidence on the value of headway and increased operating hours for ferry services. What data that is available is international, typically relates to long (international) distance trips and does not reflect restrictive operating hours (e.g. Daly *et al.*, 1998; COWI *et al.*, 1999; FTC, 1998; Bråthen and Hervik, 1997). This dearth of evidence poses a challenge for the development of the stated preference games, as the games typically are only able to recover values within a particular range. Having an *a priori* understanding of what the likely values will be is therefore an important input to the survey design. Consequently, the approach adopted is to use what evidence that is available, including evidence from the bus, rail and air sectors (see Table 2.1), to develop a broad range of target values to be used in developing the stated preference games in the pilot survey[11]. This range is presented in Table 4.1. This range is particular large as it covers all trip purposes both work and non-work. The pilot survey is then used to adjust this range, though in practice it only resulted in reducing the minimum value of operating hours (from 4.2 to

[11] Headway range: Minimum value of headway is 2 in-vehicle-time (IVT) mins per 60 mins of headway; maximum value of headway 43 IVT mins per 60 mins of headway (see Table 2.1).

Hours of operation range: From Bråthen and Lych (2004) an extension from an 18 hr to 24 hr operational day and a reduction in headway from 30 minutes to 0 minutes is valued at 13.8 IVT mins (non-work non-city centre trips) (see Table 2.1). As the value of a reduction in headway of 30 minutes ranges from 1.0 to 21.5 IVT mins, extending the hours of operation from 18 to 24hrs is worth anything between 0 IVT mins and 12.8 IVT mins. This implies a range per hour closed from 0.0 to 2.1 IVT mins. A mid-point in this range is 1.0 which is taken to be representative of the minimum end of the hours of operation range, as it reflects of the value of an hour closed in the middle of the night. In the absence of other data the value of an hour closed during the day is assumed to have a maximum value five times this (i.e. 5 IVT mins).

Value of time: To convert the derived ranges to valuations they are multiplied by the value of time. From DfT (2007b) values of time for 2005 are derived. A lower bound is taken to be 55% of the lowest average value (non-work other trips) derived from DfT (2007b) (i.e. 4.73p/min), whilst the maximum value is taken to be 130% of the maximum value derived (i.e. 54.83p/min – from car driver work trip).

1.4 pence per hour closed).

Table 4.1: Target range of marginal values for the headway and operating hours (inter-island ferry survey)

	Valuation (equivalent in-vehicle time minutes)		Valuation (pence)	
	Min	Max	Min	Max
Headway (1 min)	0.03	0.73	0.16	18.28
Operating hours (1hr closed)	1.0	5.0	4.2	274.14

Inter-island stated preference game design and simulation

The stated preference game for the inter-island ferry is set within a choice between two alternative ferries for the current journey. The starting point for the stated preference design is a main effects orthogonal design in four variables, each with four levels. The main effects design template was obtained from Kocur *et al.* (1982 cited in Wardman and Toner, 2004) and involves 16 experiments (questions). The starting design is orthogonal in differences in headway between the two ferry services on offer, differences in fare and the number of hours closed of each ferry service. This mixture of differences and absolute values of the attributes was chosen as it was felt that the value per hour closed may vary with the number of hours closed – with for example night time hours being valued less than late afternoon hours. As can be seen from Table 4.2 the levels chosen permit an examination of large changes in headway (up to 3 hours) and large changes in operational hours (from a 24 hour service to a service that only operates between 9am and 5pm). In developing the design from this starting point the values of each attribute were adjusted on a question by question basis to avoid dominant choices and to improve both the range of boundary values (Fowkes and Wardman, 1988) and the recovery of target values. The latter was tested through simulation[12,13].

[12] The utility of each ferry option is simulated using target values for the respective attributes, headway and hours closed, plus an error term – giving a utility specification akin to a random utility model. The error term is generated through the use of random numbers drawn from a probability distribution, the standard deviation of which is adjusted to ensure that the adjusted rho-squared statistic from the logit model estimation was less than 0.2. The simulated mode choice is the mode which offers the highest utility (i.e. lowest disutility). This gives a set of simulated choices to each stated preference scenario, from which a logit model is estimated. The output from the model estimation is compared to the target values to see how well the stated preference design recovers attribute values within a certain range. The simulated sample was 40 completed sets of 16 stated preference scenarios (i.e. 640 scenarios).

Table 4.2: Definitions of levels - inter-island ferry design

		Variables			
		Difference in headway (mins)	Ferry Service A Hours closed	Ferry Service B Hours closed	Difference in fare (£ single)
Levels	0	-120	0	0	+15.00
	1	-60	7	7	+7.00
	2	0	12	12	0
	3	-180	16	16	+22.00

The final design is presented in Table 4.3. For the variables that are orthogonal in differences, headway and fare, the base variables are a four hour (240 minute) headway and a fare of £25.

Boundary ray diagrams (Fowkes, 2000) and results from the simulation of 40 respondents (each facing all 16 questions) are presented in Figure 4.2, Figure 4.3, Table 4.4 and Table 4.5. As can be seen from these tables and figures there is a good spread of boundary rays throughout our range of interest in both variables. The design also appears to recover well values of headway and hours closed at all levels of the anticipated range except at the absolute lower end of the expected range (in both headway and hours closed). The design has been based on fares for cars and vans. The final design for commercial vehicles and foot passengers (including cyclists and bus users) is just an inflation/deflation of the car and van fares.

[13] During the simulation phase of the survey design it was found that designs that included journey time as an additional variable could not recover values of time with an appropriate level of accuracy. This was attributed to the limited range of journey times that could be regarded as plausible by survey respondents and the high valuations attributed to other variables. The final design therefore did not include journey time as a variable.

Table 4.3: Inter-island ferry final design

Scenario	Inter-island Ferry A					Inter-island Ferry B				
	Headway	Hours closed	Ferry Fare			Headway	Hours closed	Ferry Fare		
			Cars and small vans	Foot passengers	Lorries and large vans			Cars and small vans	Foot passengers	Lorries and large vans
1	240	0	£20.00	£4.00	£100.00	60	0	£21.00	£4.20	£105.00
2	240	0	£40.00	£8.00	£190.00	240	7	£25.00	£5.00	£120.00
3	240	0	£25.00	£5.00	£120.00	60	12	£25.00	£5.00	£120.00
4	240	7	£20.00	£4.00	£100.00	180	0	£35.00	£7.00	£170.00
5	240	7	£25.00	£5.00	£120.00	180	0	£31.00	£6.20	£150.00
6	240	7	£25.00	£5.00	£120.00	60	7	£40.00	£8.00	£190.00
7	60	7	£30.00	£6.00	£145.00	240	7	£25.00	£5.00	£120.00
8	240	7	£20.00	£4.00	£100.00	105	16	£20.00	£4.00	£100.00
9	120	12	£25.00	£5.00	£120.00	120	0	£30.00	£6.00	£140.00
10	220	12	£20.00	£4.00	£100.00	120	7	£35.00	£7.00	£170.00
11	220	12	£25.00	£5.00	£120.00	165	12	£26.00	£5.20	£125.00
12	220	12	£31.00	£6.20	£150.00	60	16	£25.00	£5.00	£120.00
13	120	16	£25.00	£5.00	£120.00	120	0	£47.00	£9.40	£230.00
14	210	16	£20.00	£4.00	£100.00	192	7	£25.00	£5.00	£125.00
15	210	16	£20.00	£4.00	£100.00	110	12	£26.00	£5.20	£130.00
16	120	12	£25.00	£5.00	£120.00	120	0	£26.00	£5.20	£125.00

Note: 0 hours closed is a 24 hour ferry, 7 hours closed is 6am to 11pm, 12 hours closed is 7am to 7pm and 16 hours closed is 9am to 5pm.

Figure 4.2: Boundary value ray diagram for headway – inter-island ferry survey (cars and vans)

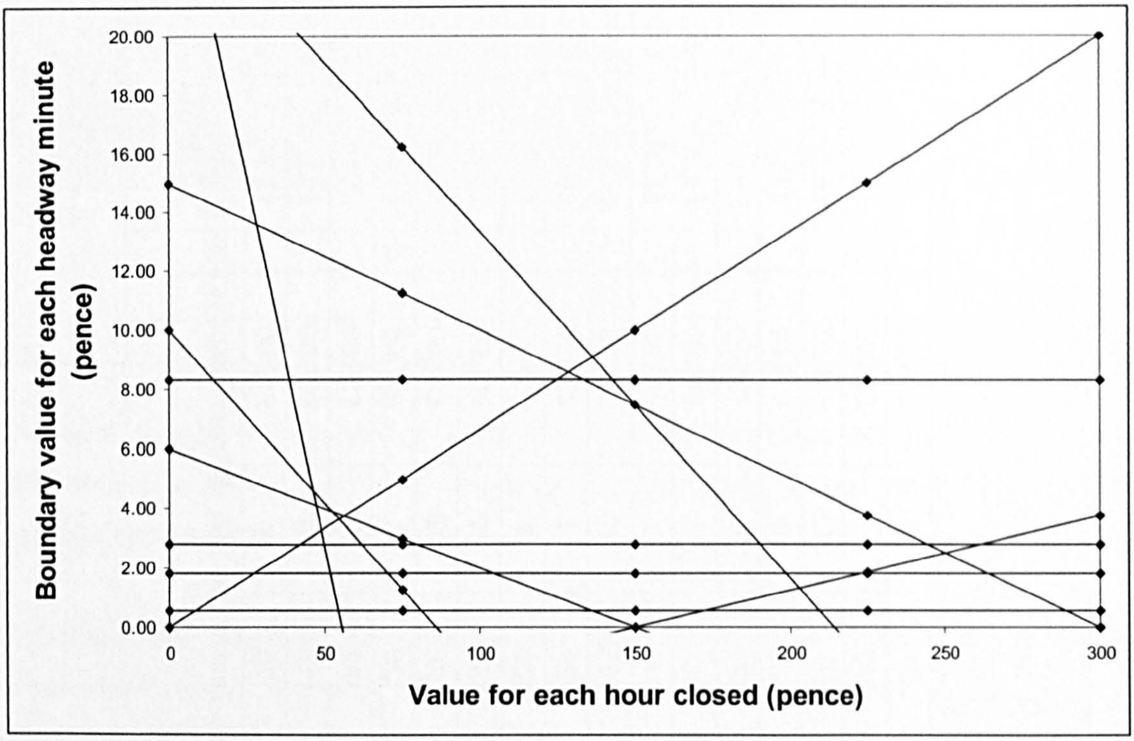


Figure 4.3: Boundary value ray diagram for numbers of hours closed – inter-island ferry survey (cars and vans)

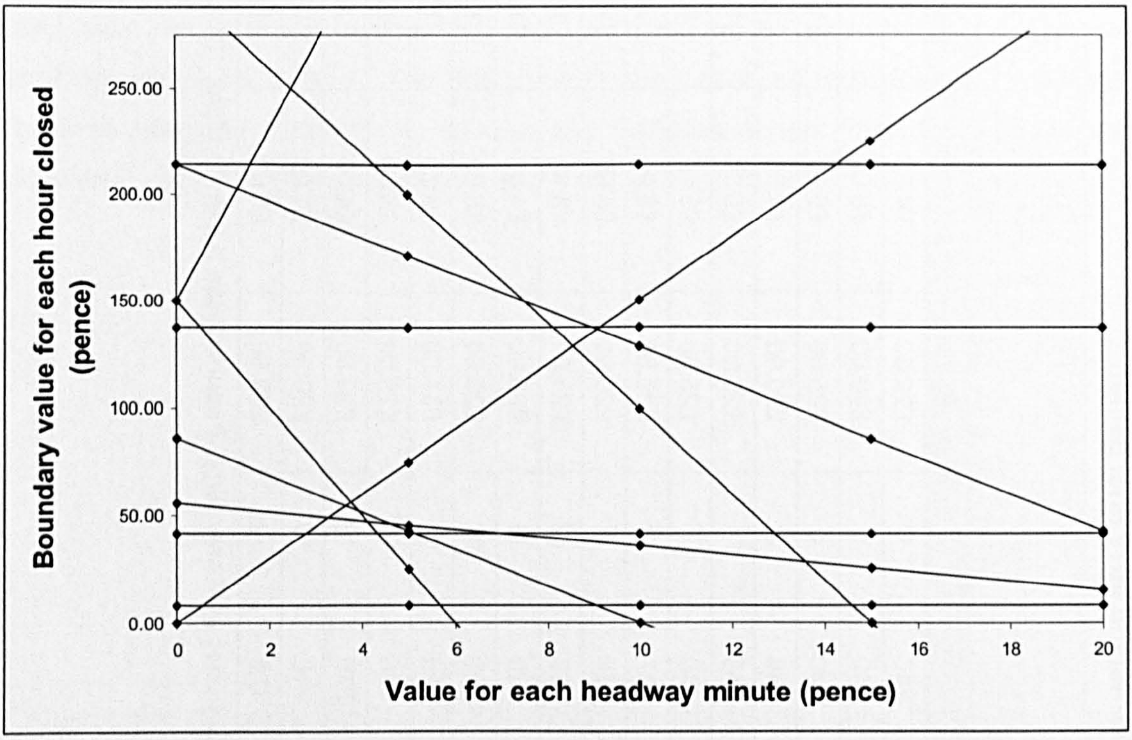


Table 4.4: Recovered value of headway values – inter-island ferry survey (cars and vans)

	Headway target value (p/min)	Recovered value in:						Percentage difference from target
		Simul-ation 1	Simul-ation 2	Simul-ation 3	Simul-ation 4	Simul-ation 5	Average	
Low values (hours closed = 4.73p/hour closed)	0.16	*0.41*	*0.43*	*0.40*	*0.28*	*0.21*	0.35	121.1%
Low to mid values (hours closed = 93.64p/hour closed)	6.14	6.21	6.05	6.26	6.91	6.99	6.48	5.6%
Mid values (hours closed = 139.44p/hour closed)	9.22	8.44	9.97	9.35	8.48	9.68	9.18	-0.4%
Mid to high values (hours closed = 185.24p/hour closed)	12.30	11.36	13.64	11.91	13.95	14.01	12.97	5.5%
High values (hours closed = 274.14 p/hour closed)	18.28	15.70	18.01	15.37	22.60	15.36	17.41	-4.8%

Note: Values in red italics are not significantly different from zero at the 5% level.

Table 4.5: Recovered value of hours closed values – inter-island ferry survey (cars and vans)

	Hours closed target value	Recovered value in:						Percentage difference from target
		Simul-ation 1	Simul-ation 2	Simul-ation 3	Simul-ation 4	Simul-ation 5	Average	
Low values (headway = 0.16p/min)	4.73	9.99	8.76	9.34	*4.17*	*3.16*	7.08	49.7%
Low to mid values (headway = 6.14p/min)	93.64	105.26	91.15	83.68	103.63	89.38	94.62	1.0%
Mid values (headway = 9.22p/min)	139.44	134.68	149.32	150.89	121.00	144.57	140.09	0.5%
Mid to high values (headway = 12.30p/min)	185.24	186.93	175.33	162.22	196.55	184.64	181.14	-2.2%
High values (headway = 18.28p/min)	274.14	234.50	289.41	238.94	315.47	254.85	266.63	-2.7%

Note: Values in red italics are not significantly different from zero at the 5% level.

Inter-island stated preference game - question framing and presentation

The stated preference questions were included in the self-completion questionnaire in the format shown in Figure 4.4. The question was worded as follows:

> *We would now like to know how you would react if the travel conditions were as described in the tables below. In each of the 8 situations presented, we would like you to indicate which type of ferry service you would prefer for THIS JOURNEY. If travelling on employer's business please bear in mind your company's travel policy.*

Figure 4.4: Sound of Harris Survey Card for Inter-Island Ferry Stated Preference Game

	Single Fare (for your group)	Frequency and hours of operation (Mon - Sat)	Choice Please tick one
Ferry Service 1	£31.00	Every 3 hrs 40 mins 7am to 7pm E.g. Sailings at: 0700, 1040, 1420, 1800	○
Ferry Service 2	£25.00	Every hour 9am to 5pm E.g. Sailings at: 0900, 1000, 1100,....etc...., 1500, 1600	○

The pilot survey also helped inform the design of the question in that example sailing times are included to aid the respondent in distinguishing the implications of different combinations of frequency and operating hours, as this had been a problem in the pilot. The 'baseline' operating hours - a 12 hour operating day (7am to 7pm) - also differ from those in the pilot as it was felt that the 8 hr operating day (9am to 5pm) used in the pilot tended to encourage some respondents into non-trading behaviour. The pilot survey also raised a number of issues associated with the wording of some of the non-stated preference elements of the questionnaire. These were relatively simple to address and ensured that the final questionnaire was straight forward for respondents to complete.

Wardman and Toner (2004) suggest that good practice in the industry is to limit the maximum number of stated preference questions faced by a respondent to between 9 and 16. Their analysis also indicates that the average number of questions faced by respondents in stated preference studies has been falling over time from 12.48 between 1980 and 1988 to 10.13 between 1993 and mid-1996. To avoid respondent fatigue the stated preference design was therefore split into two random groups of 8 questions. In administering the survey, respondents were randomly allocated one of the two sets of 8 questions.

4.3 Household survey methodology and design

The purpose of the household survey was twofold. Firstly to elicit scheduling costs associated with local trips, as opposed to longer distance trips, and secondly to elicit the relative difference in risk premium values between a fixed link and a ferry. As in the inter-island survey, scheduling costs were elicited by directly surveying the willingness to pay for changes in transport scheduling constraints (ferry frequency and operating hours) at the trip level. As the risk premium, in the context of island communities, is primarily associated with the burden that uncertainty of access to employment, health and service opportunities places on households, it is not related to a household's existing use of the infrastructure or service. A different approach to that used to elicit scheduling costs is therefore needed, as the payment vehicle and question framing cannot be set within the context of a trip. As option values are a specific type of risk premium, the limited empirical work that has been undertaken in this field (see Chapter 2 and Chapter 3) provides a starting point for the development of an appropriate survey methodology. The household survey therefore contained two stated preference designs. The first design (the local ferry stated preference game) focused exclusively on ferry scheduling costs, whilst the second design (fixed link stated preference game) supported by three contingent valuation questions examined whether a difference in risk premium exists between a fixed link and a ferry. The design of each of these questionnaire components is described separately below.

Households were surveyed, for this particular aspect of the study rather than transport users, as one of the variables of interest, the risk premium, is unrelated with use. The sample unit is also the household, rather than individuals, because travel and expenses within a household are often shared – both in terms of budget and in terms of vehicle. Additionally, the council tax, one of the chosen payment vehicles, is a household expense.

The household survey was administered through face-to-face interviews on the islands of Berneray, Eriskay, Scalpay and Vatersay which have all recently been connected to one of the bigger islands in the Outer Hebrides by a fixed link. This is unusual in that for most stated preference experiments the respondents typically have most familiarity with the scenario depicted as the base or existing case – which in this survey is the ferry infrastructure. This lack of realism in the base scenario in each stated preference game was felt to be outweighed by the benefits of surveying households who have had experience of both ferries and fixed link infrastructure. Such households are better able to appreciate the difference between the two types of infrastructure compared to those who have only experience of one type of infrastructure. With such an emotive subject as island transport links, people who have not got a fixed link may not appreciate how much they will depend on it, or conversely may think that it will give them more advantages than it does in reality. The questionnaire was designed such that no interview would last longer than 15 minutes. This was to ensure that householders would be willing to participate in the survey and to maximise the number of households the survey enumerators could visit during the survey period.

Whilst risk premiums (and option values) are held by both households and businesses the present study, for the budgetary reasons outlined earlier, focused on those held by households only. In this regard the household questionnaire is set within the context of household travel for household purposes only (i.e. non-work travel).

Local ferry stated preference game - survey method and model

Ideally scheduling costs associated with local trips should be obtained by intercepting and interviewing travellers on a ferry that serves such a market. However, there is no such ferry in the Outer Hebrides. Given the limited survey budget it was therefore felt that the best possible way to obtain such data would be to include it in the household survey, as the majority of households on Berneray, Eriskay, Scalpay and Vatersay would have experienced the constraints of living with a lifeline ferry service until the recent completion of the fixed link to their island.

Given the equivalence in the object of both the inter-island ferry stated preference game and this stated preference game (hereafter referred to as the local ferry stated preference game) a similar approach in design was adopted. The only differences that arise between the designs stem from the context in which the experiment is conducted and the definition of the sample. Thus whilst the inter-island ferry survey intercepted travellers on the ferry and administered a self-completion questionnaire, the local ferry survey was conducted by interview and the stated preference games were presented to interviewees on cards (one per stated preference question). The context of the trip in which the stated preference game is set differs, as higher frequencies, lower fares and shorter trip durations are associated with local ferries compared to inter-island ferries. In all other aspects the stated preference games between the two surveys are identical (variable definitions, number of variables and number of levels and choice is between two ferry services)[14]. The model that is being estimated therefore has the same specification as that presented in equation 4.1 – that is utility is a function of unobserved attributes of the ferry, a function of headway, a function of operating hours and an error term that represents taste variation within a population segment.

Local ferry stated preference game – design and simulation

The starting point for the local ferry stated preference design is therefore the same main effects design from Kocur *et al.* (1982 cited in Wardman and Toner, 2004) that requires 16 experiments (stated preference scenarios) as used in the inter-island survey design. The values for each level differ from the inter-island design reflecting the potential for higher frequencies and lower cost of the local ferries since replaced by the fixed links. As can be seen from Table 4.6 the levels chosen once again permit an examination of large changes in headway (up to 3.5 hours) and large changes in operational hours (from a 24 hour service to a service that only operates between 9am and 5pm).

Table 4.6: Definitions of levels – local ferry stated preference game

		Variables			
		Difference in headway (mins)	Ferry Service A Hours closed	Ferry Service B Hours closed	Difference in fare (£ single)
Levels	0	-180	0	0	+8.00
	1	-120	7	7	+4.00
	2	0	12	12	0
	3	-210	16	16	+12.00

The design was tested through simulation, with variable levels in individual stated preference scenarios being adjusted to avoid dominant choices and to improve the range of boundary values and the recovery of the target valuations. The range of target values derived from the literature is set out in Table 4.7. These have the same source as those in Table 4.1 except that the maximum value is determined by an upper

[14] In the pilot survey journey time was also included as a variable. However, it was found that respondents firstly queried the realism of the ferry times presented and secondly typically ignored them in their decision making. Journey time therefore was not included as a variable in the main survey.

limit to the value of non-work time (as opposed to work time). As mentioned earlier the pilot survey identified that the minimum value for operating hours maybe lower than indicated in this table at 1.4 pence per hour closed.

Table 4.7: Target range of marginal values for the headway and operating hours (local ferry stated preference game)

	Valuation (equivalent in-vehicle time minutes)		Valuation (pence)	
	Min	Max	Min	Max
Headway (1 min)	0.03	0.73	0.16	9.3
Operating hours (1hr closed)	1.0	5.0	4.2	57.8

The final design is set out in Table 4.8 for each of the 16 stated preference scenarios. Figure 4.5 and Figure 4.6 demonstrate that the boundary rays are well spread out, though they do not cover the values at the higher end of the target ranges particularly well. This occurs as the emphasis in the design was placed on obtaining good coverage of the lower to mid ranges in the target range as this is where it is expected (and the pilot survey indicated) there is a higher probability that the values would lie. The design is tested through the simulation of responses from 40 respondents (each facing all 16 questions). For each pair of target values the simulation was undertaken five times. The results of these tests, in terms of the ability of the design to recover the target values are detailed in Table 4.9 and Table 4.10. In the main the design appears to recover the target values to a reasonable degree of accuracy, however, the design can be seen to be weaker at high values of headway and at very low and high values for each hour closed.

Table 4.8: Local ferry final design

Scenario	Local ferry A			Local ferry B		
	Headway (mins)	Hours closed (hrs)	Ferry fare (return)	Headway (mins)	Hours closed (hrs)	Ferry fare (return)
1	205	0	£7.00	60	0	£7.50
2	180	0	£8.00	180	12	£7.00
3	205	0	£5.00	60	7	£5.00
4	205	7	£7.00	120	0	£13.00
5	205	7	£5.00	120	0	£7.00
6	205	7	£7.00	30	7	£15.00
7	60	7	£6.50	205	7	£5.00
8	205	7	£7.00	60	16	£7.00
9	180	12	£7.00	180	0	£9.00
10	180	12	£7.00	60	7	£11.00
11	180	12	£7.00	120	12	£13.00
12	180	12	£8.50	30	16	£7.00
13	240	16	£7.00	240	0	£8.00
14	240	16	£7.00	130	7	£9.00
15	240	16	£5.00	60	12	£6.50
16	180	12	£7.00	180	0	£7.50

Note: 0 hours closed equates to a 24 hour ferry, 7 hours closed equates to one from 6am to 11pm, 12 hours closed from 7am to 7pm and 16 hours closed from 9am to 5pm.

Figure 4.5: Boundary value ray diagram for headway – local ferry stated preference game

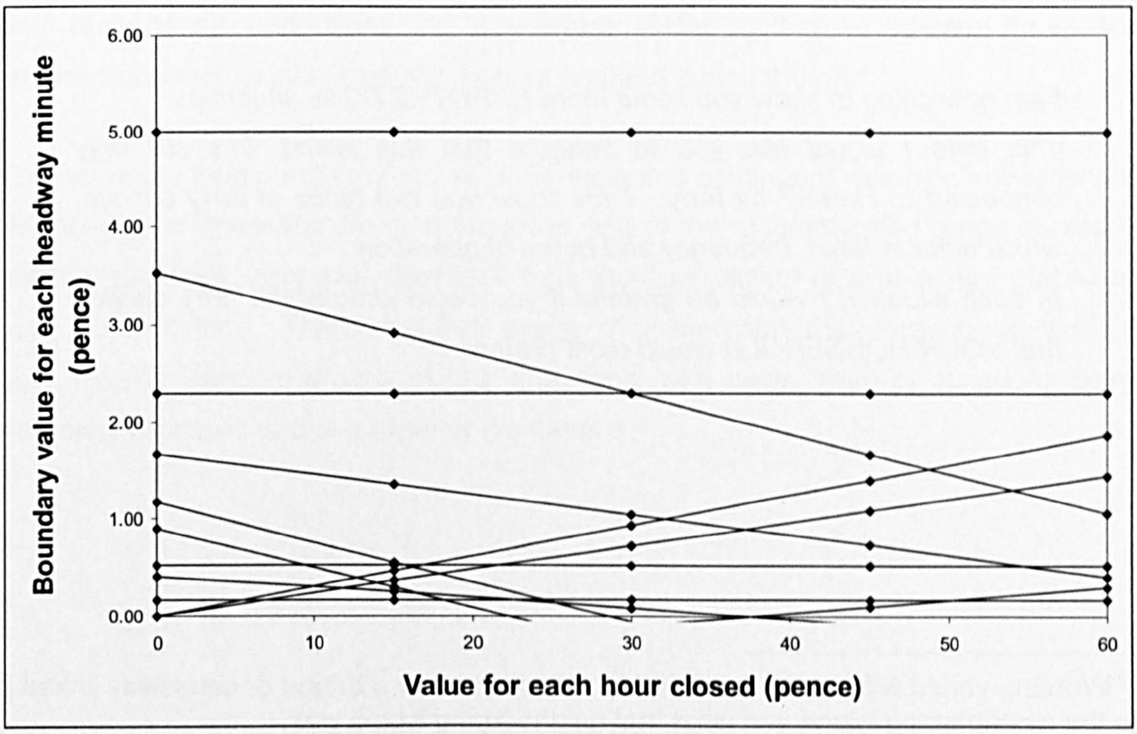
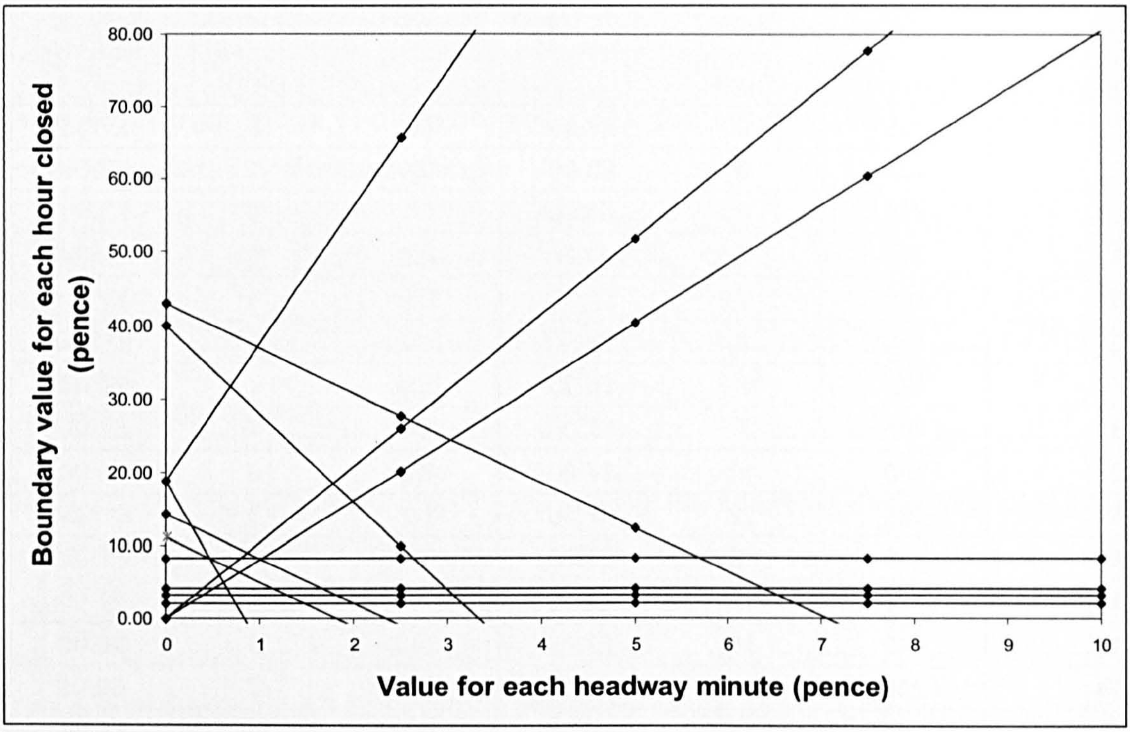


Figure 4.6: Boundary value ray diagram for numbers of hours closed – local ferry stated preference game



Local ferry stated preference game – question framing and presentation

As mentioned earlier the stated preference scenarios were presented to interviewees in the form of one card per question (scenario) as illustrated in Figure 4.7. The question that supports this card is:

> *I am now going to show you some more HYPOTHETICAL situations.*
> *This time I would like you to imagine that this island was still only connected to Harris*[15] *by ferry. I will show you two types of ferry service, which differ in fares, frequency and hours of operation.*
> *In each situation I would be grateful if you could choose the ferry service that YOUR HOUSEHOLD would most prefer.*

---

15 Wording varied with island surveyed to reflect whether a bridge or causeway linked it to the neighbouring island and what that neighbouring island was.

Figure 4.7: Scalpay Survey Card - local ferry stated preference game

	OPTION A Vehicle Ferry	OPTION B Vehicle Ferry
Vehicle size	*No restrictions*	*No restrictions*
Fares (vehicle and passengers)	£5.00 (return)	£6.50 (return)
Frequency (average)	Every 4 hours	Every hour
Opening Hours	First ferry: 9am to Last ferry: 5pm	First ferry: 7am to Last ferry: 7pm
Example Sailing times	0900, 1300, 1700	0700, 0830, 0900, 1000,...etc...., 1700, 1800, 1900
Choose one only	A	B

The questions are set within the context of the household's preferred level of service provision to the island. This is because the pilot survey identified that householders responded in this way even when the question specifically focussed on a journey that had occurred in the preceding week. For example, in the pilot the context for one household was a shopping trip that was completed by 4 o'clock, however, rather than choosing the ferry service that best suited this trip the householder choose more expensive ferry options that included opening hours that far exceeded the 4 o'clock return time, as that would suite the household better in general. As with the inter-island example sailing times were included on the question card in the final questionnaire to help respondents understand the implications of the mixture of opening hours and service frequency, as this had also been a problem during the pilot.

To ensure the total number of stated preference and contingent valuations questions in the household questionnaire is at the lower end of the recommended range of nine to sixteen questions; only four questions from the final design of sixteen are placed on each questionnaire. That is the final design of sixteen stated preference questions is split into four random groups of four questions, with each group of questions being randomly allocated to one quarter of the sample.

Table 4.9: Recovered value of headway values – local ferry stated preference game

	Target value	Recovered value in simulation						Percentage difference from target
		1	2	3	4	5	Average	
Low end of target range	0.70	0.60	0.90	0.83	0.44	0.59	0.67	-4.0%
Low to mid part of target range	3.16	3.38	2.91	2.98	3.00	3.29	3.11	-1.7%
Mid part of target range	4.71	4.31	4.62	4.35	4.87	4.89	4.61	-2.3%
Mid to high part of target range	6.26	5.30	5.97	6.27	5.69	6.47	5.94	-5.1%
High end of target range	9.27	8.42	15.73	10.14	10.26	11.07	11.13	20.0%

Note: All coefficients significant at 5% level

Table 4.10: Recovered value of hours closed values – local ferry stated preference game

	Target value	Recovered value in simulation						Percentage difference from target
		1	2	3	4	5	Average	
Low end of target range	5.00	6.19	6.79	5.21	9.03	7.08	6.86	37.2%
Low to mid part of target range	20.88	21.33	23.84	20.49	18.33	25.13	21.82	4.5%
Mid part of target range	30.24	30.37	31.33	28.28	32.22	33.21	31.08	2.8%
Mid to high part of target range	39.61	34.71	39.85	33.89	32.67	43.08	36.84	-7.0%
High end of target range	57.79	56.03	99.77	62.65	55.07	83.52	71.41	23.6%

Note: All coefficients significant at 5% level

Fixed link stated preference game - methodology and model

The object of the second stated preference game in the household questionnaire (which is the third stated preference game developed as part of this study) - hereafter referred to as the fixed link stated preference game - was to elicit the difference in the risk premium value between a fixed link and a ferry. The risk premium in this context is not related to a household's existing use of a fixed link or ferry service. The study design cannot therefore be couched in terms of a specific trip. The design of this game has therefore taken as its starting point the limited empirical work that has been undertaken on transport related option values.

Following Bristow *et al.* (1991), Crockett (1992), Humphreys and Fowkes (2006) and Geurs, Haaijer and van Wee (2006) the Total Economic Value (TEV) of the transport good is separated into its component terms: actual use, option value (i.e. risk premium) and non-use value (Equation 4.2). By estimating the TEV and subtracting from it the actual use value an estimate of the sum of the option value (risk premium) and the non-use value is obtained. Humphreys and Fowkes further disaggregate the non-use component of TEV into a number of components (e.g. indirect use, altruistic, etc.).

Total Economic Value	=	Actual use value	+	Value of risk premium (option value)	+	Non-use value	(4.2)

Extending Equation 4.1 to include a function in journey time, $I(T)$, the utility a household, h, in population segment k derives from a fixed link or ferry can be expressed as in equation 4.3.

$$U_h^{ferry} = \alpha_k^{ferry} + \beta_k^{ferry} f(H) + \chi_k^{ferry} g(OH) + \phi_k h(P) + \gamma_k^{ferry} I(T) + \varepsilon_h^{ferry} \qquad (4.3)$$

$$U_h^{FixedLink} = \alpha_k^{FixedLink} + \phi_k h(P) + \gamma_k^{FixedLink} I(T) + \varepsilon_h^{FixedLink}$$

Here the marginal utility of income for the household, ϕ_k, is taken to be independent of the transport infrastructure, whilst the marginal utility of time, γ_k, is allowed to vary by infrastructure type reflecting, for example, the differing levels of comfort associated with travelling by the two modes. If **all** the use costs and activity scheduling costs associated with the ferry and fixed link are captured through the functions in headway, hours closed, price and journey time then the marginal value of the alternative specific constants (ASCs), $\frac{\alpha_k^{ferry}}{\phi_k}$ and $\frac{\alpha_k^{FixedLink}}{\phi_k}$, can be thought of as representing the sum of the risk premium value and the non-use value. The risk premium is illustrated in Figure 2.1 in Chapter 2.

The two equations in (4.3) are not identified due to the presence of intercept terms in both equations. To estimate the utility functions it is necessary to re-arrange them as in Equation 4.4. In equation 4.4 the functions have been re-arranged to allow the difference in utility between the two alternatives (ferry and fixed link) to be calculated. The term $\alpha_k^{FixedLink-Ferry}$ is the difference between the ferry and the fixed link intercepts.

$$\begin{aligned} U_h^{ferry} &= \beta_k^{ferry} f(H) + \chi_k^{ferry} g(OH) + \phi_k h(P) + \gamma_k^{ferry} l(T) + \varepsilon_h^{ferry} \\ U_h^{FixedLink} &= \alpha_k^{FixedLink-Ferry} + \phi_k h(P) + \gamma_k^{FixedLink} l(T) + \varepsilon_h^{FixedLink} \end{aligned} \quad (4.4)$$

$\alpha_k^{FixedLink-Ferry}$ can be estimated directly from a stated preference experiment in which respondents are asked to choose between the preferred form of connectivity to an island – a fixed link or a ferry. In practice care needs to be made in placing such an economic interpretation on estimated ASCs as to do so means it is necessary to ensure that all use costs are explicitly included in the utility function and that there is no mis-specification of the function. Clearly unobserved attributes of the ferry or fixed link will bias the ASC away from the sum of the risk premium value and the non-use value, whilst a mis-specification of the utility function (including an inappropriate treatment of the error term in the estimation) can bias all estimated coefficients (Bates and Terzis, 1997; Hensher and Greene, 2003). Such requirements are very arduous and as a consequence, industry practice typically avoids, where possible, placing an interpretation on the ASC.

Unfortunately the two alternative approaches to estimating option values adopted in the literature, and used respectively by Humphreys and Fowkes (2006) and Geurs, Haaijer and van Wee (2006), cannot be adopted in this study. The approach adopted by Geurs, Haaijer and van Wee is consistent with strategies adopted in the environmental economics literature (e.g. Mitchell and Carson, 1989 pp.288-292) in that the sample is split into non-users, option users and users, with the particular valuations from the different population segments being attributed to the different motives for valuing the good (non-use, option use and actual use). This was particularly effective for Geurs, Haaijer and van Wee as they considered a rail line which some people had never used and never intended to use (the non-users), others did not use but might use at some point (the option users) and others who did use the service (the users). For the present study this approach is unworkable as the transport link being valued is a lifeline link for which all people are users. The approach used by Humphreys and Fowkes in contrast is workable but would have required a much larger survey programme than was available. This is because Humphreys' and Fowkes' method estimates option and non-use values for a specific infrastructure. As the present interest is the difference in the risk premium value between a ferry and a fixed link, the application of Humphreys' and Fowkes' approach would necessitate surveys in two locations – one with an existing ferry and one with a fixed link. Survey resource constraints meant that this was not possible.

Instead the approach of the present study is to base an estimate of the sum of the risk premium value and the non-use value on the difference between the value of the ASCs of a fixed link and a ferry. This is estimated through stated preference questions in which respondents are asked to choose between a ferry and a fixed link. Given the noted weaknesses in this approach two contingent valuation (CV) questions are also asked. The CV questions act as a validation of the stated preference results as well as allowing respondents to express their true willingness to pay.

The present study does not separate the risk premium value from the non-use value. Primarily this is because the disaggregation process increases the complexity of the questionnaire and therefore lengthens it. Humphreys and Fowkes disaggregate between the option value (risk premium) and the different components of the non-use value by using three variables as proxies for the different non-use components. This is because Bristow *et al.* (1991) had found respondents experienced difficulty valuing the non-use component separately from the use component for a transport good (in contrast to the literature on environmental goods). Using proxy variables significantly increases the burden on the respondent and the length of the questionnaire. To ensure the difference in the ASCs estimated reflect differences in risk premium and not use values the ferry proposed as an alternative to the bridge was free, there were no vehicle restrictions and it provided a high quality half hourly service[16].

---

[16] SQW (2003) identified that substantial financial savings were made as a consequence of the construction of the untolled fixed links (an average of £830 per household on Scalpay). In the main these savings come from no longer having to pay

An important component of a stated preference valuation study is the choice of payment vehicle. For the fixed link stated preference survey the payment vehicle cannot be associated with use (such as a toll) as the risk premium (in this context) and non-use values are not associated with use. Council tax was chosen as the payment vehicle because of its lump sum nature and its relationship between local services and local taxation. The council do subsidise local transport services – for example the old ferries to Eriskay and Vatersay were operated by the council – so this linkage is familiar to respondents. The difficulty with using an existing form of local taxation, such as the council tax, as a payment vehicle is that the payment vehicle is associated with opinions the respondent may hold towards the local council and, as such, this can introduce a bias into the data. Alternative options to council tax would have been a form of infrastructure fund. The infrastructure fund would represent an unknown funding process to households and would therefore add to the complexity of the questionnaire. These disadvantages were felt to outweigh its advantage of not being associated with local authority's decision making and therefore it was rejected as a payment vehicle.

A further consideration was whether to associate a council tax premium with the fixed link (willingness to pay) or a council tax reduction with the ferry (willingness to accept). It could be argued that the later would present a more realistic scenario to the respondent, in that no council tax premium has been associated with the construction of the fixed links. However, the interest of the study is in willingness to pay for an improvement in transport quality as would be used in a cost benefit analysis of a fixed link, rather than the compensation necessary for a loss in quality, such as the loss of a bridge. This would suggest that the willingness to pay measure is the correct measure. Furthermore there are strong theoretical and practical reasons why willingness to pay and willingness to accept measures may differ (for a discussion see Mitchell and Carson, 1989 pp.30-38; Bateman *et al.*, 2002 pp.24-28 & pp.385-391). For example, questions have been raised regarding the plausibility of the willingness to accept

---

ferry fares, but also derive from access to cheaper goods and services and employment. Clearly such financial benefits reflect the minimum a household would be willing to pay for a fixed link if presented with a ferry service similar to that which used to serve the islands. By presenting respondents with a high quality ferry (no vehicle restrictions and a half hourly frequency) that was free at the point of use such financial savings would be minimised or zero. This would ensure any premium associated with the fixed link over the ferry, aside from user costs associated with a 30 minute headway and a 15 minute journey time increase, relates to the risk premium and non-use value (e.g. altruistic, bequest, etc.).

question to respondents, whilst prospect theory (Kahneman and Tversky, 1979) emphasises that gains and losses maybe valued differently. A council tax premium is therefore associated with the fixed link in the stated preference scenarios. This premium is couched both in terms of a weekly payment and an annual payment to help the respondent understand the financial implications of the premium. This is because the pilot survey identified that when respondents were faced with only a weekly payment they did not appreciate the full financial implications of their choice. The council tax premium was also accepted by respondents without difficulty in the pilot survey.

Stated preference game design and simulation – fixed link stated preference study

As simple a model as possible is proposed so as to minimise model mis-specification errors. Such errors make it difficult to place an economic interpretation on the ASC. Between the stated preference questions the properties of the ferry are therefore kept fixed aside from opening hours[17], whilst the properties of the fixed link are kept fixed aside from the Council Tax premium. The model to be estimated therefore has the form set out in Equation 4.5.

$$U_h^{ferry} = \chi_k^{ferry} g(OH) + \varepsilon_h^{Ferry} \qquad (4.5)$$
$$U_h^{FixedLink} = \alpha_k^{FixedLink-Ferry} + \phi_k h(P) + \varepsilon_h^{FixedLink}$$

Some use costs associated with travel time differences and the half-hourly headway of the ferry are included in the intercept term ($\alpha_k^{FixedLink-Ferry}$). The intercept term represents the difference in the fixed link and ferry's ASCs. To estimate the sum of the risk premium and non-use value these use costs need to be deducted from the value of the intercept term. Estimates for headway costs are obtained from the local ferry stated preference design, whilst estimates for the journey time costs are obtained from the contingent valuation question on journey time.

[17] The shortness of each of the crossings meant that it is not possible to offer a 'fast' ferry option that would reduce the journey time advantage of the fixed link over the ferry. In each scenario presented the fixed link therefore has a 15 minute advantage over the ferry, which broadly comprises of several minutes wait time, several minutes boarding time (including fare collection) and 7 to 8 minutes crossing time. A fast ferry may only have reduced this total journey time by ferry by a few minutes. This is consistent with the ex-ante appraisal of the Berneray Causeway (Halcrow Fox, 1996) used as a case study in Chapter 9.

The target range for the marginal values are the same as those used for the local ferry stated preference design (see Table 4.7), with the addition that the target range for the risk premium is £41 to £190. Given that the payment vehicle in the fixed link stated preference survey is annual council tax premiums these target values need adjusting to an annual basis (to reflect annual use costs). Such an adjustment is presented in Table 4.11.

Table 4.11: Target range of marginal values - fixed link stated preference game

	Valuation	
	Minimum	**Maximum**
Main survey (annual for 2 return trips per week, 50 week year)		
Alternative specific constant (ASC) of fixed link relative to ferry	£152	£937
Operating hours (1hr closed)	£4	£116
Main survey (annual for 10 return trips per week, 50 week year)		
Alternative specific constant (ASC) of fixed link relative to ferry	£758	£4,686
Operating hours (1hr closed)	£21	£578
Main survey (annual for 15 return trips per week, 50 week year)		
Alternative specific constant (ASC) of fixed link relative to ferry	£1,136	£7,029
Operating hours (1hr closed)	£32	£867

Note: Minimum value of time used is 4.73 p/min/trip; headway 0.16 p/min/trip; operating hours 2.1 p/hr/trip and option value plus non-use value £41 per year. Maximum value of time used is 12.64 p/min/trip; headway 9.3 p/min/trip; operating hours 57.8 p/hr/trip and option value plus non-use value £190 per year.

An important point emphasised by the lower rows of Table 4.11 is that households with the same unit values per trip, but exhibiting very different trip making characteristics, have very different annual valuations. These annual valuations can, for high trip-making households, be very large. Analysis indicated that to set boundary values to recover such values would require very high levels of council tax. To ensure a degree of realism to the survey the council tax premium was limited to a maximum of £1,000. For all households on Berneray, Eriskay, Scalpay and Vatersay, except two, this would represent at least a doubling of council tax (e.g. from £750 to £1,750) and for some it would represent a tripling (e.g. from £455 to £1,455).

The final design is set out in Table 4.12 for each of the 16 stated preference scenarios. The starting point was a main effects design for two variables with four levels each from Kocur *et al.* (1982 cited in Wardman and Toner, 2004). Such a design requires 16 experiments (stated preference scenarios). As can be seen from Figure 4.8 and Figure 4.9 the boundary rays are well spread but only really cover the mid and lower annual values detailed in Table 4.11. It can also be seen that, aside from one incidence, the hours closed boundary rays do not cross (see Figure 4.9). The lack of intersecting boundary rays weakens the design in its ability to recover the target values for hours closed. These two weaknesses are borne out by the simulation results (see Table 4.13 and Table 4.14) which indicate that the design performs well at recovering values for the ASC and each hour closed that lie within the middle and lower part of the target range. However, the design does not appear to be able to recover very low values for each hour closed (£5 per hour), nor can it recover high values for either the ASC (greater than £1,200) or each hour closed (greater than £100 per hour). In the main this is felt to be a consequence of restricting the maximum council tax premium to £1,000 to maintain realism. It was considered unlikely that many households would hold such high values for the ASC and each hour closed when considered against net household incomes and average household expenditure on transport[18]. The design was therefore considered appropriate, but given the potential that a household's willingness to pay may lie outside the range the design can recover one of the contingent valuation questions was designed to corroborate the stated preference results.

---

[18] In 2005-6 transport comprised 14% of average household expenditure in Britain (ONS, 2007). For a household with a net income after deductions of £15,000 household expenditure on transport is therefore in the region of £2,100. 45% of households in Scotland have a net income of £15,000 or less (Scottish Executive, 2007 Table 4.4).

Table 4.12: Fixed link stated preference game – final design

Scenario	Fixed link	Local ferry
	Council Tax	Opening hours(no.of hours closed)
1	£300	24 hrs (0 hrs)
2	£180	24 hrs (0 hrs)
3	£120	24 hrs (0 hrs)
4	£20	24 hrs (0 hrs)
5	£1,000	6am to 11pm (7 hrs)
6	£800	6am to 11pm (7 hrs)
7	£350	7am to 7pm (12 hrs)
8	£60	24 hrs (0 hrs)
9	£1,000	7am to 7pm (12 hrs)
10	£800	7am to 7pm (12 hrs)
11	£220	24 hrs (0 hrs)
12	£150	7am to 7pm (12 hrs)
13	£600	9am to 5pm (16 hrs)
14	£800	9am to 5pm (16 hrs)
15	£300	9am to 5pm (16 hrs)
16	£100	9am to 5pm (16 hrs)

Note: The fixed link is untolled and 15 minutes quicker than the ferry. There are no vehicle restrictions on the ferry, no ferry fare and the ferry operates at half hourly intervals.

Figure 4.8: Boundary value ray diagram for the alternative specific constant – fixed link stated preference game

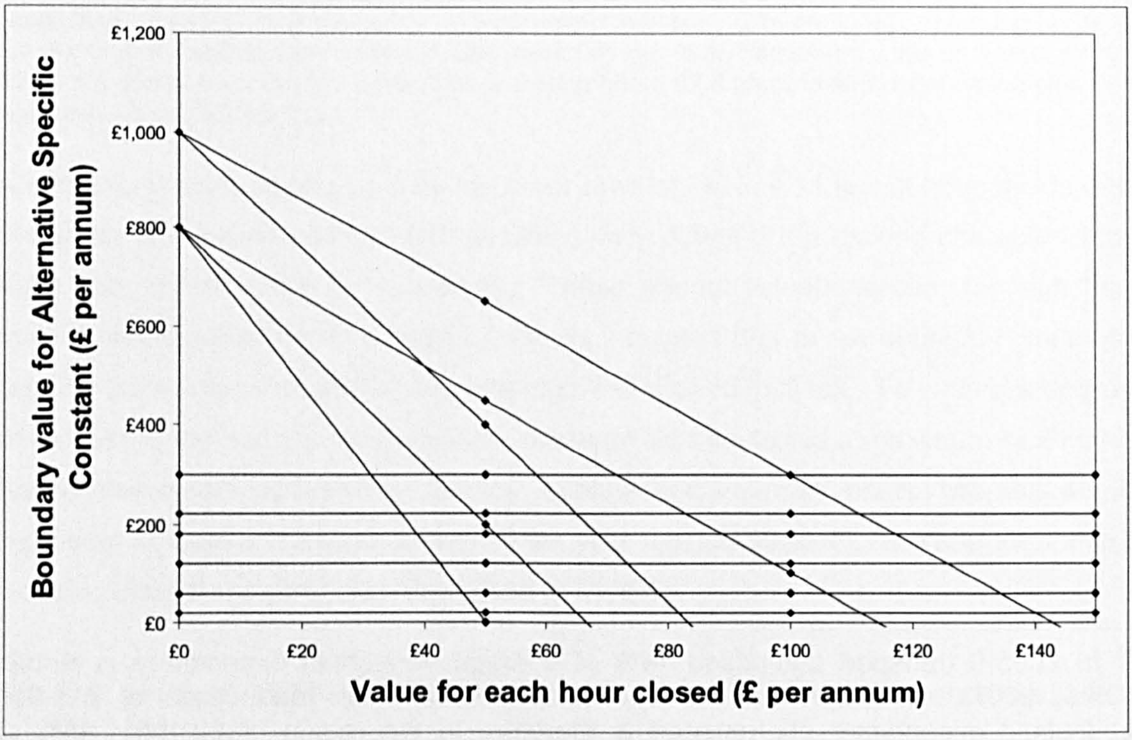


Figure 4.9: Boundary value ray diagram for numbers of hours closed – fixed link stated preference game

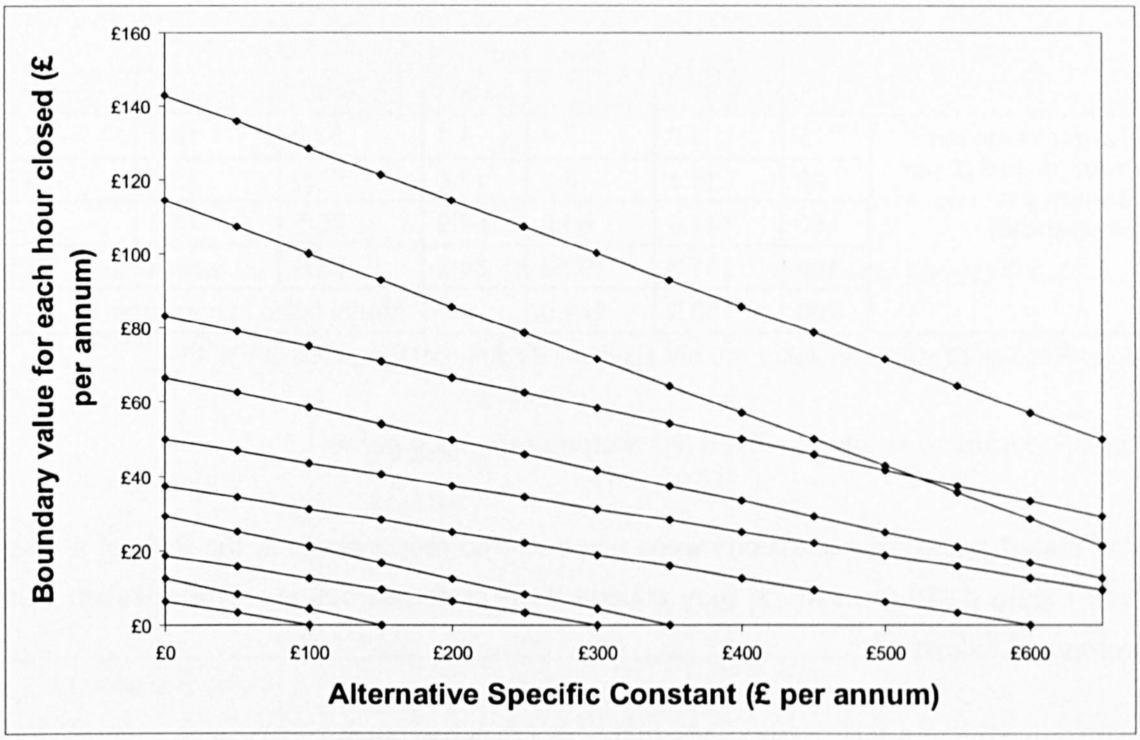


Table 4.13: Recovered value of ASC of fixed link relative to ferry - fixed link stated preference game

		Target value for modal constant of fixed link relative to ferry (£ per annum per household)					
		100	**400**	**800**	**1,200**	**1,600**	**2,000**
Target value per hour closed (£ per annum per household)	**5**	157	387	824	*686*	1,140	2,148
	20	164	391	890	1,062	1,235	*2,854*
	50	134	351	762	991	1,645	*2,800*
	100	*75*	366	896	1,461	1,023	895
	200	124	504	Model failed to converge			

Note: Recovered values in italics are not significantly different from zero at 5% level

Table 4.14: Recovered value for each hour closed - fixed link stated preference game

		Target value for modal constant of fixed link relative to ferry (£ per annum per household)					
		100	400	800	1,200	1,600	2,000
Target value per hour closed (£ per annum per household)	**5**	*3.0*	*7.4*	*1.1*	*58.8*	*19.3*	*-38.3*
	20	16.4	18.3	*12.6*	17.0	33.6	*-16.3*
	50	41.6	66.5	61.9	48.5	71.5	*14.3*
	100	131.8	102.3	84.3	85.9	66.3	*78.5*
	200	158.9	174.9	Model failed to converge			

Note: Recovered values in italics are not significantly different from zero at 5% level

Question framing strategy – Fixed link stated preference game

The stated preference questions were presented to respondents in the form of a card (see Figure 4.10) from which they choose their preferred option. The question was worded as follows:

> *I am now going to show you a number of HYPOTHETICAL situations.*
> *I would like you to imagine the situation before the bridge was constructed but YOUR HOUSEHOLD could choose whether this island was to be connected to Harris with a FREE ferry or with a bridge*[19]*. However, as the bridge has to be constructed by the local council, council tax must go up to pay for it.*
> *In each situation I would be grateful if you could choose the transport and council tax option that YOUR HOUSEHOLD would most prefer.*

As with the local ferry stated preference design the final design of 16 questions was split into four groups of four questions at random. Each set of four questions was administered to quarter of the sample. A fifth question was added (which was common across the complete sample). This question attached a low council tax premium to the fixed link (£0.50 per week) and acted as a dominant choice logic check. Importantly it also gave householders a means to express their strong approval for the replacement of the ferry with a fixed link.

[19] Wording varied with island surveyed to reflect whether a bridge or causeway linked it to the neighbouring island and what that neighbouring island was.

Figure 4.10: Scalpay Survey Card for Fixed Link versus Ferry Stated Preference Game

	OPTION A (Vehicle Ferry)	**OPTION B (Bridge[19])**
Funding	*Fully subsidised through council tax*	*Constructed by the council*
Vehicle size	*No restrictions*	*No restrictions*
Journey time	---	*15 minutes <u>quicker</u> than ferry*
Fares/tolls	*No fares*	*No tolls*
Frequency	*Half Hourly*	---
Opening Hours	First ferry: 7am Last ferry: 7pm	24 hrs
Council Tax	As existing	Existing + £15.38 per week (£800 per year)
Choose one only	A	B

Contingent valuation question design

Three contingent valuation questions were included in the questionnaire. The first two were set within the context of the stated preference games and therefore the answers could be used to corroborate the stated preference results. The third question related to the value of a journey time saving. It was necessary to understand the value of time as this formed one of the elements of user cost comprising the difference in TEV between the fixed link and the ferry.

A number of different approaches are available for eliciting monetary values with contingent valuation (for a discussion see Mitchell and Carson, 1989 pp.97-104; Bateman *et al.*, 2002 pp.135-145). Each approach has its strengths and weaknesses. The format chosen is an 'open-ended direct' question followed up by a question to determine the reason for any zero response. If respondents have difficulty replying to the open ended question, as some did in the pilot survey, an iterative bidding approach starting at bids of £0.50 per week (£26 per year) is adopted. That is the householder is asked if they would be willing to pay £26 per year, and if they said yes they would be asked if they would be willing to pay £52 per year, and so on.

The main advantage of using an open-ended direct approach to elicit willingness to pay is that it is straight forward and does not provide respondents with cues about what the value of the change might be. There is no starting point or anchoring bias. Its main weakness is that it can be difficult for respondents to come up with their true willingness to pay 'out of the blue' for something they are not familiar with valuing. This can lead to high non-response rates, protest answers, zero answers and outliers. As the contingent valuation question followed a set of stated preference questions respondents already have some familiarity with the task at hand. It is therefore felt that within this context the strengths of the open-ended question outweighed its weaknesses. Despite the familiarity from the stated preference questions some respondents experienced difficulty answering the open-ended question, in which case an iterative bidding game is adopted. This is easy for respondents to answer as it is similar to the process of an auction. Its main weakness is in the possibility of starting point bias occurring. That is the outcome of an iterative bidding game can be heavily influenced by the starting bid. For this reason the starting bid was very low (£0.50 per week) to ensure that any value elicited would be a conservative estimate of willingness to pay. Alternatives to the iterative bidding approach would include the use of a payment card or ladder or dichotomous choice questions. The iterative bidding approach was preferred as whilst the payment ladder approach is not subject to starting point bias it is subject to other biases. These relate to the values presented to the respondent. This, combined with the fact that the iterative bidding approach was more efficient for the survey enumerators to implement, meant the iterative bidding approach was preferred. Dichotomous choice questions are often viewed as being less open to bias than other types of contingent valuation elicitation approaches. They do not however provide the same level of information to the analyst as the alternatives, and it is for this reason that they are not used. Dichotomous choice questions only indicate whether willingness to pay is higher or lower than the amount presented in the question, much the same as the stated preference questions. Dichotomous choice does not therefore indicate maximum willingness to pay (as the other contingent valuation approaches do).

A general concern with contingent valuation methods, and stated preference methods for that matter, is the hypothetical nature of the questions. Unlike real choices there is no obligation on the respondent to purchase the good. This can lead to study estimates of willingness to pay that exceed real willingness to pay. This is known as hypothetical bias. Meta-analysis by List and Gallet (2001) and a review by Harrison (2006) suggest that this overestimation occurs quite frequently. Two basic approaches have evolved to address the bias: these are known as 'cheap talk' and 'certainty'. In the cheap talk approach respondents are read a script advising them of the potential biases that may occur. In the certainty approach a simple follow-up question is asked regarding how certain a respondent is that they would purchase the good at the price quoted – once they have expressed either their choice (in a stated preference question) or expressed their willingness to pay. Blumenshein *et al.* (2008) suggest that the certainty approach removes hypothetical bias, but that the cheap talk approach does not. Both methods are still quite experimental and represent ongoing research areas. Given that the main focus of the work is on the use of stated choice methods in a little researched area, rather than the enhancement of the stated choice methods *per se*, neither approach was adopted on grounds of complexity. Hypothetical bias may therefore be present in the results. To ensure that hypothetical bias is minimised survey enumerators are briefed to impress on respondents that extra council tax is a household expense, additional to existing household expenditure and would not be accompanied by a corresponding increase in income (e.g. pensions). The effect of hypothetical bias on estimates derived in this study represents an area for future research'.

Contingent valuation question framing

For the fixed link and local ferry contingent valuation questions the scenarios were presented to respondents in the form of a card, that had exactly the same design as the stated preference questions (see Figure 4.10). The value of time question was only asked orally. No card was given to support the value of time question, due to the relatively simple nature of the scenario considered compared to the local ferry and fixed link scenarios. The precise wording of the three contingent valuation questions is set out below.

LOCAL FERRY CONTINGENT VALUATION QUESTION

> *I would now like to find out what the maximum amount YOUR HOUSEHOLD would be willing-to-pay in ADDITIONAL council tax if this island had a ferry linking it to Harris and that ferry service was improved.*
> *If the island had a free ferry operating for 12 hrs (from 7am to 7pm) at a half hourly frequency, but through additional council tax contributions the service could be extended to 24 hrs. However to extend the hours of the ferry would require an increase in the subsidy from the council, therefore Council Tax would have to go up.*

How much more Council Tax would you be willing-to-pay for such an improvement to the ferry service?

FIXED LINK CONTINGENT VALUATION QUESTION

I would now like to find out what the maximum amount YOUR HOUSEHOLD would be willing-to-pay in ADDITIONAL council tax if this island had a free 24 hour ferry with a half hourly frequency, but through additional council tax contributions a bridge could be constructed. The increase in council tax would fund construction of the bridge.
How much more Council Tax would you be willing-to-pay to have a bridge constructed if it was to replace a free 24 hour ferry service with a half hourly frequency?

VALUE OF TIME CONTINGENT VALUATION QUESTION

The value of time contingent valuation question was set within the context of the road either side of the fixed link being upgraded to deliver between a 10 and 20 minute time saving over a return trip between the householder's island and the nearest service centre on the neighbouring island[20].

I would now like you to imagine a situation in which the road either side of the bridge had been improved at the same time that the bridge had been built. A return trip to Tarbet would have been 15 minutes quicker than it is today (i.e. 7.5 minutes quicker each way).
If such a road improvement was funded through Council Tax what would be the maximum amount YOUR HOUSEHOLD would be willing-to-pay in ADDITIONAL council tax.

Household survey background questions

The background information collected in the household survey includes household car ownership, income, composition, the number and purpose of trips made by each member of the household over the fixed link in the previous week, and whether the household had experience of living on the island without a bridge. This data was

[20] 10 minute return time saving for Eriskay and Vatersay, 15 minutes for Scalpay and 20 minutes Berneray.

collected as it was thought these characteristics would affect the valuation a household may place on the fixed link. Ideally, a travel diary as utilised by Bristow *et al.* and Crockett would have been included, however, interview time constraints precluded this. Instead only the number of trips over the fixed link in the last week by each household member and trip purpose were collected. Data on pre-fixed link behaviour was not collected as SQW, in their 2004 survey of Scalpay and Berneray residents, found that the elapsed time between construction of the link meant that many households had difficulty re-collecting pre-fixed link behaviour. The downside of not collecting travel diary information or pre-fixed link crossing trip data is that no information is available on origins, destinations and trip durations of current trips and pre-fixed link trips – a point that will be returned to when interpreting the model estimations. A question on the time saving between the ferry and the fixed link was dropped from the final questionnaire after being tested in the pilot survey. The reason for this is that it produced a wide variation in responses, and the data was not needed in the model estimation process. Aside from that the pilot survey did not identify any other issues with the formulation of the background questions.

4.4 Survey administration

Passengers were intercepted on board the Sound of Harris and Sound of Barra ferries and householders were interviewed over a three week period between April 12th 2005 and May 4th 2005. Four survey enumerators were used, two were locally based on the islands and two travelled out from the mainland. Three were briefed by myself and the fourth was briefed by one of the interviewers. Table 4.15 and Table 4.16 present a summary of the number of interviews completed, the target number of interviews and, for the inter-island ferry survey, the days of the week on which the interviews took place.

Table 4.15: Inter-Island Ferry survey schedule and returns

Route	Days surveyed	Interviews completed	Target
Sound of Barra	Wednesday, Sunday, Monday (bank holiday) (3 days)	71	-
Sound of Harris	Tuesday * 2, Saturday *2, Wednesday (5 days)	172	-
Total	4 weekdays, 4 weekend days (incl. 1 Bank Holiday Monday)	243	80

Note: All interviews undertaken between April 12th 2005 and May 4th 2005

Table 4.16: Household survey schedule and returns

Island	Interviews completed	Target
Scalpay	70	70
Berneray	33	34
Eriskay	28	33
Vatersay	18	18
Total	149	155

Note: All interviews undertaken between April 12th 2005 and May 4th 2005

The inter-island ferry received a much better completion rate than had been anticipated. Furthermore no problems were experienced during the survey. The following chapter, Chapter 5, describes the analysis of the inter-island ferry survey data and presents the surveys findings.

A target of 155 households was set for the household surveys – which is approximately half the total number of households on the islands of Berneray, Eriskay, Scalpay and Vatersay. On the basis that it would not be possible to obtain a response from all households approached, all households on the island were included in the sampling strategy. The survey enumerators were therefore issued with a local map and address list (derived from the council tax register) and proceeded door-to-door on each island. The household surveys achieved a slightly lower completion rate than was initially targeted. This was due to problems experienced on Eriskay. On Eriskay a lot of the ferry alternatives were considered unrealistic by respondents due to the presence of skerries and reefs. These sea hazards restrict the operating hours and type of vessel used for any ferry service. This has a detrimental effect on the data from Eriskay as discussed in Chapter 6 – which presents the findings of the household survey.

5 INTER-ISLAND FERRY ANALYSIS

5.1 Introduction

The focus of this chapter is scheduling costs for long duration trips which include a journey on a low frequency ferry. Scheduling costs, the costs that travel constraints place on activity schedules, are of great interest as they are additional to user benefits in a transport cost benefit analysis (see Chapter 2). If scheduling costs are found to be significant, this research has important implications for not only appraisals of enhancements to the services surveyed but also to other ferry services in Scotland.

The surveyed Sound of Harris and Sound of Barra ferry services (see Figure 1.2 and Figure 4.1 for the locations) are themselves not particularly long (1 hour and 40 minutes respectively), but the types of journeys that utilise them have long durations. The long durations arise as a consequence of the main population and service centres being distant from the ferry end points, dispersed populations in general, and high fare costs (typically £50 return for a car). *A priori* there is an expectation that scheduling costs for long duration trips will differ from local trips. This is because for long duration trips the day's activities focus around travel. Compared to local trips this leads to a larger degree of flexibility in departure time choice (i.e. lower valuations of headway/frequency) and less need for late night or early morning sailings - as the trip is timetabled for the middle of the day. For day return trips (e.g. a business trip) overly restrictive operating hours may prevent the possibility of completing the trip in a day therefore some sensitivity to opening hours is expected.

The uniqueness of the analysis presented here arises from the focus on low frequencies (long headways) and restrictive hours of operation as perceived by travellers making trips of a long duration. The Sound of Harris service in the summer has either 3 or 4 sailings a day (dependent on the day of the week) over an 11 hour day, whilst in the winter it has 2 sailings a day over a 6 hour day. That is headways of around 3 hours. The Sound of Barra service on the other hand has 5 sailings a day in the summer and 4 in the winter and operates over an 11 hour day in the summer and slightly less in the winter. That is headways are around 2.5 hours. The ferries are small. The ferry that serves the Sound of Harris (see Figure 5.1) has a capacity of 36 cars, whilst that which serves the Sound of Barra (see Figure 5.2) has a capacity of 18 cars. Total patronage on the routes in 2004 (the year before the survey) was 51,800 passengers on the Sound of Harris route and 38,700 on the Sound of Barra route. The majority of this demand occurs in the summer months. Travellers were interviewed in April and May (i.e. when the ferries were operating on the summer timetable and when patronage was picking up after the winter).

Figure 5.1: Sound of Harris ferry (the Loch Portain)

Figure 5.2: Sound of Barra ferry (the Loch Bhrusda)

A self-completion questionnaire was issued to travellers on each of the ferry services. The stated preference scenarios presented travellers with ferry services that had headways ranging from 1 hour to 4 hours and operating hours from 9am to 5pm to 24 hours. The design of the stated preference questions (SP) has been presented and discussed in the preceding chapter, Chapter 4. The survey also complements the household survey which looks at scheduling costs for local trips, the analysis of which is presented in the following chapter, Chapter 6.

This chapter is structured in the following manner. After this introductory section, the second section describes the dataset collected. The third section presents the econometric models estimated and discusses the evidence on the distribution of willingness to pay. The estimation strategy and results are presented in the fourth and fifth sections respectively, whilst the final section discusses these results in the context of cost-benefit analysis in sparse networks.

5.2 The dataset

252 inter-island ferry questionnaires were returned by respondents, of which 70% were collected from users of the Sound of Harris ferry and 30% from the Sound of Barra ferry. This places a slightly greater weight in the sample on Sound of Harris users as 2004 annual patronage data indicates a 60:40 split between the two ferry services (Reference, 2006 Table 3.25). 77% of the returned questionnaires were from the car/LGV passenger questionnaire, 16% from foot/cycling/bus ferry passenger questionnaire and 7% from HGV ferry passenger questionnaire. These ratios are consistent with annual patronage data for the Sound of Harris ferry where commercial vehicle volumes are 11% of car/LGV volumes (Grangeston Economics, 2003 Table 2.7).

The sample also reflects national evidence that men travel more than women, working age adults travel more than children and retired people and those with high incomes travel more than those with lower incomes. This is because in the sample two thirds of respondents are male, whereas women form 51% of the population in the Outer Hebrides (GROS, 2008 Table UV03). Two thirds of respondents are also between the ages of 36 and 65 years old, whilst this group only comprises 52% of adults in the

Outer Hebrides (GROS, 2008 Table UV04). The median income group[21] in the sample is £21,000 to £35,000 (gross annual household income). This is higher than the median household incomes reported in the household survey (see Chapter 6) and also implies a net (after tax) household income greater than the median for the Outer Hebrides (£13, 026)[22].

39% of those interviewed are travelling for work (employers' business), whilst 24% of respondents are on holiday. The remaining 37% are travelling for other non-work purposes. The high proportion of business traffic and the low proportion of commuting traffic (4%) are indicative of the strategic function of the ferry routes[23]. Annual patronage figures for the Sound of Harris suggest that visitor traffic (i.e. holiday traffic) forms 50% of all vehicle trips (Grangeston Economics, 2003 Table 2.13). The sample therefore under represents this segment of demand. Primarily this is a consequence of the surveys being undertaken in late April and early May when the majority of the holiday traffic occurs in the summer months. Even so, at 24% of responses holiday traffic forms a sizeable proportion of the sample and is sufficient to allow tests examining whether such traffic holds different marginal valuations from other types of traffic. The relative proportions between business and other non-work traffic (51:49) in the sample are similar to those found for the Sound of Harris (64:36) by Grangeston Economics in 2003 though the business proportion is lower. This is re-assuring as it suggests that there is no bias in the sample between business and other non-work journey purposes.

Facts that once again emphasise the strategic and long distance nature of the ferry is that almost two thirds of respondents (63%) are spending 1 or more nights away from home, and frequency of use by users is low. For example for all the holiday makers this ferry trip was the first time they had travelled on either the Sound of Barra or Sound of Harris ferry, whilst for the business travellers and the other non-work travellers just under half use the ferries less than once a month.

The majority of respondents (84%) planned their own journey, rather than having

[21] Just over 20% of respondents withheld their income.

[22] Source: 2003/4 Scottish Household Survey variable *annetinc* (MORI Scotland *et al.* 2005)

[23] Across the UK an average 13% of car traffic is business traffic and 25% is commuting traffic(DfT, 2007b Table 7). On the Skye Bridge 18% of total vehiclular traffic (including goods vehicles) is on employers business whilst just over 80% of vehicles are making non-work trips (DHC, 2007 Appendix C).

someone else plan it for them (e.g. work or a relative). This would suggest that respondents are capable of treating the stated preference elements of the questionnaire seriously. Almost all business travellers had their ticket paid for by their employer, whilst 25% of non-work travellers had their ticket paid for by someone else. This was usually the employer (for commute trips), family and friends, or the council (for concessionary travel). In the econometric analysis it is therefore important to examine whether those who do not have to pay the ferry fare themselves have a different attitude to cost.

Despite the ferries on the respective crossings having a relatively low frequency (every 3 hours) 80% of respondents were able to plan their trip around this and did not experience inconvenience in making their trip. A reflection of this is that only 11% of respondents indicate they would change the number of nights spent away from home if a more 'ideal' timetable was available[24]. This is consistent with the *a priori* view that the journey the travellers are undertaking forms the major activity of the day and there therefore exists some flexibility in departure times. A comparison might be an air trip from a mainland location to central Europe.

With eight SP questions per questionnaire and 252 returned questionnaires a potential 2,016 responses to SP scenarios exist. Data cleaning however reduces this by 382 to 1,634. Data is excluded where:

Step 1: No response to SP question. This is because the reason for the non-response cannot be determined. A valid reason for non-response would be that both ferry services offer equal value, however, as other reasons include not taking the survey seriously, these responses are excluded.

Step 2: Respondent was a minor (under 18 years old). The reason for this is that the analysis is focussed on adults.

Step 3: Respondent qualified for a concessionary fare (free travel for OAPs) and the two ferry fares in the SP scenario differed. This is because OAPs only get free ferry travel for a limited number of ferry trips. It is uncertain whether the respondent was travelling for free or had paid for their trip. This meant that only responses where the two ferries in the SP scenario differed in service quality only (no difference in ferry fare) are included in the analysis.

Step 4: Group size is equal to or more than 5 (in adult fare equivalents: under 5 yrs

[24] Poor timetabling can mean that some travellers spend less or more time (including nights away from home) at their destination than they would wish in an ideal world.

old free, other children half price). This is because such parties include organised groups such as local football teams and school trips travelling by minibus. Such groups along with organised tour parties might be expected to behave differently from adult and family groups or business traffic – the focus of the analysis. Organised tour parties were not issued with questionnaires.

Table 5.1 summarises the number of cases excluded by each of these steps.

Table 5.1: Inter-island ferry dataset cleaning

Criteria for exclusion	Number of cases excluded	Number of cases remaining
Total number of cases	---	2,016
Step 1: No response to SP question	203	---
Step 2: Respondent was a minor (under 18 years old)	16	---
Step 3: Respondent qualified for a concessionary fare (free travel for OAPs) and the two ferry fares in the SP scenario differed.	67	---
Step 4: Group size equal to or more than 5 (in adult fare equivalents: under 5 yrs old free, other children half price)	96	---
Total cases excluded	382	---
Total cases remaining	---	1,634

Note: coach tour parties and pre-paid excursions are excluded from survey at outset.

Analysis of the SP responses indicates that 9 respondents (of the 252) choose the same ferry option in all 8 scenarios (e.g. Ferry A), whilst a further 10 choose the cheapest option (i.e. the lowest quality ferry) in each scenario and another 6 choose the most expensive option in each scenario (i.e. the highest quality ferry). The responses from these 'non-traders' (comprising 10% of the sample) are included in the model estimation. This is because they could be perfectly valid responses, albeit those who choose the same ferry option have not provided fully consistent responses between SP scenarios. Respondents are also included in the model estimation when the ticket price paid is significantly different from the prices faced in the SP scenarios and when better ferry times would mean a change in the number of nights spent away from home.

To ensure that these respondents do not bias the model estimation process the models are firstly estimated including and excluding non-traders, and model structures that allow these respondents to hold different marginal utilities from other respondents are examined.

Table 5.2 gives further reassurance regarding the success of the survey, in that there is generally a good spread of respondents choosing either Ferry A or Ferry B in the stated preference (SP) scenarios. Neither ferry dominated the responses. This is good as it suggests that the design was successful in allowing people to trade between the lower cost alternative (usually Ferry A) and the alternative with the better service quality but higher cost (usually Ferry B). By comparing Table 5.2(a) and Table 5.2(b) it can also be seen that respondents travelling during the course of work typically prefer the ferry alternative with the better quality (and higher fare) than non-work travellers. This is expected as business travellers typically have higher marginal valuations of time and headway.

Table 5.2: Responses to stated preference questions

(a) By those travelling in the course of work

SP Question	Percentage of respondents choosing		Percentage of returned questionnaires where question was not answered
	Ferry A	Ferry B	
Qu. 1	36%	64%	4%
Qu. 2	30%	70%	9%
Qu. 3	65%	35%	9%
Qu. 4	52%	48%	6%
Qu. 5	56%	44%	9%
Qu. 6	30%	70%	9%
Qu. 7	70%	30%	9%
Qu. 8	50%	50%	11%
Qu. 9	27%	73%	2%
Qu. 10	25%	75%	2%
Qu. 11	40%	60%	4%
Qu. 12	52%	48%	4%
Qu. 13	12%	88%	4%
Qu. 14	16%	84%	6%
Qu. 15	60%	40%	4%
Qu. 16	44%	56%	4%
Average	**41%**	**59%**	**6%**

Shaded cell identifies cheapest ferry option

(b) By those travelling for non-work purposes

SP Question	Percentage of respondents choosing		Percentage of returned questionnaires where question was not answered
	Ferry A	Ferry B	
Qu. 1	27%	73%	9%
Qu. 2	45%	55%	10%
Qu. 3	64%	36%	9%
Qu. 4	66%	34%	13%
Qu. 5	45%	55%	13%
Qu. 6	25%	75%	13%
Qu. 7	75%	25%	12%
Qu. 8	43%	57%	12%
Qu. 9	32%	68%	13%
Qu. 10	22%	78%	18%
Qu. 11	77%	23%	14%
Qu. 12	81%	19%	17%
Qu. 13	23%	77%	14%
Qu. 14	7%	93%	14%
Qu. 15	90%	10%	14%
Qu. 16	82%	18%	20%
Average	**50%**	**50%**	**13%**

Shaded cell identifies cheapest ferry option

5.3 The econometric model and the distribution of willingness to pay

Discrete choice models based in random utility theory are the dominant model form used to explain travel choices within the transport economic literature. Following Train (2003 Chapters 3 and 6), Hensher and Greene (2003) and Cirillo and Axhausen (2006) the properties of these models with reference to their application to these data are briefly recalled.

Within random utility models the utility (U_{qi}) derived by an individual q from travel alternative i comprises of an observed component V_{qi} and an unobserved term ε_{qi} as follows:

$$U_{qi} = V_{qi} + \varepsilon_{qi} \qquad (5.1)$$

where $V_{qi} = \Omega_q x_{qi}$

and x_{qi} are observable variables that characterise the individual q and alternative i, whilst Ω_q is a vector of parameters relating these variables for individual q.

A central tenet of the random utility model is that the probability of an individual q choosing alternative i from j alternatives is equal to the probability that utility i is greater than that of the alternatives j (as in equation 5.2):

$$P_{qi} = \Pr ob((V_{qi} + \varepsilon_{qi}) > (V_{qj} + \varepsilon_{qj})) \text{ for all } j,\ j \neq i \tag{5.2}$$

By assuming that ε_{qi} is independently and identically distributed (IID) with a type I extreme value (Weibull) distribution the probability P_{qi} that individual q will choose alternative i from j alternatives is:

$$P_{qi} = \frac{e^{V_{qi}}}{\sum_j e^{V_{qj}}} \tag{5.3}$$

This is the choice probability of the multinomial logit (MNL) model. For the present context a number of attributes of the data give rise to three limitations to this model form:

(i) As each respondent answers eight different SP questions, the unobserved elements of each respondents utility (i.e. the ε_{qi}) are correlated. This is known as the problem of repeated choices and violates the MNL condition of independence between cases. Correlations in ε_{qi} between cases bias the standard errors of the coefficients downwards in an MNL, giving a false impression of the significance of the estimated parameters.

(ii) Different respondents hold different marginal utilities for the attributes. Such taste variation can, in an MNL model, only be represented in a deterministic manner. An MNL model can for example reflect differences in the mean marginal utilities of different attributes by socio-economic category, but not the distribution of those marginal utilities.

(iii) The data derives from three questionnaire types (car/LGV, foot and HGV) and as a consequence it is possible that the error variance in each of the datasets (ε_{qi}) will have a different scale. For a joint estimation using all the datasets this violates the

MNL condition of homoscedasticity (identical variance) in all ε_{qi}.

A mixed logit (MXL) model resolves the first two of the identified problems associated with repeated choices and taste variation (Train, 2003 Chapter 6). Mixed logit models of course bring their own challenges, as will be discussed below. The innovation of the MXL model is that the observed component of utility V_{qi} (in equation 5.1) is assumed to have a distribution as expressed in equation 5.4.

$$U_{qi} = V_{qi}(\Omega) + \varepsilon_{qi} \qquad (5.4)$$

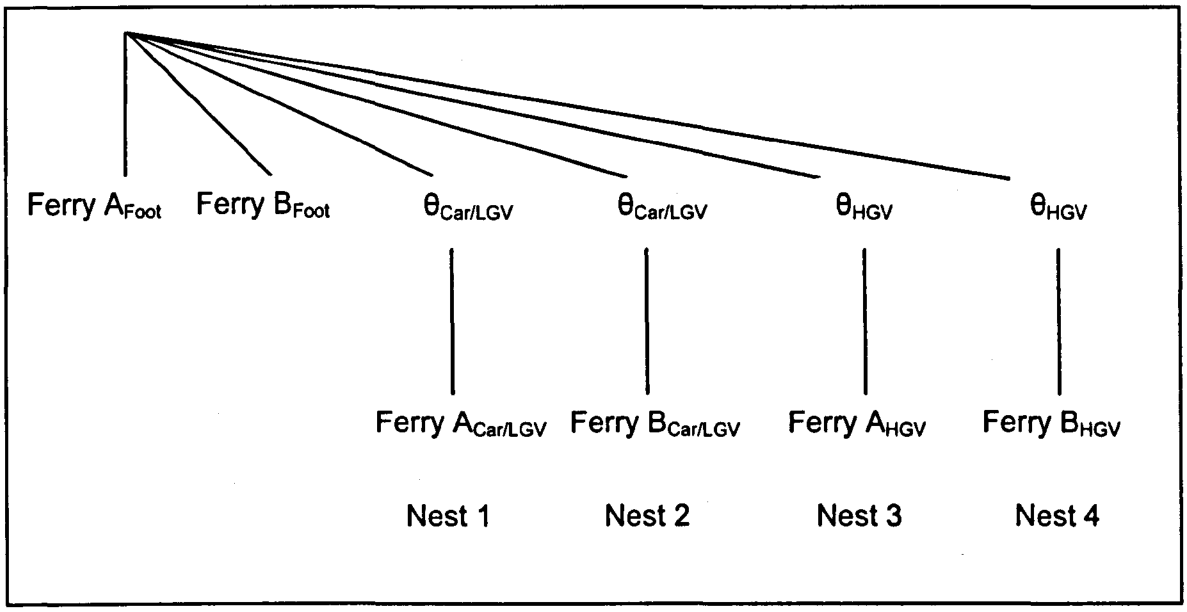
where $V_{qi}(\Omega) = \Omega'_q \, x_{qi}$

and the Ω'_q parameters vary over individuals with density $m(\Omega)$.

The third problem of merging data with different error variances (i.e. hetroskedastic data) in a joint estimation can be resolved by using a nested logit model structure but with single alternative nests (Bradley and Daly, 1997). This 'trick' uses the estimated nest coefficient (θ) to scale utility (i.e. the coefficients and ε_{qi}) to a common base. For the joint estimation of data from multiple questionnaire types, a base questionnaire is therefore chosen and each alternative from the other questionnaires is given its own nest. The nest coefficient (θ) is common to each alternative from the same questionnaire. For the present context this means that respondents to each of the three questionnaires (car/LGV, foot and HGV) choosing between the alternatives Ferry A and Ferry B, gives four lower nests and two nest scaling coefficients ($\theta_{Car/LGV}$ and θ_{HGV}) (see Figure 5.3).

The MXL can approximate any random utility model including the nested logit (Train, 2003 Chapter 6). The Bradley and Daly (1997) scaling 'trick' to merge different datasets can therefore be employed in a MXL model. To approximate a nested logit the error components interpretation of the MXL model is adopted. In the context of the application of the Bradley and Daly trick to this study a dummy variable for each of the four 'nested' alternatives is introduced to the estimation. Within the MXL estimation each nest dummy variable is treated as random with a normal distribution of mean zero and a standard deviation σ_n (where n is the nest). For alternatives deriving from the same questionnaire σ_n is forced to be equal during the estimation. In this application therefore $\sigma_1 = \sigma_2$ and $\sigma_3 = \sigma_4$.

Figure 5.3: Model structure for the merging of data from the foot, car/LGV, and HGV questionnaires



Within such a MXL model σ_n is the 'scale' parameter. This scale parameter is not directly comparable with the Bradley and Daly scale parameter (θ). To reconcile the two[25], following Batley, Toner and Knight (2004), the relationships developed by Ben-Akiva and Lerman (1985 pp.289-290) between correlation between alternatives within a nest and the nest coefficient can be utilised[26]. The relationship is:

$$\theta = \sqrt{1 - Corr(U_{qi}, U_{qj})} \tag{5.5}$$

where $Corr(U_{qi}, U_{qj})$ is the correlation between the utility U for individual q of any two alternatives i and j in nest n and is given by:

25 It is desirable to reconcile the MXL scale factor (σ_n) and the Bradley and Daly scale factor (θ) as the Bradley and Daly scale factor is much easier to interpret. If θ is unity there is no scale difference between the different datasets.

26 It should be noted that within this application no statistical or economic meaning should be attached to the correlation term in the Ben-Akiva and Lerman relationship. This is because correlation between alternatives within a single alternative nest is nonsensical. In this application the Ben-Akiva and Lerman relationship is just the medium through which the MXL scale factor (σ_n) and the Bradley and Daly scale factor (θ) can be compared.

$$Corr(U_{qi}, U_{qj}) = \frac{\sigma_n^2}{\sigma_n^2 + \pi^2/6} \qquad (5.6)$$

The final requirement for the employment of the Bradley and Daly trick in a MXL model is to identify the dataset with the lowest IID extreme error variance. This is because the MXL scale factor (σ_n) can only scale error variance downwards. The dataset with the lowest error variance forms the 'base' with the alternatives from the other datasets forming the nests.

In estimating a MXL model there is a tremendous scope for interpretation by the analyst. The analyst has to choose the number of parameters that are allowed to have taste variation, the distributions assumed for these parameters and choose a preferred model from the several estimated. Whilst the analyst can systematically vary the model structure to test for taste variation on different parameters and which parameters have the most explanatory power, the lack of overall measures of goodness of fit for mixed logit models (Hess, Bierlaire and Polak, 2005; Hollander, 2006) make choosing the distribution function for taste variation difficult.

The use of easily tractable distributions, such as the normal, can lead to significant proportions of the population being attributed a marginal utility with a counter-intuitive sign (e.g. positive for travel time). The normal distribution is also one of a class of distributions that are unbounded. That is, there is no limit to the size of the marginal utility of the attribute for which taste variation is to be estimated. Such properties are not particularly desirable in a model both from a theoretical and a practical perspective. For example, micro-economic theory indicates that travel time has a zero or negative marginal utility as it is either a leisure activity or an intermediate activity (for non-work travellers) and is as productive, or less productive, than normal work time (for business travellers). Hess, Bierlaire and Polak (2005) therefore strongly argue that negative marginal values of travel time are inconsistent with theory and primarily arise through model mis-specification. This mis-specification may of course result from a lack of explanatory power in the data. For example it may be difficult to separate out positive travel-experience attributes from that of travel time when the two are highly correlated. Unbounded distributions can also give rise to very large estimates of average marginal values. For example Cirillo and Axhausen (2006) find that a log-normal distribution (which is bounded at zero but unbounded in the positive tail) gives a mean between 5 and 6 times the size of the median value for travel time savings. Such a large discrepancy is problematic in a practical sense and also raises the question as to whether the nature of the distribution assumed can lead to mis-leading results – something Hess, Bierlaire and Polak (2005) argue it can.

The assertion that travel time cannot have a positive marginal utility, in the short term, has been challenged by Cirillo and Axhausen (2006). In the long term they argue that the time constraint will always bind and long run marginal utilities of travel time will be negative. In the short term the time constraint is unlikely to bind. This is because activity schedules are not optimised and "there is a large amount of buffer time and spontaneous activity performance in many persons' days" (Cirillo and Axhausen, 2006 p.445). This would suggest at the minimum that a large number of people may have a zero marginal utility of travel time. Positive marginal utilities could also occur in the short term if a traveller wished to extend their journey because they "enjoyed the conversation with the passenger, liked cycling in the sun, dreaded the activity waiting at the end of the walk" (Cirillo and Axhausen, 2006 p.445) or had a bad day at the office and needed more journey time to 'unwind'. Strictly speaking this is a confounding of the travel experience attribute with the travel time attribute. However, in these instances the travel experience attribute is unobserved and positive utilities for the time attribute can result from the model estimation.

These arguments illustrate that the choice of the distribution function is not simple, nor with the potential presence of mass points at zero will it naturally coincide with a relatively easy to estimate classic distribution function such as the normal, log-normal, uniform or triangular. A mass point in this context can be thought of as an inflated probability of zero. Furthermore if fitting such a distribution function to a dataset, with say a mass point at zero, standard measures of overall model fit – such as maximum likelihood value – are not necessarily good indicators with which to choose between different model forms (Hess, Bierlaire and Polak, 2005; Hollander, 2006). Choice of model form therefore needs to be supported by a careful argument supporting the theoretical and behavioural rationale for the distribution function used. Endogenous to the problem of choosing the distribution function and choosing between model forms is the choice as to which attributes to assign taste variation to. The identification of parameters exhibiting taste variation is an empirical matter, but the endogeneity of the problem means it is also dependent on the choice of model form and the choice of the distribution function. At the limit model identification issues can also imply restrictions on the number of parameters that can be specified as random. A comprehensive analysis of potential model variants is therefore also needed to support the choice of the preferred MXL model.

In the present context respondents make choices between two ferry services based on differences in three attributes fare, headway and operating hours. From a theoretical perspective any distribution for the marginal utility of cost is expected to give a distribution function that is always negative. A model that has positive marginal utilities of cost would imply that all else being equal respondents would always choose the high cost alternative despite the same service being available at a lower cost. This is implausible for rational acting economic agents as the difference in fare between the high and low cost alternatives represents an income loss if the high cost alternative is chosen. From theory therefore the maximum value that the cost parameter can take is zero.

A similar argument can be extended to the attributes headway and operating hours. The shorter the ferry headways are and the longer the operating day is the more flexibility there is for travellers to arrange activities in a manner that increases utility. The attributes headway and operating hours, however, differ from the cost attribute in two ways. Firstly there is very probably a large body of travellers for whom changes in headway or operating hours make little or no impact on their activity schedule due to for example the existence of buffer time. Indirect evidence for the existence of this body of travellers in the survey sample can be found by analysing the response to ideal departure times. 80% of travellers indicated that ferry departure times on the outward and return legs are 'ideal'. Given the low headways (around 3 hours) and restricted operating hours of the services, it seems unlikely that for 80% of respondents ferry departure times happen to coincide with the travellers' first choice departure time. Instead it is more likely that the ferry departure time does not inconvenience the travellers, as they either have flexible activity schedules or have a significant amount of buffer time between activities – both of which are quite plausible within the context of a long distance trip. The existence of such a group of travellers implies a mass point at or close to zero in the distribution function for the marginal utilities of headway and operating hours.

Secondly, improvements in headway and operating hours may combine in such a way as to make the ferry departure time less convenient. This could mean that for some travellers a counter-intuitive positive utility is associated with an increase in headway or a reduction in operating hours. That is the distribution function would include both positive and negative elements. Deriving positive utility from a reduction in headway or operating hours may seem counter-intuitive but can be easily illustrated with an example. A headway of four hours on a 12 hour operating day (from 7am to 7pm) would give morning departures for the Sound of Harris ferry from Leverburgh at 7am and 11am. The 11am departure would fit perfectly with leaving Stornoway (the main town on the Isle of Lewis) by car at 9am. Without introducing a second boat a reduction in headway to three hours would mean that the ferry would leave Leverburgh at 10am, requiring the traveller to leave Stornoway at the less desirable time of 8am. Alternatively the traveller could try and fill their time at the office or at home and leave Stornoway at 11am to catch the next ferry at 1pm. This could be even more inconvenient. It is therefore possible that increases in frequency (and a lengthening of operating hours) will, for some trips, combine in such a manner that the resulting ferry timetable is less convenient. The proportion of users that this situation is expected to apply to is felt to be low for the reasons outlined in the previous paragraph.

The SP design allows a deeper analysis to be undertaken on the distribution of the willingness to pay. In the SP design there are four questions in which respondents are faced with a choice between ferries with the same operating hours but different headways and fares. Similarly, there are four questions where headways are common between the services but operating hours and fares differ. These eight SP questions therefore provide four fixed boundary values for the headway and operating hours attributes. Analysing the response to each question in turn allows the proportion of the sample with a marginal value of headway (or operating hours) above or below the boundary value to be identified. This is a form of 'bin' analysis (Fowkes, 2000). If the respondent chooses the cheapest ferry their marginal value of headway (or operating hours) lies below the boundary value, whilst if they choose the more expensive option it is equal to or above the boundary value.

Table 5.3(a) and (b) present this analysis. These tables indicate the median value of headway lies between 2.78p and 8.3p per minute, whilst the median value of operating hours lies between 8.3p and 41.7p per hour closed (for respondents to the car/LGV questionnaire). A significant proportion of respondents have values of headway (26%) and operating hours (44%) below the lowest boundary value[27]. These proportions imply the existence of a large mass point at or close to zero, or a reasonable sized proportion of respondents holding a positive utility to a worsening in headway and

[27] The exclusion of those who always choose the cheapest ferry service, the most expensive service, ferry service 1 or ferry service 2 from this analysis does not alter these proportions by more than 2 percentage points.

hours closed. As discussed earlier 80% of respondents who indicate that existing ferry times are ideal is taken to imply that they are not inconvenienced by the existing ferry timetable, rather than implying any change in the existing timetable would have a negative impact on them. The large percentage of the willingness to pay distribution below the lowest boundary value is therefore felt to arise principally through the existence of a large number of values at or close to zero, though it is expected that for a small proportion of the sample for whom a change in departure time will cause inconvenience negative willingness to pay will also exist.

Table 5.3: Distribution of willingness to pay for changes in headway and operating hours (boundary value bin analysis for cars/van)

(a) Headway

Bin for marginal value of headway (H) (p/min)	Proportion of sample	Cumulative frequency
H<0.56	26%	26%
0.56≤H<1.82	3%	29%
1.82≤H<2.78	6%	35%
2.78≤H<8.30	38%	73%
8.30≤H	27%	100%

Notes: Shaded row indicates bin holding the median value

(b) Operating hours

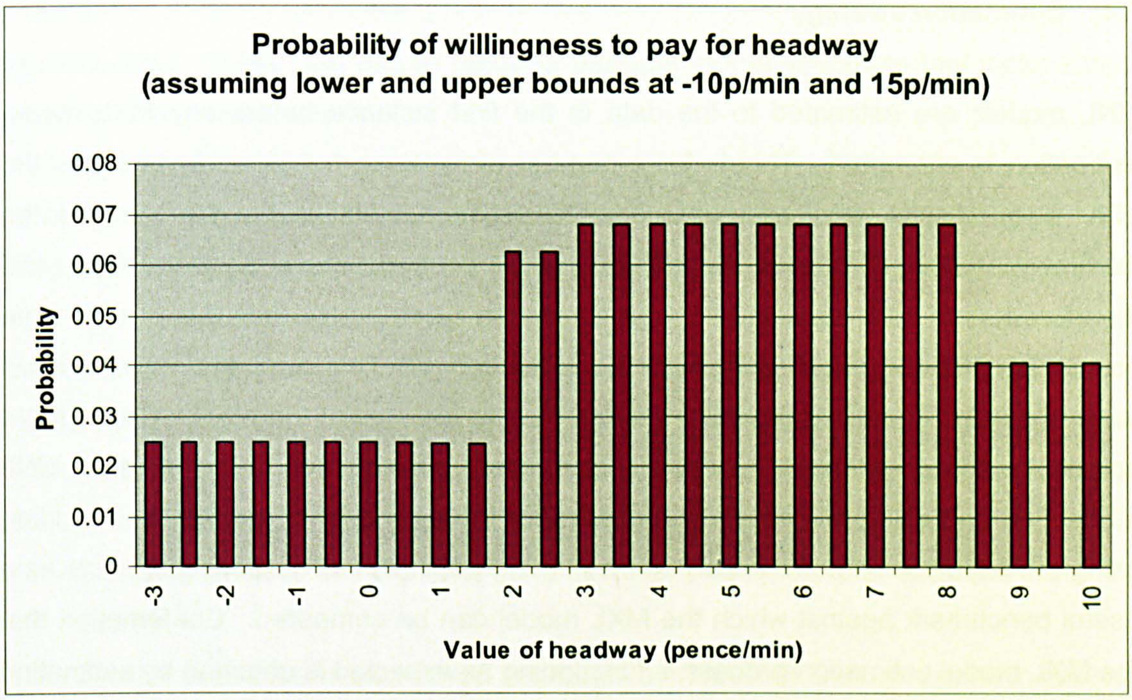
Bin for marginal value of operating hours (OH) (p/hour)	Proportion of sample	Cumulative frequency
OH< 8.3	44%	44%
8.3≤OH< 41.7	17%	60%
41.7≤OH<137.5	3%	64%
137.5≤OH<214.3	26%	90%
214.3≤OH	10%	100%

Notes: Shaded row indicates bin holding the median value

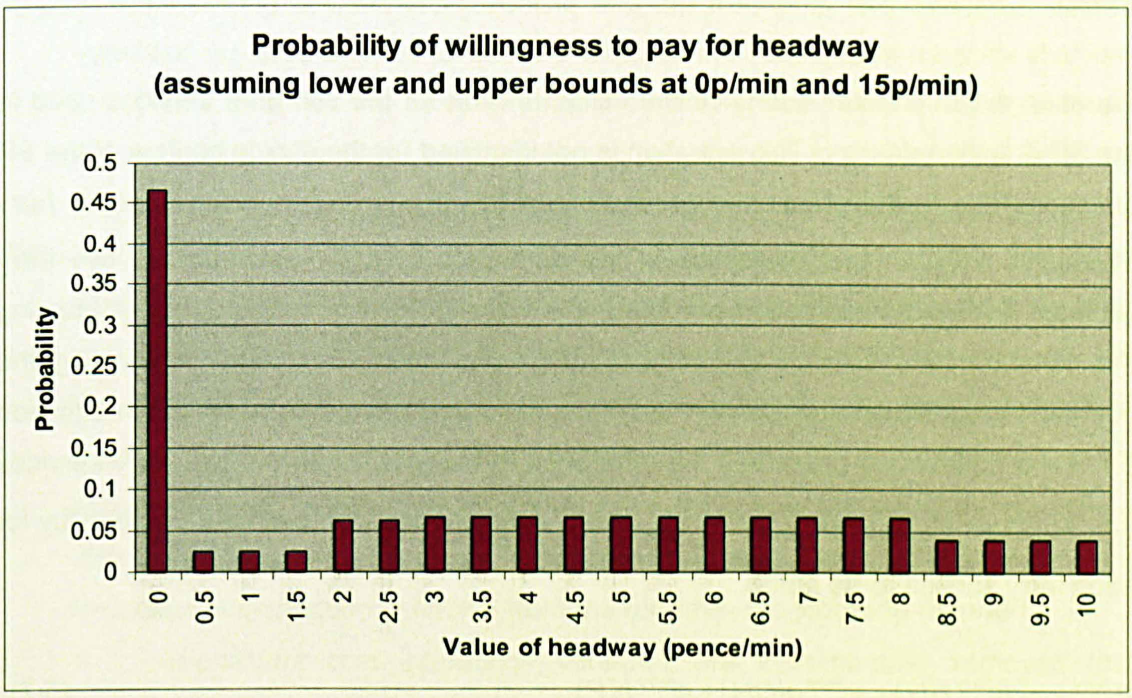
Unfortunately it is not possible with the evidence available to state categorically the proportion of the distribution that has a negative willingness to pay for an improvement in operating hours and headway and the proportion that has a zero willingness to pay. The existence and relative size of these two categories of traveller is important to the shape of the willingness to pay distribution, as illustrated in Figure 5.4(a) and (b) for headway. In Figure 5.4(a) the 25% of the distribution that lies below the lowest boundary value (0.56p/min) has been distributed uniformly between 0.56p/min and -10p/min). The overall distribution looks well behaved and can therefore be approximated by a symmetrical or asymmetrical distribution based on say the triangular

Figure 5.4: Probability distribution function of willingness to pay for headway (boundary value bin analysis for cars/van)

(a) Assuming distribution bounded at -10p/min and 15p/min



(b) Assuming distribution bounded at 0p/min and 15p/min



or normal distributions. This contrasts with the distribution illustrated in Figure 5.4(b) which is bounded at zero. Here a large spike encompassing 25% of the observations exists at or close to zero. Clearly potential distributions for the survey data intermediate to those illustrated in Figure 5.4(a) and (b) could also exist.

5.4 Estimation strategy

MNL models are estimated to the data in the first instance before any MXL model estimation is attempted. This is for a number of reasons, but primarily because the MXL is a complex and onerous model to estimate. Unlike the MNL model the maximum likelihood function for a MXL model does not have a closed form and therefore has to be maximised through simulation. Computationally this is more time consuming than the direct estimation of an MNL model. This combined with the need to examine the impact of different distribution functions make the MXL an even more complex model to estimate. Most authors therefore recommend estimating an MNL model first and using this as a starting point for the estimation of the MXL – including using the MNL parameter estimates as a starting point. An MNL model also acts as a useful benchmark against which the MXL model can be compared. Confirmation that the MXL model estimation process is functioning as expected is obtained by estimating an MXL model with all parameters fixed (i.e. non-random) and comparing it to an MNL model.

Equation 4.1 in chapter 4 defines the utility function for the two ferry services used in the SP question design. This equation is not identified for the choice context of the SP questions due to the presence of the constant α_k in the utility function of each ferry alternative. Given the interest is in the difference in utility between the two ferry services, for model estimation purposes this equation can be adjusted by subtracting the constant from both utility functions to give an identified model. Following the notation introduced in equation 5.1 the identified model has the form set out in equation 5.7. The adjustment preserves the difference in utility between the two ferry services (i.e. $U^{ferry}_{q,ferry2} - U^{ferry}_{q,ferry2} = V^{ferry}_{q,ferry2} - V^{ferry}_{q,ferry2}$) but does not allow an estimate of the utility for each ferry service to be made.

$$V^{ferry}_{q,ferry1} = \beta^{ferry}_k f(H) + \chi^{ferry}_k g(OH) + \phi^{ferry}_k h(P) \qquad (5.7)$$

$$V^{ferry}_{q,ferry2} = \beta^{ferry}_k f(H) + \chi^{ferry}_k g(OH) + \phi^{ferry}_k h(P)$$

where:

$$U^{ferry}_{q,ferry1} = \alpha_k + V^{ferry}_{q,ferry1} + \varepsilon_{q,ferry1} \qquad (5.8)$$

$$U^{ferry}_{q,ferry2} = \alpha_k + V^{ferry}_{q,ferry2} + \varepsilon_{q,ferry2}$$

A number of different functional forms for headway $f(H)$ and operating hours $g(H)$ can be envisaged. These give rise to range of possible model structures that include both linear and non-linear models.

As reasoned above MNL models are estimated before estimating MXL models. The first MNL models to be estimated are linear in headway and operating hours and do not include any fixed effects associated with socio-economic groups. Models that examine variations in willingness to pay by socio-economic group and non-linearities in willingness to pay form the second group of models estimated. The model estimation for these fixed effect and non-linear models is slightly more complex and the following strategy is adopted:

(i) Cases that meet the exclusion criteria (see Table 5.1) are excluded from the dataset;

(ii) Dummy variables for population segments by household income, gender, journey purpose, travelling in a group, economic status (retired or of working age), whether driving a commercial vehicle and trip frequency are defined. Dummy variables are also defined to capture whether the respondent pays for the ferry ticket or is refunded the cost, whether the ticket prices in the questionnaire are similar to the ferry ticket purchased and whether an improved ferry timetable would result in spending less nights or more nights away from home;

(iii) A model that includes all interaction terms between the headway and hours closed variables with the socio-economic and trip specific dummy variables is set out. The model also included all interaction terms between the cost variable and the dummy variables representing: income segments, who paid for the ferry ticket, how representative the ferry ticket prices in the SP scenarios were to the respondent and whether an improved ferry service would result in spending a different number of nights away from home. The model was refined by removing insignificant interaction variables from the model in the following manner:

- Insignificant cost interaction variables are incrementally removed first; followed by
- The most insignificant of the remaining frequency, gender, group size, retired status and journey purpose interaction variables; until

- All remaining estimated coefficients are statistically significant.

A set of MXL models are also estimated using the best performing MNL model as a starting point. Various MXL models are estimated using different distribution functions for the random parameters.

ALOGIT version 4.2 (ALOGIT, 2008) was used to estimate the MNL models. ALOGIT is relatively easy to use and is more than adequate for the estimation of MNL models. ALOGIT cannot be used to estimate MXL models or correct for the bias associated with panel data[28]. For the estimation of the MXL models the GAUSS code made available by Kenneth Train on his website is used (Train, 2006). This is an easy to use well tested and documented utility. A restriction with using Train's code is that only a limited number of distribution functions for the random parameters are available. These are the normal, triangular, uniform and the log-normal. Alternatives to both ALOGIT and Train's code would have been to use Biogeme (Bierlaire, 2008) or to develop bespoke Gauss code. As the main purpose of this section of the thesis is to examine whether scheduling costs and the risk premium are significant in sparse networks rather than develop discrete choice modelling methods *per se* the ease of use and industry standard nature of ALOGIT and Train's code were felt to offset any restrictions inherent in their application.

5.5 Estimation results

Table 5.4 presents a set of linear models with no fixed effects. Multinomial logit models IF-MNL1, 3 and 4 are estimated on the data from each of the three questionnaires individually (car/LGV, foot and HGV). IF-MNL5 to IF-MNL7 are estimated on data merged from all three questionnaires. Models IF-MNL1 and IF-MNL2, and models IF-MNL6 and IF-MNL7 differ only in that the data on which IF-MNL2 and IF-MNL7 have been estimated exclude non-traders who may not treat the questionnaire seriously.

A number of observations can be made from these results. All parameters bar one have the expected sign and in the main are statistically significant. The only

[28] ALOGIT includes a utility to estimate a model using the jack-knife technique. The jack-knife technique is often used to test for model mis-specification, and its employment can go someway to addressing the bias associated with treating panal data as cross-sectional data. Accounting for the correlation in panel data via a MXL model is preferred to employing the jack-knife technique as this method of estimation directly addresses the source of the bias during model estimation.

parameters that are not significant are for the small datasets (foot and HGV) and for the parameter with the wrong sign in model IF-MNL5. In model IF-MNL5 differences in the scale of error variance (hetroskedasticity) between datasets have not been allowed for and this leads to a poor performing model. By allowing for scale differences (as in models IF-MNL6 and 7) the log likelihood improves and all parameters are statistically significant and have the correct sign. The marginal values of headway and operating hours are also statistically significant and of the correct sign where the parameters are well estimated (i.e. for models IF-MNL1, 2, 6 and 7).

The level of model fit as given by the Rho-squared value is not particularly good. There is therefore a substantial amount of unexplained variation in the data. The exclusion of respondents who might not be taking the questionnaire seriously reduces the unexplained variation in the data giving higher rho-squared values for models IF-MNL2 and IF-MNL7 compared to models IF-MNL1 and IF-MNL6. It also lowers the marginal values of headway and operating hours slightly. In the main though, the inclusion or exclusion of these data has limited effect on the model. On the basis that these data may potentially be valid the remaining analysis is conducted with them included. The estimated models indicate that, for the car/LGV dataset (model IF-MNL1), the marginal values 7p/minute (headway) and 50p/hour closed (operating hours) are consistent with but at the upper end of the range in which the anticipated median value was expected to lie (see Table 5.3(a) and (b)). 95% confidence intervals for these values are +/-18% for headway and +/-34% for operating hours (model IF-MNL1).

Marginal values for those travelling by foot are lower than for those travelling by car/LGV. For those travelling by HGV the marginal values for headway are higher than the car/LGV values, but for operating hours are lower. Possibly restrictions on HGV driver hours means long ferry operating hours have little value to the drivers surveyed. It should however be noted that due to the low level of significance of the parameter estimates the HGV marginal values cannot statistically be relied on.

By pooling the data in a joint estimation (as in models IF-MNL6 and 7) the HGV and foot data can be utilised in a statistically robust framework. This provides more information on the willingness to pay of the sample. Looking at model IF-MNL6 the average willingness to pay of the sample for changes in headway is 7.2p/min (slightly higher than the car/LGV value) and for changes in operating hours is 40.9p/hour closed (lower than the car/LGV value). The nest coefficients in models IF-MNL5 to IF-MNL7

Table 5.4: Estimation results for linear models with no fixed effects

Model		IF-MNL1	IF-MNL2	IF-MNL3	IF-MNL4	IF-MNL5	IF-MNL6	IF-MNL7
Model type		Multinomial logit	Multinomial logit	Multinomial logit	Multinomial logit	Multinomial logit	Multinomial logit	Multinomial logit
Data		Car/LGV	Car/LGV	Foot	HGV	Foot and Car/LGV	Foot, Car/LGV and HGV	Foot, Car/LGV and HGV
Non-traders included		Yes	No	Yes	Yes	Yes	Yes	No
Attributes	Cost	-0.00094 (-9.0)	-0.00108 (-9.6)	-0.00497 (-4.2)	-0.00010 (-1.5)	-0.00028 -5.0	-0.00048 (-2.4)	-0.00073 (-3.0)
	Headway	-0.00658 (-9.3)	-0.00702 (-9.3)	-0.00692 (-4.3)	-0.00307 (-1.3)	-0.00377 -7.2	-0.00343 (-2.5)	-0.00476 (-3.2)
	Operating hours	-0.04695 (-4.1)	-0.04588 (-3.8)	-0.04361 (-1.7)	-0.00204 (-0.1)	0.00925 1.2	-0.01953 (-2.5)	-0.02477 (-2.7)
Nest coefficient	Car/LGV						1.85 (2.2)	0.15 (1.7)
	HGV						0.20 (1.6)	1.41 (2.8)
Sample mean marginal values	Headway (p/min)	7.0 (10.8)	6.5 (11.3)	1.4 (5.1)	29.4 (1.5)	13.7 (5.4)	7.2 (10.5)	6.5 (10.8)
	Operating hours (p/hour closed)	50.0 (5.7)	42.4 (5.1)	8.8 (2.3)	19.5 (0.1)	-33.5 (1.0)	40.9 (3.8)	33.9 (3.6)
Observations		1273	1137	253	108	1634	1634	1450
Log Likelihood		-810.42	-706.06	-158.65	-71.72	-1079.59	-1055.13	-914.89
Rho-squared wrt constants		0.073	0.099	0.088	0.042	0.038	0.060	0.083

Note: T-statistics in parentheses. Significant at 99% level if the t-statistic>2.33; at the 95% level if the t-statistic>1.96 and at the 90% level if the t-statistic>1.65. Estimated using ALOGIT v4.2. T-statistics for marginal values calculated following Hess and Daly (2008).

act as scaling parameters, scaling the variance of the error term in the different datasets. A coefficient value of one means that the error variance in the upper and lower nest is equivalent, and there is no need to employ the NL trick to merge datasets. For the moment the nests with coefficients that are not significantly different from one are maintained in the model. This issue is returned to later.

The aim of introducing fixed effects into the models is to reduce the unexplained variation evident. Non-linear model structures are also examined with the same purpose. Table 5.5 presents summary statistics for five further model structures that include fixed effects. The fixed effects examined are household income, gender, journey purpose, travelling in a group, economic status (retired or of working age), travelling on foot/bicycle, driving a commercial vehicle, trip frequency whether the respondent pays for the ferry ticket or is refunded the cost, whether the ticket prices in the questionnaire are similar to the ferry ticket purchased and whether an improved ferry timetable would result in spending less nights or more nights away from home. Table 5.5 shows that whilst the model fit improves (rho-squared is 0.14 and below) there still remains a substantial amount of unexplained variation. The best performing model in terms of log-likelihood and rho-squared is IF-MNL11. This is a piecewise model as the functions $f(H)$ and $g(OH)$ are defined differently depending on the values taken by H and OH. In IF-MNL11 the car/LGV and HGV nest coefficients are all significantly different from 1.0. This contrasts with model IF-MNL6 where the car/LGV coefficient was not significantly different from 1.0. Clearly a degree of confounding occurs between the nest coefficient (scale factor) and the degree of disaggregation present within model IF-MNL6. Model IF-MNL11, the preferred model from the set of fixed effect MNL models estimated, is presented in the first column of Table 5.6. The implied valuations for changes in headway and operating hours are presented in Table 5.7. Clearly different segments of the sample hold different valuations, but taking a weighted average of these valuations (based on sample proportions)[29] gives an average marginal value for changes in headway when headways are 180 minutes or greater of 4.8p/min and a marginal value for an operating hour on an 8 hour operating day (9am to 5pm) of 50.3p/hr. There is insufficient information on the covariances between the marginal values of different population segments with which to calculate T-statistics and confidence intervals for this weighted

[29] For each model the value of headway and operating hours for each statistically significant population segment is calculated as in Table 5.7. A weighted average of these marginal valuations using the sample proportions is then calculated. This is the process of sample enumeration.

average. It is expected that the t-statistics and confidence intervals for the average marginal value and will be similar to those in Table 5.4.

Table 5.5: Summary statistics for linear and non-linear MNL models including fixed effects

Model	Functional form for Headway (H) and Operating Hours (OH) (see table notes)	No. of observations	Rho-squared	Log Likelihood
Linear				
IF-MNL8	$f(H) = H$ $g(OH) = HC$	1,634	0.105	-1005.04
Non-linear				
IF-MNL9	$f(H) = \sqrt{H}$ $g(OH) = HC^2$	1,634	0.106	-1003.77
IF-MNL10	$f(H) = Ln(H)$ $g(OH) = Ln(HC)$	1,634	0.095	-1015.90
IF-MNL11	$f(H) = 0$ if $H < \bar{x}$; $= H$ if $H \geq \bar{x}$ $g(OH) = 0$ if $HC < \bar{y}$; $= HC$ if $HC \geq \bar{y}$	1,634	0.136	-970.06

Notes: Generic utility function is set out in equation 5.7. HC is hours closed. All models include fixed effects by socio-economic group. For the piecewise model (IF-MNL11) multiple steps in headway and operating hours are specified (e.g. the vector $\bar{x} = \{60,120,180,240\}$ and $\bar{y} = \{0,7,12,16\}$), though only those that are statistically significant are retained in the final model. Estimated using ALOGIT v4.2.

As can be seen from Table 5.6 and Table 5.7 in common with many value of travel time studies (see for example Wardman, 2004) the preferred MNL model (IF-MNL11) indicates that those who have low incomes and pay for the tickets themselves have higher marginal utilities of money than others (all else being equal). This implies that these socio-economic groups have lower values of headway and operating hours than other groups. Similarly in common with other evidence in the literature those who travel on business have higher valuations than those who are travelling on non-work purposes. Groups also have higher valuations than individuals.

The interesting result that comes from this model is that inter-island ferry users making long distance trips appear to only be significantly inconvenienced if headways reach 180 minutes and operating hours are restricted to between 9am and 5pm (i.e. the ferry

Table 5.6: Fixed effects models and comparable mixed logit models with fixed (non-random) coefficients

	IF-MNL11	IF-MNL12	IF-MXL1	IF-MXL2	IF-MXL3
Model structure	Multinomial logit	Multinomial logit	Mixed logit	Mixed logit	Mixed logit
Data	Foot, car/LGV and HGV	Car/LGV	Foot, car/LGV and HGV	Foot, car/LGV and HGV	Car/LGV
Traders and non-traders	Yes	Yes	Yes	Yes	Yes
Treatment of repeated choices	Cross-sectional	Cross-sectional	Cross-sectional	Panel	Cross-sectional
Cost coefficient for all household incomes	-0.00131 (-3.1)	-0.00083 (-7.3)	-0.00140 (-4.1)	-0.00044 (-3.4)	-0.00082 (-7.1)
Increment on cost coefficient for:					
Household income over £35k	0.00079 (2.3)	0.00031 (2.2)	0.00076 (2.9)	0.00043 (2.9)	0.00031 (2.1)
Ticket paid by self	-0.00117 (-2.7)	-0.00054 (-3.7)	-0.00098 (-3.2)	-0.00098 (-5.6)	-0.00052 (-3.5)
Fare paid differs significantly from fares in SP questions	-0.00104 (-2.3)	-0.00041 (-2.4)	-0.00100 (-3.1)	-0.00064 (-2.7)	-0.00050 (-2.5)
Headways ≥ 180 minutes (all trips)	-0.00439 (-3.7)	-0.00380 (-4.1)	-0.00457 (-4.0)	-0.00362 (-3.7)	-0.00428 (-4.8)
Increment on headway coefficient for:					
Work trips	-0.00447 (-1.7)	-0.00116 (-1.3)	-0.00436 (-2.3)	-0.00081 (-0.7)	-0.00087 (-1.0)
Respondent is a woman	0.00272 (2.3)	0.00159 (2.0)	0.00265 (2.3)	0.00178 (2.0)	0.00167 (2.1)
Trips undertaken by groups	-0.00365 (-2.6)	-0.00193 (-2.3)	-0.00352 (-2.8)	-0.00173 (-1.7)	-0.00142 (-1.7)
Closed for 16 hours (all trips)	-0.06347 (-4.0)		-0.06335 (-4.0)	-0.04249 (-4.2)	
Increment on hours closed coefficient for:		-0.05059 (-4.7)			-0.05120 (-4.9)
Work trips	-0.10546 (-2.3)	-0.04740 (-3.1)	-0.10572 (-3.0)	-0.03651 (-2.3)	-0.04605 (-3.0)
Mean car/LGV nest			0.00000 (0.0)	0.00000 (0.0)	
s.d. car/LGV nest			1.70674 (3.0)	-0.41205 (-4.8)	
Mean HGV nest			0.00000 (0.0)	0.00000 (0.0)	
s.d. HGV nest			8.78066 (2.4)	0.26226 (0.7)	
Bradley and Daly scale factor for car/LGV	0.55330 (3.2)		0.60075 (n/a)	0.95207 (n/a)	
Bradley and Daly scale factor for HGV	0.15198 (2.1)		0.14453 (n/a)	0.97973 (n/a)	
Observations	1634	1273	1634	1634	1273
Log-likelihood	-970.06	-748.65	-972.00	-974.84	-748.70

Note: Scale factors for car/LGV and HGV ferry passengers in the MXL models are calculated using equations 5.5 and 5.6. T-statistics in parentheses. Parameter is significant at 99% level if the t-statistic>2.33; at the 95% level if the t-statistic>1.96 and at the 90% level if the t-statistic>1.65. T-statistics for MXL models calculated using robust standard errors. IF-MNL11 and IF-MNL12 estimated using ALOGIT v4.2. IF-MXL1 to IF-MXL3 estimated using Train's Gauss code with 500 Halton draws.

Table 5.7: Headway and operating hour marginal valuations derived from preferred fixed effects model (IF-MNL11) (pence)

		Questionnaire ticket prices reflect ticket price paid by respondent				Questionnaire ticket prices do not reflect ticket price paid by respondent				Sample Average
		Pay for self		Someone else pays		Pay for self		Someone else pays		
		Gross Hhold income to £35k	Gross Hhold income £35k +	Gross Hhold income to £35k	Gross Hhold income £35k +	Gross Hhold income to £35k	Gross Hhold income £35k +	Gross Hhold income to £35k	Gross Hhold income £35k +	
Marginal value per minute of headway (pence)										
When headways ≥ 180 mins	All trips	1.8	2.6	3.3	8.4	1.2	1.6	1.9	2.8	**4.8**
	Increment: work trips	1.8	2.6	3.4	8.6	1.3	1.6	1.9	2.9	
	Increment: women	-1.1	-1.6	-2.1	-5.2	-0.8	-1.0	-1.2	-1.7	
	Increment: groups	1.5	2.2	2.8	7.0	1.0	1.3	1.5	2.3	
Marginal value for an operating hour (pence)										
During working day (i.e. between 9am and 5pm)	Work trips	25.6	37.6	48.3	121.8	18.0	23.2	26.9	40.6	**50.3**
	Non-work trips	42.5	62.5	80.2	202.5	29.9	38.6	44.7	67.4	

Note: Sample average is a weighted average over socio-economic groups.

is unavailable for 16 hours). Ferry users do not therefore seem to value changes in headway from say a 60 minute headway to a 120 minute headway; nor do they value changes in operating hours from a 12 hour operating day to a 17 hour or 24 hr operating day. In interpreting this result it needs to be borne in mind that only existing ferry users have been interviewed. Such users may experience some inconvenience from the existing timetable but if it was highly inconvenient they would probably have chosen to fly, not to travel or to travel to a different destination. The activity patterns of the majority of the users of the ferry services are therefore expected to be able to accommodate long headways and slightly restrictive operating hours. This is also a reflection of the long distance nature of the trips involved. This self-selectivity therefore means that it is unlikely many respondents will have activity schedules requiring a 60 minute headway or a 24 hour ferry. This is borne out in the model estimated.

The preferred model only includes coefficients on variables which are significant at the 90% level or higher. Clearly there is also variation in the data that cannot be described with a sufficient degree of precision in the preferred model. For example, the piecewise estimation indicated that increasing operating hours beyond 12 hours lowers dis-utility – as one would expect. It is just that the level of dis-utility could not be estimated with sufficient precision. Possibly this is due to the low incidence in the sample of those with constrained activity patterns. It was also found that commercial vehicles had higher valuations of headway than private vehicles, and those who would alter the number of nights away from home with an improved timetable also had higher valuations – but again these variations cannot be estimated with sufficient precision. A larger sample size would have gone some way to permitting the inclusion of such variables in the final model.

As discussed previously two of the advantages of MXL models over MNL models are the ability to directly account for correlations in repeated choices during estimation and the ability to introduce taste variation. A series of MXL models are therefore estimated using the preferred MNL model as a starting point. In the first instance it is useful to demonstrate that the MXL estimation process is employed correctly by reproducing the preferred MNL model with an MXL model. Model IF-MXL1 in Table 5.6 does this by demonstrating that the model IF-MNL11 can be approximated by treating the data as cross-sectional.

By correctly treating the data as panel data (model IF-MXL2) several interesting effects occur. Firstly the Bradley and Daly scale factor for the car/LGV and HGV nests tend to

1.0 in IF-MXL2. The implication of this is that the different scales in error variance between the questionnaire datasets apparent in all the MNL models are due to correlations between responses from the same individual. Secondly there is a worsening in the log-likelihood from -972.00 (in IF-MXL1) to -974.84 (in IF-MXL2). This is counter-intuitive, as by correctly treating the data as panel data the log likelihood should improve. Between models IF-MXL1 and IF-MXL2 there also occur some slight changes in the estimated parameters. This is most marked for the cost coefficients for those who come from households with a gross income in excess of £35,000 per annum and for whom someone else pays for the ferry ticket. For this sample segment the marginal utility of cost becomes very low and the corresponding marginal values of headway and operating hours become very high. Despite this population segment forming only a small proportion of the sample the change in their marginal valuations increases the weighted average for headway and operating hours across the sample by a factor of 10 compared to that suggested by IF-MNL11. Such a large value is not only at odds with the other MNL models but most importantly is at odds with the observed distributions of willingness to pay (see Table 5.3(a) and (b)).

The latter two points, the worsening in the log likelihood and the unrealistic sample means, raise concerns about the validity of model IF-MXL2. Potentially they arise as an indicator that a MXL model estimated using the panel approach cannot correctly approximate a nested logit structure. This could occur as in a nested logit structure the errors are distributed across all observations whereas when estimating a MXL model to panel data the errors are kept constant across observations for the same respondent. This would mean that an error components model estimated using the panel approach is likely to reproduce different patterns of heteroscedasticity (i.e. different scale differences) than those obtained under the nested logit approach. The proper treatment of panel data within a MXL framework is an active topic of research at the moment (see for example Hess and Rose, 2008), and a consensus as to the best econometric approach to adopt is still being sought.

For this application it is clear there is evidence questioning the validity of model IF-MXL2. The most probable reason for this is the difficulty in treating the heteroscedasticity (different error variances) across datasets in an adequate manner while simultaneously accounting for the panel nature of the dataset. Two solutions present themselves: focusing the analysis on one dataset or using alternative software (e.g. Biogeme) that can account for scale differences within a panel estimation without having to rely on error components. The former has been chosen, that is focusing the analysis on one dataset - the car/LGV dataset. Primarily this is because it is a simple solution that meets the objectives of the study – namely the investigation of the existence of significant scheduling costs for long distance trips by ferry – and because there are valid economic reasons for excluding the HGV dataset from the analysis. The HGV dataset cannot be relied on to provide valid estimates for input into a cost benefit analysis for HGVs, as the willingness to pay values derived from HGV drivers often differs significantly from those of managers (see Fowkes *et al.*, 2007 for an example). From the perspective of a cost benefit analysis it is the value to the firm (and therefore the logistics chain) that is important (Fowkes, 2001; Mackie, Jara-Diaz and Fowkes, 2001), and as drivers are not well placed to provide such estimates there is little value in including the HGV dataset in the remainder of the analysis given the problems experienced. Model IF-MNL12 in Table 5.6 therefore presents an MNL model with the structure of IF-MNL11 estimated to just the car/LGV dataset. Model IF-MXL3 reproduces this model using Train's gauss code. These models act as the starting point for introducing taste variation. It is left for future research the problem of undertaking a joint estimation of headway and operating hour marginal utilities using data from more than one dataset whilst correcting for any bias associated with panel data.

Table 5.8 presents five random parameter logit models[30]. The distribution functions for the random parameters vary between the models from the normal (IF-MXL4 and IF-MXL5), the lognormal (IF-MXL6) to the triangular (IF-MXL7 to 9). The data on which these models are based has been transformed by scaling it up by a factor 10,000 compared to the models presented earlier. This is to assist the model estimation process, particularly the estimation of lognormal distribution functions. The cost, headway and operating hour data for the lognormal model (IF-MXL6) are also transformed by inverting their sign. This is because the lognormal distribution is always positive and negative parameters cannot therefore be estimated.

Each of the models is developed incrementally using IF-MXL3 as the starting point. At each step in the process an additional parameter within IF-MXL3 is treated as random. Model IF-MXL9 also examines whether the restriction to only the car/LGV dataset and the incorporation of taste variation impacts on the 'levels' at which headway (e.g.

---

[30] A random parameter logit model, a type of MXL model, is mathematically equivalent to an error components logit model referred to in the discussion regarding merging different datasets. It differs from an error component logit model in the interpretation of the role of taste variation within the MXL model.

headways greater than 120 minutes) and operating hours (e.g. operating hours greater or equal to 12) become significant. In the final models not all of the parameters are random, some are fixed. This arises for several reasons. In models IF-MXL4, IF-MXL5, IF-MXL6 and IF-MXL7, the spread variable (*c*) is not significantly different from zero for some of the population segments. In IF-MXL5 the cost coefficient is treated as non-random (fixed) by design. This is one of the strategies that can be adopted to avoid the problem of the marginal utility of cost (income) being negative for some parts of the distribution. In the lognormal model (IF-MXL6) it is not possible to estimate a model in which the headway, operating hours and cost parameters are all random. This occurs as the maximum likelihood function of the lognormal is non-quadratic and the estimation process can have difficulty converging. Good starting values for the estimation of lognormal models are therefore essential[31], but even then it is possible, as in this instance, that identification of all random parameters in a single model remains impossible.

The introduction of random parameters into the model captures some of the variation in willingness to pay that occurs by socio-economic population segment. As a consequence some of the fixed effect parameters in IF-MNL11 lose their statistical significance. It is for this reason that the models presented in Table 5.8 have a lower level of disaggregation (by population segment) than the preferred MNL model (IF-MNL11).

Each of the random parameter logit models has strengths and weaknesses. The best performing models in terms of log-likelihood are IF-MXL4 and IF-MXL7 – the models fitted with unconstrained normal or triangular distribution functions. In both of these models almost 20% of the distribution for the marginal utility of cost is positive (i.e. has the wrong sign) (see first row in Table 5.9). As discussed earlier it is implausible with rationally acting economic agents that any portion of the sample should hold a positive marginal utility of cost. Within a modelling environment small proportions are often tolerated, but the existence of such a large proportion of the sample being attributed a positive marginal utility of cost is not satisfactory. It arises no doubt as an artefact of the distribution function imposed on the data and is indicative of the function not accurately reflecting the real underlying willingness to pay – particularly

[31] Starting values for *b* and *c* with the lognormal distribution function were estimated by taking the mean and standard deviation estimated from MXL5 (normal distribution function) and inserting into the functions defining the mean and standard deviation of the lognormal. These equations are $mean=exp(b+(c^2/2))$ and $st.dev.=mean \times \sqrt{(exp(c^2)-1)}$

Table 5.8: Random parameter mixed logit models

		IF-MXL4	IF-MXL5	IF-MXL6	IF-MXL7	IF-MXL8	IF-MXL9
Distribution for random parameters		Normal (N) and Fixed (F)	As IF-MXL4 but with fixed (F) cost coefficient)	Lognormal (LN) and Fixed (F)	Triangular (T) unconstrained and Fixed (F)	Triangular (T) constrained	Triangular (T) constrained
Treatment of repeated choices		Panel	Panel	Panel	Panel	Panel	Panel
Data		Car/LGV	Car/LGV	Car/LGV	Car/LGV	Car/LGV	Car/LGV
Cost coefficient for all trips	b	N -13.83 (-5.4)	F -10.08 (-5.6)	F 10.45 (5.9)	T -13.62 (-5.4)	T -12.79 (-5.5)	T -16.11 (-6.3)
	c	-14.14 (-5.4)			-33.20 (-5.5)	-12.79 (-5.5)	-16.11 (-6.3)
Increment for those who paid for ticket	b	F -10.35 (-3.0)	F -7.46 (-3.0)	F 9.16 (3.0)	F -10.46 (-3.0)	T -5.78 (-1.9)	T -6.23 (-2.1)
	c					-5.78 (-1.9)	-6.23 (-2.1)
Headway ≥ 180 mins (all trips) (per headway min)	b	N -84.32 (-7.4)	N -70.25 (-7.7)	LN 3.81 (18.5)	T -84.19 (-7.5)	T -84.45 (-7.7)	T -94.58 (-7.9)
	c	-78.37 (-6.4)	-68.43 (-6.6)	1.45 (6.2)	-187.06 (-6.6)	-84.45 (-7.7)	-94.58 (-7.9)
Increment for women respondents	b					T 35.50 (2.7)	T 35.19 (2.6)
	c					35.50 (2.7)	35.19 (2.6)
Operating hours (per hour closed)	b						F -489.12 (-3.5)
	c						
Increment for 16 hours closed	b	N -842.52 (-4.0)	N -616.27 (-3.3)	LN 5.44 (7.9)	T -832.65 (-4.0)	T -766.86 (-4.4)	T -661.71 (-3.5)
	c	1176.39 (4.6)	1147.77 (5.7)	2.37 (3.7)	-2741.31 (-4.6)	-766.86 (-4.4)	-661.71 (-3.5)
Increment for work trips	b	F -788.10 (-2.4)	F -812.07 (-2.9)	F 692.26 (3.0)	F -780.09 (-2.4)	T -631.01 (-2.3)	T -669.92 (-2.3)
	c					-631.01 (-2.3)	-669.92 (-2.3)
No. of observations		1,273	1,273	1,273	1,273	1,273	1,273
Log-likelihood		-693.57	-715.62	-708.72	-694.31	-722.04	-714.30

Notes: Data transformed by scaling by 10,000 for all models. For IF-MXL6 data is also transformed by inverting the sign on the cost, headway and operating hour parameters. F, N, LN and T indicate distribution function for parameters. F means fixed (i.e. no distribution function), N is the normal, LN is the lognormal and T is the triangular. For each random parameter two coefficients are estimated (b and c). For the normal distribution the *mean=b* and *st.dev.=c*; for the lognormal $mean=exp(b+(c^2/2))$ and $st.dev.=mean \times \sqrt{(exp(c^2)-1)}$; and for the triangular *mean=b* and *spread=c*. T-statistics in parentheses. Parameter is significant at 99% level if the t-statistic>2.33; at the 95% level if the t-statistic>1.96 and at the 90% level if the t-statistic>1.65. T-statistics calculated using robust standard errors. Models estimated using Train's Gauss code with 500 Halton draws.

point at zero. Treating the cost parameter as non-random, as in model IF-MXL5, is one solution to this problem. With a non-random cost parameter the distribution of willingness to pay for headway and operating hours is determined by the distribution function of the headway and operating hours parameters. With a fixed cost parameter almost 30% of the operating hours willingness to pay distribution has the wrong sign and just over 15% of the headway distribution now has the wrong sign (second column in Table 5.9). These are both sizeable proportions. Whilst there is no direct evidence as to the proportion of the sample that hold negative willingness to pay values it was earlier argued that this proportion is small. The 15.2% in IF-MXL5 who hold positive marginal utilities for a lengthening in headways could just about be tolerated, within the limitations of a modelling context, but the 29.6% with a positive marginal utility for a shortening in operating hours is unrealistic.

Table 5.9: Percentage of cost, headway and operating hours random parameters' distribution with a positive sign

	IF-MXL4 Normal	IF-MXL5 Normal with fixed cost coefficient	IF-MXL6 Lognormal with fixed cost coefficient	IF-MXL7 Triangular un-constrained	IF-MXL8 and IF-MXL9 Triangular constrained
Cost	16.4%	Fixed parameter	Fixed parameter	17.4%	0.0%
Headway (≥180 min)	14.1%	15.2%	0.0%	15.1%	0.0%
Operating hours (≥ 16 hours closed)	23.7%	29.6%	0.0%	24.2%	0.0%

Within Train's Gauss code two options are available for constraining a marginal utility distribution to be always negative thereby ensuring that willingness to pay values are positive. The first is that a lognormal distribution can be adopted, as in model IF-MXL6, whilst the second is to constrain the triangular distribution so that the spread is equal to the mean, as in models IF-MXL8 and IF-MXL9. The log-likelihood values for these two models is worse than that for the models estimated using unconstrained normal or triangular distribution functions, though still better than the models with no random parameters (e.g. IF-MXL3). The main advantage associated with IF-MXL6, IF-MXL8 and IF-MXL9 is that the resultant distributions for marginal utility are far more appealing as none of the distribution has the wrong sign. It was hypothesised earlier that a large mass point at or close to zero may exist in the willingness to pay distributions (see Figure 5.4(b)) holding up to 25% of the distribution for headway and 44% of the distribution for operating hours. Neither the lognormal or the constrained triangular distributions reflect such a mass point. This is a weakness of these models. The fact that the log-likelihood values of IF-MXL6, IF-MXL8 and IF-MXL9 have increased by only a maximum of 34 points with the inclusion of random parameters (i.e. compared to IF-MXL3) is probably in part a reflection of the inability of the distribution functions imposed to capture this mass point. This is reflected in Table 5.10 and Figure 5.5 which compares the proportion of the IF-MXL4 and IF-MXL9 fitted distribution functions lying below the headway and operating hour boundary values to the revealed proportions. As can be seen from this table the normal distribution appears to have the best fitting distribution function but this is achieved at the expense of having an unrealistic large proportion of the function having the wrong sign. The constrained triangular distribution function (as in IF-MXL9) fails to pick up the large proportion of the sample with very low marginal valuations but otherwise fits the revealed distribution reasonably well.

Table 5.10: Comparison of observed and fitted cumulative distribution functions of willingness to pay for headway and operating hours

(a) Headway

Bin for marginal value of headway (H) (p/min)	Observed	IF-MXL4	IF-MXL9
H<0.56	26%	25%	5%
0.56≤H<1.82	29%	35%	15%
1.82≤H<2.78	35%	45%	28%
2.78≤H<8.30	73%	78%	84%
8.30≤H	100%	100%	100%

Notes: Shaded row indicates bin holding the median value

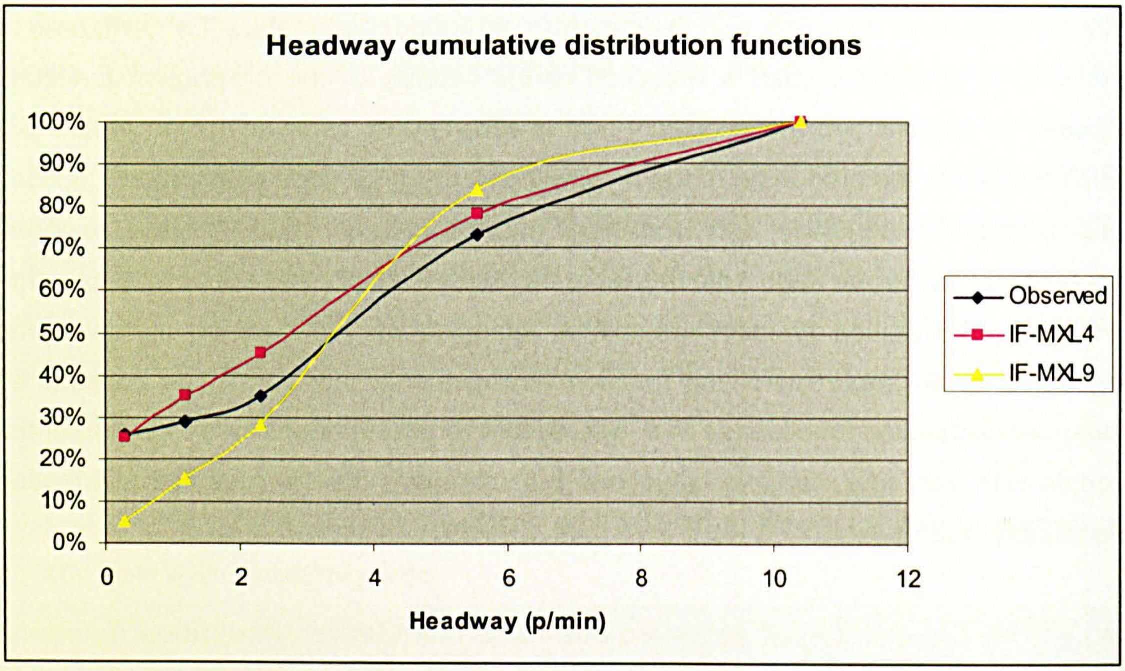
(b) Operating hours

Bin for marginal value of operating hours (OH) (p/hour)	Observed	IF-MXL4	IF-MXL9	
			During working day (9am - 5pm)	In evening and night time (5pm - 9am)
OH< 8.3	44%	29%	0%	0%
8.3≤OH< 41.7	60%	49%	15%	83%
41.7≤OH<137.5	64%	81%	84%	99%
137.5≤OH<214.3	90%	88%	94%	99%
214.3≤OH	100%	100%	100%	100%

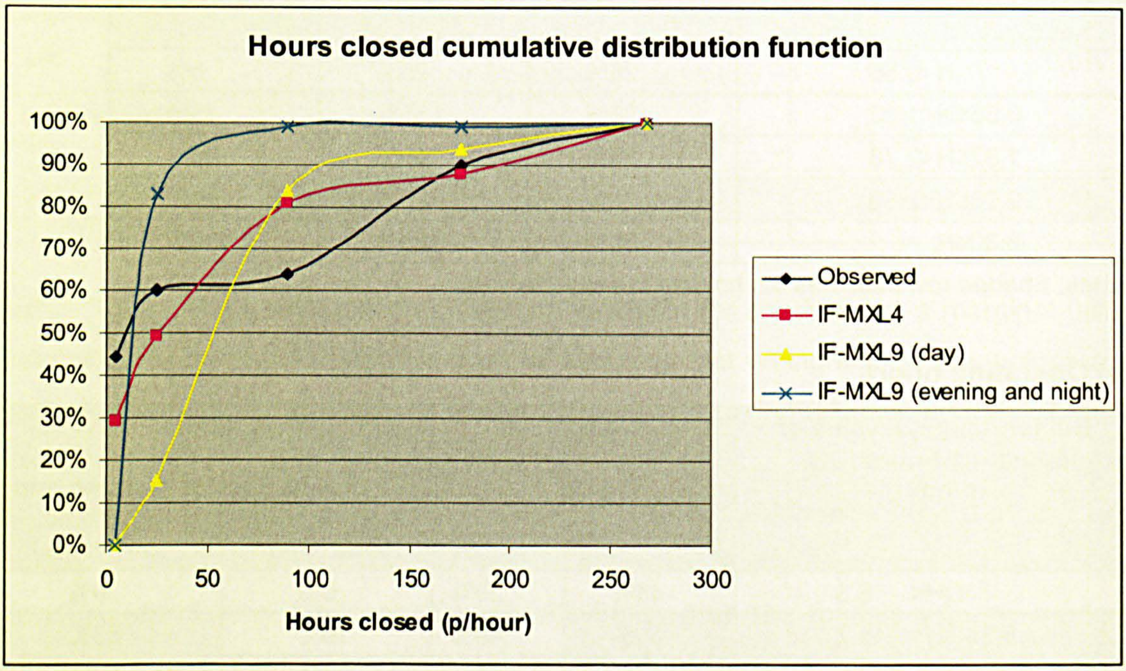
Notes: Shaded cell indicates bin holding the median value

Figure 5.5: Comparison of observed and fitted cumulative distribution functions of willingness to pay for headway and operating hours

(a) Headway



(b) Operating hours



Mean willingness to pay values for each of the models IF-MXL4 to IF-MXL9 are presented in Table 5.11. Where the willingness to pay estimates are a ratio of two random distributions (e.g. a headway and a cost distribution), the willingness to pay estimate is derived from a monte carlo simulation of 10,000 individuals. Very low values for the marginal utility of cost in all of these distributions can give rise to very high willingness to pay estimates. This is potentially problematic as the mean value is quite sensitive to outlying high valuations (of either a positive or negative sign). For this reason there is a convention to exclude the highest and lowest 2.5% from the monte carlo simulation when calculating the mean (Hensher and Greene, 2003; Cirillo and Axhausen, 2006). No t-statistics or confidence intervals for the estimates of marginal values are presented in Table 5.11, as there is no method by which they can be derived for a mixed logit model. The robustness of the model is demonstrated solely by the robustness of the parameter estimates. The MXL models all have a superior model fit to the MNL models and it is therefore felt that the robustness of the marginal values of headway and operating hours in the MNL models will be an indicative, if slightly pessimistic, view of the confidence intervals of the mixed logit models.

It is immediately apparent from Table 5.11 that the implied willingness to pay values are sensitive to the distribution function assumed for the random parameters. This is consistent with evidence in the literature (e.g. Hensher and Greene, 2003; Hess, Bierliare and Polak, 2005). The mean marginal value for a minute of headway (when headways are 180 mins or greater) ranges from 3.9p/min in IF-MXL7 to 9.6p/min in IF-MXL6, whilst the marginal value of an operating hour when an 8 hour day is operated (i.e. 9am to 5pm) ranges from 48.4 p/hour in IF-MXL7 to a value more than six times that at 310.3p/hr in IF-MXL6. In the absence of statistical indicators that measure the level of fit for the distribution functions (Hollander, 2006; Hess, Bierliare and Polak, 2007) the choice of distribution function has to be justified with reference to an *a priori* function derived from theory and also some preliminary analysis of the data. In this respect distributions which give rise to large proportion of the population being ascribed a negative willingness to pay for an improvement in headway or operating cost are rejected in favour of distributions where almost the entire willingness to pay distribution is positive (i.e. models IF-MXL6, IF-MXL8 and IF-MXL9 are preferred to models IF-MXL4, IF-MXL5 and IF-MXL7). Ideally the distribution should also have a mass point at or close to zero, though none of those tested have this property. All the models are, compared to *a priori* expectations, therefore mis-specified to a greater or lesser degree. The unbounded large positive tail associated with the lognormal distribution is primarily responsible for the large mean values for headway and operating hours that are associated with IF-MXL6. This is not a result unique to this study and the realism of

Table 5.11: Willingness to pay values for the random parameter logit models

		IF-MXL4	IF-MXL5	IF-MXL6	IF-MXL7	IF-MXL8	IF-MXL9
Marginal value per minute of headway (pence)							
When headways ≥ 180 mins	Mean	4.3	5.4	9.6	3.9	5.6	5.1
	St. Dev.	10.0	4.9	12.5	10.3	3.7	3.4
	%age of distribution negative	21.6%	15.6%	0.0%	22.5%	3.1%	2.4%
Marginal value per operating hours (pence)							
During evening and night (i.e. between 5pm and 9am)	Mean	---	---	---	---	---	30.1
	St. Dev.	---	---	---	---	---	14.4
	%age of distribution negative	---	---	---	---	---	0.0%
During working day (i.e.between 9am and 5pm)	Mean	59.8	77.0	310.3	48.4	78.8	87.7
	St. Dev.	157.9	89.0	370.4	154.9	55.3	51.8
	%age of distribution negative	25.3%	22.1%	0.0%	26.1%	0.0%	0.0%

Notes: Mean and standard deviation estimated using a monte-carlo simulation based on a population of 10,000 (split into the statistically relevant socio-economic groups from the model using sample proportions). Lowest and highest 2.5% are excluded from calculation of mean and standard deviation. Fixed cost coefficients in IF-MXL5 and IF-MXL6 mean that no monte-carlo simulation is needed for these models.

this tail has therefore been questioned by a number of authors. Comparing the willingness to pay values from the lognormal model (IF-MXL6) to those derived from the boundary value bin analysis (see Table 5.10 (a) and (b)) suggests that IF-MXL6's mean value for headway and operating hours lie in the upper bin of the sample (from the 83rd percentile for headway and the 90th percentile for operating hours). In comparison the values implied by IF-MXL8 and IF-MXL9 lie in the bin that contains the median value for headway and the bin immediately above the median bin for operating hours. IF-MXL8 and 9 are therefore preferred to IF-MXL6. On grounds of model fit (e.g. higher log-likelihood value) model IF-MXL9 is taken as the preferred model over model IF-MXL8.

The above discussion has clearly highlighted the scope for improving the fit of the distribution functions used in the MXL models. The literature suggests a number of potential avenues. In the first instance more sophisticated distribution functions can be imposed. These would include the Johnson S_b distribution function and a censored normal distribution with a mass point at zero (see Train and Sonnier, 2005 and Cirillo and Axhausen, 2006 for examples). Such distribution functions should be better able to replicate the underlying willingness to pay distribution function that is expected to exist in this data. A second avenue for investigation would be the use of non-parametric estimation methods such as a latent class model (Greene and Hensher, 2003; Hess, Bierlaire and Polak, 2007) though such models do require a large dataset. Latent class models do not impose a distribution function on the random parameters. This is particularly appealing given the difficulty in knowing *a priori* what the shape of the willingness to pay distribution is. A final avenue of investigation would be the estimation of a model directly in willingness to pay space (see Train and Weeks, 2005 for an example). Such an approach, whilst diverging from the theoretical link to utility, has advantages over estimation in preference space (coefficients in utility) as the latter can result in unrealistically high estimates of willingness to pay (as a consequence of obtaining very small estimates of the marginal utility of cost/fare).

Further investigations along any of the above three avenues has been left for future research as it is felt that whilst improving the robustness of the models estimated the underlying conclusions in relation to the objective of this thesis will not be altered. That is there are circumstances where statistically significant scheduling costs for long distance (inter-island) trips exist.

5.6 Discussion of main findings

None of the models estimated are entirely satisfactory. The parameters of the best performing multinomial logit model (IF-MNL11) are biased by the repeated measurements problem and the preferred mixed logit model (IF-MXL9) is mis-specified in the sense that the distribution function assumed for the random parameters does not allow for a mass point at or close to zero. Whilst not desirable this is a common situation in discrete choice modelling. Care therefore needs to be made when drawing policy conclusions from the models. The interest in this study is whether or not significant values in a cost benefit analysis context can be attributed to scheduling costs. Within this context, and as discussed previously, the models estimated, while not perfect are helpful. The data suggest that for long distance trips users are only inconvenienced if headways reach 180 minutes. Furthermore, the inconvenience users experience from a shortening or lengthening in the operating day varies non-linearly with the length of that day. For short operating days the value of an additional operating hour is higher than it is for long operating days. This is consistent with the conceptual idea that for trips utilising these ferry services travel forms one of the main activities of the day (undertaken in the middle of the day), around which a significant amount of buffer time exists. Users therefore are only inconvenienced once service levels drop below a relatively low threshold.

The preferred MXL model indicates that the marginal value of headway when headways are 180 mins or greater is 5.1p/min (model IF-MXL9 in Table 5.11). The marginal value of an operating hour for an operating day of 8 hours is 87.7p/hr and for operating days of 12 hours or greater it is 30.1p/hr. It has not been possible to obtain statistically robust values for the marginal value of headway when headways are less than 180 mins. This is attributed to a degree of self-selectivity in the sample. The ferries surveyed had headways around the 3 hour mark and users appear not to be significantly inconvenienced below this level. There is however a degree of arbitrariness in the definition of the step-function within the models estimated. In reality one would not expect that travellers would have a zero marginal value for a headway minute when headways are 179 minutes but a value of 5.1p/min when they are 180 minutes. It is therefore expected that a value of 5.1p/min would act as an upper bound for the marginal value of headway when headways are below 180 minutes.

As can be seen from Table 5.12 the values of headway are a significant size in relation to the value of average car/LGV in-vehicle time in the sample (car/LGV-IVT) – at around a seventh of car/LGV-IVT. The marginal value of operating hours is lower than that of headway but also significant with an additional operating hour being valued at between 0.8 and 2.4 of a car/LGV-IVT minute. A one hour reduction in headway therefore is equivalent to journey time reduction of just over 8 minutes whilst a one hour lengthening of the operating day has a journey time equivalent value of between 0.8 minutes and 2.4 minutes (depending upon what part of the day the additional hour falls). The next step in determining if scheduling costs are significant components of economic benefit is to compare them to user benefits in an actual appraisal. As will be seen in the penultimate chapter, Chapter 9, where a case study of a Sound of Harris ferry proposal (Halcrow Fox, 1996) is presented, scheduling costs are important in ferry appraisals.

Table 5.12: Inter-island ferry survey preferred willingness to pay values as a proportion of car in-vehicle-time (2005 perceived prices and values)

(a) Headway

When headways are between:	Marginal value of a headway minute	Equivalent car/LGV in-vehicle time minutes
60 and 119 mins	not significant	---
120 and 179 mins	not significant	---
180 to 240 mins	5.1 p/min (306 p/hr)	0.14 car/LGV mins per headway min (8.4 car/LGV mins per headway hour)

(b) Operating hours

When operating day is:	Marginal value of an operating hour	Equivalent car/LGV in-vehicle time minutes
8 hours (9am to 5pm)	87.7 p/hr	2.4 car/LGV mins per hour
12 hours (7am to 7pm)	30.1 p/hr	0.8 car/LGV mins per hour
17 hours (6am to midnight)	30.1 p/hr	0.8 car/LGV mins per hour
24 hours	30.1 p/hr	0.8 car/LGV mins per hour

Notes: Marginal values derived from model IF-MXL9. Average car/LGV in-vehicle time is £21.83 per hour/per group (i.e. 36.4 p/min/group) (2005 perceived prices and values). Derived from standard value of travel time savings per passenger (DfT, 2007b) using sample proportions.

The uniqueness of this work means that there are no similar studies against which the values obtained can be validated. As discussed in chapter 4 this was a source of difficulty in designing the SP questionnaire, where bus and train marginal values were used to estimate a range for headway and an educated 'guess' from the Norwegian evidence was used for operating hours. The derived values are towards the bottom end of the design range for headway and between the bottom and mid part of the design range for operating hours (see Table 4.1). This is re-assuring as it both fits with *a priori* expectations and is within the range of marginal values which the SP design could recover.

Whilst the willingness to pay values in Table 5.12 are higher than those implied by the preferred MNL model (IF-MNL11) and the median values obtained from an analysis of responses to the SP boundary value questions, they are consistent with these values. The consistency between the different strands of analysis suggests that the main conclusion in this section of the thesis is robust. That is significant scheduling costs in the region of 8 car/LGV equivalent minutes per headway hour and between 0.8 and 2.4 car/LGV equivalent minutes per operating hour exist.

A number of potential future research directions present themselves. In terms of the data collection future survey work should consider at the outset collecting more information on the shape of the willingness to pay distribution than was collected in this study. In particularly a better understanding of the proportion of the distribution that has a negative willingness to pay and the size of the mass point at or close to zero would go someway towards helping form the decision regarding the most appropriate distribution function for the random parameters. There also remain opportunities to undertake a more sophisticated analysis of the data, as improvements to the models estimated will increase their robustness and the robustness of the willingness to pay values. A joint analysis of all three datasets whilst accounting for both scale differences and the repeated measurements problem is a further line of investigation, whilst another line would be the introduction of more complicated distribution functions – such as the truncated normal or the Johnson S_b with a mass point at zero. Latent class models and estimations in willingness to pay space rather than preference space would also be of interest – the former makes no *a priori* assumption regarding the distribution function whilst the latter avoids the problem of unrealistically high willingness to pay values.

6 LOCAL FERRY AND FIXED LINK ANALYSIS

6.1 Introduction

This is the final chapter of the first part of the thesis. The focus throughout this part has been on benefits associated with activity re-scheduling and the value attributed to the risk premium (that is the increased security often associated with transport links). These benefits are of great interest in the context of ferry travel as the constraints on lifestyles that limited hours of operation and low frequencies have on island residents can be large. In focussing on households on small islands with limited employment opportunities and services the analysis presented in this chapter differs from that of the previous chapter in two important ways. Firstly the focus is on local trips associated with the everyday functioning of a household (access to employment, shops, etc.), and secondly it examines whether households perceive a difference in risk between fixed link type infrastructure and ferry type infrastructure.

The analysis presented in this chapter relates to the household survey data, the design of which has already been described in Chapter 4. Households on four of the fourteen populated islands in the Outer Hebrides are surveyed. These islands, Berneray, Eriskay, Scalpay and Vatersay, are all small. Scalpay with a population of just over 300 people is more than double the size of the other three islands. The populations on all four islands have been under pressure in recent times and there was a general concern that they, like twenty two other islands in the last 150 years in the Outer Hebrides, might ultimately be abandoned. This concern led to the construction of fixed links (a bridge or a causeway) to all four islands (see Figure 6.1 to Figure 6.4). Eriskay got its fixed link most recently (in 2002), three years before the survey, whilst the Berneray causeway opened in April 1999 and the Scalpay Bridge in December 1997. The Vatersay causeway is the oldest fixed link of the four, as it was constructed in 1991. None of the fixed links are really large. The longest is the Eriskay Causeway which links a series of small rocky islands and is just over 2km in length, whilst the Vatersay causeway is the shortest at 250m which is just smaller than the Scalpay Bridge at 300m in length. The Berneray Causeway is just over 1km in length.

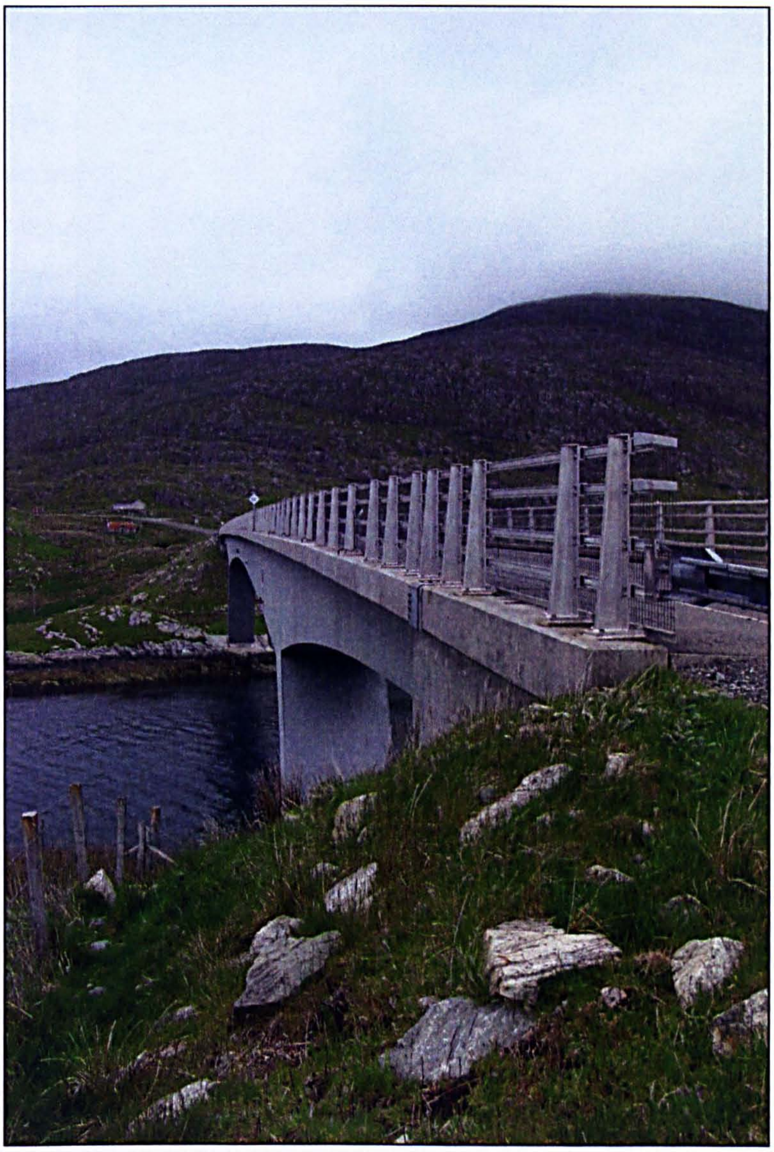
Figure 6.1: Berneray Causeway and Sound of Harris Ferry (from North Uist looking north towards Berneray)

Source: author

Figure 6.2: Eriskay Causeway (from Eriskay looking north towards South Uist)

Source: author

Figure 6.3: Scalpay Bridge (from Scalpay looking north towards Harris)



Source: author

Figure 6.4: Vatersay Causeway (from Barra looking south towards Vatersay)

Source: SeanE http://www.panoramio.com/photo/3020997 [accessed 5th November 2009]

The ferry services the fixed links replaced were quite varied. Vehicle ferries were operated to Berneray, Eriskay and Scalpay, but only a passenger ferry operated to Vatersay. Tidal conditions meant that on a daily basis some Eriskay sailings were operated using a rigid inflatable boat (passenger only). The passenger only ferry to Vatersay meant that, for the transport of bulk goods, boats needed to be hired. However, the pier and its access were difficult for such goods - particularly livestock. This led to cattle, in the age old tradition, being swum across the 250m channel to the island. In 1986 when undertaking this crossing a prized bull drowned. Whilst rightly attracting the condemnation of many animal welfare organisations this incident highlighted in the national press the economic circumstances that island residents, and Vatersay residents in particular, faced.

Ferry service timings also varied by island. First sailings of the day were usually between 7.30am and 8am, though earlier sailings during school term time also occurred. Last sailings of the day were between 6pm and 6.30pm during the winter and 6pm and 9pm during the summer. Depending on the island there could be anything from 7 sailings a day to 13 giving a range in headways from 55 minutes to just over every 1.5 hours. For the islands in the northern part of the Outer Hebrides

(Berneray and Scalpay), which are strongly Presbyterian, there were no sailings on Sundays – so the islands were completely isolated on a Sunday. For Eriskay and Vatersay Sunday sailings did occur.

The construction of the fixed links has been associated with a significant socio-economic gain by the islanders. This includes increased employment amongst women, population stability against a background of falling populations, better delivery of social care, elimination of the requirement for secondary school children to live off the island during term-time and increased economic wealth (between £400 and £800 per household the majority of which has arisen through the elimination of ferry fares) (SQW, 2004; Reference, 2007). Indirect evidence of the benefit of the fixed links to the social and economic fabric of the islands can also be seen by the fact that traffic flows across the fixed links are 6 to 8 times higher than those carried by the ferries (Laird, Nellthorp and Mackie, 2004). Despite this increase, traffic flows across the fixed links are light (at between 250 and 400 vehicles per day[32]) compared to flows found in more densely populated parts of Scotland.

Following this introductory section, the second and third section in this chapter describes the dataset collected. The fourth section contains a discussion on the distribution of willingness to pay. As the methodology underlying the econometric analysis is the same as that used for the inter-island ferry survey, as described in Chapter 5, the fifth, sixth and seventh sections therefore only describe the analysis associated with each of the different elements to the household questionnaire. That is they respectively describe the local ferry stated preference game, the contingent valuation questions and the fixed link stated preference game. An interesting result from the analysis is a difference between annual willingness to pay and willingness to pay per trip. This issue is explored in the eighth section. The ninth section draws from the analysis in the previous four sections to derive an estimate of the risk premium for fixed link type infrastructure compared to ferry type infrastructure, whilst the final section brings together the main findings of this household survey and econometric analysis.

6.2 The dataset

149 households on Berneray, Eriskay, Scalpay and Vatersay were interviewed. This is

---

[32] Adapted from annual traffic flows for 2004 presented by Reference (2007 p6)

48% of all households on these islands[33]. Simulations during the design of the survey (see Chapter 4) indicated that to obtain sufficiently robust estimates of the parameters of interest approximately 50% of the households on the islands would need to be surveyed. The previous ex-post work undertaken by SQW (2004) indicated that such an ambitious sampling strategy was achievable, and therefore the sample target was set at 50%.

Table 6.1 shows that the sample also captures the correct proportions of retired households and households with and without dependent children. The table additionally shows that household composition on Berneray, Eriskay, Scalpay and Vatersay differs from the remainder of the Outer Hebrides and Scotland, in that there are more pensioner households and correspondingly less households with a working age adult. Average household size in the sample is 2.3, which is slightly above the 2.2 persons per household average for the islands in the 2001 census but equivalent to the average for Scotland (GROS, 2008 Table UV51).

Table 6.2 shows the median gross household income of the sample lies between £10,000 and £20,999. It also shows that 38% of households have a gross income of less than £10,000 per annum. Householders on Berneray, Eriskay, Scalpay and Vatersay are therefore poor relative to other householders in Scotland. This is because the median gross household income in Scotland was almost £22,000 in 2005/6 (Scottish Executive, 2007 Table 5.2), whilst households with a net annual income of less than £8,339 fall into the poorest 20% of households in Scotland[34].

Car ownership on the islands is less than would be expected for a remote rural area. This can be seen from the fact that 32% of households do not have access to a car, which is similar to the Scotland average but significantly more than the 15% average for remote rural areas (Scottish Executive, 2006 Table 6.4). The low levels of car ownership are no doubt a reflection of the low incomes and the large proportion of pensioner households in the sample area.

---

[33] The 2001 census reports 310 households on Berneray, Eriskay, Scalpay and Vatersay (GROS, 2008 Table KS20)

[34] Source: 2003/4 Scottish Household Survey variable *annetinc* (MORI Scotland *et al.* 2005). A gross household income of £10,000 for a single adult household gives a net income of about £8,500.

Table 6.1: Household composition

		Households with dependent children	Households with no dependent children	Pensioner households	Total
Sample		21%	38%	41%	100%
2001 census	Berneray, Eriskay, Scalpay and Vatersay	25%	36%	39%	100%
	Outer Hebrides	27%	47%	26%	100%
	Scotland	28%	48%	23%	100%

Source: Survey data and 2001 census (GROS, 2008 Table KS20)

Table 6.2: Gross household income (per annum)

	Frequency	Proportion of sample	Proportion of those declaring their income
Withheld	24	16%	---
<£10,000	47	32%	38%
£10,000 to £20,999	45	30%	36%
£21,000 to £35,999	26	17%	21%
£36,000 to £50,000	3	2%	2%
≥£50,001	4	3%	3%
Total	149	100%	100%

The number and type of trips householders make over the fixed link gives an indication of the day to day dependency households have on the link. Table 6.3 shows that this dependency varies significantly by island. This can be seen from the fact that on average householders make 6 return trips per week over the fixed link on Berneray to almost 28 trips per week on Vatersay. Some of the differences between the islands stem from the amount of time land uses and behaviour have had to adjust to the presence of the fixed link - the longer the period of adjustment the more well used one would expect the fixed link to be and the Vatersay link is the oldest. In the main though the level of use made of the fixed link by households is felt to reflect the social, educational and commercial services available on each island. Vatersay has neither a primary school nor shop, which the other three islands do. Eriskay has a pub and hotel, whilst Scalpay has a doctor's branch surgery. Employment opportunities on Vatersay are more limited than on the other islands, as evidenced by the fact that 86% of households in Vatersay have 1 or more household members working off the island compared to only 55% on Berneray and 68% on Scalpay.

Table 6.3: Total number of return trips across the bridge/causeway made by household in the week before the survey

	No. of households in sample	Mean	Median
Scalpay	70	9.6	6.5
Berneray	33	6.0	3
Eriskay	28	7.6	5.5
Vatersay	18	27.6	23.5
All sample	149	10.6	7

6.3 Stated preference and contingent valuation responses and data cleaning

As can be seen from Table 6.4 there is generally a good spread of respondents choosing either Ferry A or Ferry B in the local ferry stated preference games. Neither ferry dominates the responses, though there is a slight preference for Ferry B. Further analysis indicates that over the whole questionnaire almost two thirds of responses are in favour of the most expensive ferry service (i.e. the one with the highest service levels). Additionally, it appears that only 7% of respondents exhibited non-trading behaviour in that they either choose Ferry A all the time (2 respondents) or Ferry B all the time (9 respondents). This is good as it suggests that respondents are treating the questionnaire seriously and the design is successful in posing scenarios that allow respondents to trade between a lower cost alternative (usually Ferry A) and a more expensive alternative with a better service (usually Ferry B). Given that the 11 respondents who exhibit non-trading behaviour may also be treating the questionnaire seriously they are retained in the dataset for the econometric analysis.

In contrast to the local ferry stated preference game the fixed link stated preference game indicates a much more marked preference for the second alternative (the fixed link) than for the first alternative (the ferry) (see Table 6.5). To a certain extent this was expected as it was felt unrealistic to present SP scenarios that included a council tax premium in excess of £1,000 (see section 4.3). The knock-on effect of this aspect of the design is that 54% of respondents exhibit non-trading behaviour - 9 respondents always choose the ferry and 71 always choose the fixed link. This could be for valid reasons in that the maximum council tax premium is too small to persuade respondents to choose the ferry alternative over the fixed link. A deeper analysis of the responses confirms this to a certain extent in that non-trading behaviour varies systematically with income, car ownership and the number of trips across the fixed link per week. Those with high incomes, access to a car and who make a lot of trips across the fixed link are more likely to exhibit non-trading behaviour than other respondents. The analysis also indicates a systematic variation by island, in that Eriskay households are more than twice as likely to exhibit non-trading behaviour compared to other households. As discussed in section 4.4 a lot of the ferry alternatives in the Eriskay SP scenarios were considered unrealistic by respondents. The high incidence of non-trading behaviour by Eriskay householders is therefore considered to be an artefact of the lack of realism of the questionnaire in Eriskay rather than an indication of high willingness to pay for a fixed link. Eriskay households are therefore excluded from the econometric analysis. This reduces non-trading behaviour to 45% of respondents. This is still a large proportion of the dataset and the results from the fixed link stated preference game need to be interpreted against this statistic. Fortunately the contingent valuation questions provide the means by which respondents can reveal their true willingness to pay. The contingent valuation questions therefore act as an efficient validation of the fixed link stated preference game – as is discussed later in this chapter.

Table 6.4: Responses to local ferry stated preference game

SP Question	From those who answered the SP question the percentage choosing:		Percentage of returned questionnaires with question unanswered
	Ferry A	Ferry B	
1	11%	89%	5%
2	61%	39%	5%
3	24%	76%	6%
4	69%	31%	5%
5	27%	73%	6%
6	72%	28%	8%
7	91%	9%	5%
8	69%	31%	10%
9	24%	76%	6%
10	37%	63%	5%
11	85%	15%	6%
12	62%	38%	8%
13	36%	64%	5%
14	11%	89%	5%
15	32%	68%	3%
16	16%	84%	5%
Average	45%	55%	6%

Note: Shaded cell identifies cheapest option

Table 6.5: Responses to fixed link stated preference game

SP Question	From those who answered the SP question the percentage choosing:		Percentage of returned questionnaires with question unanswered
	Ferry	Fixed Link	
1	41%	59%	3%
2	24%	76%	0%
3	29%	71%	3%
4	16%	84%	0%
5	54%	46%	0%
6	54%	46%	0%
7	46%	54%	3%
8	17%	83%	0%
9	54%	46%	0%
10	61%	39%	0%
11	31%	69%	0%
12	32%	68%	0%
13	19%	81%	0%
14	45%	55%	0%
15	14%	86%	0%
16	11%	89%	0%
Extra	9%	91%	1%
Average	29%	71%	1%

Analysis of the responses to the contingent valuation questions indicates that 70% of respondents provided a valid willingness to pay (see Table 6.6) that can be used in the econometric analysis. As noted in the literature (Mitchell and Carson, 1989, pp.97-104; Bateman *et al.*, 2002 pp.135-145) and discussed in section 4.3 open-ended elicitation contingent valuation questions can generate a lot of protest votes and non-responses due to the difficulty respondents face coming up with their true willingness to pay 'out of the blue' for something they are not familiar with valuing. Here protest votes against the payment mechanism (a council tax premium) account for between a fifth and an eighth of responses. Given the political sensitivity of council tax this is felt to be reasonably realistic and not excessive. Non-responses constitute between 9% and 17% depending on the contingent valuation question. This level of non-response is much higher than that experienced in the stated preference games (see Table 6.4 and Table 6.5), but once the influence of the Eriskay households is taken into account it is not that much higher. The level of non-response to the contingent valuation questions is therefore also viewed as acceptable. The design strategy of preceding the contingent valuation questions with stated preference games set within a similar context therefore appears to have been successful at minimising the number of invalid responses to the contingent valuation questions.

Table 6.6: Responses to contingent valuation questions

Contingent valuation question	Proportion of dataset			
	Valid WTP responses	Protest votes	Non-response	Total
12 to 24 hr ferry	68%	15%	17%	100%
24hr ferry to fixed link	71%	13%	16%	100%
Time saving	68%	22%	9%	100%

A deeper analysis of the responses to the contingent valuation questions indicates that some households indicate a very high willingness to pay relative to their income. Values in excess of £5,200 are indicated despite some of the households having a gross income of less than £10,000 p.a. Such values are unrealistic and either result from a coding error on the part of the survey enumerator (e.g. coding a willingness to pay of £100 per annum as £100 per week) or as a result of the householder not treating the questionnaire seriously. Outlying willingness to pay values of £5,200 or more are therefore excluded from the econometric analysis. This gives a maximum willingness to pay of £2,000 per annum for the 12 to 24 hr ferry, £2,500 for the 24hr ferry to fixed link and £520 for the time saving.

12% of the households interviewed moved to the islands surveyed after the fixed link had been constructed. The willingness to pay of such householders is of interest as, through the process of self-selection and all else being equal, households with high values for connectivity would choose not to live on an isolated island. Households that move to the island after the fixed link had been constructed are therefore expected to exhibit higher levels of willingness to pay, than households that were resident on the island before the fixed link was constructed. The appropriateness of the survey instrument for such householders though is uncertain. This is because the questionnaire is based around a series of 'ferry scenarios' for which households have no direct experience. Some evidence regarding inconsistency in willingness to pay by households that moved to the islands after the fixed links had been constructed is evident. Preliminary analysis indicated that on Scalpay households that moved to the island after the bridge had been constructed valued the bridge substantially less than existing residents, whilst the opposite was the case for Berneray and Vatersay. On the basis that 'incomers' to the islands post-fixed link could not properly relate to the ferry scenarios such respondents are excluded from econometric analysis.

Exclusion of cases from the sample based on the five criteria discussed above (non-response, protest vote, Eriskay household, post-fixed link and outlier) reduces the sample size down to just over two thirds for the SP games and around a half for the contingent valuation questions. This is a larger reduction than is evident in the inter-island questionnaire (where about 80% of the cases are retained) and has arisen primarily as a result of the problems experienced with the Eriskay households and the ambitious sampling strategy that included households that moved to the islands post-fixed link. With valid SP samples in excess of 400 cases and contingent valuation samples in excess of 70 cases there is still though more than sufficient data with which to proceed with the econometric analysis.

Table 6.7: Household survey dataset cleaning

		Local ferry SP game	Fixed link SP game	Contingent valuation		
				12 to 24 hr ferry	24 hr ferry to fixed link	Time saving
No. of households in sample		*149*	*149*	*149*	*149*	*149*
No. of cases in sample		*596*	*745*	*149*	*149*	*149*
Exclusion of cases by:						
Step 1:	Eriskay households	112	140	28	28	28
Step 2:	Households who moved to island post-fixed link	68	85	17	17	17
Step 3:	Non-responses	12	3	8	8	8
Step 4:	Protest votes/ Other reasons for not providing WTP value	N/A	N/A	14	10	25
Step 5:	Outlying values where WTP ≥ £5,200 p.a.	N/A	N/A	3	2	1
Valid cases		*404*	*517*	*79*	*84*	*70*

6.4 Distribution of willingness to pay

Drawing from the discussion and results from the inter-island ferry presented in the preceding chapter the main points of interest associated with the distribution of willingness to pay are the existence of:

- A mass point at or near zero;
- Negative values;
- Non-linearities (e.g. the marginal value of extending operating hours depends upon what the existing operating hours are); and
- The shape of the distribution.

The existence of a mass point in willingness to pay at or near zero occurs, as discussed in Chapter 5, because for a proportion of travellers activity schedules are either well adjusted and close to optimum or there exists a significant amount of buffer time. The long distance nature of the trips made on the inter-island ferries mean that for many travellers travelling is the major activity of the day around which other activities are centred. A reasonable sized mass point at or close to zero was therefore expected and found for the inter-island ferry (see Table 5.3(a) and (b)). This contrasts with local trips, the present interest, where travel costs can impose significant constraints on activities. *A priori* a smaller mass point at zero for the household survey is expected. Table 6.8(a) shows that between 4% and 11% of households have a value of headway less than 0.52p/min, compared to the 26% that was found in the inter-island survey. A zero mass point therefore exists but is smaller for local trips than for longer distance trips. There is an apparent discrepancy in the operating hours data in Table 6.8(b) as responses to two SP questions suggest that 40% of respondents have a value per hour closed less than 4.17p/hr closed, whilst responses to a different SP question suggest that only 13% of respondents have a value per hour closed less than 8.33p/hr closed. This apparent discrepancy is attributed to the fact that householders have a higher value of an additional operating hour if the ferry service has short operating hours (e.g. 9am to 5pm) than if it has long hours (e.g. 11am to 6pm). That is non-linearities exist for the marginal value of operating hours. This makes Table 6.8(b) difficult to interpret with respect to the size of a zero mass point, but suggests that such a mass point may vary in size depending on the existing operating hours of the ferry. The contingent valuation question comparing a 24 hour ferry to 12 hour ferry[35] however indicates that 27% of the sample hold a zero value for operating hours above 12 hours (i.e. 7am to 7pm). This is quite large but smaller than that observed for the inter-island ferry (44%) also as expected.

---

[35] Both ferries are free and run at 30 minute headways.

Table 6.8: Distribution of willingness to pay for changes local ferry schedules (boundary value bin analysis)

(a) Headway

Bin for marginal value of headway (H) (p/min)	Proportion of sample	Cumulative frequency
H<0.17	11%	11%
0.17≤H<0.52	-7%	4%
0.52≤H<2.29	70%	74%
2.29≤H<5.00	13%	88%
5.00≤H	13%	100%

Notes: Shaded row indicates bin holding the median value

(b) Operating Hours

Bin for marginal value of operating hours(OH) (p/min)	Proportion of sample	Cumulative frequency
OH<2.08	7%	7%
2.08≤OH<3.13	33%	40%
3.13≤OH<4.17	0%	40%
4.17≤OH<8.33	-28%	13%
8.33≤OH	88%	100%

Notes: Shaded row indicates bin holding the median value

A mass point at or close to zero is also evident in the value attached to a fixed link compared to a 24 hour ferry. This can be seen in Table 6.9 where 25% of SP responses indicated a value of the fixed link compared to a 24 hour ferry of no more than £60 per annum. The contingent valuation question revealed a similar but slightly higher proportion at 31%. The household survey data, just like the inter-island survey data, therefore points towards the existence of significant mass points in the willingness to pay functions at or close to zero.

Zero responses account for between a fifth and a quarter of the valid responses to the ferry and fixed link contingent valuation questions (see Table 6.10). These are comparable but slightly higher than the identified mass points in the stated preference local ferry and fixed link datasets. There is therefore consistency between these datasets. Contrastingly 70% of respondents indicated a zero willingness to pay for a time saving of between 10 and 20 minutes[36]. As each of these respondents also answered a subsequent question to indicate that the transport alternative with a lower level of service was perfectly adequate for their household these values may be a true

[36] Time saving varied by island

reflection of willingness to pay. Possibly however the large number of zero responses has arisen as a consequence of the 'unexpected' nature of the task respondents had been asked to perform. That is whilst they had developed some familiarity with choosing between different ferry and fixed link scenarios they had not developed a similar familiarity with placing a willingness to pay value on travel time savings. This characteristic of the data needs to be borne in mind when interpreting the econometric results of the time saving contingent valuation question.

Table 6.9: Distribution of willingness to pay for fixed link compared to a 24 hour ferry (boundary value and contingent valuation bin analysis)

Benefit of fixed link over 24 hr ferry (£ per annum)	Fixed Link SP Game		Contingent valuation 24hr ferry to fixed link	
	Proportion of sample	Cumulative frequency	Proportion of sample	Cumulative frequency
Benefit < £20	11%	11%	20%	20%
£20≤ Benefit < £60	14%	25%	11%	31%
£60≤ Benefit <£120	-3%	22%	8%	39%
£120≤ Benefit <£180	0%	22%	1%	40%
£180≤ Benefit <£220	3%	25%	1%	41%
£220≤ Benefit <£300	36%	61%	17%	58%
£300≤ Benefit	39%	100%	42%	100%

Note: (1) Ferry operates at 30 minute headways, is free and 15 minutes slower than fixed link.
(2) Shaded row indicates bin holding the median value

Table 6.10: Observed distribution of willingness to pay - contingent valuation questions

Contingent valuation question	Valid WTP responses			
	Negative willingness to pay	Zero willingness to pay	Positive willingness to pay	Total
12 to 24 hr ferry	2%	27%	71%	100%
24hr ferry to fixed link	4%	20%	76%	100%
Time saving	3%	70%	27%	100%

Note: Proportion of valid WTP responses with a negative WTP is obtained through an analysis of the reasons given for preferring the alternative with the lower level of service.

In addition to the existence of a mass point at or close to zero the contingent valuation data point towards the existence of a small number of negative values associated with improvements from a ferry to a fixed link, from a 12 hour to 24 hour ferry and in travel time to and from other villages (off the sampled island). This varies between 2 and 4% of all households (see Table 6.10). This small, but from an model estimation point of view important, group of householders state they prefer isolation to improved connectivity and also attribute negative impacts to the transport improvements (such as other people speeding or visual intrusion).

Figure 6.5(a) and (b) illustrates the implied distribution of willingness to pay for the ferry and fixed link contingent valuation questions and the fixed link stated preference questions (where a 24 hour ferry was compared to a fixed link). The large mass point at or close to zero, discussed at length above, is evident in each of these distributions. Interestingly the contingent valuation distributions appear to represent a form of decay function as willingness to pay increases. This contrasts with the distribution implied by an analysis of the fixed link SP game's boundary values (in Figure 6.5(b)). Here aside from the mass point near zero there appears to be a second mass point between £220 and £300. A cursory comparison between the distributions in Figure 6.5 with the normal, triangular and log-normal distributions suggests that, as with the inter-island ferry data, none of these three distribution functions appear well able to replicate the observed willingness to pay distributions.

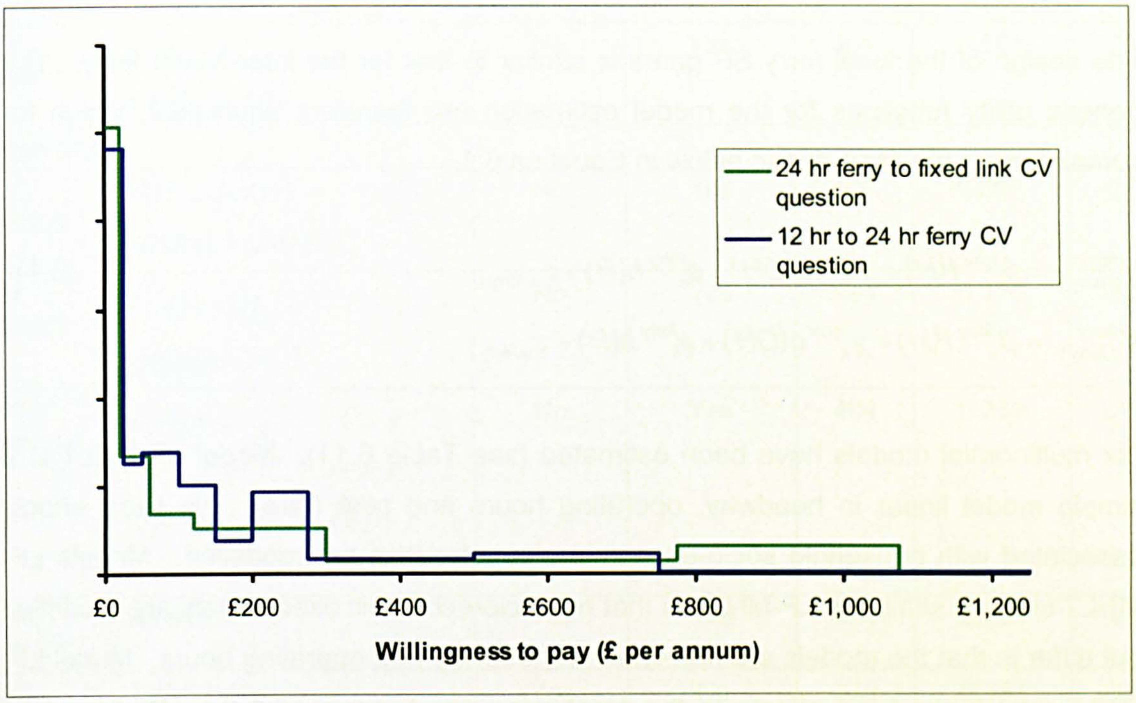
The analysis presented above allows median revealed willingness to pay values to be identified. From the local ferry SP game the median value for headway lies in the range of 0.5p to 2.3 pence per headway minute per household, whilst the median value of operating hours is in excess of 8.33 pence per hour closed per household. The fixed link contingent valuation question indicates that the median willingness to pay for a fixed link compared to a 24 hour ferry is between £220 and £300 per annum per household. This is the same as is indicated by the fixed link SP game. The consistency in median values for the same step change in transport quality between the two question types is reassuring. The local ferry contingent valuation question indicates that the median willingness to pay for a 24 hour ferry compared to a 12 hour ferry is between £100 and £150 per annum per household.

6.5 Local ferry stated preference game – estimation results

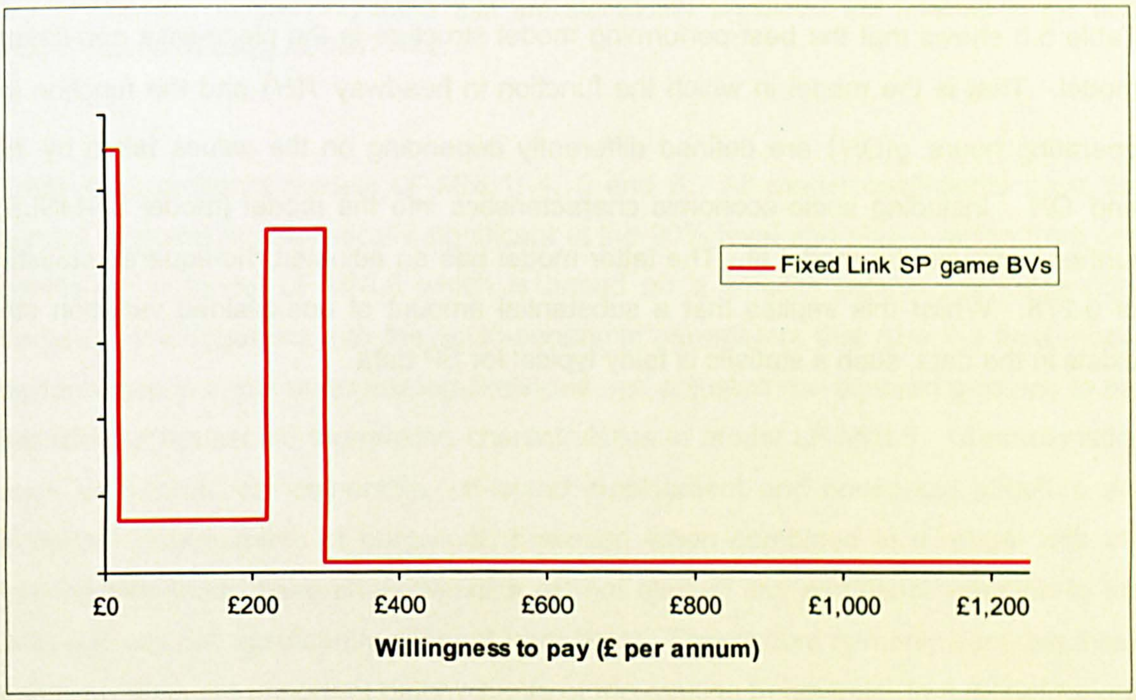
The estimation strategy used to estimate the model for the local ferry stated preference game is the same as that used for the inter-island ferry game described in detail in Chapter 5. Briefly MNL models are estimated to the data in the first instance with the structure for the best performing MNL model being used as a basis for the estimation of the MXL models. Different MNL models are estimated that examine whether utility varies linearly or non-linearly and whether interactions of the main attributes (cost, headway, operating hours) with socio-economic characteristics assist in explaining

Figure 6.5 Cumulative distribution function for willingness to pay

(a) Ferry and fixed link contingent valuation questions



(b) Fixed link stated preference game (boundary value bin analysis for willingness to pay for fixed link relative to a 24 hr ferry)



behaviour. The socio-economic characteristics examined include whether the household has access to a car, the island they lived on, household type (family, working age adult(s) and retired), household income and the number of trips made over the fixed link.

The design of the local ferry SP game is similar to that for the inter-island ferry. The generic utility functions for the model estimation are therefore equivalent, which for completeness are reproduced below in Equation 6.1.

$$V_{q,ferry1}^{ferry} = \beta_k^{ferry} f(H) + \chi_k^{ferry} g(OH) + \phi_k^{ferry} h(P) + \varepsilon_{q,ferry1} \tag{6.1}$$
$$V_{q,ferry2}^{ferry} = \beta_k^{ferry} f(H) + \chi_k^{ferry} g(OH) + \phi_k^{ferry} h(P) + \varepsilon_{q,ferry2}$$

Six multinomial models have been estimated (see Table 6.11). Model LF-MNL1 is a simple model linear in headway, operating hours and cost (fare). No fixed effects associated with household socio-economic characteristics are modelled. Models LF-MNL2 to 4 are similar to LF-MNL1 in that no socio-economic fixed effects are modelled but differ in that the models are non-linear in headway and operating hours. Model LF-MNL5 introduces fixed effects to the piece-wise non-linear model (LF-MNL4), whilst model LF-MNL6 has the same structure as LF-MNL5 but is estimated on data that excludes non-traders (i.e. those that always chose the cheapest ferry, etc.).

Table 5.5 shows that the best-performing model structure is the piece-wise non-linear model. That is the model in which the function in headway $f(H)$ and the function in operating hours $g(OH)$ are defined differently depending on the values taken by H and OH. Including socio-economic characteristics into the model (model LF-MNL5) further improves the model fit. The latter model has an adjusted rho-squared statistic of 0.278. Whilst this implies that a substantial amount of unexplained variation still exists in the data, such a statistic is fairly typical for SP data.

Table 6.11: Summary statistics for MNL models – local ferry SP game

Model	Functional form for Headway (H) and Operating Hours (OH) (see table notes)	Includes fixed effects	Includes non-traders	No. of cases	Rho-squared	Log Likelihood
Linear						
LF-MNL1	$f(H)=H$ $g(OH)=HC$	No	Yes	404	0.161	-232.34
Non-linear						
LF-MNL2	$f(H)=Ln(H)$ $g(OH)=Ln(HC)$	No	Yes	404	0.098	-249.74
LF-MNL3	$f(H)=\sqrt{H}$ $g(OH)=HC^2$	No	Yes	404	0.170	-229.93
LF-MNL4	$f(H)=0$ if $H<\bar{x}$; $=H$ if $H\geq\bar{x}$ $g(OH)=0$ if $HC<\bar{y}$; $=HC$ if $HC\geq\bar{y}$	No	Yes	404	0.239	-214.96
LF-MNL5	As MNL4	Yes	Yes	404	0.278	-200.08
LF-MNL6	As MNL4	Yes	No	372	0.327	-172.38

Notes: Generic utility function is set out in equation 6.1. HC is hours closed. All models include fixed effects by socio-economic group. For the piecewise models (LF-MNL4 to 6) multiple steps in headway and operating hours are specified (e.g. the vector $\bar{x}=\{60,120,180,240\}$ and $\bar{y}=\{0,7,12,16\}$), though only those that are statistically significant are retained in the final model. Estimated using ALOGIT v4.2.

Table 6.12 presents models LF-MNL1, 4, 5 and 6. All model coefficients have the correct sign and are statistically significant at the 90% level and above, aside from one coefficient in model LF-MNL6 which is based on a smaller sample (excludes non-traders). Investigations into the socio-economic parameters that give the best model performance in terms of largest log-likelihood and adjusted rho-squared give rise to the inclusion of household trip-making characteristics in model LF-MNL5. Characteristics such as income, car ownership, off-island employment and household structure are important determinants of behaviour, however, when combined in a model with trip making behaviour these characteristics cannot explain any additional variation in the data (i.e. are not significantly different from zero). This occurs primarily because these characteristics are important determinants of trip-making behaviour. In a model for use as a forecasting tool it would be inappropriate to include an endogenous variable (such as trip making behaviour) as an explanatory attribute in the model. In this instance it is acceptable as the interest is willingness to pay and the model with the most explanatory power is the preferred mechanism for deriving willingness to pay.

The marginal utilities presented in Table 6.12 and marginal valuations presented in Table 6.13 indicate the models estimated exhibit a number of desirable and expected properties:

- Those of low incomes have a higher marginal utility of income than those with high incomes (model LF-MNL4);
- The larger the headway the lower the marginal utility of a headway minute is (models LF-MNL4 and 5). This is consistent with the fact that at low headways a larger percentage of the time between headways is spent waiting (e.g. at the pierhead). Such time could invariably be spent in a far more productive manner (e.g. leisure). At long headways the marginal utility of a headway minute is the difference between the marginal utilities of different leisure activities. As such it is less than the marginal utility at low headways;
- Marginal utility and marginal value of an operating hour during the day (between 7am and 7pm) is more than during the evening and night (between 7pm and 7am) (model LF-MNL5). This is consistent with the fact that more activities are undertaken during the day than in the evening and at night;
- For model LF-MNL1, for which it is possible to calculate t-statistics for the marginal valuations, it can be seen that the marginal valuations are significant. 95% confidence intervals for the marginal values in model LF-MNL1 are +/-25% for the marginal value of headway and +/-22% for the marginal value of an operating hour.

The best performing multinomial model is LF-MNL5 and this is used as the basis for the development of the MXL models. Excluding non-traders from the data reduces the amount of unexplained variation (as evidenced by the higher rho-squared value for model LF-MNL6). It does not have a large effect on the estimated parameters or marginal valuations. Non-traders are therefore maintained in the data for the estimation of the MXL models.

Table 6.14 presents five random parameter mixed logit models. LF-MXL1 reproduces the best performing multinomial model by treating the data as cross-sectional. In model LF-MXL2 the data is treated as panel data but no taste variation is included in

Table 6.12: Local ferry SP game estimation results for MNL models

	LF-MNL1	LF-MNL4	LF-MNL5	LF-MNL6
Cost coefficient for all household incomes	-0.006 (-6.26)	-0.003 (-2.92)	-0.007 (-6.49)	-0.008 (-6.88)
Increment on cost coefficient for:				
Household income < £10,000 p.a.	---	-0.004 (-2.26)	---	---
Household income withheld	---	-0.009 (-2.57)	---	---
Headway coefficient (At all level of headways ≥ 30 mins and ≤ 240 mins)	-0.008 (-6.29)	-0.058 (-4.16)	-0.050 (-3.53)	-0.048 (-3.06)
Increment on headway coefficient:				
When 60mins ≤ headway < 240 mins	--- ---	0.048 (3.63)	0.042 (3.14)	0.040 (2.72)
When headways = 240mins	--- ---	0.004 (2.22)	0.004 (1.85)	0.003 (1.23)
For households making 5 or more trips per week over fixed link	--- ---	--- ---	-0.007 (-3.17)	-0.008 (-3.16)
Operating hours coefficient (no. of hours closed)	-0.131 (-7.80)	---	---	---
Increment on operating hours coefficient:				
When hours closed ≥ 12 hours (i.e. during day after 7am and before 7pm)	---	-0.129 (-8.06)	-0.062 (-3.27)	-0.071 (-3.58)
For households making 3 or more trips per week over fixed link	---	---	-0.132 (-4.18)	-0.145 (-4.29)
For households making 17 or more trips per week over fixed link	---	---	-0.140 (-2.13)	-0.187 (-2.21)
Observations	404	404	404	372
Log-likelihood	-232.34	-214.96	-200.08	-172.38
Adjusted rho-squared	0.161	0.239	0.278	0.327

Note: T-statistics in parentheses. Significant at 99% level if the t-statistic>2.33; at the 95% level if the t-statistic>1.96 and at the 90% level if the t-statistic>1.65. Estimated using ALOGIT v4.2.

Table 6.13: Marginal values of headway and operating hours (local ferry SP game MNL models)

	LF-MNL1	LF-MNL4	LF-MNL5	LF-MNL6
Marginal value of a headway minute (pence/headway minute/household trip)				
At all level of headways ≥ 30 mins and ≤ 240 mins	1.3 (8.0)	---	---	---
When 30 mins ≤headway < 60 mins	---	12.3 (N/A)	7.2 (N/A)	5.7 (N/A)
When 60mins ≤ headway < 240 mins	---	1.8 (N/A)	0.9 (N/A)	0.7 (N/A)
When headways = 240mins	---	0.8 (N/A)	0.3 (N/A)	0.4 (N/A)
Marginal value of an operating hour (pence/operating hour/household trip)				
At any time of day	22.41 (8.9)	---	---	---
Between 7pm and 7am (i.e. late evening and night)	---	0.0 (N/A)	18.5 (N/A)	17.4 (N/A)
After 7am and before 7pm (i.e. during day)	---	28.3 (N/A)	27.9 (N/A)	26.2 (N/A)

Note: For each model the value of headway and operating hours for each statistically significant population segment is calculated. A weighted average of these marginal valuations using the sample proportions is then calculated. This is the process of sample enumeration. An operating day of between 7am and 7pm implies an operating day of 12 hours.
T-statistics, in parentheses, calculated following Hess and Daly (2008). For piecewise nonlinear models LF-MNL4, 5 and 6 t-statistics cannot be calculated as there is insufficient information on covariances between the marginal values of different population segments.

the model. Taste variation is incorporated into models LF-MXL3 (normal distribution function), LF-MXL4 (triangular distribution function with no constraints on the spread) and LF-MXL5 (triangular distribution function with the spread constrained to the mean). Aside from model LF-MXL1 where the data is treated as cross-sectional all the other models correctly treat the data as panel data, as up to four observations are obtained from each respondent. The log-normal distribution is not used as it results in unrealistically high estimates of the mean willingness to pay (see Section 5.5).

As can be seen by comparing LF-MXL1 to model LF-MNL5 (in Table 6.12) the MXL model gives a good approximation to the MNL model. This gives re-assurance that the mixed logit models are being estimated correctly. There is no difference between models LF-MXL1 and 2, because without the introduction of a random parameter into the model the bias in the standard errors associated with panel data cannot be corrected. As can be seen from the log-likelihood values introducing taste variation into the model improves the level of fit significantly for the models fitted with the normal

Table 6.14: Local ferry SP game estimation results for MXL models

		LF-MXL1	LF-MXL2	LF-MXL3	LF-MXL4	LF-MXL5
Cost All trips	b	F -0.007 (-6.35)	F -0.007 (-6.44)	F -0.012 (-5.48)	F -0.012 (-5.58)	F -0.008 (-5.79)
	c	---	---	---	---	---
Headway coefficient (Headways ≥ 30 mins)	b	F -0.049 (-3.39)	F -0.050 (-3.79)	F -0.121 (-3.22)	F -0.123 (-3.29)	TC -0.006 (3.25)
	c	---	---	---	---	-0.006 (4.11)
Increment on headway coefficient for:						
Headways ≥ 60 mins	b	F 0.042 (3.00)	F 0.042 (3.30)	N 0.107 (3.07)	TU 0.110 (3.14)	---
	c	---	---	-0.018 (-3.70)	0.044 (3.92)	---
Headways ≥ 240 mins	b	F 0.004 (1.75)	F 0.004 (2.08)	---	---	---
	c	---	---	---	---	---
Households making 5 or more trips per week over fixed link	b	F -0.007 (-3.06)	F -0.007 (-2.67)	F -0.017 (-3.22)	F -0.017 (-3.20)	F -0.007 (-3.41)
	c	---	---	---	---	---
Operating hours coefficient (no. of hours closed)	b	0.000	0.000	0.000	0.000	0.000
Increment on operating hours coefficient for:	c					
Hours closed ≥ 12 hours	b	F -0.062 (-3.16)	F -0.062 (-2.93)	N -0.174 (-2.64)	TU -0.178 (-2.66)	TC -0.064 (-2.29)
	c	---	---	-0.281 (-3.56)	-0.670 (-3.85)	-0.076 (-2.29)
Households making 3 or more trips per week over fixed link	b	F -0.132 (-3.82)	F -0.132 (-2.86)	F -0.228 (-3.77)	F -0.225 (-3.71)	TU -0.201 (-4.03)
	c	---	---	---	---	-0.501 (-3.46)
Households making 17 or more trips per week over fixed link	b	F -0.139 (-2.43)	F -0.140 (-2.50)	F -0.357 (-2.47)	F -0.349 (-2.68)	F -0.154 (-2.43)
	c	---	---	---	---	---
No. of observations		404	404	404	404	404
Log-likelihood		-200.08	-200.08	-182.34	-182.26	-199.79

Notes: F, N, and TU and TC indicate distribution function for parameters. F means fixed (i.e. no distribution function), N is the normal, and TU is the triangular where the spread is not constrained in estimation and TC is the triangular with spread constrained equal to the mean. For each random parameter two coefficients are estimated (b and c). For the normal distribution the *mean=b* and *st.dev.=c*; and for the triangular *mean=b* and *spread=c*. T-statistics in parentheses. Parameter is significant at 99% level if the t-statistic>2.33; at the 95% level if the t-statistic>1.96 and at the 90% level if the t-statistic>1.65. T-statistics calculated using robust standard errors except model LF-MXL1. Models estimated using Train's Gauss code with 500 Halton draws.

(LF-MXL3) and the unconstrained triangular (LF-MXL4) distributions. The improvement in fit over the MNL model using a constrained triangular distribution (LF-MXL5) is marginal. In the models presented only some of the variables are treated as random. This is because some of the spread parameters are not significantly different from zero. It can also be seen that the introduction of taste variation reduces the number of variables (e.g. headway equal to 240 minutes) in the models. That is the distribution functions capture some of the variation in marginal utility that previously required an additional variable.

The advantage of using the constrained triangular distribution in the model estimation is that no part of the distribution of willingness to pay values has the wrong sign (negative). This is not the case for the normal distribution and the unconstrained triangular distribution. The fitted distribution of willingness to pay for model LF-MXL4 (triangular unconstrained) is set out in Table 6.15 and compared to the revealed distribution of willingness to pay. The comparison is also illustrated in Figure 6.6. The non-linear nature of the willingness to pay functions, and the mixture of fixed parameters and random parameters in the models make the fitted distributions hard to interpret and compare with the revealed distribution. It can however be seen that the fitted willingness to pay distribution has a part, between 11% and 14% (depending on the attribute), with the wrong sign. The model LF-MXL3 (with a normal distribution) has a very similar proportion of the distribution with the wrong sign. As argued earlier in this chapter and in Chapter 5 it is not expected that such proportions of the population would hold negative willingness to pay for improvements in headway and operating hours. The proportions are, however, not excessive when considered against the objective of the study - the derivation of willingness to pay values. On grounds of better model fit (higher log-likelihood) models LF-MXL3 (normal) and LF-MXL4 (triangular unconstrained) are therefore preferred to LF- MXL5 (triangular constrained). Model LF-MXL4 (triangular unconstrained) has a marginally higher log-likelihood than LF-MXL3 (normal) and the fitted distribution is also bounded which the normal distribution is not. This is more appealing as it is unrealistic to expect the marginal utility of headway and operating hours to tend to infinity for some members of the population. On these grounds LF-MXL4 is taken as the preferred model. It should be noted that if the models were to be used for forecasting a different preference might have been made as the proportions of the distribution that have a negative willingness to pay are, from a forecasting perspective, at the limits of acceptability.

Table 6.15: Comparison of observed and fitted cumulative distribution functions of willingness to pay for headway and operating hours

(a) Headway

Bin for marginal value of headway (H) (p/min)	Observed	LF-MXL4	
		When 30 mins ≤ headway < 60 mins	When 60mins ≤ headway ≤ 240 mins
H<0.00	unknown	0%	14%
H<0.17	11%	0%	16%
0.17≤H<0.52	4%	0%	21%
0.52≤H<2.29	74%	0%	57%
2.29≤H<5.00	88%	0%	97%
5.00≤H	100%	100%	100%

Notes: Shaded cell indicates bin holding the median value

(b) Operating hours

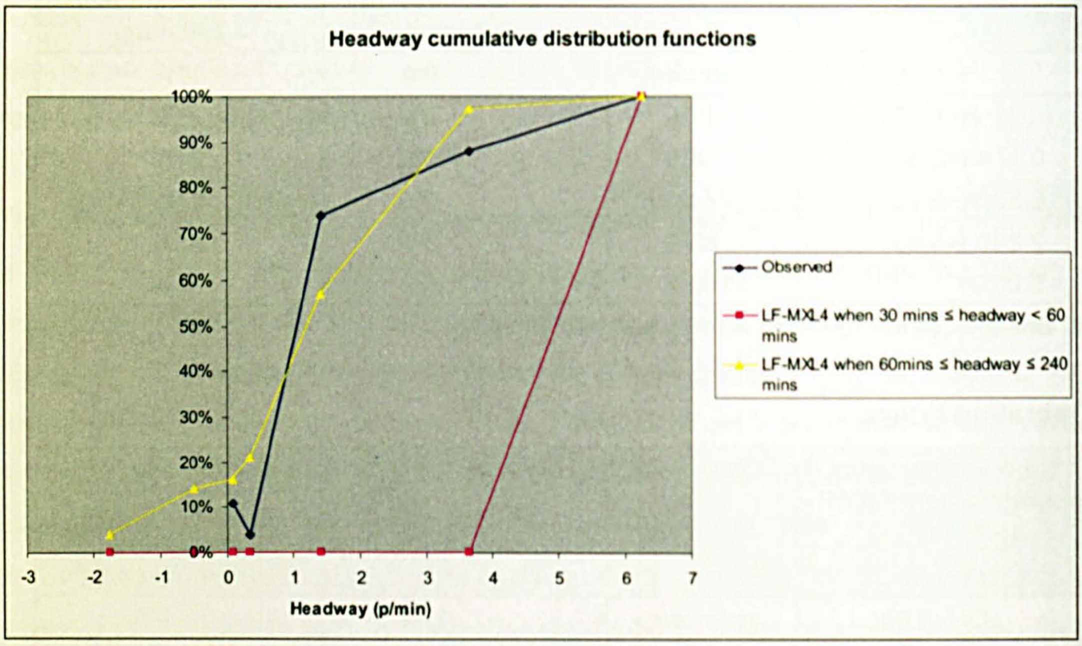
Bin for marginal value of operating hours (OH) (p/hour)	Observed	LF-MXL4	
		During day (7am - 7pm)	In evening and night time (7pm – 7am)
OH<0.00	unknown	11%	0%
OH<2.08	7%	13%	29%
2.08≤OH<3.13	40%	14%	29%
3.13≤OH<4.17	40%	15%	29%
4.17≤OH<8.33	13%	18%	29%
8.33≤OH	100%	100%	100%

Notes: Shaded row indicates bin holding the median value

Table 6.16 presents the willingness to pay values for the different MXL models. The second column of this table gives the marginal values for the preferred model (LF-MXL4). Here it can be seen that when headways are between 30 and 59 minutes, headways have a marginal value of 11.3 pence/headway minute/household trip, whilst when headways are between 60 and 240 minutes headways have a marginal value of 2.0 pence/headway minute/household trip. It can also be seen that the marginal value of an operating hour during the day (between 7am and 7pm) is more at 34.7 pence/operating hour/household trip than it is during the late evening and night (19.7 pence/operating hour/household trip). As discussed in Chapter 5 it is not possible to calculate t-statistics and confidence intervals for the marginal valuations derived from a mixed logit model. The marginal values presented in Table 6.16 are justified as statistically robust on the basis that the model parameters are statistically robust. 95% confidence intervals for the MNL model LF-MNL1, which has an inferior fit to the data, are also less than +/-25%.

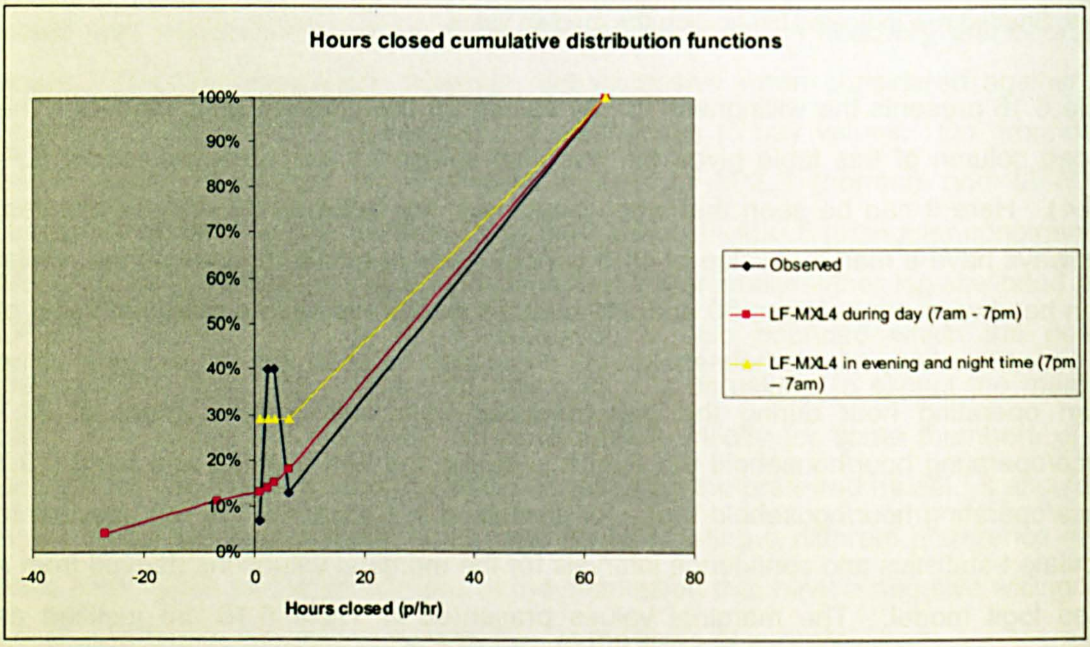
Figure 6.6: Comparison of observed and fitted cumulative distribution functions of willingness to pay for headway and operating hours

(a) Headway



Note: The apparent inconsistencies in the observed willingness to pay headway cumulative distribution function for values below 1p/min are associated with different marginal values being associated with long and short headways.

(b) Hours closed



Note: The apparent inconsistencies in the observed cumulative distribution function for values below 10p/hr are associated with different marginal values being associated with long closures and short closures.

Table 6.16: Properties of willingness to pay distributions for headway and operating hours (local ferry SP game)

	LF-MXL3	LF-MXL4	LF-MXL5
Marginal value of a headway minute (pence/headway minute/household trip)			
When 30 mins ≤ headway < 60 mins			
Mean	11.1	11.3	As for headways between 60 and 240 mins
Standard deviation	0.7	0.7	
Proportion with negative WTP	0%	0%	
When 60mins ≤ headway ≤ 240 mins			
Mean	1.9	2.0	1.4
Standard deviation	1.5	1.7	0.6
Proportion with negative WTP	13%	14%	0%
Marginal value of an operating hour (pence/operating hour/household trip)			
Between 7pm and 7am (i.e. late evening and night)			
Mean	20.0	19.7	22.3
Standard deviation	17.2	16.9	16.2
Proportion with negative WTP	0%	0%	0%
After 7am and before 7pm (i.e. during day)			
Mean	34.4	34.7	30.7
Standard deviation	25.3	28.5	16.5
Proportion with negative WTP	11%	11%	0%

Notes: Mean and standard deviation values estimated using a monte-carlo simulation based on a population of 10,000 (split into the statistically relevant socio-economic groups from the model using sample proportions). Lowest and highest 2.5% are excluded from calculation of mean and standard deviation for the unbounded normal distribution (LF-MXL3). Fixed cost coefficients and bounded distributions mean that all 10,000 simulations are used for LF-MXL4 and LF-MXL5.

6.6 Contingent valuation – estimation results

The primary purpose of the contingent valuation questions is to provide a validation of the fixed link stated preference results. As such the primary interest is in the average willingness to pay in the sample. Non-parametric methods are perfectly adequate for this and there is therefore no need to fit a distribution to the contingent valuation data (Bateman *et al.*, 2002 pp.224-228, pp.237-242). Table 6.17(a) and (b) present non-parametric summary statistics for each of the contingent valuation questions. The highest willingness to pay (£483 per annum per household) is associated with the choice between a fixed link and a 24 hour ferry that is free, has a 30 minute headway and takes 15 minutes longer than the fixed link. In contrast the willingness to pay for a free 24 hour ferry with a 30 minute headway compared to a 12 hour ferry with otherwise the same attributes is £270. A 15 minute time saving on the other hand is only valued at £43 per household per annum. This value is likely to be a lower bound, as there are a large number of zero responses to this question no doubt arising as a consequence of the 'unexpected' nature of tasking respondents to valuing travel time savings (see Table 6.10 and associated discussion).

95% confidence intervals for the mean willingness to pay values are presented in Table 6.17(b). As a proportion of the mean the confidence interval is narrowest for the 24 hour ferry to fixed link question (at +/- 25% of the mean). The 95% confidence interval for the willingness to pay for a 15 minute travel time saving is significantly larger than the other two intervals (at +/- 56% of the mean). This is most probably a direct consequence of the large number of zero responses.

Table 6.17: Non-parametric estimates of mean and median willingness to pay for transport quality improvements (contingent valuation questions)

(a) Summary statistics for willingness to pay (£ per annum per household)

Contingent Valuation question	Mean	Median	St. Dev.	Min	Max	No. of obs.
CV1: 24 hour ferry to fixed link	483.40	260.00	558.30	0.00	2500.00	84
CV2: 12 hour ferry to 24 hour ferry	269.50	104.00	385.80	0.00	2000.00	79
CV3: 15 minute time saving	43.40	0.00	104.50	0.00	520.00	70

Note: For the time saving contingent valuation question householders were presented with either a 10, 15 or 20 minute time saving depending on the island they lived on. The willingness to pay has been scaled to a 15 minute time saving for analysis.

(b) 95% Confidence intervals for the mean willingness to pay (£ per annum per household)

4	Lower bound of 95% CI	Upper bound of 95% CI	CI as percentage of mean
CV1: 24 hour ferry to fixed link	364.00	602.80	+/-25%
CV2: 12 hour ferry to 24 hour ferry	184.40	354.60	+/-32%
CV3: 15 minute time saving	18.90	67.90	+/-56%

Note: 95% confidence intervals calculated as $\overline{C} \pm 1.96.\sqrt{Var(\overline{C})}$ where $\overline{C}$ is mean willingness to pay and $Var(\overline{C}) = \frac{\sqrt{Var(C)}}{\sqrt{N}}$. N is the sample size, C is the willingness to pay.

It is reassuring to note that the median value for the 24 hour ferry to fixed link contingent valuation question is £260, which is entirely consistent with the revealed willingness to pay from the fixed link SP game (see also the discussion in Section 6.4 and Table 6.9). This is pleasing as it suggests consistency in response by householders between the SP games and the contingent valuation questions.

6.7 Fixed link stated preference game – estimation results

The same estimation strategy to that used for the local ferry stated preference game and described in section 6.5 is used for the estimation of a model to the fixed link stated preference game data. The generic utility function underpinning the model estimation was set out in Equation 4.5 in Chapter 4, but for convenience is also reproduced below:

$$U_h^{ferry} = \chi_k^{ferry} g(OH) + \varepsilon_h^{Ferry} \qquad (6.2)$$

$$U_h^{FixedLink} = \alpha_k^{FixedLink-Ferry} + \phi_k h(P) + \varepsilon_h^{FixedLink}$$

Table 6.18 presents the results of the first stage of the model estimation, the estimation of multinomial logit models. FL-MNL1 is a structurally simple model linear in operating hours with no interactions with socio-economic characteristics (i.e. no fixed effects by socio-economic segment). FL-MNL2 includes fixed effects by socio-economic segment and FL-MNL3 excludes non-traders (e.g. those who always chose the fixed link). As can be seen from this table all variables are of the correct sign and are significant at the 90% level or above. Once again it is found that trip making behaviour is the best 'fixed effect' variable to explain variations in marginal utility of operating hours by population segment. Trip making behaviour and island are the best variables to explain variations in the 'constant' utility of the fixed link. The adjusted rho-squared value for FL-MNL2 at 0.240 is not exceptionally high but, as mentioned earlier, is fairly typical for SP data. In contrast to the local ferry analysis it has not been possible to estimate a piece-wise model in operating hours to the data. That is a model in which the marginal utility associated with operating hours varied with the number of hours the ferry was available could not be estimated. Similarly no variation in the marginal utility of cost can be found. This difference between the local ferry and fixed link datasets is

Table 6.18: Fixed Link SP game estimation results for MNL models

	FL-MNL1	FL-MNL2	FL-MNL3
Cost coefficient for all household incomes	-0.003 (-8.5)	-0.003 (-8.8	-0.006 (-8.1)
Fixed link constant	1.411 (7.5)	1.421 (6.4)	1.189 (5.4)
Increment on fixed link constant for:			
Households on Berneray	---	-0.894 (-3.6)	---
Households on Vatersay	---	-1.414 (-3.3)	---
Households making 5 or more trips per week over fixed link	---	0.776 (2.9)	---
Households making 17 or more trips per week over fixed link	---	0.680 (1.7)	---
Operating hours coefficient (no. of hours closed)	-0.046 (-2.6)	---	---
Increment on operating hours coefficient for:			
Households making 3 or more trips per week over fixed link	---	-0.085 (-4.1)	-0.126 (-4.1)
Value of fixed link constant (£ per annum per household)			
Constant	-524.05 (7.3)	-514.78 (N/A)	-209.4 (6.7)
Marginal value of operating hours (£ per annum per household)			
All times of the day	17.15 (2.8)	19.62 (N/A)	15.83 (4.4)
Observations	517	517	282
Log-likelihood	-281.66	-245.92	-124.64
Adjusted rho-squared	0.130	0.240	0.362

Note: T-statistics in parentheses. Significant at 99% level if the t-statistic>2.33; at the 95% level if the t-statistic>1.96 and at the 90% level if the t-statistic>1.65. Estimated using ALOGIT v4.2. For each model the value of the fixed link constant and marginal value of operating hours for each statistically significant population segment is calculated. A weighted average of these marginal valuations using the sample proportions is then calculated and presented in the table. T-statistics for marginal valuations calculated following Hess and Daly (2008). For the piecewise nonlinear model LF-MNL2 t-statistics cannot be calculated as there is insufficient information on covariances between the marginal values of different population segments.

attributed to the coarseness of the fixed link data given the large number of non-traders.

Average willingness to pay values for models FL-MNL1 and FL-MNL2 are similar to the contingent valuation results presented in Table 6.17[37]. For the models estimated to data including non-traders (FL-MNL1 and FL-MNL2) the fixed link constant is just over £500 per household per annum whilst the marginal value of an operating hour is between £17 and £20 per household per annum. The confidence interval for the fixed link constant is +/-27% whilst that for operating hours is +/-70% (model FL-MNL1). The marginal value for operating hours is therefore not as well estimated as that for the fixed link constant.

Excluding non-traders from the data has a significant effect on the model estimated, as can be seen by comparing Model FL-MNL3 to model FL-MNL2. As expected the adjusted rho-squared statistic increases significantly, however the number of statistically significant explanatory variables is much lower and the implied willingness to pay values decrease significantly. Primarily this arises because a very large percentage of respondents (54%) exhibit non-trading behaviour with the majority always choosing the fixed link. As discussed in Section 6.3 non-trading behaviour varies systematically with income, trip making behaviour, car ownership and as such is viewed to be a valid reflection of householders choice. The mixed logit models are therefore estimated using data from both traders and non-traders.

Table 6.19 presents six random parameter mixed logit models. The first model (FL-MXL1) as in the previous SP game analysis reproduces the MNL model (FL-MNL2). The second model allows for panel data in the set-up and the standard errors are also robust to heteroscedasticity. However, the lack of taste variation in the model means that the only difference with model FL-MNL1 is that the standard errors are robust to heteroscedasticity. Taste variation is introduced in models FL-MXL3 to FL-MXL6. The differences between these models relates to their structure, as it was not possible to fit any distribution aside from the triangular distribution with the spread constrained to the mean to these data. The estimation process did not converge if a normal distribution function is used (with or without constraints on the standard deviation) or an unconstrained triangular distribution function is used. As can also be seen from this

[37] The second contingent valuation question was concerned with extending ferry opening hours from 12 to 24 hours. The mean willingness to pay for this is £269.50 i.e. £22.46 per additional operating hour.

Table 6.19: Fixed Link SP game estimation results for MXL models

(a) Models FL-MXL1 to FL-MXL4

		FL-MXL1		FL-MXL2		FL-MXL3		FL-MXL4	
Cost coefficient for all household incomes	b	F	-3.1(-8.80)	F	-3.1(-6.08)	TC	-28.5(-2.88)	TC	-8.8(-4.97)
	c		---		---		-28.5(-2.88)		-8.8(-4.97)
Fixed link constant (all households)	b	F	1,421.1(6.14)	F	1,421.1(3.65)	TC	36,367.5(3.13)	F	2,817.3 (6.33)
	c		---		---		36,367.5(3.13)		---
Increment on fixed link constant for:									
Households on Berneray	b	F	-894.2(-3.57)	F	-894.2(-1.88)	F	-23,149.4(-2.63)	F	-1,317.3(-2.11)
	c		---		---		---		---
Households on Vatersay	b	F	-1,414.2(-3.44)	F	-1,414.2(-1.98)	F	-20,385.0(-2.35)		---
	c		---		---		---		---
Households making 3 or more trips per week over fixed link	b	F	---	F	---		---		---
	c		---		---		---		---
Households making 5 or more trips per week over fixed link	b	F	775.7(2.98)	F	775.7(2.34)		---		---
	c		---		---		---		---
Households making 17 or more trps per week over fixed link	b	F	680.1(1.62)	F	680.1(1.41)		---		---
	c		---		---		---		---
Operating hours coefficient (no. of hours closed)	b		---		---		---		---
	c		---		---		---		---
Increment on operating hours coefficient for:									
Households making 3 or more trips per week over fixed link	b	F	-85.3(-4.15)	F	-85.3(-2.67)	TC	232.9(1.32)	TC	-291.3(-2.09)
	c		---		---		232.9(1.32)		-291.3(-2.09)
No. of observations			517		517		517		517
Log-likelihood			-245.92		-245.92		-112.88		-200.82

(b) Models FL-MXL5 to FL-MXL6

			FL-MXL5		FL-MXL6
Cost coefficient for all household incomes	b	TC	-9.8(-4.67)	TC	-4.3(-6.19)
	c		-9.8(-4.67)		-4.3(-6.19)
Fixed link constant (all households)	b	F	2,530.8(5.22)		---
	c		---		---
Increment on fixed link constant for:					
Households on Berneray	b	F	-1,850.6(-2.46)		---
	c		---		---
Households on Vatersay	b		---		---
	c		---		---
Households making 3 or more trips per week over fixed link	b		---	F	1,336.2(3.34)
	c		---		---
Households making 5 or more trips per week over fixed link	b		---		---
	c		---		---
Households making 17 or more trps per week over fixed link	b		---	F	867.3(1.87)
	c		---		---
Operating hours coefficient (no. of hours closed)	b	TC	-441.5(-2.03)		---
	c		-441.5(-2.03)		---
Increment on operating hours coefficient for:					
Households making 3 or more trips per week over fixed link	b		---	TC	-196.5(-2.75)
	c		---		-196.5(-2.75)
No. of observations			517		517
Log-likelihood			-196.98		-239.04

Notes: F and TC indicate distribution function for parameters. F means fixed (i.e. no distribution function) and TC is the triangular with spread constrained equal to the mean. For each random parameter two coefficients are estimated (b and c). For the triangular *mean=b* and *spread=c*. T-statistics in parentheses. Parameter is significant at 99% level if the t-statistic>2.33; at the 95% level if the t-statistic>1.96 and at the 90% level if the t-statistic>1.65. T-statistics calculated using robust standard errors except model FL-MXL1. Models estimated using Train's Gauss code with 500 Halton draws.

table only some of the parameters in each of the models include taste variation. This is because it is found that the spread of the distribution function was not statistically significant for many of the parameters.

In model FL-MXL3 it was possible to include taste variation on three parameters: cost, the fixed link constant for all households and operating hours for households making more than three trips. This gives a large improvement in the log-likelihood but also leads to an unrealistic model, as the fixed link constant is unrealistically large (greater than £1,100 see the third column of Table 6.20) and leads to the operating hours coefficient to have the wrong sign and lose its statistical significance. Model FL-MXL4 is therefore estimated without taste variation on the fixed link constant. This gives a substantial improvement in fit compared to the MNL model (FL-MNL2) as can be seen from the change in the log-likelihood value. In model FL-MXL5 all households (not just households making 3 or more trips a week) are allowed to hold a marginal utility for operating hours. This gives a further, albeit slight, improvement in model fit as judged by the log-likelihood of the model. In the final model FL-MXL6 it is tested whether trip making behaviour can better explain the variation in the data for the fixed link constant. The log-likelihood of this model is much worse than that for FL-MXL4 and FL-MXL5.

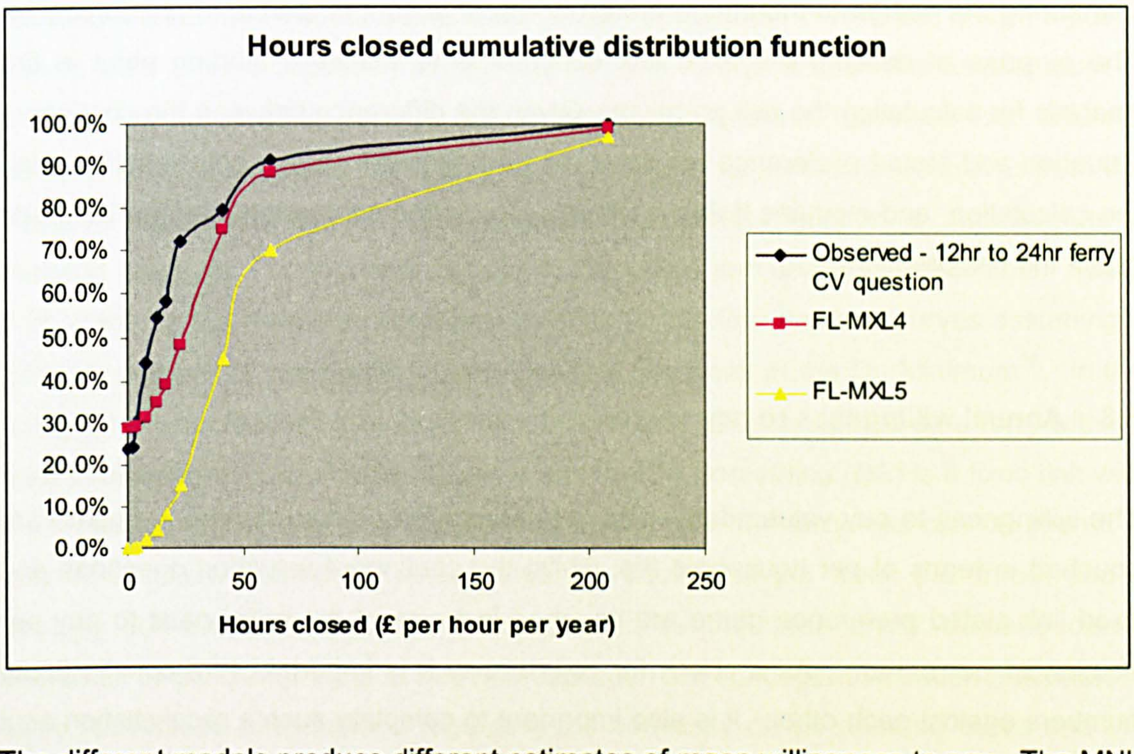
Table 6.20: Properties of willingness to pay distributions for fixed link constant and operating hours (fixed link SP game)

	FL-MNL3, FL-MXL1 and FL-MXL2	FL-MXL3	FL-MXL4	FL-MXL5	FL-MXL6
Value of fixed link constant (£per household per annum)					
Mean	514.8	1153.1	333.6	248.5	295.7
Standard deviation	N/A	982.6	284.2	216.0	275.2
Proportion with negative WTP	N/A	7%	0%	0%	0%
Marginal value of an operating hour (£per household per annum)					
Mean	19.6	-6.5	26.4	53.1	36.1
Standard deviation	N/A	-5.7	23.0	44.0	31.6
Proportion with negative WTP	N/A	100%	0%	0%	0%

Notes: Mean and standard deviation values estimated using a monte-carlo simulation based on a population of 10,000 (split into the statistically relevant socio-economic groups from the model using sample proportions). Lowest and highest 2.5% are excluded from calculation of mean and standard deviation for models FL-MXL3 to FL-MXL5 where the cost parameter is treated as random.

In choosing between models FL-MXL4 and FL-MXL5 it can be seen that whilst the log-likelihood for FL-MXL5 is the highest by a small margin, model FL-MXL4 is better able to reproduce the observed distribution of willingness to pay for hours closed (see Figure 6.7). On this basis FL-MXL4 is taken as the preferred model. It should of course be noted that in a manner similar to that observed for the inter-island ferry and the local ferry SP game analysis neither of these fitted distributions appear to reflect the revealed distributions particularly well. Further improving the fit of the distributions to that observed in the contingent valuation data is a topic for further research.

Figure 6.7: Observed and modelled cumulative distribution function for hours closed



The different models produce different estimates of mean willingness to pay. The MNL model gives willingness to pay values that are very similar to the mean willingness to pay values derived from the contingent valuation questions. However, introducing taste variation into the model significantly lowers the value of the fixed link constant and increases the marginal value of an operating hour - aside from model FL-MXL3 where the fixed link constant doubles and the marginal value of an operating hour has the wrong sign.

The preferred model, model FL-MXL4, has a value for the fixed link constant of £333.60 per household per annum. This value is outside the 95% confidence interval (£364 to £602) for the mean willingness to pay as derived from the contingent valuation question. The preferred model also has a marginal value for an operating hour of £26.40 (per household per annum). This lies within the 95% confidence interval from the contingent valuation data. The discrepancy between the contingent valuation data and the stated preference results is felt to arise from the inability of the stated preference design to recover large values for the fixed link constant (see Table 4.13 and associated discussion in Chapter 4). This stems from using a maximum council tax premium of £1,000 per annum. Whilst the design is quite able to recover values up to and slightly beyond the mean willingness to pay seen in the contingent valuation data it cannot recover values much larger. This results in a lowering in the mean willingness to pay as derived from the stated preference data. This is unfortunate but given the uniqueness of the study and lack of evidence on the value of fixed links for use during the design of the stated preference scenarios it is, perhaps, not surprising. The purpose of deriving the fixed link constant is to act as a starting point in the analysis for calculating the risk premium. Given the difference between the contingent valuation and stated preference results it will be necessary to use both results during the calculation, and examine if this materially effects the conclusion that can be made about the risk premium.

6.8 Annual willingness to pay versus willingness to pay per trip

The willingness to pay values derived from the local ferry stated preference game are couched in terms of per household trip, whilst the contingent valuation questions and fixed link stated preference game are couched in terms of the willingness to pay per household per annum. As a check for consistency it is important to reconcile these numbers against each other. It is also important to complete such a reconcilation as it is necessary to use the value for headway from the local ferry SP game (but in units of per household per annum) in the calculation of the risk premium. In converting a marginal value per trip to an annual value the usual procedure adopted within an appraisal is to multiply the per trip value by the number of trips made in a year.

As discussed below with some fairly strong assumptions regarding the curvature of the demand curve it is possible to almost reconcile the per trip and per annum marginal values as a consequence of elastic demand only. The strength of the assumptions necessary though mean that other factors most probably also influence the relationship between the per trip and per annum values. These include biases in the survey results and income effects. These are each discussed in turn. The presence of these effects, particularly the curvature of the demand curve and income effects, has important implications for the calculation of the economic impact of a transport project using the rule of a half (i.e. a linear demand curve) and assuming income effects are negligible. This is discussed in more detail below.

Elastic demand

Under elastic demand the change in consumer surplus of a policy intervention is given by Area $ABCD_1$ in Figure 6.8. The more convex to the origin the demand curve is, the smaller the change in consumer surplus is, with the limit being Area $ABCD_0$. The difficulty in estimating the change in consumer surplus in this instance comes from knowing the curvature of the demand curve and the demand before and after the policy intervention. This is because the data was not collected to facilitate the development of a model for forecasting demand. For illustrative purposes therefore four different demand curves have been fitted, ranging from a linear function to three curves from the negative exponential family. The negative exponential function is attractive as a demand curve as it is bounded, convex to the origin and analytically tractable. Table 6.21 presents the estimated consumer surplus for the four demand curves assuming a different number of vehicle trips per household per week in the Do Minimum[38]. In the policy intervention being evaluated the Do Minimum (DM) is defined as a ferry with 12 hour availability and 30 minute headway and the Do Something (DS) is a fixed link with a toll (similar to the ferry fare) but no time saving over the ferry. As can be seen it is only when a low number of person trips per household per week (i.e. three) and a strongly convex demand curve is assumed does the 'area under demand curve' estimates of consumer surplus begin to approach the contingent valuation estimates[39]. More reasonable assumptions regarding the convexity of the demand curve and the number of person trips in the Do Minimum would suggest that the per trip marginal values of headway and operating hours overestimate the per annum values by a factor of around 2.

---

[38] The *ex-ante* and *ex-post* studies of the Berneray causeway (Halcrow Fox, 1996; SQW, 2004) indicate that just over 4 vehicle trips were made per household per week. No information on household trip rates before construction of the fixed links is available for the other islands.

[39] The contingent valuation estimate of the change in consumer surplus also includes the risk premium. However, and as discussed in the following section, the risk premium is estimated to be zero. The contingent valuation estimate of consumer surplus and the area under the demand curve estimates are therefore directly comparable.

Figure 6.8: Change in consumer surplus under different demand curve assumptions - 4 person trips (1.2 vehicle trips) per household per week before improvement

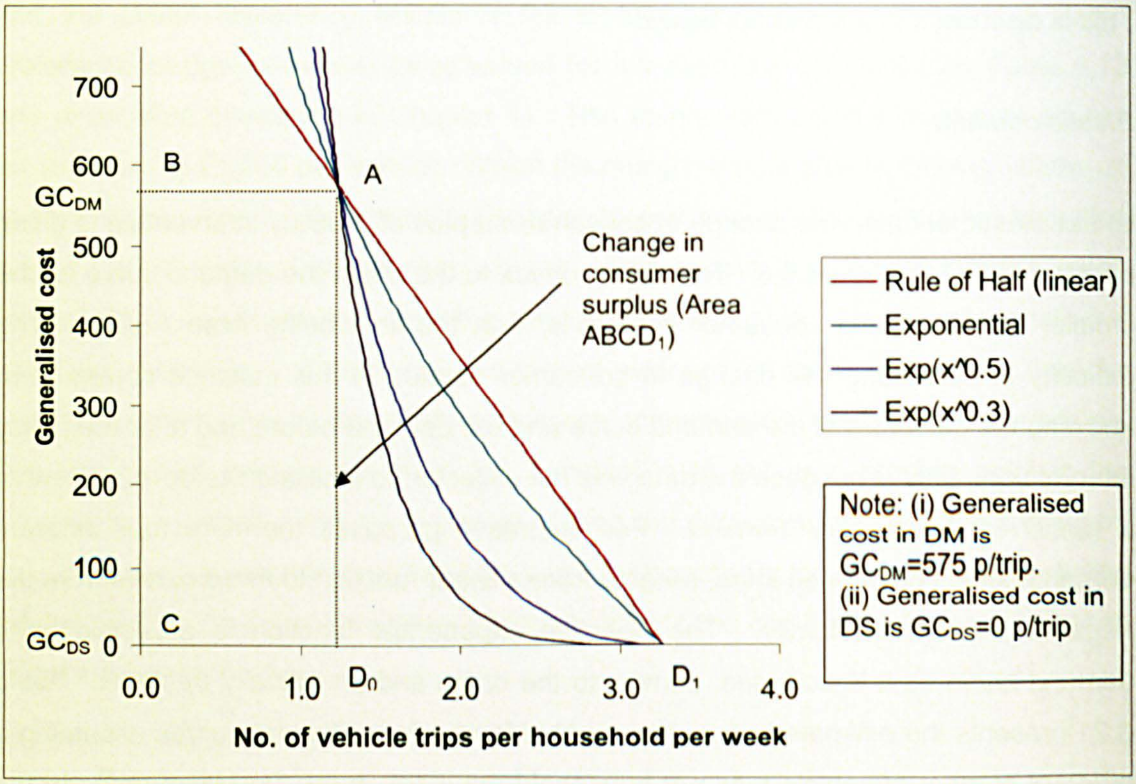


Table 6.21: Estimate of willingness to pay (£ per annum per household) for 24 hour availability and zero headway from 12 hour availability and 30 minute headway

	No. of person trips/week/household in Do Minimum (vehicle trips in parentheses) (£ per annum per household)		
	3 (0.9)	**4 (1.2)**	**6 (1.9)**
Contingent valuation estimate of change in consumer surplus	£666		
Area under demand curve (change in consumer surplus)			
Demand curve 1. Linear (Rule of half)	£1,256	£1,348	£1,533
Demand curve 2. $D_1=D_0e^{(-\beta.cost)}$	£1,112	£1,251	£1,493
Demand curve 3. $D_1=D_0e^{(-\beta.[cost]^{0.5})}$	£881	£1,048	£1,349
Demand curve 4. $D_1=D_0e^{(-\beta.[cost]^{0.3})}$	£761	£938	£1,268

Notes: D_1 is demand after intervention, D_0 is demand in reference situation. *Cost* is cost difference between DM and DS. Contingent valuation estimate of consumer surplus is sum of CV1 + CV2 – 2*CV3 (see Table 6.17). DS demand is 10.6 person trips per week (see Table 6.3). Average vehicle occupancy in presence of a fixed link toll is taken to be the same as for a ferry. Vehicle occupancy taken to be 3.24. Consumer surplus approximated for demand curves 3 and 4 as no direct integration is possible.

Scoping effect bias

Scoping effect bias occurs when respondents have difficulty valuing the size of the benefit, attributing similar values to large benefits as to small benefits. Difficulty in valuing the scale of the benefit means that values for small changes (per trip) maybe too high, whilst values for large changes (per annum) may be too low. The classic scoping bias study by Desvousges *et al.* (1993) found no significant difference between valuations to prevent the deaths of 2,000, 20,000 and 200,000 migratory waterfowl. Scoping effect bias also applies to situations in which a less than proportionate increase in willingness to pay occurs as the scale of the impact increases. This is relevant to this study, as a significant difference exists between per trip and annual values but the annual value is less than a proportionate increase in the per trip values. A rational economic explanation for diminishing marginal benefits as found in this study (i.e. the scoping effect) is one of satiation (see Bateman *et al.*, 2002 pp.392-397 for a discussion). In this context satiation would imply that willingness to pay for some trips is higher than for other trips. Higher valued trips may for example include work trips or the first discretionary (non-work related) trip a week. Therefore whilst householders were asked to respond to the service provision in general they may have in fact focussed on the higher value trips when responding[40]. Additionally householders when responding to the annual willingness to pay may have underestimated the full scale of the impact (an extra 12 operating hours a day is 4,380 extra hours a year). It is not possible to identify the impact of scoping effect bias ex-post without explicitly taking account of the effect in the survey design (which has not been done). All that can be done ex-post therefore is to treat the per trip values as an upper bound and the per annum values as a lower bound to the true willingness to pay.

Income effects

The measure of consumer benefits adopted in transport cost benefit analysis is that of consumer surplus - as illustrated in Figure 6.8. This is typically referred to as Marshallian consumer surplus. Such a measure of consumer benefits relies on nominal income being held constant. Holding utility (or real income) constant gives two alternative measures of consumer benefits – compensating variation if utility is held at

[40] Householders were asked which ferry service the household would prefer in general for the island. They were not asked which service would be preferred within the context of a specific trip. This is because the pilot survey identified that householders would choose a ferry service that was excessive for the needs of a particular trip (e.g. a service with long opening hours when the trip in question was completed by 4pm)..

initial levels and equivalent variation if utility is held at post-intervention levels. As the policy interest is in the potential benefits from the consumer's existing position for an improvement in transport quality compensating variation is the most appropriate of the two Hicksian measures. For a fuller discussion see Mitchell and Carson (1989 pp.23-26). Because it is much easier to estimate the Marshallian consumer surplus and for small income changes it is a suitable approximation to Hicksian compensating variation, Marshallian consumer surplus is used as a basis for transport cost benefit analysis.

The contingent valuation questions, both of which are couched in terms of annual willingness to pay[41], elicit the Hicksian compensating variation measure. This is because householders are asked to reveal the maximum they would be willing to pay for improved transport quality. The reference point is pre-intervention utility levels. In comparing the annual and the per trip willingness to pay values, as has been done in Table 6.21, a Hicksian compensating variation measure is therefore being compared to a Marshallian consumer surplus measure. For small income changes these would be expected to be similar. The Marshallian consumer surplus measures in Table 6.21 are not however small in relation to household incomes. Median gross household incomes are between £10,000 and £20,999 with 38% of households having a gross income of less than £10,000 p.a. Additional expenditure of between £1,200 and £1,500 per annum (as suggested by the Marshallian consumer surplus measure) therefore seems large. Across the UK average expenditure on transport by households in rural areas is £74.50 per week (or £3,874 per annum) (ONS, 2007 p.4). This includes vehicle replacement costs. Average expenditure on petrol and fuel is £17.50 per week (£910 per annum). This is slightly higher in the Outer Hebrides at £960 per annum[42]. An increase in expenditure of between £1,200 and £1,500, as suggested by the more realistic demand curves used in Table 6.21 to estimate the Marshallian consumer surplus, therefore is equivalent to an increase between 125% and 160% of petrol and fuel costs and an increase of up to 40% of average UK rural household transport expenditure. The lower 'Hicksian compensating variation' measure of £666 estimated from the contingent valuation data in Table 6.21 seems a more realistic estimate of willingness to pay when set in the context of average household incomes and existing expenditure patterns. This would suggest that including the income effect in the

[41] Householders were presented with both weekly and annual increments to council tax payments. Annual increments were included to ensure the full impacts on the household budget are appreciated.
[42] Source: 2003/4 Scottish Household Survey variable *HD19* (MORI Scotland *et al.* 2005).

estimate of consumer surplus may erroneously double the estimate of benefit received by households. This is because, from the evidence presented here, the Hicksian compensating variation measure of consumer surplus is 50% of the Marshallian measure. This is larger than the 30% for low income people found by Cherchi and Polak (2007) based on simulated data.

Summary

Under strong assumptions, regarding the curvature of the demand curve, it is possible to reconcile the marginal values from the local ferry stated preference game against the willingness to pay values from the fixed link stated preference game and the contingent valuation questions. More realistic assumptions suggest a difference between the two values of about 2. It is however not possible to state categorically why such a difference occurs between these data sources. This is because these data have not been collected in a manner that permits investigation for scoping effect bias, diminishing benefits per additional trip or for income effects. From an appraisal perspective the existence of substantial income effects is quite worrying as an implicit assumption in the use of the Marshallian measure of consumer surplus is that income effects are small. The difference between per trip levels aggregated to an annual basis and annual willingness to pay values is an interesting result from this study. Given the importance of income effects to the measure of total economic impact further research explaining this discrepancy would be of value.

6.9 The risk premium and non-use values

Risk premia occur because for risk averse individuals or firms under conditions of uncertainty the expected utility from an income is less than if that income was available with certainty. Option values are a form of risk premium and evidence of their existence for rail and bus services and the implications for economic appraisal in sparse networks have already been presented (in Chapter 3). It is expected that a risk premium will be attached to the availability of a transport link to and from an island. A fixed link is always available with certainty, whilst a ferry's availability is uncertain. It is therefore hypothesised that a risk premium for the fixed link will exist.

As discussed in section 4.3 (in Chapter 4) the fixed link constant is used as a basis for estimating the risk premium. For the reasons set out in that chapter, this is not an ideal approach and the contingent valuation questions were therefore used as validating mechanism. In addition to the risk premium the fixed link constant also includes elements of user benefit (reductions in journey time), scheduling costs (changes in headway) and non-use benefits (see Table 3.1 and discussion in section 3.1). To obtain an estimate of the risk premium we therefore need to subtract the willingness to pay for a headway reduction, for a journey time saving and for the non-use benefits from the value of the fixed link constant. However, to avoid overburdening respondents the risk premium and the non-use value are not separately identified, therefore only a combined estimate of the risk premium and the non-use value is obtained.

The fact that income effects probably influence total willingness to pay over a year for headway means it is necessary to adjust the headway (per trip) values before making the risk premium and non-use value calculation. Analysis indicates that per annum values for operating hours are 124 times larger than per trip values[43]. Using this factor would suggest that a per trip marginal value of headway of 11.3p/min leads to a per annum value of £14.01. A reduction in headway from 30 minutes to zero therefore has a value of £420.36 per household per annum.

Two values for the fixed link constant have been used given the difference between the value derived from the fixed link stated preference game and that derived from the contingent valuation question. The contingent valuation estimate is felt to be more robust as the fixed link stated preference game could not recover high values for the fixed link constant. Table 6.22 presents the estimate of the risk premium and the non-use value. As can be seen from this table both estimates are negative, though the one based on the contingent valuation data is only just negative. The lack of confidence intervals for the marginal values derived from the mixed logit models means no confidence interval can be derived for the risk premium and non-use value estimate. However, from the confidence available from the contingent valuation data and the indicative ones available from MNL models it is anticipated that the confidence interval for the risk premium and non-use value would easily encompass zero.

[43] From local ferry SP game the marginal value of an operating hour is 19.7p per hour per trip(single) per household. From the fixed link SP game the marginal value of an operating hour is £26.40 per annum household. From the contingent valuation question the willingness to pay for 12 additional operating hours is £269.50 implying a marginal value of an operating hour of £22.46 per annum household. This suggests that per annum values are between 114 and 134 times bigger than per trip values, the average of which is 124.

Table 6.22: Risk premium and non-use value of fixed link compared to 24 hour ferry with a 30 minute headway

	Fixed link SP game (FL-MXL4)	Contingent valuation
Fixed link constant (willingness to pay for an untolled fixed link from a base of a free 24 hour ferry with a 30 minute headway and a journey time that is 15 minutes longer (1-way))	334 (N/A)	483 (364, 603)
Minus:		
Value of 30 min time saving (1-way time saving of 15 mins) (source: contingent valuation question)	87 (38, 136)	87 (38, 136)
Value of 30 min headway	420 (N/A)	420 (N/A)
Risk premium and non-use value (£ p.a. per household)	-173.60 (N/A)	-23.80 (N/A)

Notes: Value of headway factored down by 8.9 to reflect difference between per annum and per trip valuations. 95% confidence intervals in parentheses were available.

This result is interpreted as indicating that householders do not perceive a difference between a 24 hour ferry with a very high frequency and a fixed link beyond user benefits (journey time savings) and scheduling benefits (headway costs). This could arise as both transport options offer a high quality service. With a free 24 hour ferry islanders do not feel cut-off from employment, services and leisure facilities and so on. This is an interesting result and would suggest that if a fixed link holds any risk premium over a ferry it is associated with operating hours. Such a line of investigation is left for further work, though it is noted that such a risk premium would be included in the willingness to pay value derived from the contingent valuation question on a 12 and 24 hour ferry.

6.10 Discussion of main findings

An analysis of responses to the SP and contingent valuation questions suggest that mass points exist at or close to zero willingness to pay. That is a proportion of the sample have a zero willingness to pay for changes in headway and operating hours. This is consistent with activities for some of the sample being unconstrained by poor quality transport schedules. The large proportion of pensioner households with few time constraints on the islands could well give rise to this mass point. The mass points appear to be about half the size of those observed for the inter-island ferry. This is consistent with the fact that travel for users of the inter-island ferry forms the major activity of the day, whilst for householders on Berneray, Eriskay, Scalpay and Vatersay travel is a facilitator of the day's activity. Transport schedules will therefore act as more of a constraint than in the inter-island case. There is some evidence of negative willingness to pay for transport links in the data, though this is a small proportion of the total sample. The evidence for this comes from the contingent valuation data where between 2 and 4% of households cited a preference for isolation rather than paying a council tax premium for improved transport quality. This is considered to reflect a net willingness to pay of several confounding attributes rather than representing a negative willingness to pay for a time saving. Improved transport quality increases utility through better activity scheduling, but may decrease a householder's utility as some characteristics of an island can be lost – for example the increased accessibility of the island to the outside world may result in an increase (or a fear of an increase) in crime.

The estimated models have acceptable levels of fit, but do not seem to replicate particularly well the observed distribution of willingness to pay near to and at zero. Improving the fit of the distribution functions through the same lines of investigation as proposed for the inter-island ferry remains an outstanding research issue (see section 5.5).

The data suggests that the marginal value of a headway minute and an operating hour vary non-linearly with headway and the length of the operating day. When headways are short marginal values are higher than when headways are long. This is consistent with the fact that with short headways a larger proportion of the time will be spent in an unproductive manner (e.g. waiting) than if headways are long. When the operating day is short the marginal value of an operating hour is more than when the operating day is long. This is also consistent with *a priori* expectations as, because most activities take place in the core part of the day, a long operating day will not impose many constraints on activity schedules.

Table 6.23 presents the marginal values for headway and operating hours on a per trip basis and their car in-vehicle-time equivalent minutes. The marginal values are, depending on headway length, 2.0 and 11.3 pence per headway minute and, depending on the length of the operating day, 19.7 and 34.7 pence per operating hour. These marginal valuations are within design range of the stated preference questions and this gives confidence in the validity of the results (see Table 4.7, 4.9 and 4.10 in Chapter 4). The calculation of car in-vehicle time minutes presented in Table 6.23 is dependent on vehicle occupancy for which there is no data. Using average occupancies from the Berneray ferry suggests that a headway minute is valued between 0.07 and 0.42 of a car-IVT minute (depending on headway length), whilst an operating hour is valued between 0.73 and 1.28 car-IVT minutes. No confidence intervals are available for these results which derive from the preferred mixed logit models. The case for these results being robust therefore centres on how well the parameters of the distribution functions for the different marginal utilities have been estimated. Some confidence in the robustness of the results can also be gained from the preliminary MNL model where the confidence intervals for the marginal value of headway and operating hours are +/-25% or below.

Table 6.23: Local ferry SP game preferred willingness to pay values as a proportion of car in-vehicle-time (2005 perceived prices and values)

(a) Headway

When headways are between:	Marginal value of a headway minute (per single trip)	Equivalent car in-vehicle time minutes (assumes average vehicle occupancy of 3.2)
30 and 59 mins	11.3 p/min (678 p/hr)	0.42 car-IVT mins per headway min (25.2 car-IVT mins per headway hour)
60 and 240 mins	2.0 p/min (120 p/hr)	0.07 car-IVT mins per headway min (4.2 car-IVT mins per headway hour)

(b) Operating hours

When operating day is:	Marginal value of an operating hour (per single trip)	Equivalent car/LGV in-vehicle time minutes (assumes average vehicle occupancy of 3.2)
8 hours (9am to 5pm)	34.7 p/hr	1.28 car-IVT mins per hour
12 hours (7am to 7pm)	19.7 p/hr	0.73 car-IVT mins per hour
17 hours (6am to midnight)	19.7 p/hr	0.73 car-IVT mins per hour
24 hours	19.7 p/hr	0.73 car-IVT mins per hour

Notes: Marginal values derived from model LF-MXL4. Average vehicle occupancy of 3.2 for an island residents' trip on a ferry - derived from analysis of Berneray Causeway *ex-ante* and *ex-post* studies (Halcrow Fox, 1996 and SQW, 2004 respectively). Average car occupant value of time is £5.07 per hour (i.e. 8.5 p/min) (2005 perceived prices and values). Derived from standard value of travel time savings per passenger (DfT, 2007b) using non-work other value of time.

In comparison to the inter-island ferry results the marginal values in pence per headway minute or pence per operating hour are a lot less, but as a proportion of car-

IVT the results are comparable. It seems therefore that different values of time (primarily the presence of work related trips on the inter-island ferry) are the main reason for the differences in values between the two surveys. The major difference between the local ferry data and the inter-island data is that with the local ferry data headways below 180 minutes have a marginal value attached to them.

The uniqueness of this research makes it difficult to make comparisons with other empirical evidence. The only empirical evidence in the literature to which it is directly comparable is that by Bråthen and Hervik (1997) that has been adapted into Norwegian appraisal guidance (Bråthen and Lyche, 2004). The latter give values for inconvenience costs (i.e. scheduling costs and queuing costs imposed by headway and operating hour restrictions) of 22 NOK for non-city centre ferry links that are replaced by a fixed link. This compares to a value of time of 96 NOK/hr. For infrequent departures and for high dependence ferry links the inconvenience costs are weighted by 1.5. The implication is that the inconvenience costs for replacing a 'lifeline' ferry with a fixed link is equivalent to a 21 minute time saving. The five case studies reported by Bråthen and Hervik had ferries that operated from 0530 to 2400 and operated with peak headways of less than 30 mins and slightly more in the off-peak. Using the car-IVT results in Table 6.23 the Outer Hebrides data suggests replacing a ferry operating at a 45 minute headway from 0530 to 2400 with a fixed link would have a marginal value per vehicle of 17 car-IVT minutes[44]. This is similar to the Norwegian appraisal advice and gives confidence in the validity of the results. The added value of this research over the Norwegian research is that the results can be applied to any ferry enhancement (including replacement by a fixed link), whereas the Norwegian work only relates to a particular type of ferry service (high frequency and long operating hours) and its replacement by a fixed link. Saying that the results here are restricted to non-work trips only, whilst the Norwegian research encompasses business trips and trips by commercial vehicles.

An interesting result that arises from this study is that the annual willingness to pay values surveyed are about half what might have been expected *a priori* from the marginal values per trip derived from the local ferry stated preference game. Given the low household incomes evident in the islands this potentially arises as a consequence of an income effect. This is important from the perspective of modelling the economic

[44] Calculated as the sum of 30 headway minutes at 0.42 car-IVT mins per headway minute, 15 headway minutes at 0.07 car-IVT mins per headway minute and 5.5 hours at 0.73 car-IVT mins per operating hour.

impact of a transport project as it would suggest aggregating values up to an annual basis using marginal values per trip will overestimate the economic impact of the transport project. It could however result from a form of respondent bias – a scoping effect. With the existing data it is not possible to identify the exact cause of the difference and this avenue of investigation would form an interesting topic for further research.

The data on annual willingness to pay is regarded as reasonably robust in that the fixed link stated preference game and the contingent valuation questions are consistent with one another. Furthermore there is a degree of consistency between the per trip values and the per annum values in that the proportion of consumer surplus attributed to a lengthening in operating hours and to headway is similar between the local ferry stated preference data and the contingent valuation and fixed link stated preference data. Given these consistencies and the potential for a significant income effect it is felt that willingness to pay values for island residents (who are always going to be frequent users of transport link to/from their island) should be based on the annual willingness to pay values. Such values are presented in Table 6.24. For occasional users of the transport link (namely those based off the island) per trip valuations are appropriate (see Table 6.23). Clearly these data relate to non-work trips only. There remains an evidence gap for business trips and for valuations associated with commercial vehicles, which future research should aim to fill.

The final finding of the study is that the data suggest no risk premium is associated with a fixed link type of infrastructure compared to a ferry type of infrastructure (see Table 6.24). This finding relates to the differences in infrastructure and not the level of service that is typically associated with each infrastructure type. That is the data indicates that householders attach no risk premium to a fixed link compared to a ferry service as long as that service offers a similar level of availability to the fixed link. This contrasts with the option value literature, where risk premiums are associated with transport type (bus or train). Potentially in the island context risk premiums may instead be associated with differing levels of availability (e.g. 9am to 5pm or 24 hours). Further research, however, is needed to confirm this.

Table 6.24: Annual willingness to pay values for island residents (2005 perceived prices and values)

	Marginal value per annum per household
When headways are between:	
30 and 59 mins	£14.01 per headway min
60 and 240 mins	£ 2.48 per headway min
When operating day is:	
8 hours (9am to 5pm)	£43.02 per operating hour
12 hours (7am to 7pm)	£24.42 per operating hour
17 hours (6am to midnight)	£24.42 per operating hour
24 hours	£24.42 per operating hour
Risk premium	
Fixed link infrastructure compared to ferry infrastructure	£0.00

Notes: Annual value of headway and operating hours is a factor of 124 times the per trip values (see Table 5.12). This is based off a comparison between annual willingness to pay values for a change in operating hours compared to willingness to pay for a change in operating hours at the level of a trip (see footnote 43).

These results have demonstrated that significant scheduling costs exist for households making short distance/local trips. Whether these are large relative to the other components of economic benefit is a different question, which the Berneray Causeway case study presented in the penultimate chapter addresses. If they are these results have important implications for the appraisal of ferries and new fixed links in the Outer Hebrides and Scotland in general. This chapter has brought to a conclusion the first part of the thesis in which benefits associated with activity re-scheduling and the value attributed to the increased security that households attribute to transport links have been examined.

7 WIDER ECONOMIC IMPACTS

7.1 Introduction

This chapter forms the start of the second part of the thesis. While the first part concerned the identification and quantification of benefits important in sparse networks but not included in an appraisal, this part concerns the economic impact of peripherality. Peripheral regions in a geographic sense are those that are located along the boundary of a nation, whilst peripheral in an economic sense are those of minor economic importance relative to other regions (the core). Here the concern is with regions that are both geographically and economically peripheral. Such regions are typically characterised by low population densities and incomes, and being located along the boundary of a nation, have high transport costs to the core. Sparse networks and geographic and economic peripherality tend to go hand in hand, though the effect of each characteristic on the economic impact of a transport project is distinct.

The low economic wealth of peripheral regions means that any impacts of transport projects on the rest of the economy, particularly the labour market, have high policy relevance. Creating and maintaining employment along with population is often cited as one of the key reasons for investing in transport infrastructure in peripheral regions. Poor transport infrastructure, it is argued by politicians, results in consumers facing high prices, residents not being able to access jobs and businesses being inhibited in their growth. A strong policy goal of maintaining a distributed population in an economically sensible way and reducing regional disparities is explicit in government actions both in the promotion of lifeline transport links to remote areas (Scottish Executive, 2004 p.19; 2006 p.56) and promoting economic growth in the most remote parts of Scotland (Scottish Government, 2007 p.19, pp.36-39). To date wider economic impacts in peripheral areas have been largely ignored in the literature. This chapter asserts that this is a mistake and wider economic impacts are likely to be as important to transport improvements in peripheral regions as they are in core regions.

In the literature a lot of consideration has been given to agglomeration externalities as the principal channel by which wider economic impacts will be felt (van Exel *et al.*, 2002; Laird, Nellthorp and Mackie, 2005; DfT, 2005; Eddington, 2006; Venables, 2007, Graham, 2007). This interest has led to a focus on urbanisation economies and productivity gains in large cities. This is of little relevance to peripheral regions with their sparse populations and primary sector industries. In contrast localisation economies associated with industrial clusters can be important in a peripheral region. Transport projects can therefore generate localisation externalities in peripheral regions and these should be taken into account where relevant. Next in importance the literature suggests are the wider economic impacts associated with imperfect competition in the goods and services market (Venables and Gasiorek, 1999; DfT, 2005). This impact is arguably more important in peripheral regions, as in peripheral regions markets are isolated and competition less intense. Labour economic literature would also suggest that two other market failures may be important in peripheral areas. These failures lead to involuntary unemployment (Elhorst and Oosterhaven, 2008) and thin labour markets (Findeis and Jenson, 1998; Vera-Toscano, Phimister and Weersnik, 2004; Pilegaard and Fosgerau, 2008).

This chapter is organised as follows. To set the context of the later sections section 2 discusses the benchmark competitive case. The next sections take each of the market failures in turn. They discuss the economic cause of the failure; the evidence to date on the additional transport related welfare benefits associated with the failure; and the relevance of the market failure to peripheral areas. Agglomeration economies are discussed in section 3, whilst additional impacts as felt in the product and services markets are discussed in section 4. Section 5 presents the labour market failures that lead to involuntary unemployment and thin labour markets. The final section brings the discussion together and identifies a future research agenda. This chapter also acts as a starting point for Chapter 8 which picks up one of the outstanding research issues and addresses it.

7.2 The competitive case

As transport is an intermediate good, the linkages between it and other sectors of the economy are numerous and varied. Changes in transport cost affect business operating costs, as the cost of transporting factor inputs to the production process, the costs of distributing finished goods and the productivity of employees travelling on company business are altered. A reduction in business costs in a perfectly competitive market reduces output prices and increases the demand for finished goods and services. This affects the labour market in that increased demand for goods and services will shift the demand curve for labour upwards[45]. If labour supply is perfectly elastic there will be no change in the wage, however, if it is less than perfectly elastic the market wage will increase[46]. This is illustrated in Figure 7.1 for a reduction in freight costs. As well as indirectly affecting the labour market via the goods market transport cost changes directly affect the labour market. This is because the cost of accessing employment is part of the labour supply decision. In a perfectly competitive labour market a reduction in commuting costs will shift the labour supply curve downwards lowering the market wage. With less than perfectly elastic labour supply the reduction in the wage will be less than the reduction in commuting costs. As the market is competitive firms pass on the reduction in wages to consumers in the form of lower product prices and an expanded output. This is illustrated in Figure 7.2 for the case of a commuting cost reduction. The land market is also affected by transport cost changes, with rents adjusting to reflect changes in accessibility and associated changes in real income.

These price and wage changes affect demand for goods, services and labour - all of which affect welfare. Demand is abstracted from competing goods and further rounds of price and output adjustments occur - all as a consequence of a transport investment. None of this is disputed; the important question from the perspective of a transport cost-benefit analysis is whether these effects have additional welfare impacts to those experienced by users, transport operators and the government (as set out in the economic identity in Chapter 1 – Figure 1.1).

Measuring the economic benefits of a transport initiative in the transport market gives a correct measure of total economic impact when perfect competition and constant returns to scale exist in the wider economy (i.e. outside the transport market) (Dodgson, 1973; Jara-Diaz, 1986). Changes in land values therefore double count transport user benefits (Mohring, 1961) and summing all the changes in profits for all firms in the supply and distribution chains (as conventionally reported in economic development reports) also represents duplication of the same benefit (Dodgson, 1973). Furthermore, if the price of land, labour or any factor input is less than perfectly elastic

[45] The size of the shift in the labour demand curve is a function of the labour-technology relationship for each industry.

[46] Under perfect competition the supply of labour in the labour market can be elastic (as in Figure 7.1(c)) or perfectly elastic, but the labour supply curve faced by the firm is always perfectly elastic.

Figure 7.1: Wider economic impact of a reduction in freight costs with perfect competition

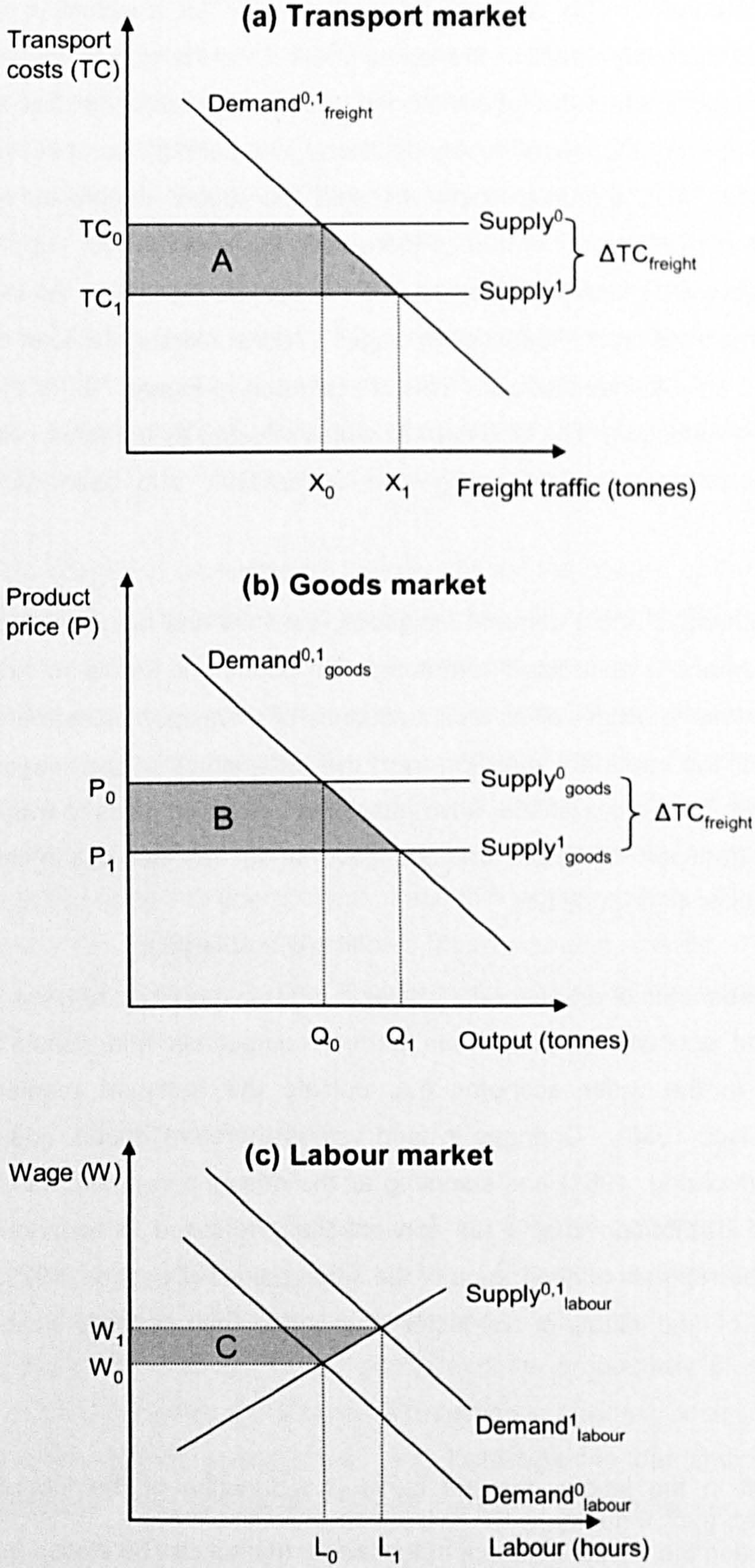
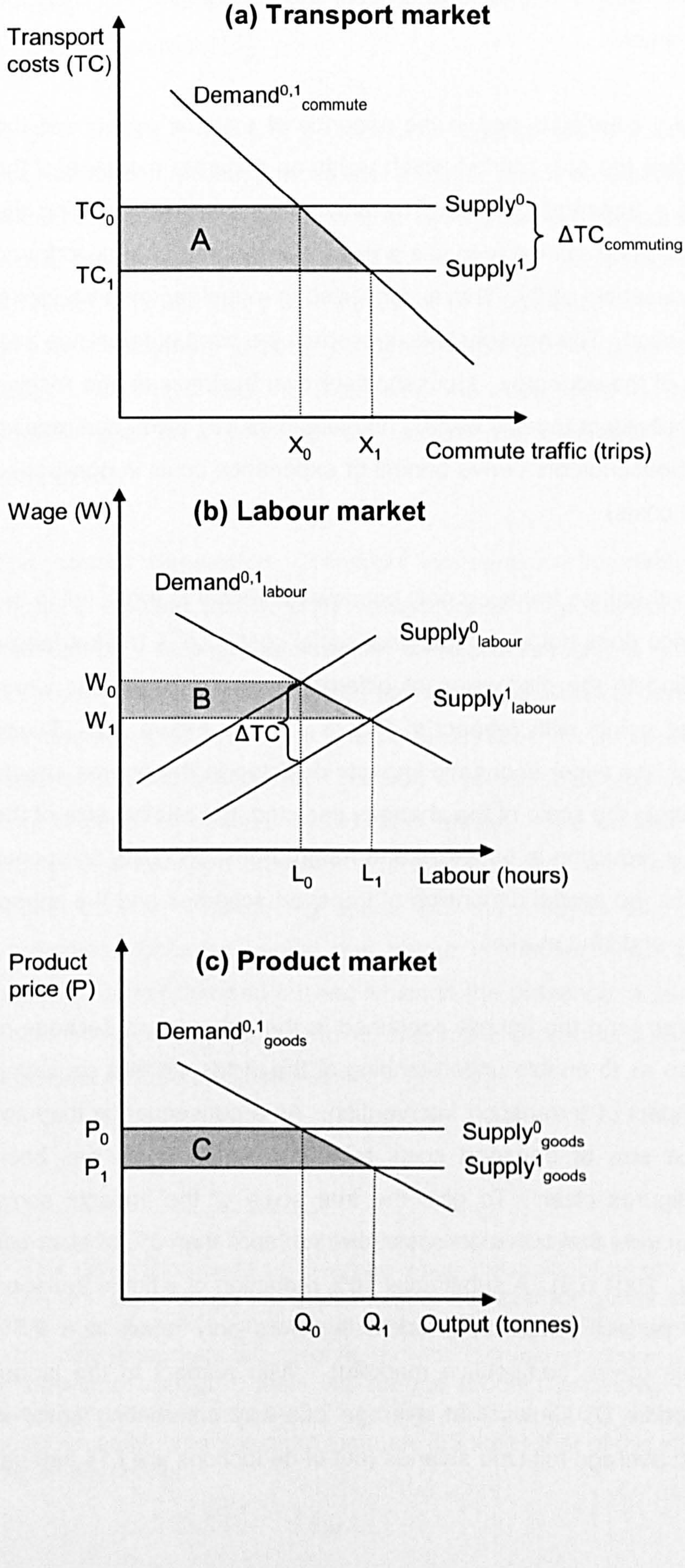


Figure 7.2: Wider economic impact of a reduction in commuting costs with perfect competition



only the transport market can be used to measure the full magnitude of the economic impacts (Nash and Mackie, 1990). This can be seen in Figure 7.1 and Figure 7.2, where the surpluses in the labour market and product market can be less than the surplus in the transport market.

Under perfectly competitive conditions and in the absence of external economies the transport market is therefore the only market which yields an accurate measure of the total economic impact of a transport project. The only alternative to measuring the economic impact in the transport market is to use a general equilibrium framework and measure the change in household utility. This is converted to monetary units via Hicks' concept of equivalent variation. The household is chosen as the point of reference as it brings together all facets of the economy. Householders own businesses and receive a share of the profit, householders receive wages, householders pay taxes and receive state social security and householders derive benefit or experience costs in non-traded items (e.g. environmental costs).

Surpluses felt in markets other than transport only become additional to those felt in the transport market when price does not equal marginal social cost – i.e. a market failure occurs. Before proceeding to the discussion of different market failures it is worth emphasising a number of points with respect to Figure 7.1 and Figure 7.2. These affect the context in which the wider economic impacts depicted in the figures should be seen. The points relate to the scale of the changes depicted, the relative size of the effect on employment of a reduction in business and freight transport costs compared to that of commuting costs, the spatial dimension of transport schemes and the impact of an elastic labour supply and land market.

Scale. Each of the figures (and the figures contained in the subsequent sections of this chapter) are drawn so as to enable understanding of the incidence and causation of the wider economic impact of a transport intervention. As a consequence they are not drawn to scale - the size of transport costs relative to other costs has been magnified to make the figures clear. To give the true scale of the impacts some context, there is a general view that transport costs form no more than 5% of business costs (e.g. McQuaid *et al.*, 2004 p.3). A substantial 10% reduction of a firm's transport related costs, assuming perfect competition, would therefore only result in a 0.5% reduction in output prices (given competitive markets). With respect to the labour market Chapter 8 (Appendix D) shows that average one-way commuting costs in Scotland are £2.10, whilst average full-time salaries (net of deductions are £14,840 per annum). This implies that commuting costs form about 6.5% of total full-time salary costs[47]. A substantial 10% reduction in commuting costs, with a perfectly competitive markets and a perfectly elastic labour supply curve, would therefore only reduce wages by an average of 0.65%.

Employment. The lack of a scale to the figures makes it difficult to ascertain whether the reduction in product prices has a bigger effect on employment than a reduction in commuting costs. For the illustrative case of perfect competition everywhere, perfectly elastic labour supply curve, constant returns to scale and a one region one sector economy, it is estimated that the effect of a reduction in transport costs faced by the firm on employment is about 3.5 times larger than it is for a reduction in commuting costs[48]. Output effects are most likely therefore to be the main driver to changes in employment, and therefore the arguments regarding the effects of imperfect competition.

The spatial dimension. Transport interventions invariably have a very focussed impact in a spatial sense. Only a proportion of the population will feel the impact of any intervention. A single intervention therefore has only a small impact on the whole economy. This is not to say that transport interventions have no impact, it is just that the overall impact on wages and product prices will be small relative to the size of a regional or national economy - possibly even too small to observe at an aggregate level (e.g. regional or national employment levels). The easiest place to observe a final impact of a transport project is in the land market, as this by definition has a strong spatial context. Introducing space into the analysis also has important economic implications because capital and labour is mobile. This can lead to shifts in the regional market demand curves, which in the presence of perfect competition have no additional wider economic impact, but in the presence of imperfect competition have important welfare implications.

---

47 Assumes 5 commuting trips per week and a 48 week year.

48 This calculation uses an average wage elasticity of labour supply of 0.1 (DfT, 2005 p.53) and an average price elasticity of demand for goods of 0.5 (DfT, 2005 p49). A 10% reduction in commuting costs, gives a 0.65% increase in the real wage unemployed workers will receive, thereby increasing labour supply by 0.065%. A 10% in business transport costs will reduce product prices by 0.5%, thereby increasing output and employment by 0.25%. The effect of a 10% reduction in business transport costs on employment is approximately 3.5 times that of the effect of a 10% reduction in commuting costs.

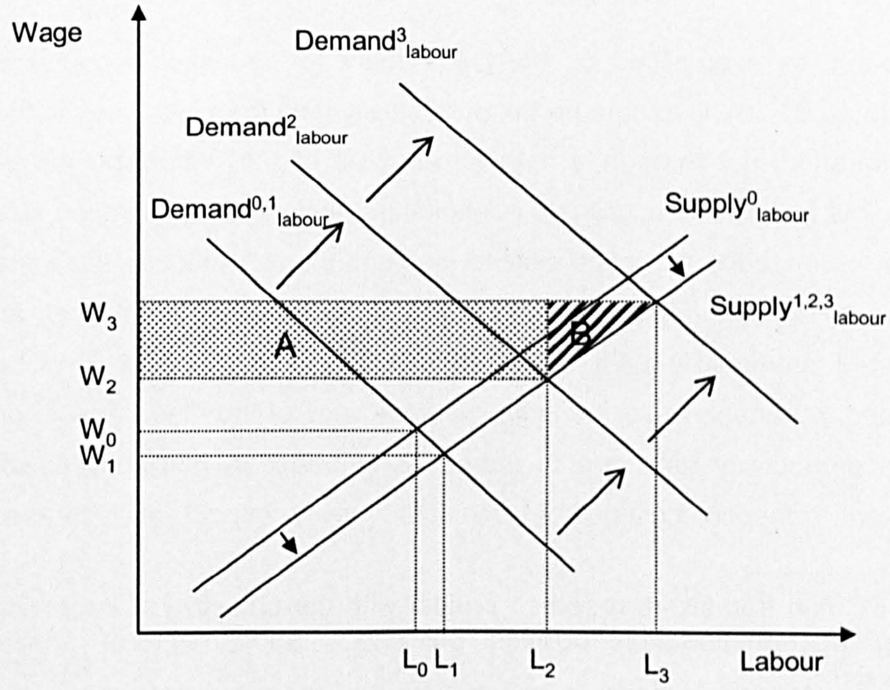
Elasticities of demand and supply. The benefits generated by changes in demand as a consequence of a change in input costs are heavily dependent on the elasticities of demand and supply. It should therefore be noted that Figure 7.1 and Figure 7.2 have been drawn for quite elastic situations. The reality may be very different as output or employment may, for example, not be sensitive to changes in travel cost. This is of importance for two reasons. The elasticity of the supply curves determines the proportion of the transport benefit that feeds through into a particularly market as a final impact; and secondly the elasticities of the demand and supply curves determine the changes in output/labour which act as the driver for any additional welfare impacts that may be felt in imperfect markets. The relevance of wider economic impacts to a transport intervention is therefore heavily dependent on the elasticities of demand and supply.

7.3 Agglomeration economies

Agglomeration economies have been the main focus of attention in the literature on the wider economic impact of transport interventions (van Exel *et al.*, 2002; Laird, Nellthorp and Mackie, 2005; DfT, 2005; Eddington, 2006; Venables, 2007, Graham, 2007). They arise as a consequence of the positive consumption externalities that occur when economic agents in transport using sectors of the economy are brought closer together by a transport improvement. By bringing these agents closer together labour productivity is raised above and beyond what would be expected from the transport efficiency saving alone. The numerous micro-economic linkages between economic agents, brought closer together, generate the externalities which, collectively and at a localised level, give rise to aggregate increasing returns or agglomeration economies. Whilst Marshall (1890) is credited with the first description of the sources of agglomeration, the literature describing the exact micro-economic linkages and evidence for them is, almost 120 years on, still evolving - see Duranton and Puga (2004) and Rosenthal and Strange (2004) for reviews.

Where agglomeration economies exist and where as a consequence of the transport intervention employment increases, Venables (2007) shows that two measures additional to transport user benefits are needed to capture the full welfare impact of the intervention. The first of the two additional measures relates to the productivity increase that occurs to existing and new workers. The second arises as a consequence of the distorting effects of taxation. The productivity effect is illustrated in Figure 7.3 for the case of an uncongested transport network. Here an improvement in transport quality lowers commuting costs, business transport costs and freight transport costs. With elastic labour supply some of the commuting cost reduction is passed on to the firm as a reduction in real wages – from W_0 to W_1 – via a shift in the labour supply curve. The reduction in business and freight transport costs leads to a fall in finished good prices, an expansion in output and an increase in employment from L_1 to L_2 (given appropriate labour-technology ratios). This is as discussed in section 7.2 for the competitive case. This leads to the first upward shift in the labour demand curve. The increase in employment from L_0 to L_2 increases the economic mass of the agglomeration and therefore the productivity of all workers increases. This gives the second outward shift in the labour demand curve. The final equilibrium position is given with employment L_3 and wages W_3. The benefit to firms from the reduction in wages and the benefit to workers from the increase in wages (due to the first shift in the demand curve) double count the commuter, business and freight traffic user benefits. The surplus to workers brought about by the second shift in the labour demand curve, that is Areas A and B, is additional to transport user benefits. This is Venables' first point. The presence of an income tax, by driving a wedge between the marginal product of labour (MPL) and the wage workers receive, creates an additional surplus to that depicted by Areas A and B when average (national) worker productivity increases. This surplus is received by the government in the form of additional tax revenue. This is Venables' second point.

Figure 7.3: Transport quality improvement with an endogenous productivity gain (and no labour tax)



There exists a substantial literature on the variation in worker productivity with agglomeration size (see Rosenthal and Strange 2004 for a review), though much of this data is international rather than British in nature. Rice, Venables and Patacchini (2006) and Graham (2007, in press) present recent UK evidence on such relationships.

There are two distinct approaches to the inclusion of transport/economy network effects in the literature. The first is to use a SCGE model to explicitly model the external economies of scale that arise through proximity in a detailed microeconomic framework, whilst the second is to use a partial equilibrium approach. The two principal examples of SCGE applications are the RAEM model in the Netherlands (Elhorst and Oosterhaven, 2008), and the CGEurope model which has been applied in a variety of European Commission (EC) research projects examining the economic impact of the Trans-European Transport Network (TEN-T) most notably in IASON[49] (Bröcker *et al.*, 2004). With respect to the TEN-T network the IASON research indicated that completion of all of the TEN-T priority infrastructure projects may generate between 20 and 30% more economic benefit than would be measured in a normal transport cost-benefit analysis. The additionality measured in CGEurope arises through productivity effects and imperfect competition in the goods and services market (as discussed in section 7.4), though it is not possible to disaggregate the results between the two effects. Elhorst and Oosterhaven (2008) find increases in labour productivity are between 12% and 21% of transport user benefits depending on the MAGLEV variant appraised.

The second approach, as exemplified by the Department for Transport's appraisal guidance (DfT, 2005 pp.55-58), is to capture the productivity gain from increases in the size of the agglomeration, not through a detailed analysis of the underlying micro-economic linkages, but through an aggregate relationship between agglomeration size and productivity. In essence the approach aims to measure the proportion of the wage increase (from W_0 to W_3 in Figure 7.3) that arises as a consequence of an agglomeration related productivity gain. This then allows Areas A and B to be calculated and added to transport user benefits. The success of the method rests on separating out the productivity gain due to increases in transport efficiency (lower business and freight transport costs) from the productivity impact of increased

[49] IASON was an EC fifth framework research project with the objective of improving the understanding of transportation policies on short- and long-term spatial development in the EU.

economic mass. The use of appropriate elasticities of productivity to economic mass is therefore critical otherwise some double counting will occur (see DfT, 2008 p.4 for a discussion). For Crossrail this method suggests that increased productivity generates an additional 24% of welfare benefits on top of transport user benefits. This increases to 52% when the income tax welfare effects associated with the additional employment and labour productivity are taken into account (DfT, 2005 p.8). As Crossrail re-distributes employment to the most productive part of the UK its agglomeration related wider economic impacts are representative of the largest such impacts one would expect to find in the UK.

As far as it can be ascertained the Department for Transport guidance has not been applied to a transport project in a peripheral region. The principal reason for this is that the guidance utilises Graham's research on the relationship between productivity and population mass. Graham's research, and Rice, Venables and Patacchini's research, relate to urbanisation economies – that is where the agglomeration economies are driven by pure economic mass (e.g. city size) rather than specific linkages between firms within a city. By definition urbanisation economies are those which are external to the firm and the industry but internal to the city (or region). Clearly such economies are of little relevance to sparsely populated peripheral regions.

Localisation economies are a different form of agglomeration economy and in contrast to urbanisation economies may prove of some importance to the appraisal of certain transport projects in peripheral regions. Localisation economies are those that are external to the firm but internal to the industry. They are therefore driven by proximity of firms to firms within the same sector or related sectors and to the size of the industry specific workforce. Of the industries Graham (2004 Table 1) identifies as exhibiting strong tendencies towards localisation (or clustering) several of them are prevalent in the peripheral parts of Scotland. These include textile manufacturing, oil and gas extraction, fish processing and food and drink processing. In terms of the spatial distribution of these industrial clusters of the top 30 local authorities exhibiting industry localisation 6 of them are in peripheral regions of Scotland (Graham, 2004 Table 4). These regions include the Shetland Islands (oil) and the Scottish Borders (textiles). Fishing is the main clustered industry in Eilean Siar (Outer Hebrides) and Argyll and Bute. The other two areas that exhibit industrial clustering are the Orkney Islands and Dumfries and Galloway. Whilst an international literature on localisation economies exists this mainly focuses on the manufacturing sector (see Rosenthal and Strange, 2004). Graham (in press) presents new evidence on localisation economies in the UK, and importantly he does not confine his analysis to the manufacturing sector. Amongst the industries Graham finds statistically significant evidence of localisation economies are the food and drink sector (which includes fish processing) and the paper and pulp sector - both of which are important employers in the peripheral parts of Scotland. He reports an elasticity of productivity to industry employment of 0.074 and 0.059 respectively for these industries. With respect to other industries in peripheral regions exhibiting localisation (fishing, oil extraction and service activities and textiles) he does not find any statistically significant localisation economies. For the primary sector industries this may have arisen as these industries are treated as a single sector. Graham also finds that localisation economies tend to attenuate quite rapidly with distance. Almost all localisation externalities are found within 10km of a firm.

How localisation economies will impact on the appraisal of a transport project in a peripheral area is uncertain, as to date the data on elasticities of productivity to localisation have not been used in this context. It is expected that localisation economies will have a positive impact on the economic benefit of a transport intervention where they exist, but will probably be more muted than the effect of urbanisation economies. This is for several reasons: the elasticities of productivity to localisation are much smaller than the corresponding elasticities of productivity to urbanisation (Graham, in press); the effect of localisation economies dissipates quite rapidly with distance (a quite limiting factor in an area where populations are dispersed); and the proportion of the population that work in the clustered industries is small. For example, only 6% of the population work in the fishing sector in the Outer Hebrides and 5% in the Shetland Islands, whilst only 3% of the population work in the mining and quarrying sector (includes oil extraction) in the Shetland Islands (GROS, 2008 Table UV77). This view is supported by the fact that Bråthen (2001) found no evidence of external economies affecting the growth of four firms located near to recently constructed fixed link crossings. In the main therefore localisation economies are probably not going to be of significant relevance to an 'average' transport scheme in a peripheral area. Clearly, there will be exceptions to this, such as where a transport intervention specifically targets a known cluster (e.g. improving road links to/from Peterhead an important fishing cluster in Aberdeenshire). To understand the full relevance of localisation economies in these exceptional cases, further work is needed to expand the evidence base on the elasticities of productivity and to disaggregate it further (e.g. identify elasticities of productivity for known clusters in peripheral areas).

7.4 Market failure in the product and services markets

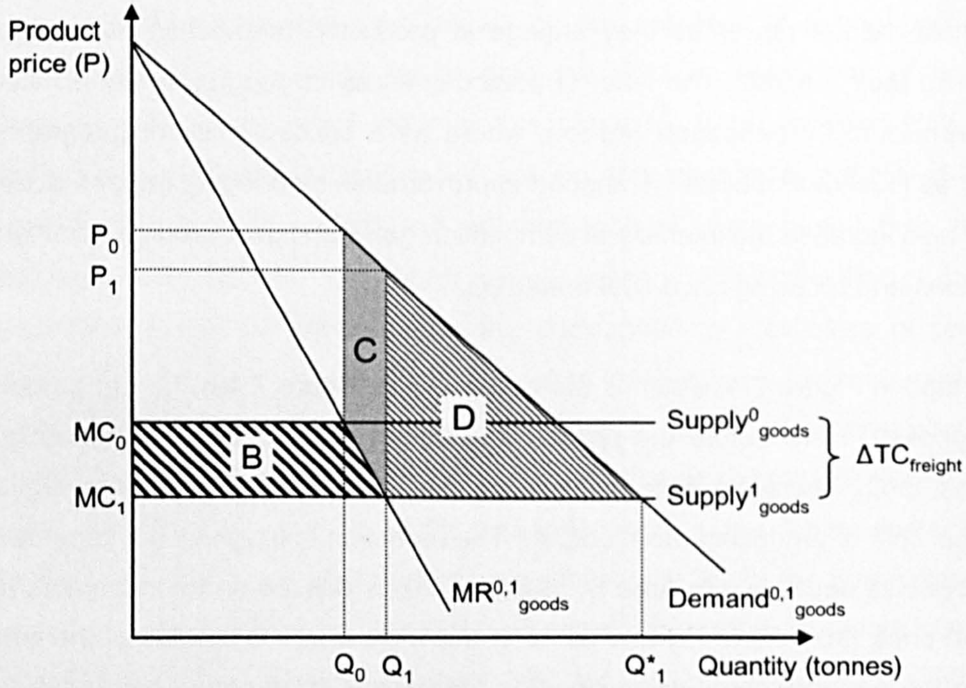
If a market failure occurs in the product and services market then a transport induced expansion of output will give rise to an additional welfare impact stemming from this market. This is because with a market failure output is not at its socially optimum level. Two sources of market failure can be identified; that associated with taxation on final products (i.e. indirect taxation) and that arising through the market power of firms. Since transport appraisal practice in the UK already takes account of the additional welfare impacts associated with indirect taxation (Sugden, 2002 pp.8-10; 2005) this issue will not be considered further. The remainder of this section focuses on market failure from imperfect competition (i.e. the market power of firms).

Firms may hold market power as they engage in product differentiation or become large relative to their market. The latter is particularly true in geographically isolated areas as exemplified by peripheral regions, where as a consequence of geography firms can act as local monopolists. Transport improvements by bringing regions closer together can also increase the intensity of competition between firms, eroding dominant market positions and reducing price-cost mark-ups.

This is illustrated in Figure 7.4, which is the equivalent to Figure 7.1(b) for the product market monopolist. Here before the reduction in freight costs (ΔTC) the monopolist restricts output to Q_0 where the marginal revenue (MR) from additional output is equal to the marginal cost of producing more output. The reduction in freight costs generates freight user benefits equivalent to Area B. Some of this is passed on to consumers as a reduction in price (from P_0 to P_1) and some of this increases the surplus of the firm. Compared to the perfectly competitive situation the expansion in output generates an additional surplus depicted by Area C. The transport improvement may also erode any geographically induced source of market power. At the limit, when all market power has been eliminated, price (P_1) will equal marginal cost (MC_1) and output will be at the optimum level (Q_1^*). If a freight cost reduction led to an erosion of all market power an additional surplus given by Area D would be generated.

Venables and Gasiorek (1999 Table 2) using synthetic data estimate that in a two region one sector economy with imperfect competition Area C is between 30 and 40% of Area B. This should not be interpreted as a mark-up of 30 to 40% on user benefits from a normal transport cost benefit analysis, as Area B relates to trade flows only (i.e. the consumer surplus derived by business and freight users). This result relates to a partial equilibrium analysis, in that changes induced in other sectors of the economy (the general equilibrium effects) are of no net social value – that is price equals marginal social cost in all other sectors of the economy. If prices do not equal marginal social costs in other parts of the economy additional welfare effects will be felt – which could be both positive and negative. Additionally, if only some of the sectors in the product and services markets operated imperfectly (rather than all of them), the 30-40% figure would represent an upper limit. That the 30-40% figure is an upper limit is re-enforced by Davies (1999), who undertook a review of the Venables and Gasiorek research.

Figure 7.4: Welfare impact of a reduction in freight costs with a monopoly producer of goods



For the UK as a whole the Department for Transport estimate that on average Area C is 10% of Area B – where Area B relates to business and freight time and reliability savings (DfT, 2005 p.49). This is based on a UK wide price-cost margin of 0.2 and an elasticity of demand for goods and services of 0.5. These data are sourced from a range of studies on price-average cost and price-marginal cost margins for the UK plus an estimate of the elasticity of demand for goods and services[50]. It should be noted

[50] An assessment of imperfect competition should be based on price-marginal cost margins as the market failure occurs when prices do not equal marginal costs. Price-cost margins and price marginal cost margins are only equivalent when industries exhibit constant returns to scale.

that this calculation rests on the assumption that the monopolist does not price differentiate. If a monopolist is able to discriminate between consumers they will expand output towards the socially optimum level (Q^*_1) and convert some of the surplus under the demand curve to producer surplus. In this scenario there will be a lower, and at the limit zero, additional welfare impact in the product market. With a price differentiating monopolist average price-cost margins will not be a good indicator of market power. To date this issue has not been explored in the literature, but such an argument may undermine the general case for wider economic benefits in the product market.

Market isolation in peripheral areas mean that firms can hold more market power in these areas than they do in core regions. Prices are certainly higher in peripheral regions. In 2003 petrol prices were on average 9.7% higher than in urban areas whilst food was 11.0% higher (Sneddon Economics, 2003 p.1). Not all of this price difference can be attributed to differences in market power as the cost of transporting goods to the region and differences in economies of scale in retailing account for some of this difference. With respect to petrol prices the Office of Fair Trading concluded that some of the price difference is definitely attributed to a lack of competition (i.e. market power of petrol wholesalers, BP, and the independent petrol retailers) (OFT, 1998 pp.69-72). There is no reason to expect the petrol wholesale and retail market to be different from other markets in peripheral areas, therefore it is contended that market power is a more relevant issue in peripheral areas than it is in core regions.

Aside from the reported studies there is a notable lack of evidence on price-cost margins specific to the remoter parts of the UK. The most disaggregate data available separates Scotland and Wales from the English regions (e.g. Harris, 1999) but does not disaggregate further. This is too coarse, as in a Scottish context there needs to be disaggregation between North West Scotland and the islands and the rest of Scotland. To understand the full wider economic impact of imperfect competition in peripheral areas it will therefore be necessary to undertake new research into price-cost margins in these areas. Consideration also needs to be given to the ability of firms to price discriminate, as with price discrimination the wider economic impact of a transport intervention will be reduced.

7.5 Market failure in the labour market

Three potential sources of market failure in the labour market exist. The first derives from the presence of a labour tax that distorts the supply of labour from the social optimum, the second can occur in the presence of involuntary unemployment, and the third occurs in the presence of thin labour markets.

It is important to realise that wider economic impacts will only be felt in the labour market if either employment expands at a national level, or employment is re-distributed between regions and there exist differences in the scale of market failure between regional labour markets. As very few transport projects are expected to increase employment at a national level the case that a transport project will generate wider economic benefits in the labour market rests on demonstrating that regional employment levels alter and regional differences exist between labour markets [51,52].

Excess labour supply (involuntary unemployment)

If involuntary unemployment exists and a transport project both reduces commuting costs and increases the demand for labour a calculation of the welfare impact in the transport market (using the rule of a half) will incorrectly estimate the benefit attributed to the generated traffic. This can be illustrated by drawing on an example in which wages in the labour market exceed the market clearing wage – that is wages are sticky in a downwards direction and a labour supply surplus exists. With reference to Figure 7.5(b) involuntary unemployment exists as the wage (W_0) is higher than the equilibrium wage (W^*_0). A transport project that lowers commuting costs results in a downward shift in the labour supply curve. With sticky wages employment levels and wages remain unaffected (i.e. L_1 = L_0 and W_1 = W_0). The welfare impact of the transport improvement equals Area A. This is the benefit felt by existing workers travelling to work more easily and can be correctly measured in the transport market – as can be seen in Figure 7.5(b). Now if business and freight transport costs also reduce, regional output and employment will expand (as in the competitive case Figure 7.1(c)). This is akin to a rightward shift in the regional labour demand curve. The final level of employment becomes L_2 and the level of involuntary unemployment is reduced. A

[51] For this to hold the marginal product of labour of the worker holding a job that is re-distributed to a different region, as a consequence of the transport intervention, has to be the same in different regions. This does not imply that average regional labour productivity across different regions has to be the same.

[52] Interestingly DfT (2005 pp.51-52) appear to assume that all transport projects can expand employment at a national level as they include the additional tax revenue generated by improved labour supply as a wider economic impact. It is understood that this guidance may alter in the near future, in the sense that its application maybe restricted to certain 'large' schemes.

welfare gain equivalent to the shaded area Area D, is therefore felt by workers, no longer involuntarily unemployed, in the form of wages paid over and above the reservation wage. A welfare gain is also felt by employers, equivalent to Area C, as they enjoy an increase in producer surplus – their willingness-to-pay for the additional labour exceeds the wage they pay. A conventional transport user benefit analysis that correctly estimated the increase in commuting trips would, however using the rule of half, incorrectly assign half the economic benefit of existing trips to these generated trips (i.e. Area B in Figure 7.5(a)) - when in fact the benefit is given by the sum of Areas C and D. The total welfare impact of the transport cost reduction and the associated increase in employment is given by the sum of Areas A, C and D of which only Area A can be measured in the transport market.

Elhorst and Oosterhaven (2008) show in their appraisal of four variants of a MAGLEV[53] line that labour market effects in peripheral areas can have a substantial impact on scheme benefits. Depending on the route of the MAGLEV line under consideration, they found that wider economic impacts may change benefits as measured in a conventional transport cost benefit analysis by between -1% and +38%[54]. Their results are very interesting in a number of ways. Firstly, they demonstrate that including wider economic impacts into an appraisal can lower as well as increase economic welfare, and secondly they indicate that for what appear to be very similar projects (each project variant is a MAGLEV line) very different levels of additionality can be obtained. The differences between the project variants arise as a result of the different impacts they each have on the labour market. The two variants that provide a high speed link between the four cities of the Randstad, that is the variants that re-enforce the Randstad agglomeration, have positive impacts for overall productivity of the Randstad region, as discussed in the previous section, however, these variants also have a negative welfare impact on the regions from which labour is extracted. The opposite is the case for the variants that link the periphery (Groningen) to the core (the Randstad). As the welfare gain from improving the efficiency of the labour market exceeds the productivity decrease from shifting employment from the core to the periphery, the MAGLEV variants which link the Randstad (the core) to Groningen (the periphery) have more net positive additionality than the projects that link the four cities of the Randstad.

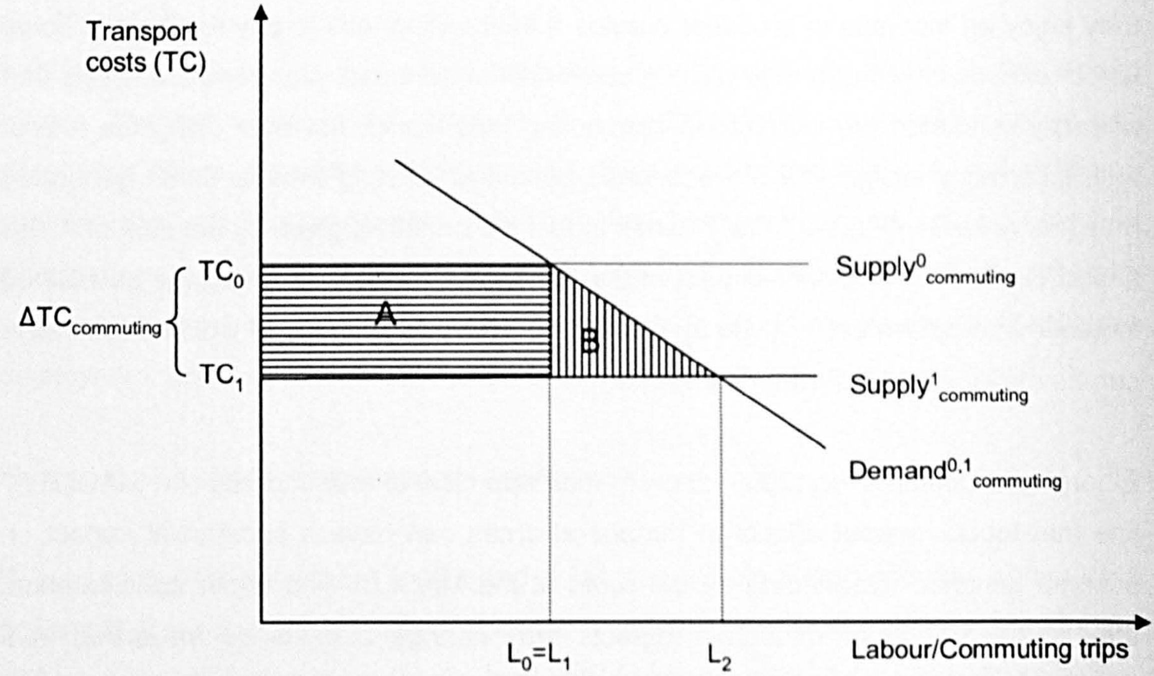
---

[53] Magnetic levitation train

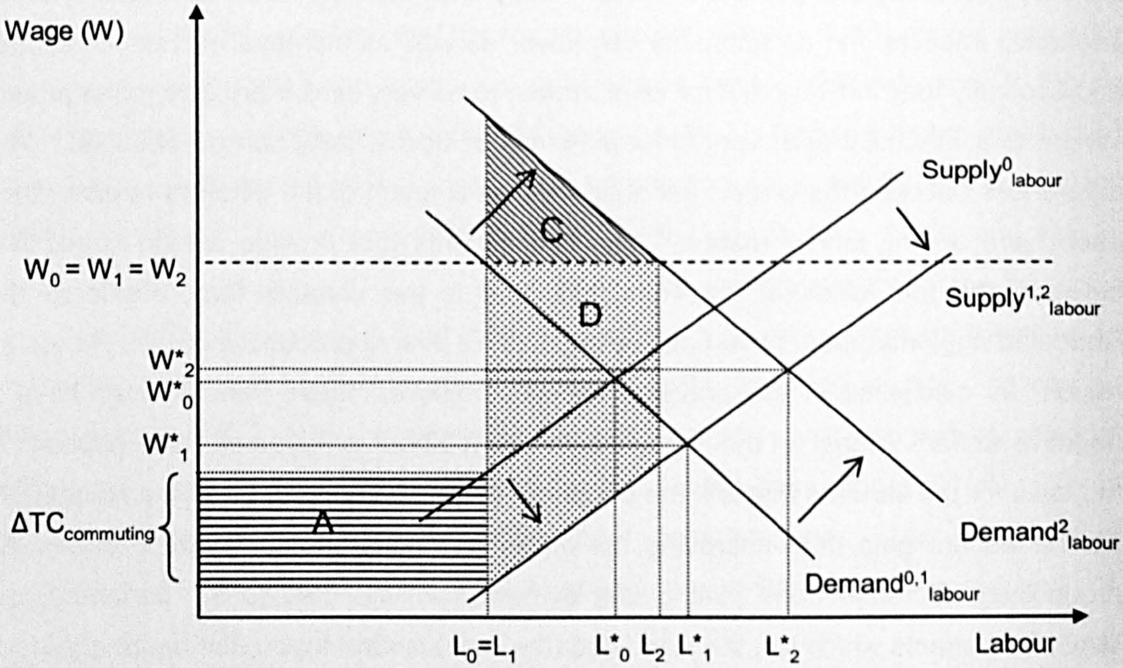
[54] Oosterhaven and Elhorst (2003) report a wider range (-15% to +83%) derived from earlier versions of the model.

Figure 7.5 Welfare impact of a commuting cost reduction and shift in regional labour demand under regional labour supply surplus (with no labour tax)

(a) Commuter transport market



(b) Labour market



This example on the face of it suggests that there could be substantial additional economic impacts for transport projects in peripheral regions. The results are, however, case dependent. In this instance they arise as a consequence of both the characteristics of the regional labour markets, the manner that the project variants redistribute employment between regions, and the manner that national wages by industry prevail in the Netherlands. The latter point is extremely important. In the Netherlands there is a legal mechanism, the setting of national wages by industry, which means an excess supply of labour will prevail in peripheral regions when the market clearing wage is below the minimum industry wage. In contrast there is no legal mechanism in the UK that keeps the wage above the market clearing wage. This combined with the fact that those losing jobs in rural areas are thought to have a higher propensity to migrate away from the an area completely rather than remain in an area and search for a job (Monk and Hodge, 1995) mean that in the UK this market failure probably has less relevance to peripheral areas despite the evidence from the Netherlands. Evidence for this position includes the fact that of the eight local authorities that might be considered peripheral in Scotland only one (the Outer Hebrides) has an unemployment rate in excess of the Scottish average. Furthermore, three of the lowest five regional unemployment rates are associated with peripheral areas. Falling population levels as evidence of out-migration are also certainly evident for all the Scottish island groups[55] and the north and north-west coasts of Scotland (Sutherland, Caithness and Lochaber) (HIE, 2003b Table 2). This would suggest that in peripheral areas of Scotland there is no significant discrepancy between the wage and the market clearing wage. Unlike the Netherlands there is therefore no market failure that brings about involuntary unemployment in peripheral areas. In the UK market failures that bring about involuntary unemployment may be more relevant to urban areas where unemployment is high (e.g. Glasgow).

Thin labour markets

Labour markets in rural areas are often viewed as thin as job opportunities are limited (Findeis and Jenson, 1998; Vera-Toscano, Phimister and Weersnik, 2004). The limiting case of a thin labour market is the monopsony case where only one employer exists for labour. This illustrative case is worth examining as whilst it is not a realistic depiction of a modern labour market the consequence of the market failure (a wedge between the marginal product of labour and the wage) is relevant to thin labour markets.

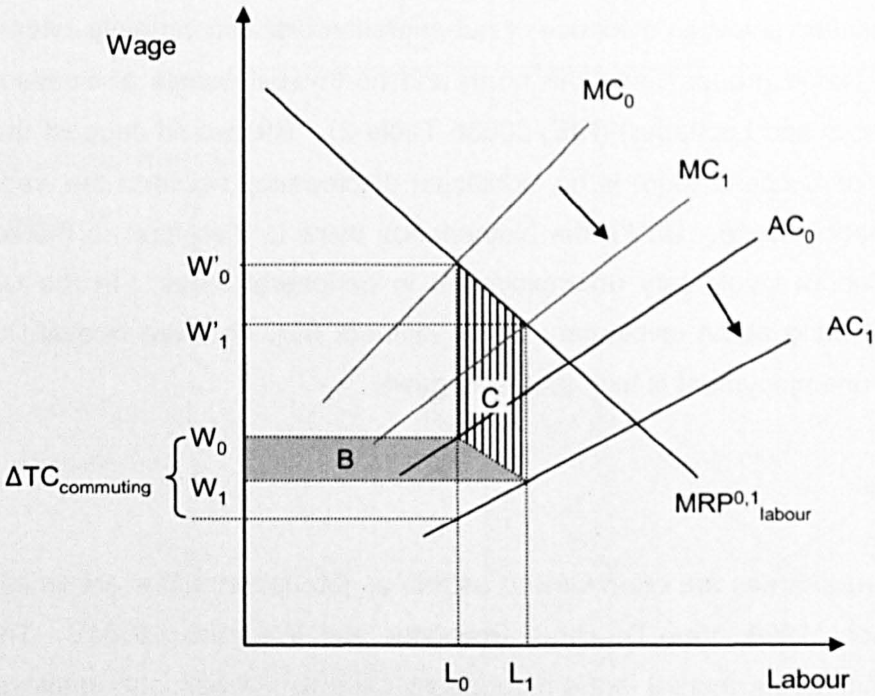
A monopsony employer faces an upward sloping labour supply curve. If it cannot discriminate then to recruit additional workers it needs to raise the wage paid to all

---

[55] The population of the Outer Hebrides (Eilean Siar) dropped by 10% between 1991 and 2001

workers. This implies that the marginal cost (MC) of labour supply to the firm lies above the average cost of labour supply (AC). This is illustrated in Figure 7.6. To maximise profits the firm will therefore employ L_0 workers and pay them W_0. This is because when employment is at L_0 profits for the firm are maximised with the marginal cost of labour equal to its marginal revenue product (MRP_{labour}). Employment levels (L_0) are therefore below those of full employment. That is the labour market is inefficient. In equilibrium therefore a wedge exists between the marginal revenue product of labour and the wage received by workers. The surpluses felt in the labour market are therefore given by Areas B and C. Area B double counts commuter user benefits (Area A in Figure 7.2(a)), whilst Area C, the welfare benefit of expanding employment, is additional to transport user benefits.

Figure 7.6: Welfare impact of a commuting cost reduction under monopsonistic competition (with no labour tax)



The limiting monopsony case of a single employer is not in itself of direct relevance to modern economies or peripheral areas. For example, only 26.2% of workers in the Highlands and Islands work in a firm with more than 100 workers (HIE, 2003b). The modern monopsony literature in which (a lot of) competing firms have some market power over workers, is of relevance to modern economies (Bhaskar, Manning and To, 2003; Manning, 2003a). In this literature it is argued that a large number of independent and competing firms are able to exert market power over workers due to:

the presence of imperfect information on the part of workers and firms; the heterogeneous preferences of workers; and workers' mobility costs. Job search models (see Rogerson, Shimer and Wright, 2005 for a survey) encapsulate some aspects of this source of market power. In these models unemployed workers have difficulties in finding information on job vacancies, and even if there are many jobs within the workers' neighbourhood only a small percentage of them become vacant at any one time. From the perspective of the employee labour markets are therefore thin, even if there are many firms.

The wedge between the wage and the marginal product of labour is critical to the estimation of the wider economic impact of a transport project in a thin labour market (i.e. Area C in Figure 7.1). The wedge itself depends on the elasticity of the labour supply curve faced by the firm (noting under perfect competition it should be perfectly elastic), however, a good estimate of this elasticity still eludes labour economics. On average what estimates that are available suggest that wages will on average be about 17% below the marginal product of labour (Manning, 2003a Chapter 4). With reference to Figure 7.6 this implies that the average difference between W'_0 and W_0 represents 17% of W'_0. This suggests that if employment generation effects are significant (i.e. the difference between L_0 and L_1 is important) the size of Area C may well be substantial. This hypothesis is confirmed by Pilegaard and Fosgerau (2008) who implement a Pissarides (1990) type job search model into a spatial computable general equilibrium (SCGE) model populated with Danish economic data. The model is then used to evaluate a transport quality improvement that increases labour supply at a national level. They report significant additional benefits of around 30% of commuter user benefits arising from the labour market (for an economy with no labour tax) as a consequence of search imperfections.

From the perspective of modelling the wider economic impact of a transport project in a peripheral area, where there is no net increase in employment at a national level, a key issue is whether the size of the wedge between the marginal product of labour and the wage is bigger in peripheral regions than it is in core regions. This is because if there is no difference in the wedge re-distributing employment between the regions will have no net impact (in much the same way that a labour tax wedge has no net impact on a re-distribution of employment). High mobility costs and high job search costs would suggest that labour markets are thinner in peripheral areas than in core areas and this would suggest that the wedge is larger in peripheral areas. Mobility costs are high in peripheral areas as workplace density is low and commuting distances are long. Job search costs for workers and firms are also higher in peripheral areas, as workers do not have ready access to job centres, vacancies are often not advertised, and successful job search is often attributed to contacts and networks (Monk and Hodge, 1995; Lindsay, Greig and McQuaid, 2005). The presence of higher search and mobility costs in peripheral areas is therefore expected to lead to a larger degree of inefficiency in peripheral and rural labour markets, with the result that an increase in employment in a peripheral labour market will have a positive wider economic impact. This form of wider economic benefit it is asserted may have a significant effect on the economic benefits of a transport project in a peripheral region.

7.6 Measuring wider economic benefits in practice

An initial review of the literature would suggest that localisation economies, imperfect competition, involuntary unemployment and thin labour markets may all act as sources of wider economic benefit for transport interventions in peripheral areas. A deeper analysis of each of the market failures and the underlying economic conditions in peripheral parts of Scotland indicates that of these four sources thin labour markets and imperfect competition will be the most important. Localisation economies will be important for certain transport interventions when the scheme is specifically aimed at an industrial cluster. There is no evidence of significant involuntary unemployment in peripheral areas despite the poor economic performance of many of these areas, probably due to outward migration. It is therefore asserted that wider economic impacts are of importance to transport projects in peripheral regions.

The framework for capturing wider economic impacts set out by the DfT (2005) can accommodate wider economic impacts resulting from imperfect competition and those resulting from localisation economies. There is however an absence of detailed data with which the framework can be implemented. The best data on localisation economies in the UK is that presented by Graham (in press), but this does not separately identify clustered industries of most relevance to the peripheral parts of Scotland (e.g. oil and fishing). The evidence on price-cost margins which forms the basis of the imperfect competition calculations relates to the core regions of the UK. Evidence from North West Scotland and the Scottish islands suggests that a lack of competition in the periphery allows firms to mark prices up further than they do in core regions. There is therefore a need to expand the existing evidence base to include data pertinent to peripheral areas.

The existing DfT guidance does not include what is expected to be an important source of wider economic benefit in peripheral areas, that associated with thin labour markets. In thin labour markets search frictions (i.e. costs associated with job search), amongst other things, drive a wedge between the marginal product of labour and the wage. This argument is based on the fact that mobility costs in peripheral areas are high due to the long distances of travel and the need for workers and firms to engage in informal methods to make a job match. There is therefore a need to investigate objectively whether such market failures occur in peripheral areas. Such an investigation is reported in the next chapter, Chapter 8. Further research is also needed to understand the size of the wedge between the marginal product of labour and the wage in peripheral areas.

It is important to recognise that wider economic impacts will only occur if surpluses are felt in markets other than the transport market. For this to happen supply and demand in other markets has to be elastic (but less than perfectly elastic) and transport user benefits have to pass through from the transport market to the product and labour market. The two principal mechanisms for the linkages between the transport market and other markets, as discussed in the competitive case, are that business and freight time savings reduce business costs and a reduction in commuting costs reduces wages. Both outcomes lead to a reduction in product prices and an expansion in output. Frictions that block these linkages include wages that are sticky in a downwards direction and firms not being able to take advantage of small time savings. Evidence for the existence of such frictions include that on average 55% of workers in the UK exhibit real or nominal wage rigidity (Barwell and Schweitzer, 2007) and that small time savings for road freight lie below the lorry drivers' wage rate (e.g. Fowkes *et al.*, 2007). In such situations the wider economic impact of transport projects in peripheral areas will be much smaller than might have first been thought, unless alternative mechanisms exist by which transport user benefits can be passed through into final markets. One such alternative mechanism comes from the job search literature. In this literature a reduction in commuting costs means that workers expand their area of search, leading to a reduction in search costs and an expansion in employment (even in the presence of sticky wages). A further mechanism by which regional output can expand in the presence of frictions is that businesses can re-locate from one region to another in response to a change in transport costs. It can therefore be seen that surpluses can still occur in the product and labour markets when search frictions are introduced into the competitive case. This is of most relevance to peripheral areas as it is those areas where it is argued search frictions are greatest.

As just mentioned Chapter 8 takes the review presented here forward with an investigation as to whether a failure in the labour market occurs in peripheral areas as a result of the labour market being thin. In thin labour markets models of job search indicate that workers are not paid their marginal product and are only partially compensated for commuting costs. Evidence of partial compensation of commuting costs in peripheral areas of Scotland is therefore looked for. Chapter 9 brings together, in a case study, estimates for relevant market failures. It therefore gives some context to the relative importance of the different market failures with respect to user benefits and also to scheduling costs.

8 EVIDENCE OF LABOUR MARKET FAILURE IN PERIPHERAL AREAS

8.1 Introduction

This chapter presents research that uses the Scottish Household Survey dataset (Mori Scotland *et al.*, 2005) to investigate whether a failure in the labour market occurs in peripheral areas. In thin labour markets models of job search indicate that workers are only partially compensated for commuting costs (Manning, 2003b; van Ommeren and Rietveld, 2005; Rouwendal and van Ommeren, 2007). This chapter therefore looks for evidence of partial or zero compensation for the commute. This is taken as evidence that search costs prevail, and a wedge exists between the wage and the marginal product of labour in peripheral areas. Such a wedge has implications for the existence of wider economic impacts (see section 7.5 in Chapter 7). As also discussed in Chapter 7 net wider economic impacts will only be felt with a re-distribution of employment between regions if the size of this wedge varies between regional labour markets. Therefore the ancillary hypothesis being tested is that the level of compensation will be lower for workers in peripheral compared to central areas (i.e. the wedge will be larger in peripheral areas). As discussed in Chapter 7, in peripheral areas mobility costs and search costs are higher than in central areas, and therefore the labour market is expected to be thinner and workers are less likely to be compensated for their commute. The labour market literature suggests that workers in peripheral regions are not the only ones to face thin labour markets. Women, ethnic minorities and unskilled or low skilled workers, also face thin labour markets as a consequence of restricted geographic search areas (Madden, 1981, 1985; Zax, 1991; Ihlanfeldt, 1992; McQuaid, Greig and Adams, 2001). Evidence for partial rates of compensation for these groups is also therefore investigated.

The investigation into a failure in the labour market in peripheral regions focuses on commuting costs rather than directly on the wedge between the wage and the marginal product of labour (via the elasticity of the labour supply curve to the firm) for two reasons. Firstly the elasticity of the labour supply curve to the firm (and therefore the wedge between the wage and the marginal product of labour) is difficult to estimate. This is due to the lack of an appropriate instrument to control for the endogeneity between employment and wages. Manning (2003a chapter 4) for example cites only eight studies in the whole labour economic literature where the labour supply curve to the firm has been estimated directly. He tries to estimate the labour supply curve to the firm indirectly via wage elasticities of job separations to employment and non-employment and in a different study through the wage elasticity of recruitment costs (Manning, 2003a chapter 4; 2006). The second reason is that the datasets available for such empirical work, the Labour Force Survey and the Labour Turnover Survey, do not provide data at a sufficiently detailed geographic level to identify those who live in peripheral areas and those who do not. The approach adopted for this thesis has therefore focussed on finding evidence of an outcome of thin labour markets (partial compensation for the commute) rather than identifying the presence of the market failure itself. It is therefore left for future research the task of describing the actual size of the wedge between the marginal product of labour and the wage between peripheral and central areas.

Manning (2003b) and Rouwendal and van Ommeren (2007) present evidence of partial compensation for commuting costs for the UK and the Netherlands respectively. This evidence is based on the level of compensation received by workers per hour (or minute) of the commute. From this Manning infers partial compensation as the rate of compensation is less than the wage rate, whilst Rouwendal and van Ommeren infer partial compensation as the rate of compensation is less than the average value of travel time. Neither Manning nor Rouwendal and van Ommeren are able to explicitly determine the actual rate of compensation as they do not use the full cost of the commute in their econometric analysis. The first contribution of the present research is therefore to estimate the rate of compensation by using the full cost of the commute. From this starting point the second contribution is to examine whether the rate of compensation varies by region (peripheral or central) and by socio-economic status (gender and occupation).

The direction of causation between generalised commuting costs (i.e. commuting costs that include both time costs and money costs) and income is ambiguous. Job search models imply that wages are a function of commuting costs, whilst the travel time and travel demand literature emphasises that commuting costs are a function of income. The latter occurs as not only is the value of travel time a function of household income and commute length (see for example the empirical work of Algers *et al.*, 1995; Mackie *et al.*, 2003; Axhausen *et al.*, 2004; Wardman, 2004), but the demand for travel, as with other economic goods, is also a function of household and personal income. For the UK, for example, Goodwin, Dargay and Hanly (2004) in a meta-analysis of published studies found long run income elasticities of demand of between 0.49 and 0.73 for car vehicle-kms over all trip purposes (depends on estimation method). Given this endogeneity the third contribution of the research is therefore to use the method of instrumental variables (IV) to estimate the rate of compensation.

The remainder of this chapter is set out as follows: sections 2 and 3 introduce the economic model and the dataset respectively. Section 4 presents wage equations estimated using the method of ordinary least squares (OLS) and section 5 presents the wage equations estimated using the IV method. As is discussed in the final section, section 6, the estimated earnings function for workers in peripheral areas imply a rate of compensation for the commute that is not significantly different from zero. The estimates are not particularly precise, possible arising as a consequence of the instruments used in the IV estimations not being particularly strong. It is difficult to draw firm conclusions regarding the other labour market groups due to the problem of weak instruments and the inability to test competing hypotheses from the urban economics literature. It does appear though that women and low skilled occupations receive little compensation and men and those in central areas receive more compensation. What is also evident is that the endogeneity of commuting costs and income can introduce a large bias into any estimate of the rate of compensation for the commute, and OLS estimates should therefore be treated with caution.

8.2 The model

The literature on job search models is large (Rogerson, Shimer and Wright, 2005 present a recent survey). Briefly, job search models are characterised by workers facing two potential pay-offs, one associated with unemployment and the other associated with employment. Workers seek to maximise their lifetime payoff (discounted) given that job offers arrive at a particular rate. The wage associated with each job offer derives from a wage distribution. The reservation wage (the wage above which a job offer will be accepted) becomes a function of the payoffs, the arrival rate of job offers and the wage distribution associated with those job offers. Worker turnover is achieved through the use of a separation rate – that is jobs end for some exogenous reason – and through on the job search. The rate of job offers to those in employment and out of employment can differ. Job search models also include assumptions regarding how firms and workers meet (a matching function) and how wages are determined (a bargaining function). In different models workers and firms meet randomly or actively choose a search method. Once workers and firms have met different models assume wages are either determined through a bargaining process (e.g. Nash bargaining) or wages are posted ex-ante by either the firm or the worker. The behaviour of the firm in this process is dictated by the fact that creating a vacancy is costly and the expected value of a job to the firm is a function of the amount of time that the job will be occupied. Occupied jobs become vacant as workers engage in on the job search and time is needed by a firm to fill a vacancy. An important characteristic in some job search models is to allow for heterogeneity amongst workers, through heterogenous leisure. This gives rise to heterogeneity in reservation wages (i.e. the expected payoff when unemployed).

The model makes the assumption that workers cannot change residential location and there exists homogeneity in space, that is it assumes a uniform distribution of residences and firms. With this assumption and in perfect competition workers are fully compensated for their commute by a wage premium. In perfect competition the arrival rate of job offers is infinite so full employment always occurs and vacancies fill instantaneously. Firms also employ the workers living closest to them, so commuting is minimised. As the job search literature indicates a finite arrival rate of job offers (within a search area), jobs ending for exogenous reasons, the costs of opening a vacancy and the need to search for a job lead to the co-existence of unfilled vacancies and unemployment. Different search based models can also explain other labour market phenomena such as the relationship between tenure, wages and staff turnover, the existence of wage dispersion and the characteristic that high wage firms are larger than low wage firms *ceteris paribus*. Within a transport context job search models offer an explanation of the phenomena of excess or wasteful commuting by which firms employ workers who do not reside close to them (i.e. workers in region A commute to work in region B, whilst equivalent workers from region B commute to equivalent jobs in region A).

Search frictions dependent on commuting costs can be introduced into these models in several ways. Firstly commuting costs affect the payoff received when employed and therefore the reservation wage (Manning, 2003b; van Ommeren and Rietveld, 2005; Rouwendal and van Ommeren, 2007). Commuting costs can also affect the search strategy of workers (Pilegaard and Fosgerau, 2008) and the search strategy of firms (Rouwendal and van Ommeren, 2007). Increasing search over larger areas for both workers and firms increases the arrival rate of job offers – as whilst the arrival rate of job offers is infinite only a finite number are within an acceptable commuting distance to the worker. A lowering of commuting costs increases the size of the area which is searched over, and therefore reduces the expected periods of unemployment and the expected duration vacancies remain unfilled. Rouwendal and van Ommeren also allow the rate at which workers quit a job for another job to be dependent on the commuting distance.

If search frictions exist it can be shown that commuting costs will only be partially compensated (Manning, 2003b; van Ommeren and Rietveld, 2005; Rouwendal and van Ommeren, 2007). This result holds despite the different assumptions made in each of the job search models presented in these papers. These models indicate that in the presence of search frictions wages are an increasing function of commuting costs ($TC_{commute}$). A hedonic earnings function can therefore be expressed as in Equation 8.1.

$$I_q = f(\mathbf{X}_q, TC_q) \tag{8.1}$$

Here, earnings for individual q (I_q) are a function of a vector of pre-determined variables ($\mathbf{X}_q$), including human capital variables and job type variables, as well as location specific variables, and commuting costs (TC_q). For full compensation of commuting costs a £1 rise in annual commuting costs leads to a £1 increase in the annual wage (net of deductions). Clearly therefore when estimating (8.1) the income units used must reflect the perspective of the worker (i.e. income after deductions) and secondly must cover an elapsed time (e.g. per week, per year rather than per hour) to have a sensible relationship to the number of commuting trips made.

Commuting costs themselves are a function of a vector of journey attributes ($\mathbf{Y}_q$), an associated vector of journey attribute valuations ($\mathbf{Z}_q$) and out of pocket costs (the price) (P_q) as indicated in Equation 8.2. The endogeneity of commuting costs and income can be seen with the aid of this equation as $\mathbf{Z}_q$, the vector of journey attribute valuations, is a function of amongst other things the marginal utility of income.

$$TC_q = g(\mathbf{Y}_q, \mathbf{Z}_q, P_q) \tag{8.2}$$

The hedonic earnings function (8.1) acts as an econometric specification for the empirical work that follows. The model estimated is specified as:

$$I_q = \alpha TC_q + \beta X_q + \varepsilon_q \qquad (8.3)$$

where α is the rate of compensation to commuting costs and is the main variable of interest; β is a matrix of the rates of return of each of the human capital variables, job type variables and location specific variables; and ε_q is a term representing unobserved attributes of each individual q that is distributed i.i.d normal.

It is important to note that the urban economic literature has had a long standing interest in the relationship between wages and commuting costs (Muth, 1969 chapter 2; Mills, 1972 chapter 6). In the monocentric model, where all employment is located in the city centre, house price differentials compensate workers for their commuting costs. In such a model there is no compensation for commuting through the wage (i.e. α=0 in Equation 8.3). When employment is spread more widely through the city, firms in the city centre must pay higher wages than those in suburban areas, for equivalent jobs, if they are to attract suburban residents who would be faced by a longer commute. Commuting costs therefore lead to the presence of wage 'gradients' as well as house price gradients in urban areas. With perfectly functioning markets the wage and house price differentials arising from the respective gradients perfectly compensate for commuting costs incurred. In such a model wages would not necessarily compensate for commuting costs, even for full compensation to occur. In fact Timothy and Wheaton (2001) show that only variations in average commuting costs between those employed at different locations are capitalised into wages. From this it follows that to test for partial wage compensation in areas where cities have a strong influence one should analyse the relationship between individual earnings and the average commuting costs of all those employed at the same workplace location ($\overline{TC}_w$). Equation 8.5 therefore sets out an alternative model specification to Equation 8.3 for an area dominated by a city.

$$I_q = \alpha \overline{TC}_w + \beta X_q + \varepsilon_q \qquad (8.4)$$

where individual q works at work place w.

8.3 The data

The primary difficulty with empirical work in this field is obtaining a dataset with sufficient information in it at an appropriately disaggregate level. Invariably for reasons of data confidentiality geographic information is suppressed if detailed income data is available, or if detailed geographic data is available detailed income data or worker/household attribute data is suppressed. The requirement for detailed commuting data upon which the full cost of the commute can be constructed adds a further dimension to this problem.

Three UK datasets contain income data at an appropriately fine level (i.e. not banded) and some commuting information. These are the Scottish Household Survey (SHS), the British Household Panel Survey (BHPS) and the Labour Force Survey (LFS). The advantage of the SHS over the BHPS and LFS is that it contains more information on the commute. For example, data regarding whether the commuting journey is between home and the main place of work or whether ancillary tasks are undertaken as part of the commute (e.g. dropping children off at school or going shopping) is available via the travel diary. Commuting distance is also available in the SHS, and whilst parking fees and public transport fares are not available it is possible to identify those who do not have to pay anything other than vehicle operating costs as part of their commute. At a geographic level, which is of particular relevance to this thesis, the SHS offers the ability to identify 'accessible' households that live up to 30 minutes from an urban area (of more than 10,000 people), 'remote' households that live between 30 and 60 minutes from an urban area and 'very remote' households that live more than 60 minutes from an urban area (see Figure 1.2). With the SHS it is therefore possible to quite easily distinguish households that reside in a peripheral area from those that reside in a central area. This is not possible with the BHPS or the LFS. The sampling strategy of the SHS also aims to provide sufficient data at a local authority level for the calculation of robust statistics. This therefore provides a reasonable number of cases for the estimation of a model of a peripheral region. Nothing of course is gained without something being lost. The BHPS and the LFS are large panel surveys and contain more information on the type of job, the experience of the worker and remuneration for the job than does the SHS. The panel aspect of these surveys could also be advantageous in addressing some of the endogeneity between wages and commuting costs.

Five years of data relating to the years 1999 to 2003 are used. The dataset and the process of obtaining a representative sample are described more completely in Appendix D. Briefly, the SHS is a continuous cross-sectional household survey. The 1999-2003 data contain 75,746 households, however, in only 23,564 households was the selected random adult a full-time employee (the focus of the econometric analysis). After cleaning the commuting data and restricting the sample to full-time workers for whom both commuting and income data is available, a potential sample of 6,747 cases is obtained. Elimination of cases with imputed income data and restricting the sample to those fully immersed in the labour market gives a final sample of 4,417. Of this 2,520 are men and 1,897 are women, while 528 live and work in a peripheral area and 3,805 live in a central area. Peripheral area cases are defined as those who both live and work more than 30 minutes drive from a conurbation with 10,000 people or more. Central area cases are defined as those who live in an urban area or within 30 minutes of a conurbation with 10,000 people or more (see Figure 1.2).

Commuting costs were constructed as the sum of the value of journey time plus, for the car/van mode only, an estimate of vehicle operating costs. Unit values for this calculation were sourced from Mackie *et al.* (2003) and DfT (2007b). Values of commute time for each individual are a function of income, commute distance and mode. Vehicle operating costs for both the fuel and non-fuel elements of costs are a function of speed and distance.

8.4 Ordinary least squares estimation

Two methods are used to estimate the earnings function (8.3); each of which assumes a different structure to the endogeneity problem: ordinary least squares (OLS) which assumes all variables are exogenous and instrumental variables (IV) which controls for potential endogeneity of commuting costs. In each method personal earned income (net of deductions) is regressed against commuting costs and human capital variables (including 3 qualification categories and two age/experience variables), as well as controls for 9 occupation classes, 16 industrial categories, temporary job status and size of work place. Variations in labour market operation and agglomeration effects are controlled for through dummy variables on workplace location representing each of the 32 local authorities in Scotland. Aside from commuting costs these variables are classic components of a reduced form wage equation. As under perfect competition economic theory indicates annual earnings increase by £1 if annual commuting costs increase by £1, no transformation on income or commuting costs has been undertaken in the models estimated.

Results for a limited number of variables from the OLS estimation of the earnings function are presented in Table 8.1. A full description of the models estimated is contained in Appendix E. As can be seen from this table in all the models, except the peripheral model, the coefficient on commuting costs is positive and significantly different from zero at the 1% level. In the peripheral model the coefficient on commuting costs is positive but only significant at the 5% level.

The coefficient on commuting costs is interpreted as the level of compensation required per annum (£) for a 1 pence change in one-way commuting costs. Thus in the all worker model, column (a), for every 1 pence of one-way commuting costs full-time workers are on average compensated with £2.82 per annum (net of deductions). This compares to, for example, the £3.52 that managers, professionals and technical occupations receive, column (d), the £2.16 that other occupations receive, column (e), and the £2.46 that women receive, column (g). A pattern therefore emerges: men receive more compensation than women, and those with 'higher skilled' occupations receive more compensation than 'lower skilled' occupations for every penny of commuting costs incurred. Such a pattern is consistent with the arguments that labour market frictions arise because of thin labour markets, familial constraints and market power. Contrary to these arguments, however, are model results that suggest the level of compensation is higher for those living and working in peripheral areas (£3.15) than for those living in Central areas (£2.58).

Table 8.1: Full-time employees' earnings function – ordinary least squares estimation

	Men and women					Men	Women
	All (a)	Central (b)	Peripheral (c)	Managers, professionals and technical occupations (d)	Other occupations (e)	(f)	(g)
Generalised cost of one-way commute (pence)	2.821 (6.43)	2.583 (5.30)	3.154 (2.25)	3.517 (4.88)	2.158 (4.61)	2.945 (4.31)	2.463 (3.97)
Potential experience (yrs)	453.6 (10.12)	475.1 (9.94)	333.2 (5.78)	783.9 (11.26)	244.9 (5.88)	543.5 (8.92)	341.2 (6.20)
Potential experience squared (yrs^2/1000)	-7,430 (-8.55)	-7,884 (-8.45)	-5,221 (-4.04)	-12,722 (-8.87)	-4,152 (-4.75)	-8,917 (-7.42)	-5,522 (-5.14)
School certificate or no qualification (dummy variable)	-1,933 (-9.18)	-2,044 (-8.47)	-1,141 (-3.70)	-3,333 (-6.00)	-1,525 (-6.51)	-1,831 (-6.69)	-2,096 (-9.85)
Degree or higher (dummy variable)	2,849 (10.69)	3,111 (13.18)	542 (0.67)	3,051 (9.93)	2,276 (4.63)	3,072 (7.01)	2,639 (9.86)
Female (dummy variable)	-4,762 (-11.93)	-4,634 (-10.60)	-4,802 (-5.65)	-4,647 (-13.01)	-2,516 (-5.49)	--- (---)	--- (---)
Constant	13,232 (20.25)	12,910 (18.84)	12,787 (18.27)	8,478 (8.84)	9,420 (17.34)	11,721 (14.75)	10,021 (12.06)
Sample size	4,417	3,805	528	1,865	2,552	2,520	1,897
R-squared	0.428	0.424	0.521	0.310	0.283	0.391	0.455

Notes: Dependent variable is annual earned income net of deductions (£). T-statistics calculated using robust standard errors are reported in parentheses. Standard errors are also adjusted for spatial correlation in the residuals by clustering on local authority of workplace. T-stat>2.58 indicates coefficient is significantly different from zero at <1%, T-stat >1.96 at <5% level (two tailed t-test). Models also include dummy variables for occupation (9), industrial sector (16), temporary job, size of workplace and local authority of workplace (33). Estimated using STATA9 econometric software.

To understand whether or not any socio-economic group is receiving full compensation we need to compare the level of compensation received by different socio-economic groups to that required for full compensation[56]. As can be seen from Table 8.2 the level of compensation for commuting costs incurred varies from 74% for managerial, professional or technical occupations to 45% for those with other occupations, with the average level of compensation across all full-time workers at 59%. This average level of compensation across all full-time workers is statistically different from exact compensation at the 5% level. This suggests that frictions occur thereby preventing workers receiving full compensation for their commuting costs. There is also variation by socio-economic group as the hypothesis of partial compensation is rejected for managerial, professional or technical occupations and accepted at the 1% level for those with 'other occupations' and those living in central areas. The weaker level of precision in the estimates of the compensation received by women and those living and working in peripheral areas means that the hypothesis of partial compensation is rejected for these groups.

Table 8.2 : Compensation for commuting costs – OLS estimation

Model		Estimated annual compensation for 1p change in one-way commuting costs (£ per annum)		Level of compensation (a)/(b)	T-stat of difference between (a) and (b)
		Received (a)	Required for full compensation (b)		
Men and women	All	2.82	4.751	59.4%	2.49
	Central	2.58	4.751	54.4%	2.69
	Peripheral	3.15	4.751	66.4%	1.03
	Managers, professionals and technical occupations	3.52	4.751	74.0%	1.28
	Other occupations	2.16	4.751	45.4%	3.27
Men		2.94	4.801	61.3%	1.97
Women		2.46	4.665	52.8%	0.87

Notes: T-statistic calculated assuming covariance between the two distributions is zero. T-stat>2.58 indicates level of compensation is significantly different from 100% at <1%, >1.96 at <5% level (two tailed t-test).

[56] The SHS does not contain data on the total number of commuting journeys made in a year by each respondent. This variable is therefore estimated from the Labour Force Survey for 2006 Spring quarter (variable *dayspz* - the number of days usually worked per week). Assuming that two one-way commutes occurred on each day worked and a 46 week working year the number of days usually worked in a week can be aggregated to an estimate of the number of one-way commuting trips per year. This gives the mean number of one-way commutes per annum of 475.1 (64.0) for all full-time employees, 480.1 (65.0) for men and 466.5 (61.2) for women - standard deviations in parentheses.

8.5 Instrumental variable estimation

As argued earlier there is good reason to believe that commuting costs are endogenous to earnings, and consequently, as is standard, the method of instrumental variables has been employed to account for this endogeneity. The instruments employed are based on the categories of residential rural/urban classification contained within the SHS data[57].

Good instruments in non-experimental data (i.e. natural data like the SHS) are difficult to identify in practise. This is a consequence of the inter-relationship of most observable economic variables. A strong instrument will be good at predicting variations in the endogenous variable[58] – in this instance commuting costs – and will not be correlated with the error term in the regression. The instrument will not therefore be correlated with the dependent variable (income) except through its effect on the endogenous variable (commuting costs). For that reason good instruments are often found to be the endogenous variable but with a very long lag. This requires time series data as may be found in a long standing panel dataset, but not unfortunately in the SHS. Other good instruments are those associated with a naturally occurring 'experiment'. An exogenous change in policy that shocks one part of the system but not another part can often act as a good instrument. Bearing in mind that wages are sticky downwards such a policy shift to instrument commuting costs would need to increase the cost of travel. This would suggest instruments such as a congestion charge or a large and sudden increase in parking charges in one part of the country but not another might be effective. No such exogenous price changes occurred during the period (1999-2003) and in the geography (Scotland) to which the data relate. The instrument used therefore is one of the 'naturally' occurring cross-sectional variables contained in the SHS dataset.

Rural/urban classification of the household is used as an instrument, because

---

[57] The eight rural urban classifications are: (1) Large urban areas; (2) Other urban; (3) Small accessible towns; (4) Small remote towns; (5) Very remote small towns; (6) Accessible rural; (7) Remote rural; (8) Very remote rural. Peripheral areas in this study have been defined as remote or very remote (see Figure 1.2).

[58] In the context of simultaneous-equation models the jointly dependent variables are called endogenous variables and the variables that are either truly non-stochastic or can be so regarded are called exogenous variables. In a simultaneous equation model, endogenous variables can therefore appear on the right hand side of the equation estimated. This is the case for the model estimated here.

commuting costs are dependent on the geography of the location the worker resides in. If the area is sparsely populated (e.g. rural) invariably distances between origins and destinations are long. If an area is densely populated (e.g. urban) distances are short. There is also no reason to expect that preference for a rural or urban environment to be correlated with income. It might be argued that an educated household with high earning potential may locate in a large city to be close to the arts, but a counter argument would run that an educated household would desire the tranquillity of a rural environment. At lower income and educational levels preferences will be just as mixed. There will be those that prefer to be close to lots of different shops and pubs, and there will be those that like clean air. Unfortunately in natural data such as the SHS preferences are unobserved, only choices are observed. In the SHS the choice that is observed is the environment of the residence (i.e. the eight categories of residential rural/urban classification given to the household). These give a good indication of preferences for a rural/urban environment. As can be seen in Table 8.3 each area has close to 20% of each income quintile in its area. This is reflective of the fact that preferences for household location are not dependent on income. Two small trends are however visible. Large urban areas have lower number of low income earners and higher number of high income earners, whilst very remote small towns have the opposite trend. These trends are attributed to the fact that industry and productivity has a spatial dimension. For example, jobs in the financial sector (which pay more) are in urban areas, whilst jobs in agriculture (which pay less) are in rural areas. Jobs in productive agglomerations are also likely to be in large urban areas. By controlling for the industry classification characteristics of a job and also workplace location the instruments should then be uncorrelated with the remaining error term in the IV equation.

The validity of the chosen instrument can be assessed by the results from the first stage linear regressions and the Sargan test as summarised in Table 8.4. In all instances the Sargan test accepts the null hypothesis that the instruments are valid, that is they are independent of the error term. The Sargan test is a weak test, in the sense that acceptance of its null hypothesis does not constitute a valid IV estimation, though rejection of the null hypothesis is evidence of a poor performing IV regression. This is because weak instruments, that is instruments that are only weakly correlated with the endogenous variable (in this instance commuting costs), can pass the Sargan test. If instruments are weak the sampling distributions of the IV statistics are non-normal and the resulting IV point estimates, hypothesis tests and confidence intervals become unreliable. There is no robust statistical test for weak instruments, though a rule of thumb proposed by Stock, Wright and Yogo (2002) is that the F-statistic from the 1st stage regression should be large. If it is small, less than 10 they suggest, then the instruments should be considered weak. As can be seen from Table 8.4 the 1st stage F-statistic is just greater than 10 for four of the models, but less than 10 for three of the models. The instruments therefore appear borderline acceptable - they are not categorically weak, but neither are they strong.

Table 8.3 : Income quintiles by rural/area area type

	Income quintile					
	1 (lowest)	2	3	4	5 (highest)	Total
Instruments for whole area and central areas						
1. Large urban areas	18%	19%	21%	22%	22%	100%
2. Other urban	20%	21%	21%	21%	18%	100%
Rest	*22%*	*20%*	*19%*	*18%*	*20%*	*100%*
Scotland	20%	20%	20%	20%	20%	100%
Instruments for central areas						
1. Large urban areas	18%	19%	20%	21%	21%	100%
2. Other urban	21%	21%	20%	21%	17%	100%
Rest	*22%*	*20%*	*19%*	*18%*	*21%*	*100%*
Central area	20%	20%	20%	20%	20%	100%
Instruments for peripheral areas						
1. Remote small towns	22%	16%	22%	18%	22%	100%
2. Very remote small towns	18%	21%	24%	20%	17%	100%
Rest	*20%*	*20%*	*18%*	*20%*	*21%*	*100%*
Peripheral area	20%	20%	20%	20%	20%	100%

Results for a limited number of variables from the IV regression are presented in Table 8.4. The full regression results and results for men and women by region and socio-economic class are contained in Appendix E along with the the first stage regressions. As can be seen from Table 8.4 the rate of compensation for commuting costs is significantly different from zero for four of the models and not significantly different from zero for three of the models – the peripheral model, the 'other' occupation model (i.e. workers with low skills) and the female model. The latter group of models reflect those who *a priori* are expected to face thin labour markets due to reasons of geography or lack of mobility due to familial constraints or inability to move house.

Table 8.4 Full-time employees' earnings function – instrumental variables estimation

	Men and women					Men (m)	Women (n)
	All (h)	Central (i)	Peripheral (j)	Managers, professionals technical occupations (k)	Other occupations (l)		
IV Regression							
Generalised cost of one-way commute (pence)	7.042 (3.44)	8.107 (3.33)	-7.429 (-0.49)	9.667 (3.65)	1.333 (0.55)	11.22 (3.37)	-1.077 (-0.41)
Potential experience (yrs)	443.7 (9.88)	467.5 (10.00)	385.1 (3.13)	747.7 (9.73)	245.0 (5.86)	519.1 (7.86)	353.1 (6.34)
Potential experience squared ($yrs^2/1000$)	-7,246 (-8.36)	-7,729 (-8.55)	-6,095 (-2.71)	-11,957 (-7.56)	-4,147 (-4.68)	-8,605 (-6.87)	-5,834 (-5.41)
School certificate or no qualification (dummy variable)	-1,808 (-8.08)	-1,900 (-7.37)	-1,478 (-2.36)	-3,189 (-5.3)	-1,550 (-6.67)	-1,586 (-4.83)	-2,203 (-10.31)
Degree or higher (dummy variable)	2,622 (8.55)	2,828 (10.12)	989 (1.06)	2,742 (7.82)	2,330 (4.16)	2,605 (4.65)	2,803 (8.38)
Female (dummy variable)	-4,686 (-11.94)	-4,517 (-10.51)	-4,829 (-5.64)	-4,557 (-12.81)	-1,440 (-1.45)	--- (---)	--- (---)
Constant	12,111 (16.81)	11,307 (14.1)	13,994 (15.13)	6,943 (7.24)	9,804 (10.61)	9,887 (9.56)	11,077 (9.94)
Sample size	4,417	3,805	528	1,865	2,552	2,520	1,897
R-squared	0.415	0.402	0.462	0.282	0.282	0.343	0.445
Wu-Hausman test (p-value)	0.028	0.009	0.137	0.028	0.748	0.001	0.246
Sargan test (p-value)	0.236	0.124	0.350	0.340	0.484	0.14	0.549
Number of instruments	2	2	2	2	2	2	2
1st stage regression							
R-squared	0.129	0.123	0.165	0.146	0.104	0.145	0.147
F-test on instruments ($F_{2,sample\ size}$)	10.42	10.78	11.32	6.27	8.43	10.70	6.61

Notes: Dependent variable is annual earned income net of deductions (£). Dependent variable in 1st stage regression is commuting cost. T-statistics (in parentheses) based on robust standard errors adjusted for spatial correlation in residuals by clustering on local authority of workplace. T-stat>2.58 indicates coefficient is significantly different from zero at <1%, T-stat >1.96 at <5% level (two tailed t-test). Instruments are dummy variables for large urban areas (population>125,000) and urban areas (population > 10,000) except for Peripheral model - where instruments are dummy variables for remote small towns and very remote small towns (population > 3,000). Models also include dummy variables for occupation (9), industrial sector (16), temporary job, size of workplace and local authority of workplace (33). Estimated using STATA9 econometric software.

The IV estimation is preferred for all the models estimated despite the Wu-Hausman test suggesting that for three models the OLS models are sufficient. This is because there is a systematic relationship between the role of commuting costs in the earnings function and the results of the Wu-Hausman test for exogeneity. For the models in which the Wu-Hausman test indicates commuting costs are endogenous to income (p-value≤0.05) the coefficient on commuting costs is significant (at less than the 1% level). Where the Wu-Hausman test indicates commuting costs are exogenous to income (p-value>0.05) the coefficient on commuting costs is not significant. A classic interpretation of acceptance of the null hypothesis (variable exogeneity) in the Wu-Hausman test is that an OLS estimation would not have a deleterious effect on the model and is therefore preferred on grounds of efficiency. However, for the labour market segments where the null hypothesis is accepted (women, low-skilled and peripheral areas) commuting costs have no explanatory power. It is for this reason that the Wu-Hausman test accepts the null hypothesis, rather than a lack of endogeneity between commuting costs and income. Where commuting costs appear in an earnings function (men, highly skilled and central areas) they are clearly endogenous. The IV estimation is therefore preferred for all market segments.

Aside from the insignificance of the role of commuting costs in explaining earnings for those in peripheral regions, for women, and those in low skilled occupations the other clear difference with the OLS results is that the coefficient on commuting costs, where significant, has increased significantly with an IV estimation. A 1p increase in one-way commuting costs is associated with a £7.02 increase in annual earnings (after deductions) across the whole sample, an £8.11 increase in central areas and £11.22 for men. Comparing the rate of compensation for commuting costs with that required for exact compensation (see Table 8.5) indicates that, for each of the four labour market segments in which the rate is significant, it is larger than that required for exact compensation. Statistically however we only accept the hypothesis of over compensation for one of these segments – the male model.

Table 8.5: Compensation for commuting costs – IV estimation

Model		Estimated mean annual compensation for 1p change in one-way commuting costs (£ per annum)		Mean level of compensation	T-stat of difference between mean compensation received and mean of that needed
		Received	Required for full compensation		
Men and women	All regions	7.04	4.75	148.2%	-1.07
	Central regions	8.11	4.75	170.6%	-1.33
	Peripheral regions	-7.43	4.75	-156.4%	0.80
	Managers, professionals and technical occupations	9.67	4.75	203.5%	-1.80
	Other occupations	1.33	4.75	28.0%	1.35
Men		11.22	4.80	233.7%	-2.35
Women		-1.08	4.67	-23.1%	2.28

Notes: The t-statistic is calculated assuming that the covariance between the two distributions is zero. T-stat>2.58 indicates level of compensation is significantly different from 100% at <1%, >1.96 at <5% level (two tailed t-test).

For the other three models the point estimates of the rate of compensation are either negative (the peripheral and female models) or just above zero (the 'other' occupations model). Clearly these models predict under compensation. As mentioned earlier the rate of compensation for each of these models is not significantly different from zero, however, only one of the models (the female) has a rate that is significantly different from full compensation. That is only the female model statistically demonstrates a rate of compensation below full compensation. The standard errors of the point estimates are too large therefore to reject either the hypothesis of zero compensation or full compensation for the peripheral model and the other occupations model. The results of these different hypothesis tests are summarised in Table 8.6.

Table 8.6: Full and zero rate of compensation hypothesis testing

Model		Rate of compensation (point estimate)	Hypothesis: H0: Full compensation (e.g. α = 4.75 for both genders)	Hypothesis: H0: Zero compensation (i.e. α = 0)
Men and women	All regions	Over-compensation	Accept	Reject
	Central regions	Over-compensation	Accept	Reject
	Peripheral regions	Negative compensation	Accept	Accept
	Managers, professionals and technical occupations	Over-compensation	Accept	Reject
	Other occupations	Under-compensation	Accept	Accept
Men		Over-compensation	Reject	Reject
Women		Negative compensation	Reject	Accept

8.6 Discussion

The picture presented by the IV model estimations regarding the rate of compensation is less than clear. There are a number of reasons for this: weak instruments is one, but possibly some of the models are mis-specified. Taking each model in turn.

The peripheral model (column (j) in Table 8.4) has acceptable 1st stage regression statistics, so the estimates can be considered reliable, though the instruments are not strong. Surprisingly, the rate of compensation is on average negative, though there is a lot of uncertainty in the estimate with the t-statistic indicating that there is only a 34% chance that the value is significantly different from zero (i.e. there is a 66% chance of positive compensation). Examination of the rate of compensation in peripheral areas by gender indicates that the negative rate is primarily driven by women, as men receive a rate that is negative but very close to zero (see Tables E and F in Appendix E). The 1st stage regression for men in peripheral areas also produces acceptable Sargan and F-statistics. Whilst the data suggest that zero compensation is the most likely hypothesis it is worth exploring whether a negative rate of compensation is plausible. The implication of a negative rate of compensation is that some workers have a job which pays a lower wage and has a longer commute than an identical job that is closer to home. This might seem irrational at face value, but the plausibility of the result can be illustrated with an example. Workers might accept a lower paying job with a longer commute if for example there were no opportunities for other employment and/or on the job search is more effective than off the job search (that is firms are more likely to employ those in employment than those out of work). A characteristic of job search models is that if on the job search is more effective than off the job search workers will accept a wage that is below the 'unemployed' payoff (Rogerson, Shimer and Wright, 2005). This can lead to the wage gross of commuting costs decreasing in the commute. The lack of precision in the estimate of the rate of compensation is a weakness of the peripheral model that ideally stronger instruments would have addressed, but there is no reason to consider the result of the peripheral model unreliable.

The whole study area model, the central area model, the high skilled occupation model and the male model (columns (h), (i), (k) and (m) in Table 8.4) all predict rates of compensation that exceed the commuting costs incurred. This seems unrealistic. The IV estimates are also higher than the OLS estimates. This runs counter to the bias that endogeneity between income and commuting costs would be expected to induce. The overly high rate of compensation found cannot be purely attributed to weak instruments, as only one of the models, the high skilled occupation model, has 1st stage regression statistics that are indicative of weak instruments. Neither can it be attributed to measurement error – in the sense that the SHS contains insufficient data on job descriptions to distinguish between the very high paying jobs held by high skilled workers. This is because the problem is evident in all four models, not just that associated with high skilled workers. It is for this reason that the model for these socio-economic segments may be mis-specified. The urban economic literature would suggest an alternative specification as set out in Equation 8.4 earlier in the chapter.

Unfortunately the lowest level of geographic detail available in the data is the local authority level. This is too coarse a level to re-specify the earnings function to test the urban economic hypotheses regarding the rate of compensation via the wage for commuting. For example the lowest level of disaggregation for Scotland's four main cities is the cities themselves. It is also difficult to predict the bias that this mis-specification has on the rate of compensation in the estimated earnings function due to correlations with the workplace dummy variables (see Timothy and Wheaton, 2001). The evidence from the IV estimation and urban economic theory cast sufficient doubt on the results for the models containing city workers for these models (and the corresponding OLS models) to be considered unreliable. The fact that in peripheral areas workers and firms are much more evenly spread through space means that the concerns regarding the validity of the estimated earnings function are not pertinent to the peripheral model. It is interesting to note that whilst the scale of the IV estimates for the rate of compensation for commuting is large enough to raise questions over their validity this is not the case for the OLS estimates. The criticisms associated with these models are also pertinent to Rouwnendal and van Ommeren (2007) and Manning (2003b) as they use a model specification as in Equation 8.3 (a job search specification) to estimate an earnings function for the Netherlands and the UK respectively rather than the urban economic specification as in Equation 8.4.

The two remaining models, the female model and the low skilled occupations model suggest a low rate of compensation or negative rate of compensation. Neither rate of compensation is significantly different from zero. For the reasons set out earlier a negative rate of compensation is viewed as plausible. The low and even negative rates of compensation are consistent with *a priori* views regarding the socio-economic groups that face thin labour markets due to restricted mobility (and therefore geographic search areas). The weaknesses of these models are that the instruments fail the Stock, Wright and Yogo rule of thumb test, in that the 1^{st} stage F-statistic is less than 10. The instruments are therefore weak and the point estimates cannot be viewed as reliable. The models are also estimated to data that includes city workers. Consequently these models can also be viewed as mis-specified. Interestingly if women and low skilled workers do not receive compensation for commuting costs (i.e. $\alpha = 0$) the job search specification and the urban economics specification collapse down to the same model as set out in Equation 8.5 below:

$$l_j = \beta \mathbf{X}_j + \varepsilon_j \tag{8.5}$$

It is tempting to believe that this is what is happening in the female and low skilled occupation models. Further research using the urban economic model specification and stronger instruments is needed though to make this a firm conclusion.

8.7 Conclusion

To summarise, evidence from Scotland indicates that those living and working in peripheral areas face a wage that appears independent of the commute. This is taken as evidence that those in peripheral labour markets face thin labour markets and firms therefore have market power. Alternative hypotheses contained in the urban economic literature, that predict zero or partial wage compensation for the commute in perfectly competitive markets, are not applicable to peripheral regions as employment and population are dispersed.

As such firms in peripheral areas face a rising labour supply curve, rather a perfectly elastic supply curve as in the competitive case. From a transport appraisal perspective this is important as it means that if employment expands as a consequence of a transport improvement, wider economic impacts will occur in the labour market. Of course the fact that workers in peripheral areas receive no compensation for the commute blocks one mechanism for expanding employment, and as discussed in Chapter 7 unless employment expands there will be no wider economic impact. Job search models identify an alternative mechanism by which employment can expand, in that a lowering of commuting costs increases the geographic area over which workers and the unemployed will search. A lowering of commuting costs can therefore expand employment even if workers are not compensated for their commute. The relevance of this to scheme appraisal is explored in the next chapter with a case study of the Berneray Causeway.

This research has only partially answered the questions raised at the outset of the chapter. Whilst evidence for a zero rate of compensation for workers in peripheral regions has been found it is subject to a large degree of uncertainty. A stronger set of instruments would have been beneficial. Furthermore the data do not allow the specification of an earnings function consistent with the urban economic hypotheses of wage compensation for the commute. This means it is difficult to draw any conclusions regarding how the rate of compensation varies between regions and workers. What indicators there are suggest that compensation for women and low skilled occupations is low (possibly zero), whilst compensation for men in central areas is higher. How much higher is difficult to say. Further research is needed. The key challenge for future research is to obtain data that contain sufficiently detailed income and commuting information with a large enough sample size to be able to calculate average commuting costs of all workers at a workplace (or small work zone). It seems unlikely that one of the national datasets (the LFS, the BHPS or the SHS) will ever be able to provide such data given the need to protect confidentiality. Future research may therefore need to consider commissioning surveys and analysing behaviour at particular firms or organisations. This combined with a good transport or traffic model may provide sufficient data on the commute.

An ever present problem will be the need to account for the endogeneity between commuting costs and income. This research has identified the importance of the bias introduced by endogeneity, as apparently sensible OLS estimates show significant scope for change under an IV estimation. This bias can also be counter-intuitive thereby indicating model mis-specification. The need for strong instruments may well mean that future research has to wait until a large exogenous change in transport prices occurs in one region or area but not in another. Given sticky wages in a downward direction this change probably needs to be an increase in price. A good instrument might therefore be the implementation of a congestion charge if implemented in one city but not in any other city. It is also left for future research the task of describing the actual size of the wedge between the marginal product of labour and the wage between peripheral and central areas.

9 AN APPRAISAL CASE STUDY

9.1 Introduction

This chapter brings together the different thoughts, arguments and findings of the earlier chapters into a single case study. The previous chapters have argued that there are theoretical grounds for including scheduling costs, the risk premium and wider economic benefits in an economic appraisal. Evidence has also been presented, some of it surveyed as part of this research, demonstrating the existence of statistically significant welfare costs for these benefit categories in sparse networks and peripheral regions. These arguments however do not demonstrate that scheduling costs, the risk premium and wider economic benefits give rise to a significant proportion of the total economic impact of a transport project. Such a demonstration can only be undertaken through a comparison with user benefits using a realistic case study. The contribution of this chapter is therefore to make this comparison. In doing so it not only highlights the relevance of the research to a real transport intervention but identifies the areas where further research is needed. The case study, the Berneray Causeway and the Sound of Harris ferry appraised ex-ante by Halcrow Fox (Halcrow Fox, 1996)[59], has been chosen as each of the issues researched, scheduling costs, the risk premium and wider economic benefits, is relevant.

The Berneray Causeway, which opened in April 1999 at a capital cost of £6.6 million, is just less than 1km in length and is free to use (i.e. there is no toll). As illustrated in Figure 9.1 the causeway replaced the Berneray ferry (between Berneray and North Uist) and shortened the Sound of Harris ferry crossing between Harris and North Uist. The shorter crossing for the Sound of Harris ferry was expected to lead to an increase in service frequency in the summer (to two hourly). As is standard the economic impacts included in the ex-ante appraisal were:

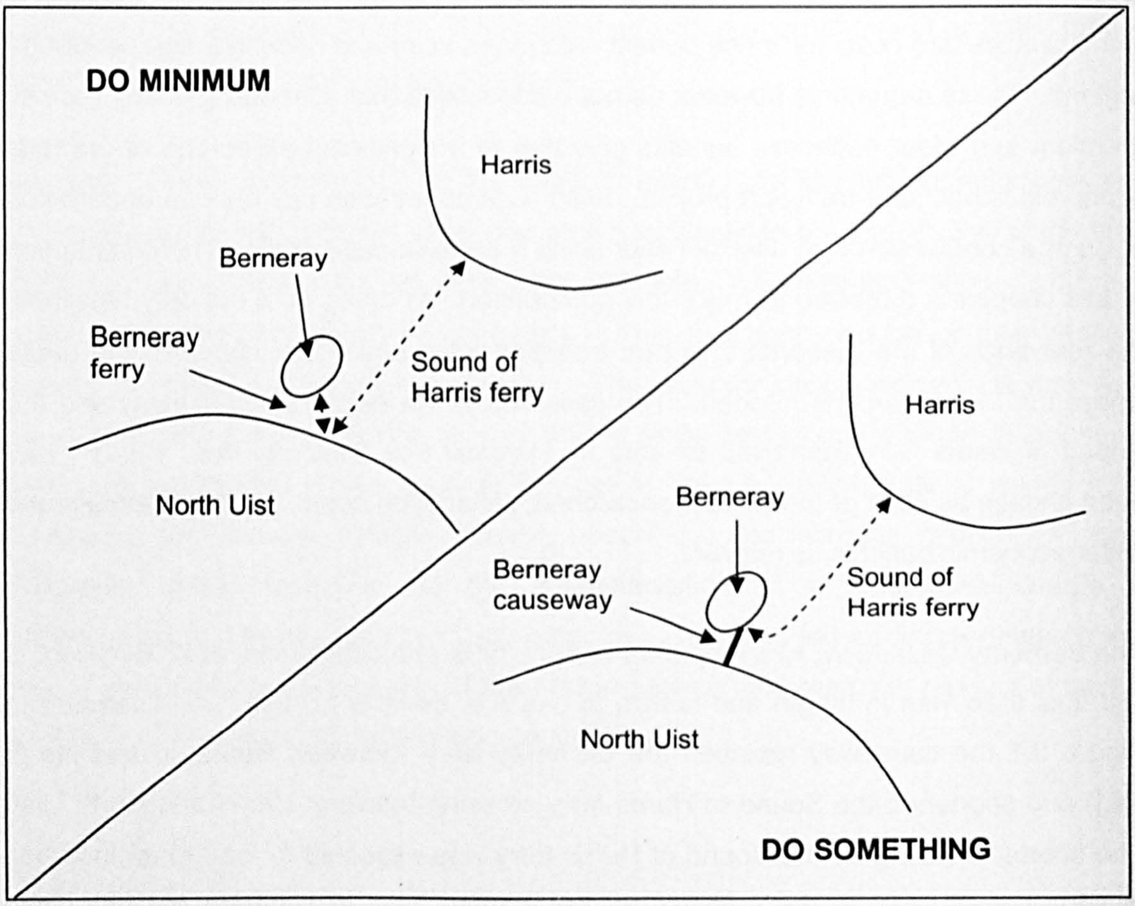
- travel time savings for users of the Berneray and the Sound of Harris ferries;
- vehicle operating cost increases due to the increased distance spent driving (equivalent to the length of the causeway and access roads); and

[59] It should be noted that this case study uses the ex-ante data developed by Halcrow Fox including traffic forecasts, journey purpose proportions and expected time savings. It does not use ex-post data on actual traffic volumes, or Sound of Harris ferry realised time savings and ferry frequency. In comparison to the ex-ante data traffic volumes are higher than expected, but the Sound of Harris ferry time savings and frequency increases are lower than expected.

- ferry fare savings for users of the Berneray ferry who no longer have to pay to cross between North Uist and Berneray.

The ex-ante appraisal also included ferry operating cost and capital cost calculations, which when combined with the above user benefit calculations gives an estimate of the total economic impact of constructing the causeway and altering the operation of the Sound of Harris ferry.

Figure 9.1: Berneray Causeway and Sound of Harris ferry: Do Minimum and Do Something



Source: Halcrow (1996, Figure 1.3)

The proposition made in this thesis is that an economic impact appraisal based on time and cost savings and capital and maintenance costs will understate the true economic impact of a transport intervention by excluding scheduling costs, changes in the risk premium (or option value) and wider economic impacts. Each of these 'additional' impacts is considered in this chapter and quantified where possible. The comparison is made for the first full year of operation (2000) and, for ease of comparison, has been undertaken in the price base of the original ex-ante appraisal. That is prices are 1996 resource prices at year 2000 values.

This chapter is structured as follows: the benchmark ex-ante appraisal undertaken by Halcrow Fox is summarised in Section 2, whilst Section 3 considers the benefits that arise as a consequence of a reduction scheduling costs, and Section 4 the benefits that occur as a consequence of a change in the risk premium. Wider economic impacts are considered in Section 5. The overall economic impact of widening the scope of the appraisal is set out in the final section, Section 6, along with recommendations for enhancing the evidence base.

9.2 The benchmark case

The Do Something delivers the following benefits compared to the Do Minimum (Halcrow Fox, 1996 p.4 Table 2.4):

Berneray traffic

- a time saving of 12 minutes and the elimination of queuing time;
- a fare saving of 48p per passenger and £1.92 per car (for residents) and 75p per passenger and £2.60 per car (non-resident)
- no net vehicle operating cost saving.

Sound of Harris ferry traffic

- a time saving of 16 minutes and no change in queuing time;
- no fare saving; and
- increase in vehicle operating costs associated with increased causeway length and access roads on North Uist (0.9km)

In the opening year (2000) this delivers a single year's user benefits of £200,000, of which just over 60% come from traffic to/from Berneray and the remaining 40% comes from traffic using the Sound of Harris ferry (see Table 9.1).

Table 9.1 User benefits by market segment, Year 2000 (£ 1996 resource prices)

	Berneray Traffic	Sound of Harris traffic	Total traffic
Time savings	51,000	80,000	131,000
Fare savings	75,000	0	75,000
VOC savings	0	-6,000	-6,000
Total	126,000	74,000	200,000

Source: Halcrow Fox (1996, Table 2.5)

9.3 Scheduling costs

Scheduling costs are the costs imposed on activity scheduling by the existence of transport constraints. When these are confounded with use costs (e.g. queuing time or interchange time) the confounded value is sometimes known as inconvenience costs (Bråthen and Hervik, 1997). The headway and operating hour constraints that give rise to scheduling costs in this case study are as follows:

Berneray traffic

- The Berneray ferry had an average headway over the year of 89 minutes. This reduces to zero with the construction of the causeway; and
- The ferry had an average operating day of 12 hours, whilst the causeway is available for 24 hours.

Sound of Harris traffic

- In May, June, July and August the Sound of Harris ferry had an average headway of 3hrs 45mins. This reduces to 2 hrs with the service re-cast after construction of the causeway. 62% of the ferry's annual demand occurs in these four months;
- In April and September the Sound of Harris ferry had an average headway of 3hrs 13mins. This also reduces to 2 hrs with the service re-cast. 18% of the ferry's annual demand occurs in these two months;
- There is no change to the ferry timetable in the winter months; and
- There is no change to the operating hours of the ferry.

Chapters 5 and 6 present values of headway and operating hours derived from travellers undertaking long distance journeys and from householders making short distance trips. The results presented in Chapter 5 are pertinent to the Sound of Harris ferry traffic, whilst those in Chapter 6 are pertinent to the Berneray traffic. The valuations presented in these chapters are in 2005 perceived prices and as a consequence need to be converted to 1996 resource prices in 2000 values for use in the case study. This is undertaken using the procedures set out in the Department for Transport's guidance on values of time and vehicle operating costs (DfT, 2007b).

Table 9.2 presents the sources for the marginal values used in the case study. As can be seen from this table the surveys presented in Chapters 5 and 6 do not cover all the market segments affected by the transport intervention. Marginal values for those

Table 9.2 Marginal values for scheduling costs used in case study

		Marginal values available from research	Values used in case study
Berneray Traffic			
Resident	Non-work	Yes	Derived from fixed link stated preference game. These are annual values per household. See Table 6.25 in Chapter 6. The values need adjusting to resource prices.
	Work	---	Assumed zero. The fixed link stated preference game only surveyed household trips and not business trips. The estimates from the local ferry stated preference game and the inter-island stated preference game are not appropriate for high frequency local business trips.
Non-resident	Non-work		Derived from the local ferry stated preference game (see Table 6.24 in Chapter 6). These values relate to non-work trips made by residents. They are taken as a best estimate of non-resident values. As non-work values they are also assumed to be a conservative estimate of business/work and commercial vehicle values. The values are adjusted in two ways: (i) to resource prices; (ii) to reflect the fact that non-residents will not value high frequencies and long operating days in the way that residents do. It is assumed that non-residents attach no value to headways less than 30 mins and operating hours longer than 6am to 11pm.
	Work	---	
	Commercial vehicle		
Sound of Harris traffic			
Resident	Non-work	Yes	Derived from inter-island ferry stated preference game (see Table 5.12 in Chapter 5). Non-work trips have resource price correction applied.
	Work	Yes	
	Commercial vehicle	---	As resident work
Non-resident	Non-work	Yes	Derived from inter-island ferry stated preference game (see Table 5.12 in Chapter 5). Non-work trips have resource price correction applied.
	Work	Yes	
	Commercial vehicle	---	As non-resident work

market segments not included in the surveys have been transferred from the data that is available. Clearly to undertake a complete appraisal there remains an evidence gap. This is most acute for non-residents making short/local trips (both business and non-work trips), for residents making short/local business trips and for commercial vehicles making both long distance and short distance trips.

Table 9.3 presents the additional value that scheduling costs add to the appraisal of the Berneray causeway and the Sound of Harris ferry. As can be seen from the first column of this table, the benefits to Berneray traffic are substantial relative to the traditional elements of user benefit – the scheduling benefits are just under 50% of user benefits (comparing the first columns of Table 9.1 and Table 9.3). The scheduling benefits to the Sound of Harris traffic are much smaller, despite the higher marginal values per trip (14% of user benefits). This arises as the change to the Sound of Harris service is not as large as that to the Berneray service, but also because users of the Sound of Harris service only value changes in headway up until headways of 3 hrs. The benefit is therefore driven by reductions in headway to 3hrs since, as seen in section 5.6, further reductions (to 2 hours) hold no value. It is interesting to note that the proposal to reduce headways to 2 hours was never implemented – possibly in recognition of the preferences of the existing customer base.

The values of headway include both scheduling costs and use costs – the latter associated with queuing time at the pier. To avoid double counting, the proportion of time savings attributed to queuing time is deducted from the total scheduling benefits. This gives the portion of scheduling benefits that are additional to user benefits, as calculated in a standard appraisal.

Table 9.3 Additional benefits due to scheduling costs (£ 1996 resource prices 2000 values)

<table>
<tr><th></th><th>Berneray Traffic</th><th>Sound of Harris traffic</th><th>Total traffic</th></tr>
<tr><td>Queuing time at pier
(double counted with time savings)</td><td>-£18,000</td><td>£0</td><td>-£18,000</td></tr>
<tr><td>Residents</td><td>£49,000</td><td rowspan="2">£10,000</td><td rowspan="2">£90,000</td></tr>
<tr><td>Non-residents</td><td>£31,000</td></tr>
<tr><td>Total</td><td>£62,000</td><td>£10,000</td><td>£72,000</td></tr>
</table>

9.4 Risk premium

As discussed in Chapter 2 the risk premium is the maximum amount individuals would be willing to pay to have a certain income when currently faced with an uncertain income without being any worse off (in utility terms). A change in the risk premium is additional to transport user benefits in a cost benefit analysis. The risk premium is analogous to the option value - case studies for which were presented in Chapter 3.

As presented and discussed in section 6.9 no difference in risk premium between a fixed link and a free 24 hour ferry with a high frequency could be identified using the data from the household surveys. This was surprising as it is imagined that a ferry would be unavailable more often than the causeway due to for example bad weather and mechanical failure/servicing, and as such a difference, even if small, between the risk premia should exist. The data collected as part of the household survey cannot however pick up this difference. The main reason for this is that it is felt that the difference in risk premia due to unavailability of the ferry in times of bad weather and mechanical failure (noting that a fixed link can also be unavailable in bad weather) is too small to detect with these surveys, possibly due to the methodology adopted. It is however also felt that the primary driver behind the result is that islanders do not feel cut-off from employment, services, leisure facilities, etc. with a high quality ferry service. If large risk premia exist for ferry services and fixed links this would suggest in the main that they are driven by operating hours and headway rather than infrastructure *per se*. To the extent that annual willingness to pay values of households for operating hours and headway are used in the calculation of scheduling costs (in the previous section) these may already include the risk premium associated with any change in operating hours - as also discussed in section 6.9.

No change in risk premium is therefore attributed to the construction of the Berneray causeway.

9.5 Wider economic impacts

Chapter 7 identified three wider economic impacts that may be relevant in a peripheral region. These are localisation economies, imperfect competition and thin labour markets. As discussed in that chapter, two methods exist to incorporate the effect of these market failures in a transport cost benefit analysis: the partial equilibrium approach, as exemplified by DfT (2005), and a more sophisticated general equilibrium approach using SCGE models. To date the partial equilibrium approach has been applied to more projects than the alternative SCGE approach – of which, as far as it can be ascertained, there are only two 'real' transport project examples in the literature (as discussed in Chapter 7).

Conceptually the use of SCGE models is preferable as with the partial equilibrium approach changes induced in other sectors of the economy (the general equilibrium effects) are assumed to have no net social value. However, SCGE models are only in the infancy of their development and as such, are not widely available, with the few in existence typically having been developed in universities (Gunn, 2004). Furthermore simplifications in the representation of labour markets, labour migration, household behaviour, the product market, the land market and the level of industrial disaggregation have to be made. This and the need to interact it with a transport model mean that the application of a SCGE model to the appraisal of a transport improvement is a far from trivial task (Laird, Nellthorp and Mackie, 2005). Whilst a SCGE model is conceptually preferable for the modelling of the wider economic impact of a transport project a substantial research effort would be required to undertake such an exercise that goes beyond the scope of this thesis. The wider economic impacts of localisation economies, imperfect competition and thin labour markets are therefore calculated using the partial equilibrium approach, with its inherent assumption that impacts induced in other sectors of the economy have no net social value.

Localisation economies

Businesses within certain sectors cluster together as by sharing a pooled labour market, sharing common suppliers and utilising knowledge spillovers between firms they can increase productivity and reduce exposure to demand shocks. As discussed in Chapter 7 (Section 7.3) transport interventions can make a positive contribution to this clustering process and in so doing create externalities (agglomeration externalities) that are additional to transport user benefits. Graham (2004) identifies the Outer Hebrides as an area in which the fishing sector is clustered. No elasticity of productivity to increased employment that is significantly different from zero for the primary sector has been identified to date (e.g. Graham, in press). This would suggest that no localisation externalities would be associated with the Berneray causeway.

The proportion of the working population employed in the fishing sector on Berneray and North Uist is 21% and 10% respectively (GROS, 2008), though the absolute numbers are small – 8 people on Berneray and 38 people on North Uist. This comprises of about 7% of those working in the fishing sector in the Outer Hebrides. The main fishing industry in the Outer Hebrides is based in the Isles of Lewis and Harris, which between them have about 50% of those employed in the fishing sector in the island group. The main deep water harbour in the island group is also located on Lewis. As the Berneray causeway does not impact on transport costs of businesses in Lewis (the location of the main cluster), and the fishing sector in Berneray and North Uist is small, the Berneray causeway is not expected to enlarge the existing cluster. This view is supported by the evidence gathered by Halcrow Fox who did not identify any employment impacts of the Berneray causeway for businesses in the agriculture or fishing sectors (Halcrow Fox, 1996 Table 3.1). The Berneray causeway is not therefore expected to generate any wider economic impacts due to localisation externalities.

Imperfect competition

Wider economic impacts are felt in product markets with imperfect competition when a transport intervention leads to an expansion in output. The Department for Transport (DfT, 2005) estimate that this wider economic impact is equivalent to about 10% of business and freight user benefits, on average, in the UK. This is still an emerging area and as discussed in Chapter 7 this may in fact be an overestimate if producers are able to price discriminate. For a peripheral region where markets are isolated it was argued in Chapter 7 that price-cost margins are higher due to a lack of competition. The petrol wholesale and retail market was cited as an example of a sector where this occurs. This would suggest that the wider economic impact of an expansion of output in peripheral areas will be higher than it is in more central areas. Given these competing hypotheses, and in the absence of alternative evidence, the Department of Transport estimate is used here to calculate the wider economic impact of imperfect competition.

A wider economic impact arising from imperfect competition in the product market can only occur if there is an expansion in output. There is only indirect evidence that such an expansion in output occurs as a consequence of the Berneray causeway. Halcrow Fox found evidence that businesses on and off Berneray expected turnover to increase, whilst a real cost of living reduction was also anticipated by Halcrow Fox. If households experience a cost of living reduction then the surplus can be used to purchase other goods that were not previously available (i.e. expand output). The

SQW (2004) ex-post study confirms that such a cost of living reduction did occur, as it finds that households through reduced transport costs and lower prices were £407 better off per year (in 2003).

A wider economic impact of £17,000 (1996 resource prices and 2000 values) attributed to imperfect competition is estimated for the first full operating year (2000). This is 10% of the sum of user benefits and scheduling costs accruing to businesses.

Thin labour markets

If the wage does not equal the marginal product of labour then changes in employment lead to wider economic impacts in the labour market. Once again wider economic impacts will only be felt if employment levels change. Halcrow Fox estimate that construction of the Berneray causeway leads to a net increase of 38.5 full-time equivalent jobs. If the marginal product of labour therefore does not equal the wage in the Outer Hebrides a wider economic impact in the labour market is expected.

If labour markets in the Outer Hebrides are thin, in the sense that there are limited job opportunities and vacancies only appear intermittently, job search models indicate that a wedge will exist between the marginal product of labour and the wage. This is discussed in Chapter 7 (section 7.5). Chapter 8 investigated whether a symptom of thin labour markets, partial or non-compensation for commuting costs, was evident in peripheral regions (including the Outer Hebrides). Evidence of this is found.

To take these findings and apply them within a transport appraisal, within a partial equilibrium context, requires knowledge of two other important pieces of data:

- The size of the wedge between the marginal product of labour and the wage; and
- Whether the size of the wedge varies between regions.

These data are needed because the additional surplus that is felt in the labour market (Area C in Figure 7.5) is a function of the gap between the wage and the marginal product of labour and the increase in regional employment.

Importantly, as discussed in Chapter 7, there is only limited data on this. The best estimates are that wages lie 17% below the marginal product of labour (Manning, 2003a Chapter 4), but there is no firm evidence as to how this gap varies by labour market segment. Ideally Chapter 8 would have helped illuminate this issue, however, data limitations mean that the findings of the empirical work presented there are inconclusive regarding the rate of compensation for commuting costs outside of peripheral regions. The indications are that, aside from those in peripheral regions, women and those in low skill occupations also face thin labour markets and receive no compensation for the commute. In comparison it was felt that the indications were that men in medium and high skilled occupations face a thicker labour market. Primarily this is because men in medium and high skilled occupations are more mobile than other segments of the labour force.

It is therefore difficult, without further research, to give more than an indicative estimate of the wider economic impact of additional employment. Such an indicative estimate can be made with the following assumptions:

- Workers in peripheral regions, women and those of low skill levels face thin labour markets and receive wages 17% below their marginal product;
- Men with medium and high skills working in a central area face thick labour markets and are paid their marginal product;
- Employment does not increase at the national level. That is all the jobs created by the project are re-distributed from other parts of the UK; and
- The additional jobs are re-distributed from central areas.

This gives an estimate of the wider economic impact due to efficiency gains in thin labour markets for the first full operating year of £16,000 (1996 prices and 2000 values). This is based on an assumption that 22% of the 38.5 full time equivalent jobs created by the causeway will be held by men in medium to high skilled occupations. This proportion derives from the Scottish Household Survey dataset analysed in Chapter 8. The estimate is also based on a median gross weekly wage in the Outer Hebrides for all full time employees of £445 in July 2008 (Scottish Government, 2008). This is equivalent to a gross weekly wage of £263 in 1996 prices and 2000 values. Clearly the wider economic impact estimate of £16,000 is sensitive to the gap assumed between the wage and the marginal product as well as the wage assumed for the additional jobs created.

9.6 Conclusions

The revised economic impact of the Berneray causeway and re-cast of the Sound of

Harris ferry is summarised in Table 9.4. As can be seen from this table, the inclusion of scheduling costs and wider economic impacts increases the overall benefit of the project by just over 50%. Two thirds of these additional benefits derive from scheduling costs. Wider economic impacts are estimated to give an economic benefit that comprises 17% of user benefits. If scheduling costs had been included in an appraisal in addition to user benefits, wider economic benefits would have added an additional 12% to the estimated total economic impact of the project.

Table 9.4 Benefits of the Berneray causeway and Sound of Harris ferry service enhancement in first full operating year (2000)

	Economic impact	
	Existing approach	Extended scope
User Benefits	200,000	200,000
Scheduling costs	N/A	72,000
Risk premium	N/A	0
Localisation	N/A	0
Imperfect competition	N/A	17,000
Thin labour markets	N/A	16,000
Total	200,000	305,000

Note: 1996 resource prices and 2000 values

This case study and the rail case studies presented in Chapter 3 provide the final piece of evidence in support the hypothesis of the thesis: that standard transport cost benefit analysis methods significantly understate the economic impact of transport projects in sparse networks and peripheral regions. The proposition that wider economic impacts are only relevant to big projects in big cities is also refuted. Whilst existing methods significantly understate the economic impact of a transport project, user benefits still appear to form the majority of the total economic impact of the project. The missing benefits do not therefore appear to be of different order of magnitude to user benefits.

The case study has also emphasised the evidence gaps identified in earlier chapters. In terms of scheduling costs there is a need for evidence on the values held by non-residents making short/local trips and the values that should be attributed to commercial vehicles. With respect to the wider economic impacts there remains an evidence gap regarding the level of imperfect competition within the regional economy and also how the gap between the wage and the marginal product vary between different segments of the labour market. Furthermore, ideally the wider economic impacts should be modelled using a general equilibrium method that allowed second order changes induced in other sectors of the economy to have value. This can be done with a SCGE model. Such models are not widely available and therefore their application will represent a significant future research effort.

On the basis of the evidence available, it is found that the wider economic impacts in a peripheral region are significant. However, in the particular case of a ferry replaced by a fixed link, it is more important for the appraisal to be specified to measure all relevant transport benefits, including those associated with activity re-scheduling, than to attempt to model wider economic impacts. This is because scheduling costs form two thirds of the missing benefits, whilst the two wider economic impacts modelled here only contribute a third of the missing benefits between them. Clearly for other projects, such as upgrades in road quality or the opening of new rail stations and strengthening of train services, the balance between the benefit categories will be different.

BLANK PAGE IN ORIGINAL

10 CONCLUSIONS

10.1 The contribution of this thesis

The research question addressed by this thesis is whether cost benefit analysis methods need to be adapted to deal with the special case of transport projects in sparse networks and peripheral regions. It is motivated by the fact that this geography is distinct from the inter-urban routes and urban areas upon which cost benefit analysis methods were developed. The principal distinguishing feature of the geography is a lack of alternatives (or choices). Route choices, mode choices and departure time choices are limited in sparse networks. Furthermore job opportunities for workers, choices between workers for firms and choice of suppliers/retailers are limited in peripheral regions. From the perspective of modelling the economic impact of a transport project, this lack of alternatives brings to a prominence a particular set of issues: scheduling costs, the treatment of uncertainty and the existence of wider economic impacts.

This thesis has therefore brought together several different strands of the literature to demonstrate a theoretical argument for the inclusion of scheduling costs, uncertainty and wider economic benefits when modelling the economic impact of transport projects in sparse networks and peripheral regions. The argument draws on the literature on time use (Becker, 1965; Oort, 1969; De Serpa, 1971; Evans, 1972), departure time choice (Vickrey, 1969; Small, 1982) and activity scheduling (Winston, 1982; Wilson, 1989) to identify that some activities can be constrained by transport constraints. This gives rise to the existence of scheduling costs. The argument for the inclusion of uncertainty in the analysis draws from the large body of literature concerned with the cost that uncertainty places on economic decision-makers. These costs give rise to the analogous concepts of the risk premium (Pratt, 1964) and option values (Weisbrod, 1964). It has been argued that these concepts are relevant to transport networks and have a particular resonance to sparse networks in peripheral regions. This is because in these networks supply side uncertainty and demand side uncertainty exist and alternatives are limited. Supply side uncertainty exists as random shocks to the transport network reduce supply and in extreme cases completely sever supply. Demand side uncertainty exists as future preferences are unknown and demand side shocks (e.g. closure of place of work) can occur. As a consequence it is not known for example where one's place of employment will be in 10 years time, nor whether one will need to access specialist healthcare in the next year. This uncertainty places a burden on economic agents, which can be reduced if the transport network is either more resilient to supply side shocks or for example can connect economic agents to more opportunities for obtaining employment. Wider economic impacts are also relevant to transport interventions in sparse networks and peripheral regions. In contrast to the other literature drawn on in this research, the literature on wider economic impacts of transport projects is much smaller (SACTRA, 1999; Venables and Gasiorek, 1999; DfT, 2005; Venables, 2007; Graham, 2007; Elhorst and Oosterhaven, 2008; Pilegaard and Fosgerau, 2008). A significant contribution of this work has therefore been to bring the different strands relevant to peripheral regions together. The lack of alternatives in peripheral regions mean that economic agents can face monopolistic conditions in the supply of goods and services and have difficulty finding employment as labour markets are thin. Such conditions lead to prices departing from marginal social costs. In such conditions any expansion in output or employment as a result of a transport intervention will lead to additional impacts in the goods market and/or the labour market. Furthermore industrial clusters are evident in peripheral regions. If a transport intervention strengthens such a cluster an increase in productivity beyond that expected from a reduction in transport costs may arise as a result of localisation economies. This too is a wider economic impact.

The empirical research presented in this thesis has then demonstrated that these effects can be quantitatively significant. From the case studies undertaken they appear for public transport projects, in totality, to be of a similar order of magnitude to user benefits. A clear case therefore exists for widening the scope of a cost benefit analysis of a transport project in a sparse network and peripheral region to a model as set out in Figure 10.1. The additional costs that should be incorporated into the analysis are highlighted in italics. This is the main finding of the thesis.

This conclusion is based on a series of reviews, experiments, econometric analysis and case studies presented in different chapters throughout the thesis and brought together in this chapter, the concluding chapter. The contribution of each element of the research is detailed in this section. Ancillary findings relevant to empirical investigation in the transport field in general are also presented in this section. The limited research previously undertaken in the field means that many of the issues raised warrant a much more thorough investigation than has been possible here. Suggested extensions to this research are therefore proposed in the second and final section of this chapter.

Figure 10.1: A revised economic identity

Economic Benefit	=	Transport Users' Benefit (Consumers' Surplus)	+	Change in Transport Operators' Profits (Producers' Surplus)	+	Changes in Government grants and indirect tax revenue	+	Change in external costs (e.g. accidents, pollution, etc.)
	+	*Change in scheduling costs*						
	+	*Change in risk premium / option value*						
	+	*Wider economic impact due to imperfect competition*	+	*Wider economic impact due to thin labour markets*	+	*Wider economic impact due to localisation economies*		

Scheduling costs

Scheduling costs, in a transport analysis context, are the welfare costs imposed upon activity scheduling by transport constraints. They arise as activities cannot be undertaken at the desired time, or for the desired duration in the presence of transport constraints. These welfare costs are additional to user benefits in a transport cost benefit analysis. With an emphasis on the timing and duration of activities as the source of the welfare cost temporally sparse networks are likely to give rise to the largest scheduling costs. That is networks that are sparse in terms of departure time choices are those in which scheduling costs will be the highest. This leads to a focus on public transport networks. There are of course instances where long journey times arising through limitations in route or mode choice will also give rise to scheduling costs, but in the main restrictions in departure time choices will be the primary driver to scheduling costs. There is a close relationship between departure time choice, headway and some forms of use costs, such as queuing time. Consequently surveys that directly elicit willingness to pay values for marginal changes in transport constraints (e.g. headway) will include some elements of use costs. This needs to be borne in mind when undertaking survey work in support of a transport cost benefit analysis.

Headway and operating hours are two of the most important determinants of departure time constraints in public transport networks and therefore two of the most important determinants of scheduling costs. An evidence gap, however, exists for long headways (2 hours plus) and the effect of operating hours in general, and for ferry services in particular - issues of particular relevance in peripheral regions of the UK. A contribution of this research is to start to fill that evidence gap. The surveys undertaken found evidence of significant marginal values for headway and operating hours of a ferry service. For long distance trips the marginal value of headway was found to 5.1p/min/veh-trip for headways of 3 hours or more, whilst the marginal value of an operating hour varies between 30.1 to 87.7p/hr/veh-trip. For local non-work trips the marginal value of headway varies between £2.48 and £14.01 per min/household/year, whilst the marginal value of an operating hour varies between £24.42 and £43.02 per hr/household/year.

Evidence that marginal values depend on both the journey purpose (work and non-work) and socio-economic characteristics of the traveller (gender, whether someone else pays for the ticket and trip-making characteristics) is also found. Furthermore evidence that the marginal values are non-linear in headway and operating hours is found. This is as expected and gives rise to the range of values described above. The marginal value of increased availability is more during the day (e.g. 87.7p/hr/veh-trip) than at night (e.g. 30.1p/hr/veh-trip), when increased availability is less useful. *A priori* the marginal value of a headway minute is expected to increase the smaller the headway between services is. Primarily this is because the marginal value of headway is confounded with use costs associated with waiting time – usually one of the least productive uses of time. At small headways a marginal change in headway will affect queuing time, which it does not at long headways, as at long headways arrivals are planned. This leads to the expectation that the value of a marginal change in headway will be larger at short headways than at long headways. This result is found for local short distance trips where the marginal value of headway is £14.01 per min/household/year for headways of 60 minutes or less compared to £2.48 per min/household/year for headways greater than 60 minutes. Interestingly it is not evident for long distance trips, where the opposite is the case. For long distance trips the data indicate that for headways up to 3 hours a marginal change in the headway has no value, whilst the marginal value of a change in headway when headways exceed 3 hours is found to be 5.1p/min/veh-trip. This is attributed to the fact that when the trip is the major activity of the day, as it is for long distance trips, there exists a reasonable amount of flexibility and/or buffer time in the day's activity schedule. Variations in marginal valuations also occur by journey purpose with business trips and long distance trips having higher marginal values than short distance and non-work trips.

These findings have important implications for the economic appraisal of ferry services and fixed links. By applying the findings to a case study of the Berneray Causeway and Sound of Harris ferry scheduling costs are shown to be between 14% and 50% of forecast user benefits. The upper end of the range is associated with the reduction in scheduling costs of travellers to/from Berneray when the short ferry crossing is replaced with a fixed link. The lower end of the range is associated with an increase in frequency of the Sound of Harris ferry which serves long distance trips, for which there is found to be no benefit from reducing headways below 3 hours.

A further important finding of the survey work is a substantial difference of about 50% between the estimated annual Marshallian consumer surplus felt by householders (calculated using marginal values per trip) and the surveyed willingness to pay value per year. This is very important in the context of an economic appraisal where it is standard practice to aggregate per trip marginal valuations up to an annual basis. This difference derives from a number of characteristics including the curvature of the demand curve and income effects. The first effect, the curvature of the demand curve, emphasises the importance of forecasting demand correctly and avoiding the assumption of a linear demand curve when estimating the change in consumer surplus in the economic appraisal. The income effect is important where the annual willingness to pay value calculated using marginal values per trip forms a significant percentage of annual income. In the geography of interest high frequency users of a new fixed link combined with the low household incomes typically found in peripheral regions makes it extremely likely that an income effect will be important. Here for example it is estimated that the annual Marshallian consumer surplus felt by households was equivalent to approximately 40% of average UK household expenditure on transport (or about 6% of average household expenditure), whilst household incomes are well below average UK levels. For this reason, when modelling the economic impacts of a transport project in a sparse network and a peripheral region, it is important to give due consideration to the curvature of the demand curve and the potential for income effects.

Uncertainty

In the presence of uncertainty, either supply side uncertainty or demand side uncertainty, a risk premium exists. On the supply side alternative routes and mode choice are limited, whilst on the demand side employment, leisure, shopping and healthcare opportunities can be limited within close proximity to place of residence. The risk of closure of any of these facilities, including loss of employment, creates the demand side uncertainty. The risk premium is defined as the difference between the maximum willingness to pay to have a certain income when faced with an uncertain income without being any worse off (in utility terms). Option values are analogous to the risk premium for the situations where alternatives exist. Risk premia (and option values) are always additional to transport user benefits in a cost benefit analysis. The concept of the risk premium and option value is relevant to households and businesses reliant on a sparse network in a peripheral region due to the limited number of alternatives in such networks. There is no evidence on the risk premia of transport infrastructure and services aside from that associated with option values - which is in itself restricted to a handful of studies on rail and bus services. In a review of the evidence base on transport option values the research presented in the thesis is able to qualitatively reconcile the apparent wide range in empirical values on the basis of: survey year; mode; quality; and availability of alternatives. Case studies of rail proposals also demonstrated the importance of option values to rural rail projects on lightly trafficked lines, as are found in thinly populated peripheral regions. Option values are equally applicable to rail projects in more densely populated areas and on busy lines. However, the scale of user costs on such lines means that the inclusion of option values in the appraisal has only a small effect on total benefits. This is in contrast with the Highland case studies which demonstrated an increase in benefits of between 60% and 120% from the inclusion of option values.

Survey work was undertaken to examine the size of the difference in risk premia between a fixed link and a ferry. Interestingly no difference could be identified. It is felt this arises as islanders are comfortable with the access they have to employment, services, leisure facilities, etc. with a high quality ferry service (in this case a half hourly 24 hour ferry free at the point of use). That is they perceive little or no difference in demand side and supply side uncertainty between a fixed link and a high quality ferry ferry. There may of course be differences, but if such differences exist they were too small to detect in these surveys. This is possibly a consequence of the method adopted. If large risk premia exist for ferry services and fixed links this would suggest that, in the main, they would be driven by operating hours and headway rather than infrastructure *per se*. Thus one might expect a difference in risk premia between a ferry that is available for 12 hours a day with an hourly frequency and a fixed link that is available for 24 hours a day.

The applicability of scheduling costs and risk premia as sources of welfare benefit is not solely confined to transport projects in sparse networks and peripheral regions. The concepts are universally applicable to all transport projects and regions. However in terms of having a significant effect on an economic appraisal, scheduling costs and risk premia are only likely to be of relevance to the appraisal of public transport projects, and furthermore risk premia are only likely to be important on lightly trafficked parts of the network. As a consequence, aside from ferries, scheduling costs are likely to be applicable to the appraisal of air, rail and bus projects, but probably not road projects. This research identified that for services serving the long distance market where the trip can often form the main activity of the day there is a threshold (e.g. services every 3 hours) below which marginal changes in headway have limited value. It is imagined that such a finding would also be applicable to long distance rail, bus and air services involving overnight trips. This is because for these trips the journey will form the main activity of the day. It is also expected that risk premia would be applicable to air services as well as ferry, rail and bus services, though as discussed above if the services are busy and use costs are large then risk premia, like option values, may only form a small percentage of the total economic value of a transport project. Furthermore part of the benefits of having a public transport network resilient to shocks in demand or supply, including the loss of supply through natural disaster or terrorism, would be captured in a risk premium.

Wider economic impacts

Wider economic impacts are the economic impacts that occur in markets other than transport as a result of prices not equalling marginal social cost in these markets. The literature on wider economic impacts has to date focussed on large projects in big cities as the main incidence of where these benefits will typically be found. The conclusion of this research is that this focus is too narrow as sparsely populated peripheral regions with their isolated markets also exhibit economic conditions that mean prices do not equal marginal social costs in the wider economy. A review of the literature indicates that three wider economic impacts can be of relevance to a transport project in a peripheral region. These are localisation economies, imperfect competition and thin labour markets. Localisation economies occur when a transport project specifically benefits an industrial cluster of which several are noted in peripheral regions, often associated with the exploitation of natural resources. Imperfect competition is expected to be more extensive in peripheral regions due to the isolated nature of the markets allowing retailers to mark prices up more than they do in more central areas. The petrol retailing and wholesale market is an example of a market where this occurs. The long distances and sparse populations lead to thin labour markets in peripheral areas. This increases job search costs and leads to a wedge appearing between the marginal product of labour and the wage.

Evidence on each of these impacts is scarce and the argument of relevance is therefore also based on persuasion. For example, whilst some evidence on localisation economies and imperfect competition already exists there is nothing specific to peripheral regions. Furthermore there is no evidence suggesting that labour markets are thinner in peripheral regions than elsewhere in the economy. Search costs are one of the main factors that give rise to thin labour markets, and job search models suggest that in the presence of search costs commuting costs will only be partially compensated. One of the contributions of this thesis therefore has been to look for evidence of partial compensation of commuting costs for workers in peripheral areas.

Wage equations estimated to data from the Scottish Household Survey indicate that workers in peripheral regions are not compensated through their wage for the time and money commuting costs they incur. In line with an economic model of job search this is interpreted as evidence that labour markets are thin in peripheral areas and a wedge exists between the marginal product of labour and the wage. Data limitations meant that it was not possible to ascertain a rate of compensation for workers in central areas. The indications are, however, that women and those in low skilled occupations also face thin labour markets and receive no compensation for the commute, whilst men in medium and higher skilled occupations face a thicker labour market. The reason that differences exist between the labour markets faced by different segments of the population is that men in medium and high skilled occupations are more mobile than other segments of the labour force. They have sufficient income to afford to travel, choose between residential locations and typically their household will re-locate to be near to their job.. It is for this reason that they have the largest choice of jobs and face the thickest labour markets.

It is estimated that wider economic impacts associated with imperfect competition and thin labour markets have an economic value that is about 17% of forecast user benefits. This is based on the case study of the Berneray causeway and Sound of Harris ferry. A 17% increase in modelled economic benefit is not as large an increase as can be obtained through the inclusion of scheduling costs in a ferry appraisal or the inclusion of option values for rail projects but nonetheless is significant. Furthermore it is likely to apply to roads as well as public transport. The claim that wider economic impacts are only significant for large projects in big cities is therefore refuted. Wider economic impacts are also relevant to transport projects in peripheral regions.

Empirical methods

A key issue in the econometric analysis of stated preference data is the treatment of the distribution of marginal utilities of each attribute. The distribution of willingness to pay is dependent on the distributions of the marginal utilities. A weakness of current methods is that the distribution function is adopted *a priori* based on the anticipated shape of the distribution. In part, this is because little is known about the actual distribution of willingness to pay. This research by using fixed boundary values in the design of the stated preference questions and through the use of contingent valuation questions allows the researcher to have a much better understanding of the observed distribution of willingness to pay. For the attributes of headway and operating hours it is apparent that a large proportion of the observations exhibit a zero or very low willingness to pay. Such observations can be used to guide the researcher towards a preferred distribution function when estimating the model. A further area of contention in the literature is whether the distribution of willingness to pay can be negative. Often a negative willingness to pay arises as consequence of a confounding of highly correlated attributes - for example a willingness to pay to maintain isolation and a willingness to pay for travel time savings. The use of very low boundary values and contingent valuation questions with follow-up questions regarding zero willingness to pay can help in understanding the proportion of the sample with negative willingness to pay. For example, in the household survey in this research between 2 and 4% of respondents indicated a negative willingness to pay for improved connectivity to their island.

The final contribution of the research is in demonstrating the endogeneity of commuting costs and income. This has implications both for research on the rate of compensation for commuting costs in the wage, but also for research on the role of income in determining the demand for commuting. As far as it can be ascertained no research to date has controlled for this endogeneity either in the derivation of wage equations or in the derivation of income elasticities for the demand for commuting.

10.2 Suggestions for further research

The limited research previously undertaken in the field means that many of the issues raised warrant a much more thorough investigation than has been possible here. The suggestions cover the need for more evidence on each of three main sources of missing economic benefits for a transport project in a sparse network and peripheral region – namely: scheduling costs; the risk premium and option values; and wider economic impacts – as well as the potential for undertaking new methodological research. Research priorities are also identified.

Scheduling costs

There is a need for more evidence on scheduling costs associated with ferry services. For short distance trips this research focussed on non-work values for island residents, whilst for longer distance trips it looked at business and non-work values. There therefore remains an evidence gap for business and commercial vehicles making short distance trips, non-residents making short distance trips and commercial vehicles making long distance trips. The results presented in this research are also based on relatively small sample sizes from one geographic location. Obtaining evidence from other locations and from ferry services with different attributes and performing different roles within the transport network (e.g. linking an island to the mainland rather than just linking it to another island) is therefore needed. Scheduling costs are of course not just confined to ferry services. There remains an evidence gap across all modes, rail, bus and air, concerning the willingness to pay for changes in infrequent services. Furthermore, how such valuations vary by day of the week and hour of the day is not fully understood.

Uncertainty

A similar story is evident for option values. There exists only a handful of studies on transport related option values. From these it is possible to see that the range of potential values varies by mode, quality, availability of alternatives and access to large employment and service centres. This variation is important in the context of a cost benefit analysis, but to date there is no evidence as to the exact relationship between marginal changes in these characteristics and option values. Furthermore the evidence is confined to bus and rail values with no evidence on air values. There is also no evidence on the values that businesses may attribute to the rail network either for the carriage of freight or for employees travelling on company business. Option values are applicable to all types of transport services not just services linking outlying areas to a regional centre – which are the types of services that have been studied in the literature. What values communities attach to mainline or 'hub' stations is also therefore of interest. Filling these evidence gaps will be an important contribution of future research.

This research was not able to identify a difference in risk premium between a high quality ferry and a fixed link. This may have arisen as a consequence of the method adopted. An alternative method to that adopted here would be to estimate the risk premium associated with a fixed link and with a ferry separately. This would require surveys in at least two locations – one with a fixed link and another with a ferry. Such a method is recommended for future research, though it is more resource intensive than the method adopted here. The result found here can also be explained by the fact that the risk premium may in fact be driven by the quality of a ferry (including opening hours, headway and fare) rather than the existence of a ferry *per se*. This is because it is unfettered access to employment opportunities, services and healthcare that probably act as the main drivers to the value the risk premium takes. Further research is needed to confirm this hypothesis. A risk premium is also expected to exist for any infrastructure that may have some uncertainty in supply. Transport systems are potentially vulnerable to prolonged large scale disruption due to a long term failure in a critical link or an important hub. Such failure may occur due to a natural disaster (e.g. bridges being washed out in floods, earthquakes or volcanic lava flows) or as a consequence of say terrorist activity. The risk premium is the economic mechanism by which the willingness to pay of the population to obtain a transport network resilient to such supply shocks can enter into a cost benefit analysis. There has however been no research to date on such risk premia.

Wider economic impacts

There remain a substantial number of new research avenues that can be explored in the field of the wider economic impacts of transport projects in peripheral regions. The research presented in this thesis was not able to satisfactorily identify the level of compensation for commuting costs for workers outside of peripheral areas. In part this is due to the strength of the instruments used to control for the endogeneity between commuting costs and income, but also because the dataset was not disaggregate enough to calculate average commuting costs of all workers at a workplace (or small work zone). The lack of an appropriate dataset means that future research will need to consider commissioning surveys and analysing behaviour at particular firms or organisations. This combined with a good transport or traffic model may provide sufficient data on the commute and incomes. An ever present problem for future research in this area will be the need to account for the endogeneity between commuting costs and income. The need for strong instruments means that future research may have to wait for a natural experiment (such as a large exogenous change in transport prices occurring in one region or area but not in another). A good instrument might be the implementation of a congestion charge if implemented in one city but not in any other city.

A key difficulty when including wider economic impacts due to thin labour markets is the difference between the marginal product of labour and the wage and how this varies by region and labour market segment. There is very limited evidence on this. This is not due to a lack of interest in the topic but because it is very difficult to find data with which an estimate of the elasticity of the labour supply curve to the firm can be made. This is problematic from the perspective of a transport cost benefit analysis trying to include wider economic impacts arising through thin labour markets. An alternative approach may be to model the wedge between the marginal product of labour and the wage via job search models implemented within a spatial computable general equilibrium (SCGE) model.

This of course opens up the enormous research field of applying SCGE models to transport projects, of which there are very few examples in the literature. Conceptually SCGE models are preferable to the partial equilibrium approach to modelling wider economic impacts, as in the partial equilibrium approach changes in other sectors of the economy (the general equilibrium effects) are assumed to have no net social value. The scale of the task however is large as SCGE models are only in the infancy of their development. Some small (in the sense of the number of regions/zones) SCGE models in the UK exist such as the AMOS[60] model in Scotland (Harrigan *et al.*, 1991). The AMOS model has also been applied to small island economies (the Channel Islands and the Shetland Islands) as well as being used to model the UK economy. Given the regional trade background to SCGE models significant methodological development of these models is required before they can usefully be applied in a

[60] AMOS stands for A Macro-Micro Model of Scotland.

transport cost benefit analysis context. This can be illustrated using the AMOS model as an example. For example if the AMOS model was to be used to model the wider economic impacts of thin labour markets three particular areas stand out as requiring methodological development. First, as consumption in AMOS is modelled in an input-output type system AMOS does not output changes in welfare (economic efficiency). Household utility functions would therefore need to be introduced to the modelling system. Secondly, a job search model would need to be implemented which endogenised wage determination, commuting costs and unemployment. Currently AMOS uses a macroeconomic approach to modelling the labour market, based on a wage curve that relates the wage rate to the level of unemployment. Future wage rates are determined through the use of different wage bargaining assumptions. Thirdly the role of transport costs within the model would need to be enhanced. In a manner consistent with other trade models AMOS focuses on the direct costs of transporting goods. This would need to be enhanced to reflect the time and other components of generalised cost for business travel and commuting. Clearly all this development represents a substantial research effort.

Imperfect competition is an important source of wider economic impact in peripheral regions. There is however a notable lack of evidence on price cost margins specific to the remoter parts of the UK. The most disaggregate data available separates Scotland and Wales from the English regions but does not disaggregate further. This it has been argued is too coarse, as it is only the most peripheral parts of each of these regions that experience isolated markets with limited competition. There also remains the general point, that has received limited if any discussion in the transport economic literature, on the role of a price discriminating monopolist. If price discrimination occurs output will be much closer to the optimal level than it would without price discrimination, and the wider economic impact of transport cost reduction would therefore be smaller.

The role of localisation economies in peripheral regions has also received limited attention in the literature. Localisation economies will be important for transport projects located in or close to specific industrial clusters. There is therefore a need to examine whether evidence of localisation economies can be found in certain primary sector industries and any associated production industries (e.g. fishing, fish processing and oil exploration). This may well be a problematic avenue to pursue due to the difficulty in obtaining an appropriate dataset.

Methodological

From an economic appraisal perspective any significant difference between the Marshallian consumer surplus measure and the Hicksian compensating variation measure is very important. This is because the former measure is used to approximate the latter in cost benefit analysis. The research presented in this thesis identified that this issue is significant for this study, but was not able to resolve why the difference occurs as the stated preference survey was not designed with the objective of testing for any difference between the two measures. New data therefore needs to be collected. These data need to be collected in a manner that will allow the estimation of a model for forecasting, as well as evaluation, and for the inclusion of income effects. The inclusion of income effects (or budget constraints) in a discrete choice model is a particularly interesting research area. One of the questions that such research should look to answer is at what point do income effects become important , that is how large does the change in generalised cost have to be relative to incomes for income effects to produce a significant bias in annual willingness to pay estimates. The rising prominence of congestion charging in a policy context adds further interest to this research area.

In designing a stated preference survey to examine differences in the two measures of annual willingness to pay care needs to be made to eliminate as far as possible scoping effect bias, or if scoping effect bias cannot be eliminated then it should at least be tested for. Scoping effect bias results from respondents having difficulty valuing the size of the benefit, attributing similar values to large benefits as to small benefits. This will involve the use of focus groups and ex-post de-briefing of respondents, as well as a survey designed to elicit willingness to pay for several different quantities of the good. An additional strategy that can be adopted, if the task is felt to be too complex for respondents, is to try and break it down into manageable component parts, though this can be quite labour intensive.

Research priorities

Whilst this research has focussed on the Highlands and Islands of Scotland the findings have implications for other peripheral regions. Within the UK this would include West Wales and Cornwall and, looking further afield, the remoter parts of the European Atlantic fringe countries. Thus this research has implications for the appraisal of transport projects in places including the west coast of Ireland, the north and west coast of Norway, Brittany and the north west coasts of Spain and Portugal as well as the Highlands and Islands of Scotland. Priorities for further research within these areas are mode specific. For public transport networks this thesis indicates scheduling costs and option values are the largest 'missing' elements of benefit. These issues should therefore form the priority for future research efforts in public transport networks. Where scheduling costs and uncertainty are not important issues, such as in the appraisal of road infrastructure projects, wider economic impacts have more relevance as a 'missing' benefit category. That is not to say wider economic impacts will be larger for road investments than other forms of transport investment, it is just that the existing appraisal methods are more complete for road infrastructure than for public transport projects. Of the three different wider economic impacts identified as being relevant to a sparse network and peripheral region it is felt that research into thin labour markets is probably the most interesting and important. Research into the impact of thin labour markets will most likely require a considerable effort due to the likely need to use some form of SCGE model.

BIBLIOGRAPHY

ALGERS, S., J.L. DILLEN, and S. WIDLERT. 1995. 'The national Swedish value of time study', *Proceedings Seminar F, PTRC Summer Annual Meeting 1995*, pp. 133-149, PTRC: London.

ALOGIT. 2008. [online]. [Accessed 5th May 2008]. Available from World Wide Web: <http://www.alogit.com>

ARROW, K.J. and A.C. FISHER. 1974. Environmental preservation, uncertainty and irreversibility. *Quarterly Journal of Economics*. **88**(2), pp.312-319.

ASEK (Unpublished, 2002) *Tid och kvalitet i persontrafik*. SIKA Rapport 2002:8. Report dated August 2002. [Accessed 23 January 2008]. Available from World Wide Web: <http://www.sika-institute.se/Doclib/Import/104/sr_2002_8.pdf>

ASSOCIATION OF TRAIN OPERATING COMPANIES (ATOC). 2002. *Passenger Demand Forecasting Handbook (PDFH), 4th Edition*. Commercial-in-Confidence. London: ATOC.

AXHAUSEN, K. W. and T. GÄRLING. 1992. Activity-based approaches to travel analysis: conceptual frameworks, models, and research problems. *Transport Reviews*. 12(4), pp.323 – 341.

AXHAUSEN, K.W., A. KÖNIG, G. ABAY, J. BATES and M. BIERLAIRE. 2004. Swiss value of travel time savings, *European Transport Conference 2004, 4-6 October 2004, Strasbourg*. London: Association for European Transport.

BARWELL, R.D. and M.E. SCHWEITZER. 2007. The incidence of nominal and real wage rigidities in Great Britain: 1978-98. *The Economic Journal*, **117**(524), pp. F553-F569.

BATEMAN, I.J., R.T. CARSON, B. DAY, M. HANEMANN, N. HANLEY, T. HETT, M.J. LEE, G. LOOMES, S. MOURATO, E. OZDEMIROGLU, D.W. PEARCE, R. SUGDEN, and J. SWANSON. 2002. *Economic valuation with Stated Preference Techniques: A Manual*. Cheltenham/Northampton: Edward Elgar.

BATES, J. AND G. TERZIS (1997) Stated preference and the 'ecological fallacy'. *Proceedings of 25th European Transport Forum (PTRC Annual meeting). Seminar F,* *Transportation Planning Methods. Uxbridge, UK 1-5 September, 1997.* London: PTRC. pp.155-170.

BATES, J., J. POLAK, P. JONES, and A. COOK. 2001. The valuation of reliability for personal travel. *Transportation Research Part E.* **37**(2-3), pp.191-229.

BATLEY, R.P. 2007. Marginal valuations of travel time and scheduling, and the reliability premium. *Transportation Research Part E.* **43**(4), pp.387-408.

BATLEY, R.P., J.P. TONER and M. KNIGHT. 2004. A mixed logit model of UK household demand for alternative-fuel vehicles. *International Journal of Transport Economics*, 31(1), pp.55-77

BECKER, G. 1965. A theory of the allocation of time. *The Economic Journal.* **75**, pp.493-517.

BEN-AKIVA, M. and S.R. LERMAN. 1985. Discrete choice analysis, theory and application to trave demand. Cambridge(Massachusetts):The MIT Press.

BERDICA, K. 2002. An introduction to road vulnerability: what has been done, is done and should be done. *Transport Policy.* **9**(2), pp.117-127.

BHASKAR, V., A. MANNING and T. TO. 2003. Oligopsony and monopsonistic competition in labor markets. *Journal of Economic Perspectives*, **16**(2), pp. 155-174.

BIERLIARE, M. (Unpublished 2008). *Estimation of discrete choice models with BIOGEME 1.6.* [Accessed 30th June 2008]. Available from World Wide Web: <http://transp-or.epfl.ch/page63028.html >

BISHOP, R.C. 1982. Option value: an exposition and extension. *Land Economics.* 58(1), pp.1-15.

BLUMENSHEIN, K., G.C. BLOMQUIST, M. JOHANNESSON, N. HORN AND P. FREEMAN. 2008. Eliciting willingness to pay without bias: evidence from a field experiment. *The Economic Journal.* **118**, pp.114-137.

BRADLEY, M.A. and A.J. DALY. 1997. Estimation of logit choice models using mixed stated-preference and revealed-preference information. *In:* P.R. STOPHER and M.E.H. GOSSELIN (eds). *Understanding travel Behaviour in an Era of Change.* Oxford:Elsevier, pp.209-231.

BRÅTHEN, S. 2001. Do fixed links affect local industry? A Norwegian case study. *Journal of Transport Geography*, **9**(1), pp. 25-38.

BRÅTHEN, S. and A. HERVIK. 1997. Strait Crossings and Economic Development. Developing Economic Impact Assessment by Means of *Ex Post* Analyses. *Transport Policy*. **4**(4), pp.193-201.

BRÅTHEN, S. and L. LYCHE. 2004. *Economic impact assessment in Norwegian road ferry links. A discussion of a few cost components.* Working Paper 2004:5. Molde: Molde University College and Molde Research Institute (in Norwegian only).

BRISTOW, A.L., P.G. HOPKINSON, C.A. NASH, and M. WARDMAN. 1991. Evaluation of the use and non-use benefits of public transport. Report No. 2. Application of the method. *ITS working paper 310.* Leeds: Institute for Transport Studies, University of Leeds. [Accessed 23 January 2008]. Available from World Wide Web: <http://eprints.whiterose.ac.uk/2248/>

BRÖCKER, J., R. MEYER, N. SCHNEEKLOTH, C. SCHÜRMANN, K. SPIEKERMANN, and M. WEGENER. 2004. *Modelling the Socio-economic and Spatial Impacts of EU Transport Policy. IASON (Integrated Appraisal of Spatial economic and Network effects of transport investments and policies) Deliverable 6.* Funded by 5th Framework RTD Programme. Delft: TNO Inro.

CARL BRO. (Unpublished, 2003). *Commuting Rail Services in the Inverness Area.* A report to Highlands and Islands Enterprise. Report dated March 2003. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.hie.co.uk/rail-study.htm>

CHERCHI, E. and J.W. POLAK. 2007. Income effects in the evaluation of user benefits using discrete choice models. *Universities' Transport Study Group 39th Annual Conference, 3-5 January 2007, Harrogate.* Leeds: University of Leeds.

CIRILLO, C. and K.W. AXHAUSEN. 2006. Evidence on the distribution of values of travel time savings from a six-week diary. *Transportation Research Part A.* **40**(5), pp.444-457.

COMHAIRLE NAN EILEAN SIAR. 2008. *The lost islands* [online]. [Accessed March 17th 2008]. Available from World Wide Web: <http://www.cne-siar.gov.uk/eriskay/lost.htm>

COWI, MVA and INREGIA. (Unpublished, 1999). *Traffic Forecast Model - The Fixed Link across Øresund.* A report to Øresundskonsortiet. Copenhagen: COWI A/S:

CROCKETT, D. 1992. *Non-Use Values in Cost-Benefit Analysis,* Masters Dissertation, Institute for Transport Studies, University of Leeds.

DALY, A.J., C. ROHR, and G. JOVICIC. 1998. Application of models based on stated and revealed preference data for forecasting passenger traffic between East and West Denmark. *In:* Meersman, H., E. van de Vooorde, and W. Winkelmans, (eds). *World Transport Research, Selected proceedings of the 8th World Conference on Transport Research, Volume 3.* Oxford: Pergamon.

DALZIELL, E. and A.J. NICHOLSON. 2001. Risk and impact of natural hazards on a road network. *Journal of Transportation Engineering.* 127(2), pp.159-166.

DAVIES, S. 1999. Review of the evidence on the incidence of imperfect competition in the UK. *In:* SACTRA (ed). *The welfare implications of transport improvements in the presence of market failure and the incidence of imperfect competition in UK sectors and regions.* London: Department for the Environment, Transport and the Regions, pp. 91-104.

DE JONG, G., A.J. DALY, M. PIETERS, C. VELLAY, M. BRADLEY and F. HOFMAN. 2003. A model for time of day and mode choice using error components logit. *Transportation Research Part E,* 39(3), pp.245-268.

DE JONG, G., E. KROES, R. PLASMEIJER, P. SANDERS, P. WARFFEMIUS. 2004. The value of reliability. *European Transport Conference, 4-6 October 2004, Strasbourg.* London: AET Transport.

DE SERPA, A. 1971. A theory of the economics of time. *The Economic Journal.* **81**, pp.828-846.

DEBREZION, G., E. PELS, and P. RIETVELD. (Unpublished, 2006). The impact of rail transport on real estate prices: an empirical analysis of the Dutch housing markets. Tinburgen Institute discussion paper TI 2006-031/3. Reported dated March 2006. [Accessed 28 January 2008]. Available from World Wide Web: <http://www.tinbergen.nl/discussionpapers/06031.pdf>

DEPARTMENT FOR TRANSPORT. 2003. The Option Values Sub-Objective. *Transport Appraisal Guidance (TAG) Unit 3.6.1.* London: Department for Transport.

[Accessed 30 August 2008]. Available from World Wide Web: <http://www.webtag.org.uk/webdocuments/3_Expert/6_Accessibility_Objective/3.6.1.htm>

DEPARTMENT FOR TRANSPORT. 2005 (modified 2006). *Transport, Wider Economic Benefits and Impacts on GDP*. London: Department for Transport. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.dft.gov.uk/pgr/economics/rdg/webia/>

DEPARTMENT FOR TRANSPORT. 2006a Economic Assessment of Road Schemes. Section 1 The COBA Manual. *Design Manual for Roads and Bridges (DMRB) Volume 13.* Norwich: TSO. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.dft.gov.uk/pgr/economics/software/>

DEPARTMENT FOR TRANSPORT. 2006b. Expert Guidance on the Mixed Logit Model: Procedures and Documentation. *Transport Appraisal Guidance (TAG) Unit 3.11.5.* London: Department for Transport. [Accessed 8 April 2008]. Available from World Wide Web: <http://www.webtag.org.uk/webdocuments/3_Expert/11_Specifications/3.11.5.htm>

DEPARTMENT FOR TRANSPORT. 2006c. *Consultation on the Implementation of the Railways Act 2005 provisions on closures and minor modifications.* London: Department for Transport.

DEPARTMENT FOR TRANSPORT. 2007a. Guidance on rail appraisal. *Transport Appraisal Guidance (TAG) Unit 3.13.1.* London: Department for Transport. [Accessed 30 August 2008]. Available from World Wide Web: <http://www.webtag.org.uk/webdocuments/3_Expert/13_Rail/3.13.1.htm>

DEPARTMENT FOR TRANSPORT. 2007b. Values of time and operating costs. *Transport Appraisal Guidance (TAG) Unit 3.5.6.* London: Department for Transport. [Accessed 6 May 2008]. Available from World Wide Web: <http://www.webtag.org.uk/webdocuments/3_Expert/5_Economy_Objective/3.5.6.htm>

DESVOUSGES, W.H., F.R. JOHNSON, R.W. DUNFORD, K.J. BOYLE, S.P. HUDSON and N. WILSON. 1993. Measuring natural resource damage with contingent valuation: tests of validity and reliability. *In:* J. HAUSMAN (ed). *Contingent valuation a critical assessment.* Amsterdam, London, New York, and Tokyo: North Holland, pp.91-159.

DHC. (Unpublished, 2007). *Evaluation of the Economic and Social Impacts of the Skye Bridge*. A report to Highlands and Islands Enterprise. Report dated 22 February 2007.

DODGSON, J.S. 1973. External Effects and Secondary Benefits in Road Investment Appraisal. *Journal of Transport Economics and Policy,* **7**(2), pp. 169-185.

DURANTON, G. and D. PUGA, 2004. Microfoundations of urban agglomeration economies. *In:* J.V. Henderson and J.F.Thisse (eds). *Handbook on Urban and Regional Economics Volume 4 Cities and Geography.* Oxford: Elsevier.

EDDINGTON, R. (2006) *The Eddington Transport Study.* Norwich: Her Majesty's Stationery Office.

ELHORST, J.P. and J. OOSTERHAVEN. 2008. Integral cost-benefit analysis of Maglev projects under market imperfections. *Journal of Transport and Land Use,* **1**(1), pp. 65-87.

EVANS, A. 1972. On the theory of the valuation and allocation of time. *Scottish Journal of Political Economy.* February 1972. **19**(1), pp. 1-17.

EXEL, VAN J., S. RIENSTRA, M. GOMMERS, A.D. PEARMAN, and D. TSAMBOULAS. 2002. EU involvement in TEN development: network effects and European Value Added. *Transport Policy,* **9**, pp. 299–311.

FEHMARNBELT TRAFFIC CONSORTIUM (FTC) (Unpublished, 1998) *Fehmarnbelt Traffic Demand Model - Final Report.* Report dated 23 June 1998.

FINDEIS, J.L. and L. JENSEN. 1998. Employment opportunities in rural areas: implications for poverty in a changing policy environment. *American Journal of Agricultural Economics,* **90**(5), pp. 1000-1007.

FOWKES, A.S. 2000. Recent developments in stated preference techniques in transport research. *In:* J. de D. Ortuzar (ed) *Stated Preference Modelling Techniques,* pp.37-52. London: PTRC.

FOWKES, A.S. 2001. Value of time for road commercial vehicles. *ITS Working Paper 563, Institute for Transport Studies.* Leeds: University of Leeds.

FOWKES, A.S. and M.R. WARDMAN. 1988. The design of stated preference travel choice experiments with special reference to interpersonal taste variations. *Journal of Transport Economics and Policy,* **22**(1), pp. 27-44.

FOWKES, A.S., D.H. JOHNSON, G. HYMAN, D. FISHER and N. IBÁÑEZ. 2007. Results from the UK Department for Transport's 2006 M6 Toll research project freight study. *European Transport Conference, Noordwijkerhout, Netherlands, 17-19 October 2007*. London: AET Transport.

GENERAL REGISTER OFFICE FOR SCOTLAND (SCROL). 2008. *Scotland's census results OnLine (SCROL)*. [online]. [Accessed 30th June 2008]. Available from World Wide Web: <http://www.scrol.gov.uk>

GEURS, K.T., R. HAAIJER and B. VAN WEE. 2006. The option value of public transport: methodology for measurement and case study for regional rail links in the Netherlands. *Transport Reviews*. **26**(5), pp.613-643.

GOODWIN, P., J. DARGAY, and M. HANLY. 2004. Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A review. *Transport Reviews*, **24**(3), pp. 275-292.

GRAHAM, D.J. (In press). Identifying urbanisation and localisation externalities in manufacturing and service industries. *Papers in Regional Science*, **X**(X), pp. XX-XX.

GRAHAM, D.J. (Unpublished, 2004). The localisation of economic activity in Britain. Worker paper, Centre for Transport Studies, Imperial College, London.

GRAHAM, D.J. 2007. Agglomeration, productivity and transport investment. *Journal of Transport Economics and Policy*, **41**(3), pp. 317-343.

GRANGESTON ECONOMICS (Unpublished, 2003) *Evaluation of the Social and Economic Impacts of the Sound of Harris Ferry Service*. Final report for Highlands and Islands Enterprise and Western Isles Enterprise. Report dated February 2003. [Accessed 8 April 2008]. Available from World Wide Web: <http://www.hie.co.uk/HIE-HIE-economic-reports/HIE-harrisferryimpact03.pdf>

GREENE, W.H. and D.A. HENSHER. 2003. A latent class model for discrete choice analysis: contrasts with mixed logit. *Transportation Research Part B*. **37**(8), pp.681-698.

GUNN, H. 2004. *SCGE Models: Relevance and Accessibility for Use in the UK, with emphasis on Implications for Evaluation of Transport Investments*. Cambridge: RAND Europe.

HÄGERSTRAND, T. 1970 What about people in regional science? *Papers of the Regional Science Association.* **24**(1), pp.7-21.

HALCROW FOX. (Unpublished 1996). *Berneray Causeway scheme appraisal.* Report to Western Isles Council. Report dated June 1996.

HALCROW. (Unpublished, 2006). *Appraisal of Proposed Re-opening of Station at Conon Bridge: Transport Economic Efficiency Analysis.* Report to the Highland Rail Partnership and HITRANS. Report dated December 2006.

HARRIGAN, F., P.G. MCGREGOR, N. DOURMASHKIN, R. PERMAN, K. SWALES and Y. PING YIN. 1991. AMOS: A macro-micro model of Scotland. *Economic Modelling.* **8**(4), pp. 424-479.

HARRIS, R.I.D. 1999. Incidence of imperfect competition in UK sectors and regions. *In:* SACTRA (ed). *The welfare implications of transport improvements in the presence of market failure and the incidence of imperfect competition in UK sectors and regions.* London: Department for the Environment, Transport and the Regions, pp. 77-90.

HARRISON, G.W. 2006. Experimental evidence on alternative environmental valuation methods. *Environmental and Resource Economics.* 34(1), pp.125-162.

HENSHER, D.A. and W.H. GREENE. 2003. The mixed logit model: the state of practice. *Transportation.* **30**(2), pp.133-176.

HESS, S. and J.M. ROSE. (Unpublished 2008). *Allowing for intra-respondent variations in coefficients estimated on stated choice data.* Report dated 24th June 2008.

HESS, S., M. BIERLIARE and J.W. POLAK. 2005. Estimation of value of travel-time savings using mixed logit models. *Transportation Research Part A.* **39**(2-3), pp.221-236.

HESS, S., M. BIERLIARE and J.W. POLAK. 2007. A systematic comparison of continuous and discrete mixture models. *European Transport.* **37**, pp.35-61.

HESS, S. and A. DALY. 2008. Calculating errors for measures derived from choice modelling estimates. Paper to be presented at *European Transport Conference, Noordwijkerhout, Netherlands, 6-8 October 2008.* London: AET Transport..

HIGHLAND RAIL DEVELOPMENTS. (Unpublished, 2000). *Beauly Station Re-opening Rail Passenger Partnership Funding Bid.* Report dated May 2000.

HIGHLAND RAIL PARTNERSHIP. (Unpublished, 2003). *Invernet revenue and cost projections* [Excel spreadsheet].

HIGHLANDS AND ISLANDS ENTERPRISE (HIE). (Unpublished, 2003a). *Outer Hebrides Economic Update.* Report dated October 2003. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.hie.co.uk/area-profiles-2003.htm>

HIGHLANDS AND ISLANDS ENTERPRISE (HIE). (Unpublished, 2003b). *Highlands and Islands Economic Update.* Report dated October 2003. [Accessed 24 July 2008]. Available from World Wide Web: <http://www.hie.co.uk/area-profiles-2003.htm>

HIGHLANDS AND ISLANDS ENTERPRISE. 2006. Letter to Sir Rod Eddington. *In:* R. Eddington, (ed). *The Eddington Transport Study,* Annex B – Submissions to the Eddington Transport Study. Norwich: TSO.

HIGHLANDS AND ISLANDS ENTERPRISE (HIE). (Unpublished, 2007a). *Highlands and Islands Economic Update.* Report dated April 2007. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.hie.co.uk/hie-area-and-lec-area-economic-profiles-2007.html>

HIGHLANDS AND ISLANDS ENTERPRISE (HIE). (Unpublished, 2007b). *Outer Hebrides Economic Update.* Report dated April 2007. *[Accessed 7 January 2008]. Available from World Wide Web: <http://www.hie.co.uk/hie-area-and-lec-area-economic-profiles-2007.html>*

HOLLANDER, Y. 2006. Fitting distributions to random parameters. *Transportation Research Record: Journal of the Transportation Research Board.* **1977**, pp.53-59.

HUMPHREYS, R.M. and A.S. FOWKES, 2006. The significance of indirect use and non-use values in transport appraisal. *International Journal of Transport Economics.* **33**(1), pp.17-35.

HUSDAL, J. 2005. The vulnerability of road networks in a cost-benefit perspective. Paper presented at *Transportation Research Board Annual Meeting 2005, Washington DC, USA, 9-13 January 2005.*

IHLANFELDT, K.R. 1992. Intraurban wage gradients: evidence by race, gender, occupational class, and sector. *Journal of Urban Economics*, **32**, pp. 70-91.

JACOBS. (Unpublished, 2006). *Airdrie - Bathgate Railway and Linked Improvements Bill Design Development Appraisal Report December 2006 (Final draft and private / confidential – not for public display or release in whole or part).* Report to Network Rail. Report dated December 2006.

JARA-DIAZ, S.R. 1986. On the Relation between Users' Benefits and the Economic Effects of Transportation Activities. *Journal of Regional Science*. **26**(2), pp.379-391.

JENELIUS, E., T. PETERSEN and L.G. MATTSSON. 2006. Importance and exposure in road network vulnerability analysis. *Transportation Research Part A*. **40**(7), pp.537-560.

KAHNEMAN, D. and A. TVERSKY. 1979. Prospect Theory: An analysis of decisions under risk. *Econometrica*. **47**(2), pp.263-291.

KITAMURA, R. 1988. An evaluation of activity-based travel analysis. *Transportation*. **15**(1-2), pp.9-34.

KRUGMAN, P.R. 1991. *Geography and Trade*. Cambridge, MA: MIT Press.

LAIRD, J.J., K. GEURS, C.A. NASH. 2007. Option and non-use values and rail appraisal. *European Transport Conference, Noordwijkerhout, Netherlands, 17-19 October 2007.* London: AET Transport.

LAIRD, J.J., J. NELLTHORP, and P.J. MACKIE. (2005) Network effects and total economic impact in transport appraisal. *Transport Policy*, **12**, pp. 537–544.

LAIRD, J.J., J. NELLTHORP, and P.J. MACKIE. (Unpublished, 2004). *Option values, business and population impacts in transport assessment - scoping study.* A report for Highlands and Islands Enterprise. Report dated September 2004. [Accessed 23 January 2008]. Available from World Wide Web: <http://www.hie.co.uk/transport-option-values-study.html>

LERMAN, S. R. 1976. Location, housing , automobile ownership, and mode to work: a joint choice model. *Transportation Research Record*. **610**, pp. 6-11.

LINDSAY, C., GREIG, M. and R. W. MCQUAID. 2005. Alternative Job Search Strategies in Remote Rural and Peri-Urban Labour Markets: The Role of Social Networks. *Sociologia Ruralis*, **45**(1/2), pp. 53-70.

LIST, J.A. and C.A. GALLET. 2001. What experimental protocol influence disparities between actual and hypothetical stated values? *Environmental and Resorce Economics*. **20**(3), pp.241-54.

MACKIE, JARA-DIAZ and FOWKES. 2001. *ibid Chapter 5*

MACKIE, P.J., M.WARDMAN, A.S. FOWKES, G.A WHELAN, J. NELLTHORP and J. BATES. 2003. *Value of Travel Time Savings in the UK*. A report to the Department for Transport. Report dated January 2003. Leeds: Institute for Transport Studies, University of Leeds.

MACKIE, P.J., S. JARA-DÍAZ and A.S. FOWKES. 2001. The value of travel time savings in evaluation. Transportation Research Part E. **37**, pp.91-106.

MADDEN, J.F. 1981. Why women work closer to home. *Urban Studies*, **18**, pp. 181-194.

MADDEN, J.F. 1985. Urban wage gradients: empirical evidence, *Journal of Urban Economics*, **18**, pp. 291-301.

MANNING, A. 2003a. *Monopsony in Motion: Imperfect Competition in Labor Markets*. Princeton, NJ: Princeton University Press.

MANNING, A. 2003b. The real thin theory: monopsony in modern labour markets. *Labour Economics*, **10**, pp. 105-131.

MANNING, A. 2006. A generalised model of monopsony. *The Economic Journal*. **116**, pp.84-100.

MARSHALL, A. 1890. *Principles of economics*. McMillan: London (8th ed. published in 1920).

MCCONNELL, K. E. (1997) Does Altruism Undermine Existence Value? *Journal of Environmental Economics and Management*. **32**(1), pp.22-37.

MCGREGOR, A. and J.J. LAIRD. 2005. Economic benefits of improvements to infrequent lifeline services: a case study of air services in the Highlands and Islands.

Scottish Transport Applications and Research (STAR) conference, 26 April 2005, Glasgow. London: AET Transport.

MCQUAID, R.W., M. GREIG and J. ADAMS. 2001. Unemployed job seeker attitudes towards potential travel-to-work times. *Growth and Change*, **32**(3), pp. 355-368.

MCQUAID, R.W., M. GREIG, A. SMYTH and A. COOPER. 2004. *The Importance of Transport in Business' Location Decisions.* Report to the Department for Transport. Edinburgh: Napier University.

MILLS, E.S. 1972. *Studies in the Structure of the Urban Economy*. Baltimore: John Hopkins Press.

MITCHELL, R.C. AND R.T. CARSON. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method.* Washington D.C.: Resources for the future.

MOHRING, H. 1961. Land Values and the Measurement of Highway Benefits. *The Journal of Political Economy*. **69**(3), pp.236-249.

MONK, S. and HODGE, I. 1995. Labour markets and employment opportunities in rural Britain. *Sociologia Ruralis,* **35**(2), pp. 153-172.

MORI SCOTLAND, TNS SOCIAL RESEARCH AND SCOTTISH EXECUTIVE. 2005. *Scottish Household Survey, 2003-4* [computer file]. Colchester, Essex: UK Data Archive [distributor].

MUTH, R.F. 1969. *Cities and Housing*. Chicago: University of Chicago Press.

MVA, INSTITUTE FOR TRANSPORT STUDIES (ITS) AND TRANSPORT STUDIES UNIT (TSU). 1987. *The Value of Travel Time Savings.* Newbury: Policy Journals.

NASH, C.A. and P.J. MACKIE. (Unpublished, 1990). *Measuring the Benefits of Transport Access Projects.* Report to the Department of Environment by ITS, University of Leeds, UK. Report dated 1990.

NATIONAL STATISTICS. 2005. *UK National Accounts - The Blue Book 2005.* Palgrave Macmillan: New York.

NELSON, J.D., S. WRIGHT, J.M. COOPER, and S. MURPHY. 2008. Economic analysis of Transport to Employment scheme in Highland Scotland using Social Return on Investment. Paper presented at the *87th annual meeting of the Transportation Research Board* 13-17 January 2008, Washington D.C.

NICHOLSON, A.J. and Z.P. DU 1997. Degradable transportation systems: an integrated equilibrium model. *Transportation Research Part B.* **31**(3), pp.209-223.

NOLAND, R.B. and J.W. POLAK. 2002. Travel time variability: a review of theoretical and empirical issues. *Transportation Reviews.* **22**(1), pp.39-54.

NOLAND, R.B. and K.A. SMALL. 1995. Travel time uncertainty, departure time choice, and the cost of the morning commutes. *Transportation Research Record,* **1493**, pp.150-158.

OFFICE FOR NATIONAL STATISTICS (ONS). 2007. *Family spending: 2006 edition.* Basingstoke: Palgrave Macmillan. [Accessed 8 April 2008]. Available from World Wide Web: <http://www.statistics.gov.uk/downloads/theme_social/Family_Spending_2005-06/Familyspending2005-06.pdf>

OFFICE OF FAIR TRADING (OFT). 1998. *Competition in the Supply of Petrol in the UK.* OFT report 229. Report dated May 1998. London: Office of Fair Trading. [Accessed 24 July 2008]. Available from World Wide Web: <http://www.oft.gov.uk/shared_oft/reports/transport/oft229.pdf>

OFFICE OF NATIONAL STATISTICS (ONS). 2006a. *Retail Prices Index: annual index numbers of retail prices 1949-2005 (RPI) (RPIX).* [Accessed March 2006] Available from World Wide Web: <http://www.statistics.gov.uk/statbase/Product.asp?vlnk=868>

OFFICE OF NATIONAL STATISTICS (ONS). 2006b. Time Series: IHXW - Gross domestic product (Average) per head, CVM market prices. *United Kingdom National Accounts - The Blue Book.* [Accessed March 2006]. Available from World Wide Web: <http://www.statistics.gov.uk/StatBase/Product.asp?vlnk=1143>.

OORT, C.J. 1969. The evaluation of travelling time. Journal Transport Economics and Policy. **3**(3), pp.279-286.

OOSTERHAVEN, J. and J.P. ELHORST. 2003. Indirect Economic Benefits of Transport Infrastructure Investments. *In:* W. DULLAERT, B. JOURQUIN, and J.B. POLAK (eds). *Across the border: Building upon a quarter century of transport research in the Benelux.* Antwerpen: De Boeck.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). 2006. Purchasing Power Parities, Comparative Price Levels. *Main Economic Indicators.* [Accessed May 2006]. Available from World Wide Web: <http://www.oecd.org/std/ppp>.

PAINTER, K.M., SCOTT II, R.D., WANDSCHNEIDER, P.R. and CASAVANT, K.L. 2001. Using contingent valuation to measure user and nonuser benefits: an application to public transit. *Review of Agricultural Economics.* **24**(2), pp.394-409.

PEARCE, D.W. and C.A. NASH. 1981. *The Social Appraisal of Projects – A Text in Cost-Benefit Analysis.* London: MacMillan.

PEARCE, D.W. and R.K. TURNER. 1990. *Economics of Natural Resources and the Environment*. New York; London: Harvester Wheatsheaf.

PILEGAARD, N. and M. FOSGERAU. 2008. Cost benefit analysis of a transport improvement in the case of search unemployment. *Journal of Transport Economics and Policy*, **42**(1),pp. 23-42.

PISSARIDES, C.A. 1990. *Equilibrium Unemployment Theory.* Oxford: Basil Blackwell.

PRATT, J.W. 1964. Risk aversion in the small and in the large. *Econometrica.* **32**(1-2), pp.122-136.

REFERENCE (Unpublished 2006) *Transport Provision and Trends in the Highlands & Islands.* Final Report to Highlands & Islands Enterprise. Report dated June 2006.

REFERENCE (Unpublished 2007) *The economic impact of fixed links and enhanced ferry services in the Highlands and Ialslands.* Final Report to Highlands & Islands Enterprise. Report dated May 2007.

RICE, P., A.J. VENABLES and E. PATACCHINNI, 2006. Spatial determinants of productivity: Analysis for the regions of Great Britain. *Regional Science and Urban Economics*, **36**, pp. 727-752.

ROGERSON, R., R. SHIMER and R. WRIGHT. 2005. Search-Theoretic Models of the Labor Market: A Survey. *Journal of Economic Literature*, **43**, pp.959-988.

ROSENTHAL, S.S. and W.C. STRANGE. 2004. Evidence on the nature and sources of agglomeration economies. *In:* J.V. HENDERSON and J.F. THISSE, (eds). *Handbook on Urban and Regional Economics Volume 4 Cities and Geography.* Oxford: Elsevier.

ROUWENDAL, J. and J. VAN OMMEREN. 2007. Recruitment in a Monopsonistic Labour Market: Will Travel Costs be reimbursed? *Tinbergen Institute Discussion Paper TI 2007-044/3.* Report dated 23 April 2007. Amsterdam: Tinbergen Institute Amsterdam.

SCHMALANSEE, R. 1972. Option demand and consumer's surplus: Valuing price changes under uncertainty. *American Economic Review.* **62**(5), pp.813-824.

SCOTT WILSON KIRKPATRICK (Unpublished, 2004) *SPASM rules and modelling: A user's guide to SPASM. Edition 2:DLL25.* A report to the Department for Transport. Report dated April 2004.

SCOTTISH EXECUTIVE. 2003. *Scottish Transport Appraisal Guidance.* Edinburgh: Scottish Executive. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.scot-tag.org.uk>

SCOTTISH EXECUTIVE. 2004. *Scotland's transport future. The transport white paper - June 2004.* Edinburgh: Scottish Executive.

SCOTTISH EXECUTIVE. 2005. Economic Assessment of Road Schemes in Scotland. The NESA Manual. *Design Manual for Roads and Bridges (DMRB) Volume 15.* Norwich: TSO. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.sias.com/ng/NESA/NESA.htm>

SCOTTISH EXECUTIVE. 2006. *Scotland's National Transport Strategy.* December 2006. Edinburgh: Scottish Executive.

SCOTTISH EXECUTIVE. 2007. *2007 Scottish Economic Statistics.* Edinburgh: Scottish Executive.

SCOTTISH GOVERNMENT. 2007. *The government economic strategy.* November 2007. Edinburgh: The Scottish Government.

SCOTTISH GOVERNMENT. 2008. [online] *Labour Market - Economic Profiles for LAs - Eilean Siar.* Available on the worldwide web: <http://www.scotland.gov.uk/Topics/Statistics/Browse/Labour-Market/ProfileEileanSiar>

SMALL, K.A. 1982. The scheduling of consumer activities: work trips. *American Economic Review.* **72**(2), pp.467-479.

SNEDDON ECONOMICS. (Unpublished, 2003). *Rural Scotland Price Survey*. A report for Highlands & Islands Enterprise, Scottish Enterprise and the Scottish Executive Environment and Rural Affairs Department. Report dated 12 August 2003. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.hie.co.uk/Rural_Scotland_Price_Survey_2003>

SQW. (Unpublished, 2004). *An evaluation of the social and economic impacts of fixed links to the islands of Scalpay and Berneray*. A final report to Western Isles Enterprise. Report dated March 2004.

STANDING ADVISORY COMMITTEE ON TRUNK ROAD ASSESSMENT. 1986. *Urban Road Appraisal*. Norwich:TSO.

STANDING ADVISORY COMMITTEE ON TRUNK ROAD ASSESSMENT. 1994. Trunk Roads and the Generation of Traffic. Norwich:TSO.

STANDING ADVISORY COMMITTEE ON TRUNK ROAD ASSESSMENT. 1999. Transport and the Economy. Norwich:TSO. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.dft.gov.uk/pgr/economics/sactra/>

STEER DAVIES GLEAVE. (Unpublished, 2007). *Regional Transport Strategy for the Highlands and Islands*. A report for HITRANS. Report dated June 2007. [Accessed 7 January 2008]. Available from World Wide Web: <http://www.hitrans.org.uk/Strategy/documents/HITRANS_finalRTS_June07.pdf>

STOCK, J.H., J.H. WRIGHT and M. YOGO. 2002. A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments. Journal of Business and Economic Statistics, **20**(4), pp. 518-29

SUGDEN, R. 2002. *Multi-modal transport appraisal investment*. Report to Department for Transport. Published 28 March 2002. London: Department for Transport. Available from World Wide Web: < http://www.dft.gov.uk/pgr/economics/rdg/>.

SUGDEN, R. 2005. *The treatment of taxation in the cost-benefit appraisal of transport appraisal*. Report to Department for Transport. Published 25 November 2005. London: Department for Transport. Available from World Wide Web: < http://www.dft.gov.uk/pgr/economics/rdg/>.

TIMOTHY, D. and W.C. WHEATON. 2001. Intra-urban wage variation, employment location and commuting times. *Journal of Urban Economics*, **50**(2), pp. 338-366.

TRAIN, K.E. 2003. Discrete choice analysis with simulations. New York: Cambridge University Press. [Accessed 30th June 2008]. Available from World Wide Web: <http://elsa.berkeley.edu/books/choice2.html>

TRAIN, K.E. 2006. *Mixed logit estimation by maximum simulated likelihood* [online]. [Accessed 4th May 2008]. Available from World Wide Web: <http://elsa.berkeley.edu/Software/abstracts/train1006mxlmsl.html>

TRAIN, K.E. and G. SONNIER. 2005. Mixed Logit with Bounded Distributions of Correlated Partworths. *In:* A. ALBERINI and R. SCARPA, (eds). *Applications of Simulation Methods in Environmental Resource Economics.* , Dordrecht, The Netherlands: Springer Publisher, Chapter 7, pp. 117-134.

TRAIN, K.E. and M. WEEKS. 2005. Discrete Choice Models in Preference Space and Willingness-to-Pay Space. *In:* A. ALBERINI and R. SCARPA, (eds). *Applications of Simulation Methods in Environmental Resource Economics.* Dordrecht, The Netherlands: Springer Publisher, Chapter 1, pp. 1-17.

TRUONG, T.P. and D.A. HENSHER. 1985. Measurement of travel times and opportunity cost from a discrete choice model. *The Economic Journal.* **95**, pp.438-451.

VAN OMMEREN, J. and P. RIETVELD. 2005. The commuting time paradox. Journal of Urban Economics, **58**(3), pp. 437-454.

VENABLES, A.J. 2007. Evaluating urban transport improvements: cost-benefit analysis in the presence of agglomeration and income taxation. *Journal of Transport Economics and Policy.* **41**(2), pp. 173-188.

VENABLES, A.J. and M. GASIOREK. 1999. The Welfare Implications of Transport Improvements in the Presence of Market Failure. *In:* SACTRA (ed). *The welfare implications of transport improvements in the presence of market failure and the incidence of imperfect competition in UK sectors and regions.* London: Department for the Environment, Transport and the Regions, pp. 3-58.

VERA-TOSCANA, E., E. PHIMISTER and A. WEERSINK. 2004. Panel estimates of the Canadian rural/urban women's wage gap. *American Journal of Agricultural Economics.* **86**(4), pp. 1138-1151.

VICKREY, W.S. 1969. Congestion theory and transport investment. *The American Economic Review.* **59**(2), pp.251-260.

VON NEUMANN, J. and MORGENSTERN, O. 1947. *Theory of Games and Economic Behavior, second edition.* Princeton: Princeton University Press.

WANG, J.J. 1996. Timing utility of daily activities and its impact on travel. *Transportation Research Part A.* **30**(3), pp.189-206.

WARDMAN M.R. 2001. A review of British evidence on time and service quality valuations. *Transportation Research Part E,* **37**, pp. 107-128.

WARDMAN, M. 2004. Public Transport Values of Time. *Transport Policy.* **11**(4), pp.363-377.

WARDMAN, M.R. and J.P. TONER. 2004. *Stated Preference.* A handbook accompanying a course on stated preference techniques, organised by Institute for Transport Studies, The University of Leeds. 11-12 February 2004.

WEISBROD, B.A. 1964. Collective-consumption services of individual-consumption goods. *Quarterly Journal of Economics.* **78**(3), pp.471-477.

WILMAN, E.A. 1987. A note on supply side option value. *Land Economics.* **63**(3), pp.284-289.

WILSON, P.W. 1989. Scheduling costs and the value of travel time. *Urban Studies.* **26**(3), pp.356-366.

WINSTON, G.C. 1982. *The timing of economic activities: firms, households, and markets in time-specific analysis.* Cambridge : Cambridge University Press.

ZAX, J.S. 1991. Compensation for commutes in labour and housing markets. *Journal of Urban Economics,* **30**, pp. 192-207.

APPENDIX A – THEORY OF SCHEDULE CONSTRAINED ACTIVITIES

The utility function is:

$$U = f(X, t_1, t_2, \ldots, t_J, t_w) \qquad \text{(A1)}$$

Individuals maximise utility subject to:

Money budget constraint: $wt_w + y \geq \sum_j c(s_j) + pX$

Time resource constraint: $T \geq t_w + \sum_j t_j(s_j)$

Time consumption constraint: $t_j(s_j) \geq t_j^{*}(s_j)$

Scheduling constraint: $F(s_j, t_w, t_j(s_j); w, IC, TC) = 0$

where:
- w = wage rate,
- y = unearned income;
- X = a single numeraire good
- p = price of numeraire good X
- T = total time
- t_j = time spent in activity j
- t_w = time spent at work
- t_j^{*} = minimum amount of time for activity *J*, where $t_j^{*} \geq 0$
- s_j = start time of activity *j*
- *TC* = transport scheduling constraints (e.g. operating hours)
- *IC* = institutional/cultural constraints (e.g. work hours, shop opening hours)

Forming the Lagrangian:

$$
\begin{aligned}
L = {} & U(X, t_w, t_1 \ldots\ldots t_J, s_1 \ldots\ldots s_J) \\
& + \lambda(wt_w + y - \sum_j c(s_j) - pX) \\
& + \mu(T - t_w - \sum_j t_j(s_j)) \\
& + \sum_j \eta_j (t_j(s_j) - t_j^{*}(s_j)) \\
& + \sum_j v_j F(s_j, t_w, t_j(s_j); w, IC, TC)
\end{aligned}
$$

Differentiating and finding the conditions for a maximum when all constraints bind:

$$\frac{\partial L}{\partial X} = \frac{\partial U}{\partial X} - \lambda p = 0 \qquad \text{(A2)}$$

$$\frac{\partial L}{\partial t_w} = \frac{\partial U}{\partial t_w} + \lambda w - \mu + v_j \frac{\partial F}{\partial t_w} = 0 \qquad \text{(A3)}$$

$$\frac{\partial L}{\partial t_j} = \frac{\partial U}{\partial t_j} - \mu + \eta_j + v_j \frac{\partial F}{\partial t_j} = 0 \qquad \text{(A4)}$$

$$\frac{\partial L}{\partial s_j} = \frac{\partial U}{\partial s_j} - \lambda \frac{dc_j}{ds_j} - \mu \frac{dt_j}{ds_j} + \eta_j \left[\frac{dt_j}{ds_j} + \frac{dt_j^{*}}{ds_j} \right] + v_j \frac{\partial F}{\partial s_j} + v_j \frac{\partial F}{\partial t_j} . \frac{dt_j}{ds_j} = 0 \qquad \text{(A5)}$$

From Equation A4:

$$\frac{\partial U}{\partial t_j} = \mu - \eta_j - v_j \frac{\partial F}{\partial t_j}$$

Dividing through by λ

$$\frac{\partial U}{\partial t_j} \Big/ \lambda = \frac{\mu}{\lambda} - \frac{\eta_j}{\lambda} - \frac{v_j}{\lambda} \frac{\partial F}{\partial t_j} \qquad \text{(A6)}$$

Where the left hand term is the marginal valuation of time in activity j. From this equation four different valuations for such time can be derived:

(i) All constraints bind:

$$\frac{\partial U}{\partial t_j}\Big/\lambda = \frac{\mu}{\lambda} - \frac{\eta_j}{\lambda} - \frac{v_j}{\lambda}\frac{\partial F}{\partial t_j}$$

(ii) Time consumption constraints not binding:

$$\frac{\partial U}{\partial t_j}\Big/\lambda = \frac{\mu}{\lambda} - \frac{v_j}{\lambda}\frac{\partial F}{\partial t_j}$$

(iii) Scheduling constraints not binding:

$$\frac{\partial U}{\partial t_j}\Big/\lambda = \frac{\mu}{\lambda} - \frac{\eta_j}{\lambda}$$

(iv) Time consumption and scheduling constraints not binding: this is equivalent to the Becker model for time.

$$\frac{\partial U}{\partial t_j}\Big/\lambda = \frac{\mu}{\lambda}$$

Re-arranging Equation A6 to form an expression for the value of the difference in the resource value of time and the marginal value of time spent in activity j, it can be seen that the marginal value of time in a non-work activity only equals the resource value of time if the time consumption and scheduling constraints do not bind.

$$\text{i.e.}\ \frac{\eta_j}{\lambda} + \frac{v_j}{\lambda}\frac{\partial F}{\partial t_j} = \frac{\mu}{\lambda} - \frac{\partial U}{\partial t_j}\Big/\lambda \qquad \text{(A7)}$$

Using Equations A2 to A5 expressions relating the manner that utility varies with each of the variables of interest can also be formed:

$$\frac{\partial U}{\partial X} = \lambda p$$

$$\frac{\partial U}{\partial t_w} = -\lambda w + \mu - v_j\frac{\partial F}{\partial t_w}$$

$$\frac{\partial U}{\partial t_j} = \mu - \eta_j - v_j \frac{\partial F}{\partial t_j}$$

$$\frac{\partial U}{\partial s_j} = \lambda \frac{dc_j}{ds_j} + \mu \frac{dt_j}{ds_j} - \eta_j \left[\frac{dt_j}{ds_j} + \frac{dt_j^{*}}{ds_j} \right] - v_j \frac{\partial F}{\partial s_j} - v_j \frac{\partial F}{\partial t_j} . \frac{dt_j}{ds_j}$$
$$= \lambda \frac{dc_j}{ds_j} + \left[\mu - \eta_j - v_j \frac{\partial F}{\partial t_j} \right] \frac{dt_j}{ds_j} - \eta_j \frac{dt_j^{*}}{ds_j} - v_j \frac{\partial F}{\partial s_j}$$

Now approximate the indirect utility function

$$U \approx a + \frac{\partial U}{\partial X} X + \frac{\partial U}{\partial t_w} t_w + \sum_j \frac{\partial U}{\partial t_j} t_j + \sum_j \frac{\partial U}{\partial s_j} s_j \tag{A8}$$

Substituting for $\frac{\partial U}{\partial X}, \frac{\partial U}{\partial t_w}, \frac{\partial U}{\partial t_j}$ and $\frac{\partial U}{\partial s_j}$ in (A8)

$$U \approx a + [\lambda p] X + \left[-\lambda w + \mu - v_j \frac{\partial F}{\partial t_w} \right] t_w + \sum_j \left[\mu - \eta_j - v_j \frac{\partial F}{\partial t_j} \right] t_j \tag{A9}$$
$$+ \sum_j \left[\lambda \frac{dc_j}{ds_j} + \left(\mu - \eta_j - v_j \frac{\partial F}{\partial t_j} \right) \frac{dt_j}{ds_j} - \eta_j \frac{dt_j^{*}}{ds_j} - v_j \frac{\partial F}{\partial s_j} \right] s_j$$

Substituting constraint (A2) into (A9)

$$\begin{aligned} U \approx\ & a + \lambda [w t_w + y - c_j(s_j)] \\ & + \left[-\lambda w + \mu - v_j \frac{\partial F}{\partial t_w} \right] t_w \\ & + \sum_j \left[\mu - \eta_j - v_j \frac{\partial F}{\partial t_j} \right] t_j \\ & + \sum_j \left[\lambda \frac{dc_j}{ds_j} + \left(\mu - \eta_j - v_j \frac{\partial F}{\partial t_j} \right) \frac{dt_j}{ds_j} - \eta_j \frac{dt_j^{*}}{ds_j} - v_j \frac{\partial F}{\partial s_j} \right] s_j \end{aligned} \tag{A10}$$

For the simple case of a single activity j – equivalent to the standard case of the work-leisure choice:

$$
\begin{aligned}
U_j \approx\ & a + \lambda\left[wt_w + y - c_j(s_j)\right] \\
& + \left[-\lambda w + \mu - v_j \frac{\partial F}{\partial t_w}\right] t_w \\
& + \left[\mu - \eta_j - v_j \frac{\partial F}{\partial t_j}\right] t_j \\
& + \left[\lambda \frac{dc_j}{ds_j} + \left(\mu - \eta_j - v_j \frac{\partial F}{\partial t_j}\right)\frac{dt_j}{ds_j} - \eta_j \frac{dt_j^*}{ds_j} - v_j \frac{\partial F}{\partial s_j}\right] s_j
\end{aligned}
\qquad \textbf{(A11)}
$$

APPENDIX B - INTER-ISLAND FERRY QUESTIONNAIRE

FERRY TRAVEL SURVEY

Institute for Transport Studies

Dear Passenger

Thank you for agreeing to answer this short questionnaire about your journey today. This survey is being undertaken by the Institute for Transport Studies at the University of Leeds as part of a research project on the economic value of transport services in the Highlands and Islands. The information you provide will be treated as confidential.

THIS JOURNEY

Q1 **Please indicate which island you are travelling from and to on today's journey. (NB For day return trips please indicate the island you are visiting before returning home).**

	Barra or Vatersay	Eriskay, South Uist, Benbecula, Grimsay, North Uist, or Berneray	Harris, Lewis, Scalpay, or Great Berneray	Mainland	*Other (Please Specify)*
From... Please tick one	O	O	O	O	
To... Please tick one	O	O	O	O	

Q2 **Are you on the outward or return part of your journey?**

Outward .... O Return .... O Neither (one-way/circular journey).......O

Q3 **What is the purpose of your journey?**

Employer's Business .... O
Commuting to/from Work.......... O
Visiting Friends/Relatives .... O
Social/Recreation...................... O
Self-employed business......................... O
Shopping .... O
Personal Business (e.g. hospital) .... O
Holiday/Short Break .... O
Other (Please Specify)________________________

Q4 **How often do you make this journey?**

5 or more days a week ..... O
2 to 4 days a week............ O
Once a week .... O
1 to 3 times a month .... O
Less than once a month ....O
First time..................................O

Q5 **How many other people are travelling with you as part of your group?**

None....O Adults_____ Children aged 5-15_____ Children under 5_____

Q6 **What sort of ticket does your group have?**

Single .... O Saver 5 Day Return .... O 6 Journey .... O 10 Journey ....O
Concessionary fare ticket (OAP travel) .... O Island Hopscotch .... O

Q7 **How much did the ticket for your group cost?** £__________ Don't know..........O

Q8 **Who paid for your ticket?**

Yourself...O
Family member..O
Concessionary fare ticket (OAP travel) ......O
Employer.....................................O
Healthboard (NHS patient)...........O

Other (Please Specify)____________________

Q9 **As part of this trip will your group be spending nights away *from home?***

Yes.................. O No .... O

If yes: How many nights will you be spending away from home? __________

How much will be spent on dinner, bed and breakfast? £__________per night

Q10 **What type of vehicle has your group got on this ferry?**

Type of vehicle	Please tick one
Car	O
Van or Light Goods Vehicle	O
Heavy Goods Vehicle	O
Motorcycle	O
Bicycle	O
None - foot passenger	O
Other (Please Specify)	

THINKING BACK TO WHEN YOU WERE PLANNING THIS JOURNEY

Q11 **Did you or a member of your group plan this journey (such as choosing which ferry sailing to depart on)?**

Yes.................. O No .... O

Q12 **On two days a week (except mid-May to mid-September) there is another ferry service between North Uist and Harris (from Lochmaddy to Tarbert). If the frequency of that service was increased and return trips from Tarbert to Lochmaddy were possible, how would you (or the person who planned this journey) have chosen which ferry service to use for your CURRENT JOURNEY?**

Cheapest (ferry fare plus petrol costs or bus fares) ....O

Best departure times, service frequency and journey time ....O

Mixture of cheapness, departure times, service frequency and journey time ....O

Q13 **For the OUTWARD leg of your journey did the ferry depart at an ideal time for you?**

Yes.................. O No .... O

If no please indicate when you would ideally have liked the ferry to have left __________am/pm (delete as appropriate)

Q14 **For the RETURN leg of your journey will/did the ferry depart at an ideal time for you?**

Yes.................. O No .... O N/A (one-way/circular journey) ....O

If no please indicate when you would ideally like the ferry to depart __________am/pm (delete as appropriate)

Q15 **If you had been able to travel at your ideal times would you have spent the same number of nights away from home or more or less?**

Same............. O More.................... O Less....................... O

We would now like to know how you would react if the travel conditions were as described in the tables below. In each of the 8 situations presented, we would like you to indicate which type of ferry service you would prefer for THIS JOURNEY. If travelling on employer's business please bear in mind your company's travel policy.

SITUATION 1

	Single Fare (for your group)	Frequency and hours of operation (Mon - Sat)	Choice Please tick one
Ferry Service 1	£31.00	Every 3 hrs 40 mins 7am to 7pm E.g. Sailings at: 0700, 1040, 1420, 1800	O
Ferry Service 2	£25.00	Every hour 9am to 5pm E.g. Sailings at: 0900, 1000, 1100,....etc...., 1500, 1600	O

SITUATION 2

	Single Fare (for your group)	Frequency and hours of operation (Mon - Sat)	Choice Please tick one
Ferry Service 1	£20.00	Every 3 hrs 30 mins 9am to 5pm E.g. Sailings at: 0900, 1230, 1600	O
Ferry Service 2	£25.00	Every 3hrs 10 mins 6am to 11pm E.g. Sailings at: 0600, 0910, 1220, 1530, 1840, 2200	O

SITUATION 3

	Single Fare (for your group)	Frequency and hours of operation (Mon - Sat)	Choice Please tick one
Ferry Service 1	£30.00	Every hour 6am to 11pm E.g. Sailings at: 0600, 0700, 0800,...etc..., 2000, 2100, 2200	O
Ferry Service 2	£25.00	Every 4 hours 6am to 11pm E.g. Sailings at: 0600, 1000, 1400, 1800, 2200	O

SITUATION 4

	Single Fare (for your group)	Frequency and hours of operation (Mon - Sat)	Choice Please tick one
Ferry Service 1	£20.00	Every 3 hrs 40 mins 7am to 7pm E.g. Sailings at: 0700, 1040, 1420, 1800	O
Ferry Service 2	£35.00	Every 2 hours 6am to 11pm E.g. Sailings at: 0600, 0800, 1000,...etc..., 1800, 2000, 2200	O

SITUATION 5

	Single Fare (for your group)	Frequency and hours of operation (Mon - Sat)	Choice Please tick one
Ferry Service 1	£20.00	Every 4 hours 6am to 11pm E.g. Sailings at: 0600, 1000, 1400, 1800, 2200	O
Ferry Service 2	£20.00	Every 1 hr 45 mins 9am to 5pm E.g. Sailings at: 0900, 1045, 1230, 1415, 1600	O

SITUATION 6

	Single Fare (for your group)	Frequency and hours of operation (Mon - Sat)	Choice Please tick one
Ferry Service 1	£20.00	Every 4 hours 24 hours E.g. Sailings at: 0700, 1100, 1500, 1900, 2300, 0300	O
Ferry Service 2	£21.00	Every hour 24 hours E.g. Sailings at: 0700, 0800, 1900,...etc..., 0300, 0400, 0500	O

SITUATION 7

	Single Fare (for your group)	Frequency and hours of operation (Mon - Sat)	Choice Please tick one
Ferry Service 1	£25.00	Every 4 hours 6am to 11pm E.g. Sailings at: 0600, 1000, 1400, 1800, 2200	O
Ferry Service 2	£40.00	Every hour 6am to 11pm E.g. Sailings at: 0600, 0700, 0800,...etc..., 2000, 2100, 2200	O

SITUATION 8

	Single Fare (for your group)	Frequency and hours of operation (Mon - Sat)	Choice Please tick one
Ferry Service 1	£25.00	Every 2 hours 7am to 7pm E.g. Sailings at: 0700, 0900, 1000, 1200, 1400, 1600, 1800	O
Ferry Service 2	£26.00	Every 2 hours 24 hours E.g. Sailings at: 0700, 0900, 1100,...etc..., 0100, 0300, 0500	O

ABOUT YOU

Q16 **Are you male..... O or female.....O?**

Q17 **In what age group do you belong?**

Less than 18 .... O	26-35 .... O	51-65 .... O
18-25 .... O	36-50 .... O	over 65 .... O

Q18 **What is the annual income of your household before the deduction of tax?**

We appreciate the personal nature of this question. The answer is important to understand the value people place on ferry services in relation to their income. All information in this questionnaire is confidential.

Less than £10k .... O	£21k-£35k .... O	over £50k .... O
£10k-£20k .... O	£36k-£50k .... O	Withheld .... O

Thank you for your assistance

APPENDIX C -HOUSEHOLD SURVEY QUESTIONNAIRE

SCALPAY HOUSEHOLD QUESTIONNAIRE

Date / /2005

Time at <u>start</u> of interview (24hr)

Household surname:..

Household address: ....

..

Time at <u>end</u> of interview (24hr clock)

DECLARATION: Interview conducted by me with respondent named above in accordance with instructions and MRS code of conduct.

Signature.. Date..............................

INTRODUCTION

Hello, I am carrying out some research for the University of Leeds on the impact of the bridge to/from Scalpay and the value that the people of Scalpay place on it. We are interested in your views so that we can better understand the potential impacts of similar changes for other island communities.

I hope you received the letter, we sent recently, letting you know we were planning to call.

Would you be prepared to answer some questions now? I can assure you that what you say will be kept completely confidential and used only for the purpose of an overall report.

Arrange call back if appropriate.
Explain M.R.S. code of conduct and show the leaflet
[show a generic copy of letter, if appropriate]

If the respondent answers yes, then continue. If no, complete refusal sheet & withdraw

Q1: Can I just ask are you the householder?

[Single response only]

Yes.............O **GO TO SECTION A**

No...............O **ENQUIRE IF THE HOUSEHOLDER IS AVAILABLE. IF HOUSEHOLDER IS NOT AVAILABLE, ARRANGE A TIME TO COME BACK, OR IF NOT POSSIBLE COMPLETE REFUSAL SHEET AND WITHDRAW.**

SECTION A – HOUSEHOLD INFORMATION

A1 Did you or a member of your household live on the island before the bridge was constructed?

[Single response only]

Yes.............O No....................O

A2 How many cars does your household have for <u>personal</u> use (including the journey to work)?

[Single response only]

No car........O One car..........O Two or more cars..... O

A3 I would now like to find out how many people are in the household and some information about them particularly where they go to work or school and how many return trips they made across the bridge last week.

Household members

Include: Students at college/university off the island
Off-shore workers whose home is on the island
Contract workers off-shore or on the mainland whose home is on the island

Exclude: Contract workers working on the island whose home is off the island
Members of the armed forces who are based off the island (i.e. their base is not in the Western Isles).

Relationship to interviewee, gender and age

Use a logical approach to go through household, for example: (1) interviewee, (2) spouse, (3) children, (4) interviewee's or spouse's parents/grandparents, (5) others (but <u>exclude</u> paying guests).

Location of jobs

Record <u>ISLAND</u> rather than village, settlement or town. Record multiple jobs. Exclude jobs last undertaken over 12 months ago. Probe for seasonal self-employed part-time work, e.g. bed and breakfast and crofting.

Note 1: location of workplace for fishermen is the port where the boat is berthed.
Note 2: if job involves travelling record only the workplace at which the person reports for work (e.g. base office for businessman, or depot for lorry driver).

Number of trips

Record all person-trips occurring in personal time (leisure time). That is do not record any trips that form part of a job including self-employed (i.e. any trip for which the household member is receiving a wage whilst travelling).

Take a logical and systematic approach. Take each member of the household in turn.

If a single trip was made (with no return trip within the week), e.g. someone leaving or returning from working off-shore, or someone leaving or returning from holiday record '½'.

Sum row totals and check it makes sense with the interviewee.

TABLE A1

	Relationship to interviewee	Gender [circle answer]	Age [circle answer]	Location of workplace of MAIN job / school	Location of workplaces of OTHER jobs	No. of return trips across the BRIDGE made LAST WEEK (but not including trips that form part of a job)					
						Commute (work/ school)	Shopping	Leisure	Lifts to others	Other journey purposes	Total
Person 1 (interviewee)	N/A	**M / F**	**< 5, 5-16, 16 –retired, Retired**								
Person 2		**M / F**	**< 5, 5-16, 16 –retired, Retired**								
Person 3		**M / F**	**< 5, 5-16, 16 –retired, Retired**								
Person 4		**M / F**	**< 5, 5-16, 16 –retired, Retired**								
Person 5		**M / F**	**< 5, 5-16, 16 –retired, Retired**								
Person 6		**M / F**	**< 5, 5-16, 16 –retired, Retired**								
									Total household trips		

SECTION B – STATED PREFERENCE AND CONTINGENT VALUATION QUESTIONS

B1. I am now going to show you a number of HYPOTHETICAL situations.

I would like you to take you imagine the situation before the bridge was constructed but YOUR HOUSEHOLD could choose whether this island was to be connected to Harris with a FREE ferry or with a bridge. However, as the bridge has to be constructed by the local council, council tax must go up to pay for it.

In each situation I would be grateful if you could choose the transport and council tax option that YOUR HOUSEHOLD would most prefer.

Emphasise if necessary that extra council tax is a household expense and stress that it is additional to existing household expenditure. It would not be accompanied by a corresponding increase in income (e.g. pensions).

Re-assure if necessary that this is a university research project and will not affect local council tax. The survey is confidential and the results will be used to understand the value people place on different types of transport service.

Try to get people to answer the question honestly and within the context of their household budget.

USE GREEN CARDS.

Card No.	Option A (Ferry)	Option B (Bridge)
	[For each card tick the option preferred]	
GREEN 1	O	O
GREEN 2	O	O
GREEN 3	O	O
GREEN 4	O	O
GREEN 5	O	O

B2 **I would now like to find out what the maximum amount <u>YOUR HOUSEHOLD</u> would be willing-to-pay in <u>ADDITIONAL</u> council tax if this island had a free 24 hour ferry with a half hourly frequency, but through additional council tax contributions a bridge could be constructed. The increase in council tax would fund construction of the bridge.**

How much more Council Tax would you be willing-to-pay to have a bridge constructed if it was to replace a free 24 hour ferry service with a half hourly frequency?

[SHOW CARD GREEN 6]

Once again emphasise the constraints of the household budget. If necessary re-assure regarding the confidential nature of the survey.

If respondent has difficulty answering question using the iterative bidding procedure as follows:

Would your household be willing-to-pay:
£0.50 per week (£26 per year) <u>more</u> council tax for a bridge instead of a free 24 hr half hourly ferry?
£1 per week (£52 per year) <u>more</u> council tax ......
£2 per week (£104 per year) <u>more</u> council tax ......
£3 per week (£156 per year) <u>more</u> council tax ......
£4 per week (£208 per year) <u>more</u> council tax ......
£5 per week (£260 per year) <u>more</u> council tax ......
£6 per week (£312per year) <u>more</u> council tax ......
£7 per week (£364 per year) <u>more</u> council tax ......
£8 per week (£416 per year) <u>more</u> council tax ......
.
.
etc.

<u>ADDITIONAL</u> COUNCIL TAX **[indicate if per week or per year – tick one]**

£................ **Per week** O **Per year** O

IF £0 GOTO B3
ELSE GOTO B4

B3 **Why would your household not pay anymore Council Tax for a bridge?**
[READ OUT]

A free 24 hour a day half hourly ferry service is perfectly adequate for this household. We don't need a bridge with such a service. .... O

The household pays enough council tax as it is. .... O

Other (please state)________________________________ .... O

B4 I would now like you to imagine a situation in which the road either side of the bridge had been improved at the same time that the bridge had been built. A return trip to Tarbert would have been 15 minutes quicker than it is today (i.e. 7.5 minutes quicker each way).

If such a road improvement was funded through Council Tax what would be the maximum amount YOUR HOUSEHOLD would be willing-to-pay in ADDITIONAL council tax.

If respondent has difficulty answering question using the iterative bidding procedure as follows:
Would your household be willing-to-pay:

£0.50 per week (£26 per year) for an improved road.
£1 per week (£52 per year) more council tax ......
£2 per week (£104 per year) more council tax ......
£3 per week (£156 per year) more council tax ......
£4 per week (£208 per year) more council tax ......
£5 per week (£260 per year) more council tax ......
£6 per week (£312per year) more council tax ......
£7 per week (£364 per year) more council tax ......
£8 per week (£416 per year) more council tax ......
.......etc.

ADDITIONAL COUNCIL TAX **[indicate if per week or per year – tick one]**

£................ Per week O Per year O

IF £0 GOTO B5
ELSE GOTO B6

B5 Why would your household not pay anymore Council Tax for an improved road?
[READ OUT]

The existing road and journey time is perfectly adequate for this household ... O

The household pays enough council tax as it is. .... O

Other (please state)________________________ .... O

B6. I am now going to show you some more HYPOTHETICAL situations.

This time I would like you to imagine that this island was still only connected to Harris by ferry. I will show you two types of ferry service, which differ in fares, frequency and hours of operation.

In each situation I would be grateful if you could choose the ferry service that YOUR HOUSEHOLD would most prefer.

If necessary re-assure that there are no plans to close the bridge and re-introduce a ferry.

If queried state that we are trying to understand the value to households of different types of ferry service.

Try to get people to answer the question honestly and within the context of their household budget.

USE GREEN CARDS.

Card No.	Option A (Ferry 1)	Option B (Ferry 2)
	[For each card tick the option preferred]	
GREEN 7	O	O
GREEN 8	O	O
GREEN 9	O	O
GREEN 10	O	O

B7 **I would now like to find out what the maximum amount <u>YOUR HOUSEHOLD</u> would be willing-to-pay in <u>ADDITIONAL</u> council tax if this island had a ferry linking it to Harris and that ferry service was improved.**

If the island had a free ferry operating for 12 hrs (from 7am to 7pm) at a half hourly frequency, but through additional council tax contributions the service could be extended to 24 hrs. However to extend the hours of the ferry would require an increase in the subsidy from the council, therefore Council Tax would have to go up.

How much more Council Tax would you be willing-to-pay for such an improvement to the ferry service?

[SHOW CARD GREEN 11]

Once again emphasise the constraints of the household budget. If necessary re-assure regarding the confidential nature of the survey.

If respondent has difficulty answering question using the iterative bidding procedure as follows:

Would your household be willing-to-pay:

£0.50 per week (£26 per year) more council tax to extend a free 12 hr hourly ferry service to 24hrs?
£1 per week (£52 per year) more council tax ......
£2 per week (£104 per year) more council tax ......
£3 per week (£156 per year) more council tax ......
£4 per week (£208 per year) more council tax ......
£5 per week (£260 per year) more council tax ......
£6 per week (£312per year) more council tax ......
£7 per week (£364 per year) more council tax ......
£8 per week (£416 per year) more council tax ......
.
.
etc.

ADDITIONAL COUNCIL TAX **[indicate if per week or per year – tick one]**

£................. **Per week O** **Per year O** IF £0 GOTO B8 ELSE GOTO C1

B8 **Why would your household not pay anymore Council Tax to extend a free 12 hr hourly ferry service to 24hrs?**

[READ OUT]

A free 12 hour a day half hourly ferry service is perfectly adequate for this household. .... O

The household pays enough council tax as it is. .... O

Other (please state)________________________ .... O

SECTION C – VOLUNTARY HOUSEHOLD INFORMATION

C1 If you don't mind, I would be grateful if you could indicate the range which approximates most closely to the <u>household's income</u> (before tax).

We appreciate the personal nature of this question. The answer is important to understand the value people place on ferry services in relation to their income. All information in this questionnaire is confidential.

[READ OUT]

Household Income [tick income range]	
Withheld	O
Less than £10,000	O
£10,000 to £20,000	O
£21,000 to £35,000	O
£36,000 to £50,000	O
over £50,000	O

THIS IS THE END OF THE INTERVIEW
THANK YOU VERY MUCH FOR YOUR TIME AND ATTENTION

APPENDIX D – THE SCOTTISH HOUSEHOLD SURVEY

Five years of data, relating to the years 1999 to 2003, from the SHS are used. The SHS is a continuous cross-sectional survey based on a sample of the general population in private residences in Scotland. Its aim is to provide representative information about the composition, characteristics and behaviours of Scottish households. The questionnaire is in two parts. The householder or spouse/partner of the householder completes the first part which deals with general household issues, whilst the second part of the questionnaire is completed by a random adult in the household. This section deals with amongst other things transport, earned income and employment. Importantly for this research this part of the questionnaire also includes a travel diary. There are approximately 15,000 households interviewed each year. The data files are published by the Scottish Executive and distributed by the Economic and Social Research Council Data Archive at the University of Essex.

Two data files for each survey year were obtained from the data archive. The first contains the household and random adult variables, and the second is a trip diary (by journey). A representative sample was obtained by firstly manipulating and cleaning the travel diary information, then matching the commuting data to the household and random adult data. The household and random adult data is also cleaned, before commuting costs are calculated. The final stage involves excluding outliers and cases with missing data (from the random adult data). The process is summarised in Table D.1.

The 1999-2003 SHS has data on 75,746 households, however, the sample used in the empirical work relates to only 4,417 full-time workers. Of this 2,520 are men and 1,937 are women, while 528 live and work in a peripheral area and 3,805 live in a central area. Peripheral area cases are defined as those who both live and work more than 30 minutes drive from a conurbation with 10,000 people or more (see Figure 1.2 in Chapter 1). Central area cases are defined as those who live in an urban area or within 30 minutes of a conurbation with 10,000 people or more. The focus is restricted to full-time employees for two main reasons. The self-employed are excluded as their income can include a component representing a return on capital. Part-time

Table D.1: Sample Size

Step	Restriction	Travel Diary	Household and random adult data file
Travel diary		**139,298 one-way trips**	
Step 1	Eliminate all non-commuting trips and keep commuting trips to/from home and workplace only	24,367	
Step 2	Eliminate trips with distance or duration missing, negative or zero	23,527	
Step 3	Eliminate trips with imputed distance/duration data, very slow (≤1km/hr slow modes; ≤2km/hr motorised modes) or high speeds (> 130km/h motorised modes) or very long durations (≥60 mins slow modes; ≥180mins motorised modes)	19,977	
Step 4	Convert trips to persons	11,407	
Step 5	Calculate mean distance and duration per person	11,407	
Step 6	To exclude those undertaking other activities on their commute eliminate trips where out and return commuting trips differ in distance and duration by more than 60 mins.	11,161	
Step 7	Remove trips where a fare is paid (public transport) and non-standard modes (e.g. horse-riding)	9,660	
Household and random adult data file			**75,746 random adults**
Step 8	Merge travel diary and household data file (matched by *uniqid*). Eliminate observations with no commuting data.		9,660
Step 9	Eliminate observations where a parking charge is paid		8,666
Step 10	Derive random adult income for 1999/2000 survey year		8,666
Step 11	Eliminate observations which are not full-time employees		6,747
Step 12	Eliminate observations where income is negative, zero, missing or imputed		6,241
Step 13	Keep only those fully immersed in labour market (22 ≤ age ≥ 59 and income ≥ £5,000 per annum)		4,723
Step 14	Eliminate outlying high income observations (≥£50,000 net of deductions)		4,704
Step 15	Calculate commuting costs		4,704
Step 16	Add variables for council area of workplace (matched by *uniqid*). Band 10 qualification variables into 3 bands.		4,704
Step 17	Eliminate cases where data on one of regressors is missing		4,497
Step 18	Eliminate cases where commuting costs are outliers (<£0.05 and >£10.00 one way commuting costs)		4,417

employees are excluded as the preferred income unit is annual earnings rather than the hourly wage. Annual earnings offer a better link to the number of commuting trips than the hourly wage does, as the length of the working day will differ between workers. As there is significant variation between the number of days worked per week between different part-time workers and between part-time and full-time workers, and there is much less variation in the number of days worked a week between different full-time workers part-time workers are excluded from the sample.

As can be seen from Table D.1 the primary reason for the large reduction in sample size is the availability of commuting data – there are only just over 24,000 one-way commuting trips between the home and the main place of work in the travel diary. Restricting the data to full-time employees, excluding observations where the income data was imputed or missing and excluding those not fully immersed in the labour market are the other main reasons that dataset then reduces down in size. Table D.2 and Table D.3 demonstrate that the reduced sample, aside from including only full-time employees, is not selective. From Table D.2 it can be seen that the cleaning process has not affected the cross-sectional characteristics of the data, though there is a slightly larger proportion of women in the cleaned dataset, a corresponding reduction in skilled tradesmen (and increase in professional occupations) and a reduction in salaries. As can be seen from Table D.3 the lack of data in the SHS on public transport fares and car parking charges has resulted in the exclusion of almost all public transport trips and some car trips. This distorts the mode split of the cleaned data compared to the complete SHS data. However, the relative modal proportions between walk, car (driver and passenger), bicycle, motorcycle and works bus have not been affected by the data cleaning process to any significant degree.

In line with standard practice commuting costs are calculated as a generalised cost using an additively separable function of time and vehicle operating costs (where relevant) as in the equation below.

$$\text{Commuting costs} = \text{Value of time} * \text{Journey time} + \text{Vehicle operating costs (car/van mode only)} \qquad \text{(D.1)}$$

The value of time is sourced from the most recent UK national value of time study (Mackie *et al.*, 2003 Table 22) the main recommendations of which are now embodied in UK demand forecasting and appraisal guidance, whilst the formulation of vehicle operating costs is sourced from the DfT (2007b). In the first instance values of time are

Table D.2: Comparison of commuter characteristics between SHS and cleaned data – full-time employees only

		SHS (full-time employees)	Cleaned Data
Gender	Male	58%	57%
	Female	42%	43%
Age	25% quartile	31	32
	Median	39	39
	75% quartile	48	48
Occupation	Managers and senior officials	14%	15%
	Professional occupations	12%	14%
	Associate professional and technical occupations	13%	13%
	Administrative and secretarial occupations	15%	14%
	Skilled trades occupations	14%	14%
	Personal service occupations	13%	12%
	Sales and customer service occupations	10%	10%
	Process, plant and machine operatives	7%	7%
	Elementary occupations	2%	2%
Income (after tax and other deductions)	Mean	£15,613	£14,840
	25% quartile	£10,560	£10,296
	Median	£14,000	£13,200
	75% quartile	£18,200	£18,000
Rural/Urban classification	Large urban areas	34%	30%
	Other urban	31%	33%
	Small accessible towns	10%	10%
	Small remote towns	2%	2%
	Very remote small towns	3%	4%
	Accessible rural	12%	13%
	Remote rural	2%	2%
	Very remote rural	5%	7%
Household type	Single adult	23%	27%
	Small adult	28%	28%
	Single parent	4%	4%
	Small family	21%	23%
	Large family	8%	8%
	Large adult	13%	9%
	Older smaller	3%	1%
	Single pensioner	0%	0%
Total Records		23,564	4,417

Table D.3: Comparison of commute mode split proportions between SHS and cleaned data – full-time employees only

	SHS usual mode used to get to work (variable *rd3*)		Cleaned Data (Actual mode used on day of travel diary - variable *mainmode_1*)
	Total	Excluding fare paying modes and parking charges	
Walking	11.3%	14.3%	12.8%
Driver car/van	60.0%	68.7%	69.4%
Passenger car/van	9.8%	12.4%	12.9%
Motorcycle/moped	0.5%	0.6%	0.7%
Bicycle	1.8%	2.3%	2.4%
School bus	0.0%		
Works bus	1.4%	1.7%	1.8%
Ordinary (service) bus	10.1%		
Taxi/minicab	0.5%		
Rail	2.7%		
Underground	0.2%		
Ferry	0.2%		
Aeroplane	0.5%		
Horseriding	0.0%		
Other	1.1%		
Total records	23,564	17,524	4,417

derived for each observation by gross household income[61] and commute distance. These values have to be converted from 1997 prices and values to the survey year's prices and values using the relationship with real GDP/capita growth derived by Mackie *et al.* and data on inflation over the relevant period[62]. The values of time derived by Mackie *et al.* by income and distance are not applicable to slow mode travel (walking and cycling). For these modes the standard value of time used in appraisal was

---

[61] SHS household income is net of deductions whilst Mackie *et al.* base values of time on gross household income. Net to gross salary ratio is 0.779. Source: UK National Accounts The Blue Book 2005 (National Statistics, 2005)

[62] Annual inflation to 1998 = 3.42% , 1999 = 1.53% , 2000 = 2.96% , 2001 = 1.76% , 2002 = 1.67% , 2003 = 2.89%. Annual GDP growth in basic prices to 1998 = 4.1% , 1999 = 3.3% , 2000 = 3.7% , 2001 = 4.1% , 2002 = 5.3% , 2003 = 4.9%. Real GDP growth to 1998 = 0.66%, 1999 = 1.74%, 2000 = 0.72%, 2001 = 2.30%, 2002 = 3.57%, 2003 = 1.95%. Source: Office of National Statistics (ONS) website http://www.statistics.gov.uk [accessed 4th May 2007]
Real value of commuting time grows at 0.8 of the rate of real GDP/capita. Source: Mackie *et al.* (2003); DfT (2007b).

doubled (Wardman, 2001; DfT, 2007b) and converted to the relevant price and value base.

For drivers and passengers in cars and vans vehicle operating costs are calculated using the formulae used in UK transport appraisals (DfT, 2007b). This method involves calculating the fuel and the non-fuel element of vehicle operating cost. Both cost elements depend on vehicle type and speed. As the precise vehicle type used by the random adult is not known an average vehicle was assumed. The fuel element covers petrol/diesel costs, whilst the non-fuel element covers oil, tyres, vehicle maintenance and mileage related depreciation. It is also assumed that drivers pay all the operating costs of the vehicle and passengers pay none unless the survey respondent indicates that they are part of a car sharing scheme in which they either contribute to the cost of the journey or take a turn at driving. In such instances it is assumed that both the driver and the passenger pay half the operating costs.

Table D.4 sets out some descriptive statistics for the dataset. As can be seen from this table average commuting costs are 210 pence (one-way commute) for the sample. The average distance commuted is 9.0 km, whilst the average time spent commuting is 23 minutes. These data are however heavily negatively skewed. Analysis of commuting costs for car drivers also indicates that time costs comprise almost half of total commuting costs whilst total vehicle operating costs comprise the other half. The fuel related component of vehicle operating costs comprises 35% (of total commuting costs). There are clear gender differences in both commuting behaviour and earnings between men and women - women earn less, commute less and incur less commuting costs than men. Similar differences also occur between peripheral and central areas with those in peripheral areas earning less, commuting less and incurring less commuting costs.

Table D.4: Average annual income and commuting costs by gender (full-time employees)

	All regions	Peripheral regions	Central regions	Men	Women
Earned income (after tax and deductions)	£14,840	£14,285	£14,905	£16,018	£13,275
Commute distance (km)	9.0	8.2	8.9	9.8	7.9
Commute time (mins)	23.0	18.0	23.6	23.5	22.3
Commuting costs (generalised cost) (pence)	210.4	167.1	213.7	220.0	197.6
Sample size	4,417	528	3,805	2,520	1,897

BLANK PAGE IN ORIGINAL

APPENDIX E – EARNINGS FUNCTIONS

TABLE OF CONTENTS

Table A: Earnings Function OLS Men and women

	Men and women								
	All			Central			Peripheral		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	2.82	0.44	6.43	2.58	0.49	5.30	3.15	1.40	2.25
Potential experience (yrs)	453.60	44.80	10.12	475.14	47.79	9.94	333.19	57.61	5.78
Potential experience squared ($yrs^2/1000$)	-7430.09	869.22	-8.55	-7884.40	932.70	-8.45	-5220.92	1293.30	-4.04
School certificate or no qualification (dummy variable)	-1932.58	210.60	-9.18	-2043.68	241.31	-8.47	-1140.57	308.55	-3.70
Other qualification									
Degree or higher (dummy variable)	2849.06	266.62	10.69	3110.55	235.98	13.18	541.50	806.62	0.67
Female (dummy variable)	-4761.50	398.97	-11.93	-4634.04	437.13	-10.60	-4801.64	850.53	-5.65
Temporary job	-1307.66	432.24	-3.03	-1324.97	426.35	-3.11	-1719.32	1605.86	-1.07
Permanent job									
Works in a small workplace < 25people									
Work in a large workplace => 25 people	814.42	185.56	4.39	795.61	223.04	3.57	916.24	543.91	1.68
Agriculture, hunting and forestry	-1926.79	943.13	-2.04	-2230.87	857.32	-2.60	3617.14	5327.93	0.68
Fishing	-1797.55	694.79	-2.59	-3003.20	545.52	-5.51	-1231.35	1148.87	-1.07
Mining and quarrying	5254.11	1240.31	4.24	5351.94	1433.77	3.73	2846.78	1845.33	1.54
Manufacturing									
Electricity, gas and water supply	2486.88	759.06	3.28	2121.36	777.34	2.73	7341.24	1432.95	5.12
Construction	279.11	325.03	0.86	248.25	391.23	0.63	417.90	456.18	0.92
Wholesale and retail trade; repair trades	-2345.90	251.40	-9.33	-2277.34	250.60	-9.09	-2777.05	509.60	-5.45
Hotels and restaurants	-2761.33	282.63	-9.77	-2903.95	299.29	-9.70	-2226.46	948.10	-2.35
Transport, storage and communication	-304.77	310.52	-0.98	-581.54	304.62	-1.91	1301.51	1153.74	1.13
Financial intermediation	1915.62	859.61	2.23	1812.93	877.51	2.07	5674.69	2015.06	2.82
Real estate, renting and business activities	-1445.07	289.34	-4.99	-1443.74	299.48	-4.82	-1455.71	1036.37	-1.40
Public administration and defence; compulsory social security	134.34	385.10	0.35	50.42	424.91	0.12	630.27	538.59	1.17
Education	-1626.55	418.13	-3.89	-1531.36	477.91	-3.20	-1816.97	1175.71	-1.55
Health and social work	-841.18	408.60	-2.06	-1062.36	422.03	-2.52	1056.56	931.97	1.13
Other community, social and personal service activities	-2092.78	589.05	-3.55	-2208.70	653.86	-3.38	-1102.71	1444.75	-0.76
Private households and extra-territorial	556.52	1230.95	0.45	755.04	1395.34	0.54	-66.58	778.47	-0.09
Managers and senior officials									
Professional occupations	-353.19	463.64	-0.76	-267.42	491.53	-0.54	-602.96	1459.19	-0.41
Associate professional and technical occupations	-2824.86	511.83	-5.52	-2595.43	590.81	-4.39	-4198.96	872.78	-4.81
Administrative and secretarial occupations	-7062.06	584.08	-12.09	-7102.87	629.70	-11.28	-5105.51	1445.34	-3.53
Skilled trades occupations	-4706.90	357.48	-13.17	-4318.45	361.38	-11.95	-7134.02	506.87	-14.07
Personal service occupations	-5048.79	476.56	-10.59	-4696.15	479.15	-9.80	-7581.70	1396.23	-5.43
Sales and customer service occupations	-5835.32	459.59	-12.70	-5518.39	489.17	-11.28	-7608.06	973.77	-7.81
Process, plant and machine operatives	-6696.89	485.03	-13.81	-6577.53	454.43	-14.47	-8619.26	1726.26	-4.99
Elementary occupations	-6703.79	590.62	-11.35	-6461.37	618.76	-10.44	-8524.71	960.17	-8.88
Female Managers and senior officials									
Female Professional occupations	2581.41	539.86	4.78	2402.62	622.66	3.86	2307.15	1895.43	1.22
Female Associate professional and technical occupations	3075.26	735.60	4.18	3094.85	821.21	3.77	1960.78	1953.07	1.00
Female Administrative and secretarial occupations	3457.75	749.11	4.62	3558.36	842.01	4.23	160.11	1116.10	0.14
Female Skilled trades occupations	1670.78	813.05	2.05	1412.13	983.48	1.44	2763.00	625.87	4.41
Female Personal service occupations	1449.03	564.25	2.57	1216.90	627.29	1.94	2112.17	825.38	2.56
Female Sales and customer service occupations	1344.14	494.35	2.72	1131.61	529.12	2.14	2560.61	1018.42	2.51
Female Process, plant and machine operatives	2231.13	543.45	4.11	2527.57	581.73	4.34	552.80	1117.07	0.49
Female Elementary occupations	3313.76	903.29	3.67	3477.26	1035.78	3.36	1231.39	1560.72	0.79
Council area could not be derived	-421.73	61.67	-6.84	-376.09	62.40	-6.03			
Aberdeen City	1103.54	121.96	9.05	934.66	124.47	7.51			
Aberdeenshire	26.08	97.50	0.27	75.95	105.06	0.72			
Angus	-512.82	73.19	-7.01	-553.74	82.49	-6.71			
Argyll & Bute	-178.34	123.80	-1.44	621.59	214.11	2.90	2599.52	542.89	4.79
Clackmannanshire	-45.96	85.51	-0.54	-90.63	100.63	-0.90			
Dumfries and Galloway	-1318.40	89.51	-14.73	-1160.95	99.20	-11.70			
Dundee City	-718.70	77.72	-9.25	-719.99	88.10	-8.17			
East Ayrshire	-318.57	84.70	-3.76	-140.32	91.38	-1.54			
East Dunbartonshire	-818.95	99.35	-8.24	-841.65	116.34	-7.23			
East Lothian	-778.58	102.01	-7.63	-356.00	111.09	-3.20			
East Renfrewshire	-838.97	102.80	-8.16	-893.22	112.43	-7.94			
Edinburgh, City of	487.25	86.83	5.61	491.22	88.94	5.52			
Eilean Siar	-188.74	127.00	-1.49				2716.61	379.27	7.16
Falkirk	-93.75	69.01	-1.36	-93.66	74.35	-1.26			
Fife	-478.67	62.53	-7.66	-495.91	69.34	-7.15			
Glasgow City									
Highland	-812.99	78.45	-10.36	-920.85	99.71	-9.24	2027.61	446.07	4.55
Inverclyde	-633.62	66.24	-9.57	-604.52	67.52	-8.95			
Midlothian	-705.94	61.36	-11.51	-710.17	63.48	-11.19			
Moray	661.07	72.99	9.06	546.49	92.13	5.93	3933.27	631.20	6.23
North Ayrshire	8.19	93.43	0.09	-0.68	100.04	-0.01			
North Lanarkshire	-263.11	60.24	-4.37	-257.90	68.17	-3.78			
Orkney Islands	-116.30	104.08	-1.12				2751.63	581.12	4.74
Perth & Kinross	-1643.74	72.66	-22.62	-1502.43	71.26	-21.08	-314.57	635.87	-0.49
Renfrewshire	-223.42	53.56	-4.17	-165.71	55.87	-2.97			
Scottish Borders	-1517.32	88.83	-17.08	-1454.31	93.54	-15.55	256.97	436.14	0.59
Shetland Islands	560.96	64.72	8.67				3518.09	335.53	10.49
South Ayrshire	-568.83	57.89	-9.83	-444.24	64.46	-6.89			
South Lanarkshire	-310.20	61.63	-5.03	-373.45	68.58	-5.45			
Stirling	420.60	60.29	6.98	386.76	69.05	5.60			
West Dunbartonshire	716.66	65.62	10.92	698.94	73.21	9.55			
West Lothian	330.62	74.58	4.43	390.80	78.72	4.96			
Constant	13232.36	653.30	20.25	12909.54	685.07	18.84	12787.15	699.82	18.27
Sample size	4417			3805			528		
R-squared	0.428			0.424			0.521		

Notes: Dependent variable is annual earned income net of deductions (£). Robust standard errors reported in parentheses. Standard errors are adjusted for spatial correlation in the residuals by clustering on local authority of workplace. Red t-stat indicates coefficient is significantly different from zero at <1%, blue at 5% level (two tailed t-test). Estimated using STATA9 econometric software. Constant relates to a male employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Glasgow City (except the Peripheral model where the constant relates to a workplace in Dumfries and Galloway).

Table A: Earnings Function OLS Men and women (Contd)

	Men and women					
	Managers, professionals and technical occupations			Other occupations		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	3.52	0.72	4.88	2.16	0.47	4.61
Potential experience (yrs)	783.94	69.62	11.26	244.92	41.66	5.88
Potential experience squared (yrs^2/1000)	-12722.32	1433.93	-8.87	-4151.52	874.13	-4.75
School certificate or no qualification (dummy variable)	-3333.19	555.52	-6.00	-1525.42	234.16	-6.51
Other qualification						
Degree or higher (dummy variable)	3050.59	307.21	9.93	2275.57	491.95	4.63
Female (dummy variable)	-4646.94	357.09	-13.01	-2515.94	457.91	-5.49
Temporary job	-788.22	831.13	-0.95	-1736.42	420.16	-4.13
Permanent job						
Works in a small workplace < 25people						
Work in a large workplace => 25 people	1179.06	426.88	2.76	609.00	177.53	3.43
Agriculture, hunting and forestry	-2595.40	3614.00	-0.72	-1866.28	909.83	-2.05
Fishing	-2835.74	1152.33	-2.46	-365.24	817.08	-0.45
Mining and quarrying	5953.38	1631.28	3.65	3543.73	1212.49	2.92
Manufacturing						
Electricity, gas and water supply	3864.79	1276.91	3.03	1836.20	897.78	2.05
Construction	-395.59	972.50	-0.41	371.39	340.75	1.09
Wholesale and retail trade; repair trades	-2288.37	480.59	-4.76	-2299.38	237.44	-9.68
Hotels and restaurants	-3080.11	885.78	-3.48	-2811.82	341.94	-8.22
Transport, storage and communication	468.27	909.86	0.51	-530.15	332.69	-1.59
Financial intermediation	3426.58	1233.18	2.78	197.76	560.29	0.35
Real estate, renting and business activities	-918.18	455.41	-2.02	-1582.65	490.21	-3.23
Public administration and defence; compulsory social security	-289.75	695.63	-0.42	461.38	443.52	1.04
Education	-1306.19	655.94	-1.99	-2425.03	383.57	-6.32
Health and social work	39.94	780.30	0.05	-1702.21	321.62	-5.29
Other community, social and personal service activities	-1858.43	867.26	-2.14	-2098.59	446.17	-4.70
Private households and extra-territorial	2154.56	2283.40	0.94	-520.89	556.76	-0.94
Managers and senior officials						
Professional occupations	-774.60	434.50	-1.78			
Associate professional and technical occupations	-3089.48	525.84	-5.88			
Administrative and secretarial occupations				-214.97	461.83	-0.47
Skilled trades occupations				1942.16	331.19	5.86
Personal service occupations				1630.37	416.15	3.92
Sales and customer service occupations				808.83	316.43	2.56
Process, plant and machine operatives						
Elementary occupations				194.19	580.24	0.33
Female Managers and senior officials						
Female Professional occupations	2527.74	542.11	4.66			
Female Associate professional and technical occupations	2668.56	795.25	3.36			
Female Administrative and secretarial occupations				1269.68	611.48	2.08
Female Skilled trades occupations				-840.42	793.00	-1.06
Female Personal service occupations				-486.56	559.19	-0.87
Female Sales and customer service occupations				-859.68	566.02	-1.52
Female Process, plant and machine operatives						
Female Elementary occupations				1089.07	951.17	1.14
Council area could not be derived	-1099.19	141.65	-7.76	101.30	73.21	1.38
Aberdeen City	1667.04	246.73	6.76	500.82	57.91	8.65
Aberdeenshire	387.71	223.59	1.73	144.83	98.12	1.48
Angus	-18.63	141.77	-0.13	-688.50	100.21	-6.87
Argyll & Bute	43.77	239.18	0.18	-243.42	99.73	-2.44
Clackmannanshire	-2161.92	151.15	-14.30	1875.39	116.71	16.07
Dumfries and Galloway	-1703.14	195.54	-8.71	-977.78	89.64	-10.91
Dundee City	-712.33	119.09	-5.98	-784.51	108.46	-7.23
East Ayrshire	-367.05	164.64	-2.23	-323.16	67.50	-4.79
East Dunbartonshire	-1536.44	307.11	-5.00	-63.72	95.90	-0.66
East Lothian	-2257.05	220.66	-10.23	168.70	113.37	1.49
East Renfrewshire	-1303.59	222.76	-5.85	-318.78	100.96	-3.16
Edinburgh, City of	204.12	151.35	1.35	723.40	52.83	13.69
Eilean Siar				-548.62	108.34	-5.06
Falkirk	-132.18	184.28	-0.72	-47.13	78.50	-0.60
Fife	-1022.75	107.39	-9.52	-148.38	79.03	-1.88
Glasgow City						
Highland	-1592.45	138.74	-11.48	-240.03	85.93	-2.79
Inverclyde	-488.44	197.09	-2.48	-852.82	68.44	-12.46
Midlothian	-1213.41	181.27	-6.69	-446.99	84.24	-5.31
Moray	1157.36	144.70	8.00	252.57	52.17	4.84
North Ayrshire	-414.88	188.90	-2.20	139.68	113.44	1.23
North Lanarkshire	-1394.92	172.68	-8.08	281.59	72.16	3.90
Orkney Islands				-1077.77	115.36	-9.34
Perth & Kinross	-1839.28	126.08	-14.59	-1284.01	87.49	-14.68
Renfrewshire	-585.51	118.93	-4.92	67.59	81.97	0.82
Scottish Borders	-1518.21	224.41	-6.77	-1589.91	86.81	-18.32
Shetland Islands				1125.87	69.49	16.20
South Ayrshire	-1289.76	156.93	-8.22	52.00	74.64	0.70
South Lanarkshire	-1501.13	125.23	-11.99	358.79	79.48	4.51
Stirling	696.57	174.03	4.00	-17.79	82.73	-0.21
West Dunbartonshire	176.10	164.57	1.07	854.43	74.85	11.42
West Lothian	236.36	93.37	2.53	372.31	96.49	3.86
Constant	8477.85	958.99	8.84	9419.91	543.15	17.34
Sample size		1865			2552	
R-squared		0.310			0.283	

Table B: Earnings Function OLS Men

	Men								
	All			Central			Peripheral		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	2.94	0.68	4.31	2.58	0.67	3.86	3.51	1.88	1.87
Potential experience (yrs)	543.49	60.96	8.92	582.60	63.78	9.13	216.94	150.56	1.44
Potential experience squared ($yrs^2/1000$)	-8917.21	1201.93	-7.42	-9658.23	1300.93	-7.42	-3473.29	3055.26	-1.14
School certificate or no qualification (dummy variable)	-1830.89	273.55	-6.69	-1981.36	322.95	-6.14	-959.37	309.95	-3.10
Other qualification									
Degree or higher (dummy variable)	3072.45	438.37	7.01	3471.67	382.62	9.07	-66.82	1527.19	-0.04
Temporary job	-2042.52	594.89	-3.43	-2103.62	641.21	-3.28	-2971.56	965.99	-3.08
Permanent job									
Works in a small workplace < 25people									
Work in a large workplace => 25 people	1138.83	225.62	5.05	1072.60	276.70	3.88	1766.85	643.35	2.75
Agriculture, hunting and forestry	-2253.71	1083.62	-2.08	-2562.49	922.43	-2.78	4819.59	6325.74	0.76
Fishing	-1630.79	835.75	-1.95	-3711.13	426.54	-8.70	-954.96	1490.34	-0.64
Mining and quarrying	5749.67	2048.56	2.81	6128.28	2541.51	2.41	2714.89	2486.24	1.09
Manufacturing									
Electricity, gas and water supply	2399.57	935.79	2.56	2017.43	926.25	2.18	7795.80	1209.69	6.44
Construction	248.83	355.24	0.70	147.87	434.90	0.34	945.39	455.55	2.08
Wholesale and retail trade; repair trades	-2230.19	387.74	-5.75	-2075.61	384.86	-5.39	-3275.02	1222.25	-2.68
Hotels and restaurants	-4284.99	575.92	-7.44	-4186.48	624.07	-6.71	-4258.85	1978.44	-2.15
Transport, storage and communication	-493.24	396.10	-1.25	-849.31	378.94	-2.24	1889.53	1164.26	1.62
Financial intermediation	2638.55	924.37	2.85	2468.98	936.28	2.64	11646.23	1006.15	11.58
Real estate, renting and business activities	-1786.05	356.32	-5.01	-1862.57	404.73	-4.60	-1057.93	1755.01	-0.60
Public administration and defence; compulsory social security	35.30	423.31	0.08	43.06	445.73	0.10	184.26	690.11	0.27
Education	-2477.84	534.33	-4.64	-2489.67	639.65	-3.89	-1924.94	1971.60	-0.98
Health and social work	-585.91	787.36	-0.74	-961.52	793.59	-1.21	2990.83	2815.39	1.06
Other community, social and personal service activities	-2547.48	553.47	-4.60	-2595.87	613.47	-4.23	-923.36	1865.65	-0.49
Private households and extra-territorial	1043.69	2174.23	0.48	1005.12	2397.53	0.42	545.73	1431.52	0.38
Managers and senior officials									
Professional occupations	-178.80	552.71	-0.32	-106.94	596.50	-0.18	-675.28	1713.82	-0.39
Associate professional and technical occupations	-2842.63	501.99	-5.66	-2570.51	577.38	-4.45	-4485.39	992.83	-4.52
Administrative and secretarial occupations	-7015.14	589.20	-11.91	-7022.23	640.48	-10.96	-5050.10	1371.34	-3.68
Skilled trades occupations	-4616.79	365.52	-12.63	-4174.62	346.71	-12.04	-7543.32	620.12	-12.16
Personal service occupations	-4754.37	455.03	-10.45	-4450.56	432.00	-10.30	-7253.95	1436.80	-5.05
Sales and customer service occupations	-5788.71	455.94	-12.70	-5405.45	469.86	-11.50	-7844.30	1087.94	-7.21
Process, plant and machine operatives	-6612.42	498.82	-13.26	-6427.87	435.50	-14.76	-9083.20	1781.11	-5.10
Elementary occupations	-6632.82	585.48	-11.33	-6380.56	598.84	-10.65	-8304.03	1024.29	-8.11
Council area could not be derived	-299.52	101.26	-2.96	-168.21	100.20	-1.68			
Aberdeen City	1813.09	177.64	10.21	1541.00	192.08	8.02			
Aberdeenshire	1021.78	152.96	6.68	976.38	142.47	6.85			
Angus	-85.85	97.12	-0.88	-154.57	107.23	-1.44			
Argyll & Bute	455.65	170.90	2.67	731.98	291.45	2.51	2874.09	780.31	3.68
Clackmannanshire	540.58	137.11	3.94	442.64	154.93	2.86			
Dumfries and Galloway	-1012.30	166.95	-6.06	-936.63	188.17	-4.98			
Dundee City	-736.72	145.55	-5.06	-700.97	159.78	-4.39			
East Ayrshire	-305.08	129.02	-2.36	-66.95	145.27	-0.46			
East Dunbartonshire	-779.70	136.48	-5.71	-691.92	160.29	-4.32			
East Lothian	-787.31	163.30	-4.82	-12.81	152.04	-0.08			
East Renfrewshire	-1429.63	167.49	-8.54	-1485.25	177.56	-8.36			
Edinburgh, City of	467.51	80.93	5.78	503.27	83.61	6.02			
Eilean Siar	-951.67	193.90	-4.91	(dropped)	0.00	0.00	2227.80	555.28	4.01
Falkirk	-16.09	102.53	-0.16	6.14	111.82	0.05			
Fife	-822.08	97.47	-8.43	-835.14	110.92	-7.53			
Glasgow City									
Highland	-865.44	104.78	-8.26	-1179.10	154.40	-7.64	2499.34	597.36	4.18
Inverclyde	-180.71	139.81	-1.29	-119.82	128.30	-0.93			
Midlothian	-133.93	107.61	-1.24	-97.76	110.47	-0.88			
Moray	311.81	119.78	2.60	279.10	135.60	2.06	1808.16	645.49	2.80
North Ayrshire	368.99	135.47	2.72	374.87	136.11	2.75			
North Lanarkshire	-233.43	95.75	-2.44	-201.84	104.01	-1.94			
Orkney Islands	20.22	147.43	0.14	(dropped)	0.00	0.00	2798.20	689.03	4.06
Perth & Kinross	-1775.50	74.16	-23.94	-1688.47	72.90	-23.16	-707.91	919.07	-0.77
Renfrewshire	-350.37	110.80	-3.16	-211.92	124.97	-1.70			
Scottish Borders	-592.65	170.88	-3.47	-304.35	211.80	-1.44	673.55	476.14	1.41
Shetland Islands	952.71	79.40	12.00	(dropped)	0.00	0.00	3973.43	509.55	7.80
South Ayrshire	-191.10	110.87	-1.72	-92.52	124.13	-0.75			
South Lanarkshire	-614.77	90.18	-6.82	-723.71	93.88	-7.71			
Stirling	171.13	114.25	1.50	138.56	118.12	1.17			
West Dunbartonshire	-284.84	136.68	-2.08	-282.02	147.80	-1.91			
West Lothian	467.80	110.15	4.25	581.38	121.23	4.80			
Constant	11720.50	794.62	14.75	11197.62	774.07	14.47	13914.71	1752.93	7.94
Sample size	2520			2150			313		
R-squared	0.391			0.392			0.478		

Notes: Dependent variable is annual earned income net of deductions (£). Robust standard errors reported in parentheses. Standard errors are adjusted for spatial correlation in the residuals by clustering on local authority of workplace. Red t-stat indicates coefficient is significantly different from zero at <1%, blue at 5% level (two tailed t-test). Estimated using STATA9 econometric software. Constant relates to a male employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Glasgow City (except the Peripheral model where the constant relates to a workplace in Dumfries and Galloway).

Table B: Earnings Function OLS Men (Contd)

	Men					
	Managers, professionals and technical occupations			Other occupations		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	3.54	1.07	3.30	2.18	0.75	2.91
Potential experience (yrs)	957.02	98.49	9.72	332.24	59.56	5.58
Potential experience squared ($yrs^2/1000$)	-15470.92	2119.31	-7.30	-5695.21	1225.68	-4.65
School certificate or no qualification (dummy variable)	-2783.79	845.65	-3.29	-1510.64	278.86	-5.42
Other qualification						
Degree or higher (dummy variable)	3470.36	472.71	7.34	2267.51	758.00	2.99
Temporary job	-1959.78	1314.47	-1.49	-2258.90	550.56	-4.10
Permanent job						
Works in a small workplace < 25people						
Work in a large workplace => 25 people	1934.50	573.21	3.37	946.77	263.03	3.60
Agriculture, hunting and forestry	-3073.53	4172.43	-0.74	-2121.80	1041.88	-2.04
Fishing	-1695.97	1760.98	-0.96	-267.08	849.15	-0.31
Mining and quarrying	6604.53	2674.33	2.47	3357.88	1602.29	2.10
Manufacturing						
Electricity, gas and water supply	4445.12	1629.90	2.73	1305.98	1052.60	1.24
Construction	-519.77	1067.55	-0.49	378.89	374.32	1.01
Wholesale and retail trade; repair trades	-2255.29	841.28	-2.68	-2092.21	341.83	-6.12
Hotels and restaurants	-6746.94	1497.98	-4.50	-3828.22	789.19	-4.85
Transport, storage and communication	639.42	1012.46	0.63	-699.12	379.98	-1.84
Financial intermediation	4424.18	1552.63	2.85	-505.61	1614.15	-0.31
Real estate, renting and business activities	-382.65	645.94	-0.59	-2681.96	578.28	-4.64
Public administration and defence; compulsory social security	-404.51	752.07	-0.54	606.37	688.70	0.88
Education	-1769.58	756.88	-2.34	-3246.01	714.80	-4.54
Health and social work	1786.16	1387.82	1.29	-3771.95	512.18	-7.36
Other community, social and personal service activities	-1557.56	979.57	-1.59	-2700.87	461.17	-5.86
Private households and extra-territorial	2407.08	3335.00	0.72	-103.37	520.24	-0.20
Managers and senior officials						
Professional occupations	-970.91	488.20	-1.99			
Associate professional and technical occupations	-3369.83	501.11	-6.72			
Administrative and secretarial occupations						
Skilled trades occupations				2256.16	607.26	3.72
Personal service occupations				2232.16	690.19	3.23
Sales and customer service occupations				1056.27	524.86	2.01
Process, plant and machine operatives				379.51	532.59	0.71
Elementary occupations				614.95	763.30	0.81
Council area could not be derived	-1232.09	234.90	-5.25	734.55	149.85	4.90
Aberdeen City	3175.74	435.67	7.29	763.10	66.92	11.40
Aberdeenshire	1945.82	497.31	3.91	1138.22	149.81	7.60
Angus	1702.08	188.74	9.02	-953.60	135.59	-7.03
Argyll & Bute	370.39	453.53	0.82	449.81	179.13	2.51
Clackmannanshire	-1694.01	372.13	-4.55	2302.63	140.20	16.42
Dumfries and Galloway	600.72	397.36	1.51	-1440.33	168.97	-8.52
Dundee City	-1054.49	244.76	-4.31	-549.65	144.73	-3.80
East Ayrshire	-272.02	367.98	-0.74	-312.82	96.81	-3.23
East Dunbartonshire	4.79	344.42	0.01	-1145.04	200.22	-5.72
East Lothian	-2525.53	434.73	-5.81	-194.81	142.54	-1.37
East Renfrewshire	-3603.41	505.96	-7.12	-115.71	132.12	-0.88
Edinburgh, City of	184.47	160.42	1.15	931.09	95.85	9.71
Eilean Siar	-1219.92	451.81	-2.70	-1439.80	147.85	-9.74
Falkirk	254.40	242.70	1.05	-2.02	151.36	-0.01
Fife	-943.97	225.62	-4.18	-721.55	101.59	-7.10
Glasgow City						
Highland	-1398.42	266.56	-5.25	-332.16	123.23	-2.70
Inverclyde	3223.65	337.62	9.55	-1575.46	131.89	-11.95
Midlothian	-846.26	384.64	-2.20	56.78	136.51	0.42
Moray	-202.78	279.25	-0.73	332.70	101.95	3.26
North Ayrshire	329.33	275.87	1.19	468.74	179.71	2.61
North Lanarkshire	-1925.62	234.33	-8.22	697.31	105.47	6.61
Orkney Islands	2409.78	341.63	7.05	-1983.58	209.28	-9.48
Perth & Kinross	-1374.03	176.12	-7.80	-1769.67	123.66	-14.31
Renfrewshire	-125.44	199.60	-0.63	-189.59	159.04	-1.19
Scottish Borders	2096.61	446.90	4.69	-1884.95	127.27	-14.81
Shetland Islands	-312.25	264.10	-1.18	1392.74	88.41	15.75
South Ayrshire	-1430.64	238.97	-5.99	513.97	113.46	4.53
South Lanarkshire	-2615.69	216.83	-12.06	227.02	94.64	2.40
Stirling	663.06	425.81	1.56	110.37	165.05	0.67
West Dunbartonshire	-3261.56	399.64	-8.16	305.14	104.22	2.93
West Lothian	1380.29	271.09	5.09	306.19	123.84	2.47
Constant	5040.07	1384.44	3.64	7958.85	682.60	11.66
Sample size		959			1561	
R-squared		0.302			0.226	

Table C: Earnings Function OLS Women

	Women								
	All			Central			Peripheral		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	2.46	0.62	3.97	2.58	0.65	3.98	1.66	1.26	1.32
Potential experience (yrs)	341.18	55.02	6.20	340.73	57.61	5.91	465.84	187.13	2.49
Potential experience squared ($yrs^2/1000$)	-5521.51	1073.22	-5.14	-5598.13	1112.84	-5.03	-7178.33	3968.42	-1.81
School certificate or no qualification (dummy variable)	-2096.24	212.73	-9.85	-2096.54	246.58	-8.50	-1994.75	731.69	-2.73
Other qualification									
Degree or higher (dummy variable)	2638.77	267.61	9.86	2779.92	296.61	9.37	1651.59	587.70	2.81
Temporary job	-329.52	596.26	-0.55	-284.37	617.42	-0.46	-1054.51	2116.56	-0.50
Permanent job									
Works in a small workplace < 25people									
Work in a large workplace => 25 people	427.31	264.38	1.62	514.71	269.01	1.91	-466.77	851.61	-0.55
Agriculture, hunting and forestry	-151.66	1490.47	-0.10	-493.76	1831.94	-0.27	2969.92	1269.13	2.34
Fishing	-1047.91	474.27	-2.21	-1562.15	411.44	-3.80	-386.91	802.06	-0.48
Mining and quarrying	3092.22	404.67	7.64	2947.69	419.80	7.02	No observations		
Manufacturing									
Electricity, gas and water supply	2384.75	1266.51	1.88	2131.98	1332.39	1.60	4258.32	588.35	7.24
Construction	830.30	1107.96	0.75	1235.76	1095.70	1.13	-3631.94	1073.86	-3.38
Wholesale and retail trade; repair trades	-2151.28	399.68	-5.38	-2223.45	440.48	-5.05	-1063.40	335.08	-3.17
Hotels and restaurants	-1635.14	396.47	-4.12	-1863.90	419.40	-4.44	-563.44	447.03	-1.26
Transport, storage and communication	90.14	774.72	0.12	52.78	813.57	0.06	146.20	1917.37	0.08
Financial intermediation	1560.89	1132.21	1.38	1478.91	1190.79	1.24	3642.69	2536.72	1.44
Real estate, renting and business activities	-800.26	584.13	-1.37	-722.50	585.71	-1.23	-1462.84	666.98	-2.19
Public administration and defence; compulsory social security	427.14	575.11	0.74	220.70	627.90	0.35	2698.56	1082.28	2.49
Education	-662.24	618.26	-1.07	-463.65	674.04	-0.69	-1499.34	1314.42	-1.14
Health and social work	-512.41	407.53	-1.26	-690.05	407.61	-1.69	1168.07	539.78	2.16
Other community, social and personal service activities	-1200.58	849.21	-1.41	-1401.19	943.32	-1.49	209.29	1676.22	0.12
Private households and extra-territorial	223.49	1054.53	0.21	497.70	1165.29	0.43	186.20	1184.65	0.16
Managers and senior officials									
Professional occupations	1932.60	439.71	4.40	1763.55	461.20	3.82	2057.32	1711.09	1.20
Associate professional and technical occupations	378.73	435.14	0.87	562.69	448.85	1.25	-1649.63	1473.02	-1.12
Administrative and secretarial occupations	-3599.51	379.84	-9.48	-3584.35	404.71	-8.86	-4506.62	927.29	-4.86
Skilled trades occupations	-2823.29	835.70	-3.38	-2710.35	989.73	-2.74	-3808.63	624.55	-6.10
Personal service occupations	-3804.52	331.84	-11.46	-3751.93	345.22	-10.87	-5159.76	1139.41	-4.53
Sales and customer service occupations	-4124.13	539.25	-7.65	-4127.60	604.70	-6.83	-3882.53	653.32	-5.94
Process, plant and machine operatives	-4428.70	517.76	-8.55	-4163.49	583.26	-7.14	-6639.77	1315.68	-5.05
Elementary occupations	-3151.72	854.15	-3.69	-2924.00	966.00	-3.03	-5106.62	2098.30	-2.43
Council area could not be derived	-543.16	126.81	-4.28	-606.59	139.28	-4.36			
Aberdeen City	68.85	122.62	0.56	120.63	135.20	0.89			
Aberdeenshire	-1155.07	150.18	-7.69	-972.50	163.22	-5.96			
Angus	-1199.83	152.64	-7.86	-1175.03	164.71	-7.13			
Argyll & Bute	-981.54	129.80	-7.56	-888.64	367.09	-2.42	1585.11	1025.14	1.55
Clackmannanshire	-923.93	143.25	-6.45	-952.44	156.82	-6.07			
Dumfries and Galloway	-1589.13	105.05	-15.13	-1368.19	120.73	-11.33			
Dundee City	-796.66	123.49	-6.45	-844.01	123.19	-6.85			
East Ayrshire	-485.15	93.64	-5.18	-430.27	105.37	-4.08			
East Dunbartonshire	-897.70	172.07	-5.22	-938.01	188.63	-4.97			
East Lothian	-563.33	221.75	-2.54	-746.37	270.26	-2.76			
East Renfrewshire	-160.67	177.54	-0.90	-240.64	198.01	-1.22			
Edinburgh, City of	566.78	156.78	3.62	533.13	165.25	3.23			
Eilean Siar	836.25	177.74	4.70	(dropped)	0.00	0.00	3371.41	664.73	5.07
Falkirk	-262.20	149.62	-1.75	-228.92	152.03	-1.51			
Fife	-178.68	94.51	-1.89	-191.73	99.99	-1.92			
Glasgow City									
Highland	-1057.59	155.58	-6.80	-724.85	193.61	-3.74	708.55	740.69	0.96
Inverclyde	-880.23	145.15	-6.06	-859.54	160.58	-5.35			
Midlothian	-1805.35	124.89	-14.46	-1787.22	135.67	-13.17			
Moray	970.97	103.30	9.40	786.01	124.05	6.34	9388.77	503.31	18.65
North Ayrshire	-313.68	195.10	-1.61	-326.06	207.96	-1.57			
North Lanarkshire	-250.81	118.82	-2.11	-254.22	123.35	-2.06			
Orkney Islands	-561.22	162.92	-3.44	(dropped)	0.00	0.00	1807.46	1016.50	1.78
Perth & Kinross	-1464.83	155.25	-9.44	-1254.63	179.66	-6.98	-119.28	946.98	-0.13
Renfrewshire	-235.34	111.47	-2.11	-247.74	121.79	-2.03			
Scottish Borders	-2819.77	184.43	-15.29	-2942.17	202.97	-14.50	913.08	802.16	1.14
Shetland Islands	-158.16	147.89	-1.07	(dropped)	0.00	0.00	2583.55	702.37	3.68
South Ayrshire	-1023.69	117.49	-8.71	-814.17	128.38	-6.34			
South Lanarkshire	61.06	128.43	0.48	50.41	132.34	0.38			
Stirling	496.43	79.67	6.23	494.12	83.67	5.91			
West Dunbartonshire	1862.57	182.24	10.22	1868.54	190.76	9.80			
West Lothian	78.22	139.26	0.56	53.18	149.81	0.36			
Constant	10021.40	831.02	12.06	9997.31	848.60	11.78	6500.12	1769.40	3.67
Sample size	1897			1655			215		
R-squared	0.455			0.447			0.622		

Notes: Dependent variable is annual earned income net of deductions (£). Robust standard errors reported in parentheses. Standard errors are adjusted for spatial correlation in the residuals by clustering on local authority of workplace. Red t-stat indicates coefficient is significantly different from zero at <1%, blue at 5% level (two tailed t-test). Estimated using STATA9 econometric software. Constant relates to a female employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Glasgow City (except the Peripheral model where the constant relates to a workplace in Dumfries and Galloway).

Table C: Earnings Function OLS Women (Contd)

	Women					
	Managers, professionals and technical occupations			Other occupations		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	3.11	1.08	2.87	1.72	0.75	2.28
Potential experience (yrs)	618.41	93.37	6.62	107.78	41.04	2.63
Potential experience squared ($yrs^2/1000$)	-10195.15	1841.81	-5.54	-1743.19	887.83	-1.96
School certificate or no qualification (dummy variable)	-4404.53	668.53	-6.59	-1455.27	242.99	-5.99
Other qualification						
Degree or higher (dummy variable)	2673.77	394.63	6.78	2453.66	526.08	4.66
Temporary job	515.94	970.83	0.53	-1171.81	533.83	-2.20
Permanent job						
Works in a small workplace < 25people						
Work in a large workplace => 25 people	717.98	445.43	1.61	194.79	217.56	0.90
Agriculture, hunting and forestry	-3974.49	677.65	-5.87	282.89	1788.98	0.16
Fishing	-3390.78	2305.98	-1.47	610.76	1773.70	0.34
Mining and quarrying	2442.37	730.23	3.34	4587.30	399.43	11.48
Manufacturing						
Electricity, gas and water supply	1571.52	1852.00	0.85	2734.49	1673.80	1.63
Construction	2071.38	2165.11	0.96	-587.59	1025.09	-0.57
Wholesale and retail trade; repair trades	-2134.17	736.26	-2.90	-2380.49	416.03	-5.72
Hotels and restaurants	-1327.81	1217.09	-1.09	-2026.28	508.35	-3.99
Transport, storage and communication	-376.53	2473.30	-0.15	-362.07	619.41	-0.58
Financial intermediation	1967.99	1380.46	1.43	706.17	802.75	0.88
Real estate, renting and business activities	-1745.64	912.42	-1.91	-220.17	496.97	-0.44
Public administration and defence; compulsory social security	-109.62	962.31	-0.11	428.00	646.51	0.66
Education	-868.33	941.13	-0.92	-1767.86	533.33	-3.31
Health and social work	-726.24	805.80	-0.90	-763.74	466.02	-1.64
Other community, social and personal service activities	-1623.95	1230.94	-1.32	-1244.59	721.34	-1.73
Private households and extra-territorial	1275.23	2371.73	0.54	-449.27	795.67	-0.56
Managers and senior officials						
Professional occupations	1684.03	456.55	3.69			
Associate professional and technical occupations	215.53	519.39	0.41			
Administrative and secretarial occupations				1244.05	448.03	2.78
Skilled trades occupations				1557.90	722.14	2.16
Personal service occupations				1070.88	462.04	2.32
Sales and customer service occupations				509.96	517.81	0.98
Process, plant and machine operatives						
Elementary occupations				1571.81	835.83	1.88
Council area could not be derived	-379.74	346.87	-1.09	-989.46	192.57	-5.14
Aberdeen City	55.29	200.58	0.28	-27.83	127.29	-0.22
Aberdeenshire	-1131.84	270.06	-4.19	-1024.72	159.20	-6.44
Angus	-2801.03	200.05	-14.00	-332.06	204.16	-1.63
Argyll & Bute	-35.33	231.08	-0.15	-1412.28	200.80	-7.03
Clackmannanshire	-2423.39	265.58	-9.12	855.99	232.13	3.69
Dumfries and Galloway	-2989.08	174.32	-17.15	-801.17	151.54	-5.29
Dundee City	-814.11	202.69	-4.02	-1496.70	176.09	-8.50
East Ayrshire	-373.59	215.95	-1.73	-527.24	157.60	-3.35
East Dunbartonshire	-3295.36	597.07	-5.52	595.07	205.94	2.89
East Lothian	-1520.64	314.53	-4.83	2521.80	391.06	6.45
East Renfrewshire	2765.43	296.67	9.32	-781.07	241.30	-3.24
Edinburgh, City of	434.55	191.28	2.27	553.11	152.83	3.62
Eilean Siar	1429.29	370.59	3.86	665.02	267.32	2.49
Falkirk	-453.92	222.59	-2.04	-253.43	155.47	-1.63
Fife	-1204.91	123.73	-9.74	585.82	144.05	4.07
Glasgow City						
Highland	-2006.28	207.96	-9.65	-465.34	225.98	-2.06
Inverclyde	-1848.17	213.66	-8.65	-193.47	193.69	-1.00
Midlothian	-1777.35	291.60	-6.10	-1686.86	243.68	-6.92
Moray	2043.85	192.04	10.64	-483.10	135.99	-3.55
North Ayrshire	-1217.30	266.89	-4.56	13.06	206.86	0.06
North Lanarkshire	-716.39	305.44	-2.35	-277.65	159.11	-1.75
Orkney Islands	-702.66	312.44	-2.25	-91.57	216.92	-0.42
Perth & Kinross	-2000.57	193.68	-10.33	-747.67	206.30	-3.62
Renfrewshire	-1127.78	127.52	-8.84	341.35	143.58	2.38
Scottish Borders	-5247.57	366.62	-14.31	-1509.87	205.04	-7.36
Shetland Islands	-757.26	159.37	-4.75	258.92	198.31	1.31
South Ayrshire	-1021.57	299.56	-3.41	-864.45	156.47	-5.52
South Lanarkshire	-738.15	136.06	-5.43	630.77	165.01	3.82
Stirling	768.76	239.05	3.22	-210.20	176.78	-1.19
West Dunbartonshire	1504.57	269.80	5.58	2033.10	203.07	10.01
West Lothian	-691.50	282.05	-2.45	231.23	193.73	1.19
Constant	6905.63	1435.51	4.81	8376.45	722.83	11.59
Sample size		906			991	
R-squared		0.284			0.224	

Table D: Earnings Function IV Men and women

	Men and women								
	All			Central			Peripheral		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	7.04	2.04	3.44	8.11	2.43	3.33	-7.43	15.14	-0.49
Potential experience (yrs)	443.68	44.89	9.88	467.46	46.72	10.00	385.08	122.97	3.13
Potential experience squared ($yrs^2/1000$)	-7245.72	866.26	-8.36	-7729.49	904.47	-8.55	-6094.83	2252.64	-2.71
School certificate or no qualification (dummy variable)	-1808.11	223.87	-8.08	-1899.69	257.76	-7.37	-1478.08	627.61	-2.36
Other qualification									
Degree or higher (dummy variable)	2621.90	306.79	8.55	2827.66	279.44	10.12	988.80	930.54	1.06
Female (dummy variable)	-4686.22	392.54	-11.94	-4516.55	429.61	-10.51	-4828.90	855.82	-5.64
Temporary job	-1410.97	447.20	-3.16	-1450.10	441.13	-3.29	-927.80	2349.35	-0.39
Permanent job									
Works in a small workplace < 25people									
Work in a large workplace => 25 people	812.52	193.13	4.21	814.04	226.44	3.59	1177.47	746.70	1.58
Agriculture, hunting and forestry	-2056.71	901.22	-2.28	-2306.99	850.60	-2.71	5126.22	4856.04	1.06
Fishing	-1952.64	695.89	-2.81	-4400.43	730.16	-6.03	-721.42	1648.25	-0.44
Mining and quarrying	5163.60	1281.44	4.03	5338.72	1492.04	3.58	4715.02	2884.15	1.63
Manufacturing									
Electricity, gas and water supply	2524.81	741.43	3.41	2220.85	773.12	2.87	7667.75	2308.53	3.32
Construction	291.99	326.81	0.89	290.85	392.30	0.74	555.00	787.63	0.70
Wholesale and retail trade; repair trades	-2303.73	273.14	-8.43	-2181.78	287.45	-7.59	-2496.23	718.48	-3.47
Hotels and restaurants	-2616.72	297.70	-8.79	-2744.51	314.79	-8.72	-2493.71	884.58	-2.82
Transport, storage and communication	-323.84	316.48	-1.02	-572.32	318.67	-1.80	1701.60	1281.71	1.33
Financial intermediation	1885.33	836.36	2.25	1799.74	852.57	2.11	5895.27	2628.64	2.24
Real estate, renting and business activities	-1414.54	300.40	-4.71	-1387.97	318.35	-4.36	-1480.83	891.76	-1.66
Public administration and defence; compulsory social security	127.64	386.28	0.33	65.67	437.79	0.15	823.00	805.61	1.02
Education	-1421.07	448.67	-3.17	-1271.37	520.19	-2.44	-2387.75	1315.75	-1.81
Health and social work	-755.17	414.37	-1.82	-920.78	443.90	-2.07	1300.16	1484.38	0.88
Other community, social and personal service activities	-1984.17	607.34	-3.27	-2021.93	685.97	-2.95	-744.77	2005.14	-0.37
Private households and extra-territorial	697.19	1204.65	0.58	930.47	1369.30	0.68	-41.15	1015.90	-0.04
Managers and senior officials									
Professional occupations	-349.57	466.93	-0.75	-214.20	517.51	-0.41	168.60	1919.37	0.09
Associate professional and technical occupations	-2853.67	505.18	-5.65	-2594.02	589.22	-4.40	-4147.59	937.34	-4.42
Administrative and secretarial occupations	-6911.46	594.19	-11.63	-6871.51	653.46	-10.52	-4813.02	1425.56	-3.38
Skilled trades occupations	-4596.23	366.14	-12.55	-4126.70	385.20	-10.71	-6858.00	675.58	-10.15
Personal service occupations	-4859.64	471.85	-10.30	-4423.04	495.59	-8.92	-7657.61	1742.30	-4.40
Sales and customer service occupations	-5604.01	514.09	-10.90	-5150.21	585.58	-8.80	-7699.93	1078.74	-7.14
Process, plant and machine operatives	-6496.29	495.60	-13.11	-6278.53	492.79	-12.74	-8689.10	1808.72	-4.80
Elementary occupations	-6521.62	610.55	-10.68	-6171.87	675.14	-9.14	-8211.84	1236.52	-6.64
Female Managers and senior officials									
Female Professional occupations	2647.96	546.24	4.85	2481.43	636.71	3.90	2321.06	2018.08	1.15
Female Associate professional and technical occupations	3169.88	682.33	4.65	3186.65	765.46	4.16	1947.23	2224.71	0.88
Female Administrative and secretarial occupations	3454.38	755.05	4.58	3563.99	845.78	4.21	331.63	1112.63	0.30
Female Skilled trades occupations	1829.17	814.30	2.25	1728.75	984.90	1.76	2763.27	473.93	5.83
Female Personal service occupations	1373.21	569.93	2.41	1102.62	636.12	1.73	2157.42	777.80	2.77
Female Sales and customer service occupations	1370.16	484.23	2.83	1126.26	521.79	2.16	2439.67	1331.52	1.83
Female Process, plant and machine operatives	2110.68	528.82	3.99	2358.86	553.86	4.26	810.96	1646.51	0.49
Female Elementary occupations	3344.51	918.92	3.64	3492.20	1071.47	3.26	768.00	2113.98	0.36
Council area could not be derived	-212.50	101.33	-2.10	-78.28	130.58	-0.60			
Aberdeen City	1229.72	135.13	9.10	1173.28	165.31	7.10			
Aberdeenshire	328.67	144.62	2.27	508.94	180.80	2.81			
Angus	-228.10	116.91	-1.95	-190.95	129.08	-1.48			
Argyll & Bute	145.83	146.01	1.00	718.40	197.39	3.64	1908.37	596.18	3.20
Clackmannanshire	356.75	195.05	1.83	424.79	229.50	1.85			
Dumfries and Galloway	-1001.81	147.05	-6.81	-718.10	173.79	-4.13			
Dundee City	-539.93	92.68	-5.83	-492.90	109.30	-4.51			
East Ayrshire	-164.40	82.39	-2.00	59.22	91.28	0.65			
East Dunbartonshire	-822.61	103.75	-7.93	-852.09	124.12	-6.87			
East Lothian	-777.21	102.84	-7.56	-514.74	122.37	-4.21			
East Renfrewshire	-746.69	111.13	-6.72	-785.48	121.09	-6.49			
Edinburgh, City of	500.77	90.92	5.51	524.06	101.45	5.17			
Eilean Siar	378.75	231.70	1.63				1612.73	1138.14	1.42
Falkirk	217.10	131.79	1.65	300.01	156.71	1.91			
Fife	-177.92	156.93	-1.13	-110.59	181.85	-0.61			
Glasgow City									
Highland	-454.48	142.91	-3.18	-376.50	206.14	-1.83	1563.27	424.63	3.68
Inverclyde	-421.74	100.96	-4.18	-339.83	109.56	-3.10			
Midlothian	-382.56	176.84	-2.16	-269.45	199.92	-1.35			
Moray	876.75	91.92	9.54	897.08	129.67	6.92	5738.84	2917.84	1.97
North Ayrshire	188.81	89.64	2.11	241.12	102.33	2.36			
North Lanarkshire	18.21	134.17	0.14	99.85	156.18	0.64			
Orkney Islands	305.95	180.28	1.70				2120.60	595.79	3.56
Perth & Kinross	-1501.28	104.45	-14.37	-1334.31	111.92	-11.92	-385.12	605.04	-0.64
Renfrewshire	-116.81	58.21	-2.01	-17.76	66.72	-0.27			
Scottish Borders	-1299.89	103.58	-12.55	-1149.70	121.68	-9.45	450.85	647.10	0.70
Shetland Islands	906.80	142.55	6.36				3058.98	367.14	8.33
South Ayrshire	-299.59	124.60	-2.40	-98.70	141.44	-0.70			
South Lanarkshire	-36.20	138.89	-0.26	-27.54	155.49	-0.18			
Stirling	618.66	118.16	5.24	638.59	136.75	4.67			
West Dunbartonshire	854.04	79.66	10.72	869.02	87.83	9.89			
West Lothian	443.43	96.79	4.58	560.16	115.11	4.87			
Constant	12110.85	720.47	16.81	11307.28	801.69	14.10	13993.63	924.74	15.13
Sample size		4417			3805			528	
R-squared		0.415			0.402			0.462	
Wu-Hausman test (p-value)		0.028			0.009			0.137	
Sargan test (p-value)		0.236			0.124			0.350	
Number of instruments		2			2			2	
1st stage regression									
R-squared		0.129			0.123			0.165	
F-statistic on instruments (F2,n)		10.42			10.78			11.32	

Notes: Dependent variable is annual earned income net of deductions (£). Dependent variable in 1st stage regression is commuting cost. Robust standard errors reported in parentheses. Standard errors are adjusted for spatial correlation in the residuals by clustering on local authority of workplace. Red t-stat/F-stat indicates coefficient is significantly different from zero at <1%, blue at 5% level (two tailed t-test). Instruments are dummy variables for large urban areas (population>125,000) and urban areas except for Peripheral model where instruments are dummy variables for remote small town and very remote small town. Estimated using STATA9 econometric software. Constant relates to a male employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Glasgow City (except the Peripheral model where the constant relates to a workplace in Dumfries and Galloway).

Table D: Earnings Function IV Men and women (Contd)

	Men and women					
	Managers, professionals and technical occupations			Other occupations		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	9.67	2.65	3.65	1.33	2.44	0.55
Potential experience (yrs)	747.75	76.85	9.73	245.00	41.84	5.86
Potential experience squared ($yrs^2/1000$)	-11957.22	1582.43	-7.56	-4146.70	885.55	-4.68
School certificate or no qualification (dummy variable)	-3188.82	602.13	-5.30	-1549.83	232.32	-6.67
Other qualification						
Degree or higher (dummy variable)	2742.45	350.84	7.82	2330.22	560.39	4.16
Female (dummy variable)	-4557.04	355.76	-12.81	-1439.61	995.70	-1.45
Temporary job	-1004.93	854.94	-1.18	-1718.52	424.97	-4.04
Permanent job						
Works in a small workplace < 25people						
Work in a large workplace => 25 people	1163.55	482.36	2.41	610.70	178.13	3.43
Agriculture, hunting and forestry	-2402.12	3351.41	-0.72	-1832.91	934.40	-1.96
Fishing	-2825.23	1256.67	-2.25	-327.43	847.94	-0.39
Mining and quarrying	5929.76	1629.21	3.64	3603.26	1189.38	3.03
Manufacturing						
Electricity, gas and water supply	4233.67	1267.62	3.34	1849.22	902.23	2.05
Construction	-180.99	1043.42	-0.17	375.65	344.34	1.09
Wholesale and retail trade; repair trades	-2137.16	556.30	-3.84	-2305.69	233.24	-9.89
Hotels and restaurants	-2671.35	885.28	-3.02	-2834.93	341.31	-8.31
Transport, storage and communication	232.58	914.38	0.25	-534.35	330.64	-1.62
Financial intermediation	3580.64	1149.16	3.12	231.57	561.43	0.41
Real estate, renting and business activities	-795.31	413.34	-1.92	-1581.33	491.41	-3.22
Public administration and defence; compulsory social security	-282.20	704.94	-0.40	461.76	446.76	1.03
Education	-967.75	696.33	-1.39	-2456.38	413.57	-5.94
Health and social work	139.88	746.54	0.19	-1727.91	335.38	-5.15
Other community, social and personal service activities	-1675.66	866.68	-1.93	-2120.91	445.98	-4.76
Private households and extra-territorial	2339.98	2130.02	1.10	-565.05	576.09	-0.98
Managers and senior officials						
Professional occupations	-797.68	458.45	-1.74			
Associate professional and technical occupations	-3112.33	519.90	-5.99			
Administrative and secretarial occupations				-403.29	775.88	-0.52
Skilled trades occupations				1764.01	560.51	3.15
Personal service occupations				1435.41	654.92	2.19
Sales and customer service occupations				609.81	548.09	1.11
Process, plant and machine operatives				-193.71	590.52	-0.33
Elementary occupations						
Female Managers and senior officials						
Female Professional occupations	2672.31	555.54	4.81			
Female Associate professional and technical occupations						
Female Administrative and secretarial occupations				180.37	1175.35	0.15
Female Skilled trades occupations				-1963.07	1319.25	-1.49
Female Personal service occupations				-1559.22	1061.82	-1.47
Female Sales and customer service occupations				-1955.85	1049.14	-1.86
Female Process, plant and machine operatives				-1068.55	948.15	-1.13
Female Elementary occupations						
Council area could not be derived	-615.16	186.30	-3.30	74.84	103.16	0.73
Aberdeen City	2004.85	297.71	6.73	495.64	61.64	8.04
Aberdeenshire	764.02	208.53	3.66	83.03	205.80	0.40
Angus	181.89	150.14	1.21	-754.14	212.33	-3.55
Argyll & Bute	710.76	191.62	3.71	-290.07	162.76	-1.78
Clackmannanshire	-1574.73	238.63	-6.60	1799.87	210.55	8.55
Dumfries and Galloway	-1291.99	176.96	-7.30	-1040.54	189.96	-5.48
Dundee City	-359.89	161.09	-2.23	-809.22	139.05	-5.82
East Ayrshire	-100.51	152.70	-0.66	-348.97	93.82	-3.72
East Dunbartonshire	-1813.85	402.28	-4.51	-89.40	118.56	-0.75
East Lothian	-2738.23	296.02	-9.25	117.09	186.84	0.63
East Renfrewshire	-1311.74	237.17	-5.53	-341.31	106.02	-3.22
Edinburgh, City of	344.95	199.46	1.73	739.41	70.95	10.42
Eilean Siar				-634.03	268.10	-2.36
Falkirk	479.97	235.32	2.04	-92.47	154.51	-0.60
Fife	-656.80	215.03	-3.05	-211.93	204.08	-1.04
Glasgow City						
Highland	-898.71	261.07	-3.44	-295.56	181.33	-1.63
Inverclyde	-356.47	196.00	-1.82	-911.07	172.51	-5.28
Midlothian	-810.52	284.85	-2.85	-511.40	209.15	-2.45
Moray	1545.00	112.04	13.79	218.49	121.85	1.79
North Ayrshire	-394.54	181.48	-2.17	87.88	195.33	0.45
North Lanarkshire	-960.44	246.12	-3.90	228.88	170.33	1.34
Orkney Islands				-1139.33	217.58	-5.24
Perth & Kinross	-1668.41	159.48	-10.46	-1314.96	129.20	-10.18
Renfrewshire	-218.94	172.95	-1.27	63.78	85.23	0.75
Scottish Borders	-1055.60	238.49	-4.43	-1615.92	118.41	-13.65
Shetland Islands				1067.80	197.12	5.42
South Ayrshire	-638.77	232.38	-2.75	20.96	116.63	0.18
South Lanarkshire	-1032.36	248.73	-4.15	313.11	151.09	2.07
Stirling	836.53	202.85	4.12	-66.67	157.84	-0.42
West Dunbartonshire	356.63	127.13	2.81	828.60	106.58	7.77
West Lothian	149.37	96.62	1.55	330.70	161.08	2.05
Constant	6943.06	958.95	7.24	9804.44	923.76	10.61
Sample size		1865			2552	
R-squared		0.282			0.282	
Wu-Hausman test (p-value)		0.028			0.764	
Sargan test (p-value)		0.340			0.010	
Number of instruments		2			2	
1st stage regression						
R-squared		0.146			0.104	
F-statistic on instruments (F2,n)		6.27			8.43	

Table E: Earnings Function IV Men

	Men								
	All			Central			Peripheral		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	11.22	3.33	3.37	12.37	3.71	3.34	-0.91	11.24	-0.08
Potential experience (yrs)	519.06	66.01	7.86	568.82	68.29	8.33	253.66	160.09	1.58
Potential experience squared (yrs^2/1000)	-8605.14	1253.10	-6.87	-9551.45	1341.76	-7.12	-4075.65	2924.67	-1.39
School certificate or no qualification (dummy variable)	-1585.54	328.00	-4.83	-1733.57	378.38	-4.58	-1133.12	523.43	-2.16
Other qualification									
Degree or higher (dummy variable)	2604.99	560.44	4.65	2995.68	486.41	6.16	158.55	1588.49	0.10
Temporary job	-2431.48	610.94	-3.98	-2476.48	634.90	-3.90	-2465.75	1357.38	-1.82
Permanent job									
Works in a small workplace < 25people									
Work in a large workplace => 25 people	1088.46	236.64	4.60	1072.91	282.67	3.80	1927.15	909.07	2.12
Agriculture, hunting and forestry	-2573.70	1005.75	-2.56	-2715.72	983.28	-2.76	5866.38	4866.24	1.21
Fishing	-1999.87	881.05	-2.27	-5844.40	2025.71	-2.89	-614.01	2141.11	-0.29
Mining and quarrying	5394.02	2130.55	2.53	5933.57	2673.19	2.22	3441.94	3474.65	0.99
Manufacturing									
Electricity, gas and water supply	2400.16	861.46	2.79	2185.88	869.27	2.51	8041.23	1571.54	5.12
Construction	167.54	363.88	0.46	101.51	450.08	0.23	1063.91	776.90	1.37
Wholesale and retail trade; repair trades	-2293.31	428.56	-5.35	-2069.75	439.19	-4.71	-3097.86	1349.96	-2.29
Hotels and restaurants	-4106.00	625.18	-6.57	-4133.61	726.69	-5.69	-4518.48	1777.75	-2.54
Transport, storage and communication	-544.66	425.60	-1.28	-882.24	438.76	-2.01	2023.91	1387.85	1.46
Financial intermediation	2418.21	1023.10	2.36	2314.64	1063.25	2.18	12577.08	2962.15	4.25
Real estate, renting and business activities	-1848.94	401.71	-4.60	-1945.21	442.82	-4.39	-1104.81	1692.34	-0.65
Public administration and defence; compulsory social security	57.50	434.05	0.13	104.86	483.57	0.22	230.75	893.57	0.26
Education	-2302.74	555.74	-4.14	-2275.76	674.36	-3.37	-1977.50	1837.79	-1.08
Health and social work	-409.05	832.25	-0.49	-726.71	878.86	-0.83	3036.30	2932.49	1.04
Other community, social and personal service activities	-2253.51	591.28	-3.81	-2180.99	678.33	-3.22	-930.69	1900.98	-0.49
Private households and extra-territorial	1247.40	2024.31	0.62	1238.60	2218.62	0.56	299.68	1575.60	0.19
Managers and senior officials									
Professional occupations	-85.63	588.67	-0.15	47.50	668.36	0.07	-437.82	1849.26	-0.24
Associate professional and technical occupations	-2919.45	499.03	-5.85	-2603.53	580.53	-4.48	-4431.06	1076.05	-4.12
Administrative and secretarial occupations	-6711.74	634.30	-10.58	-6606.44	713.96	-9.25	-4963.91	1346.51	-3.69
Skilled trades occupations	-4421.80	390.88	-11.31	-3846.05	397.70	-9.67	-7455.01	640.47	-11.64
Personal service occupations	-4436.75	456.10	-9.73	-4011.96	460.37	-8.71	-7268.59	1545.32	-4.70
Sales and customer service occupations	-5365.63	562.28	-9.54	-4778.94	640.08	-7.47	-7869.90	1096.48	-7.18
Process, plant and machine operatives	-6249.55	528.08	-11.83	-5923.60	493.75	-12.00	-9145.00	1893.25	-4.83
Elementary occupations	-6243.21	622.74	-10.03	-5805.69	692.89	-8.38	-8151.34	1064.21	-7.66
Council area could not be derived	-19.22	109.61	-0.18	173.65	128.38	1.35			
Aberdeen City	1883.85	180.04	10.46	1813.16	226.77	8.00			
Aberdeenshire	1388.49	189.66	7.32	1522.03	246.73	6.17			
Angus	420.99	204.75	2.06	457.65	225.18	2.03			
Argyll & Bute	884.33	161.08	5.49	725.93	288.92	2.51	3146.53	1227.31	2.56
Clackmannanshire	1522.77	414.16	3.68	1587.83	454.74	3.49			
Dumfries and Galloway	-130.41	360.51	-0.36	78.08	355.77	0.22			
Dundee City	-392.27	156.44	-2.51	-302.37	174.23	-1.74			
East Ayrshire	-149.46	116.86	-1.28	154.89	129.26	1.20			
East Dunbartonshire	-1666.60	397.58	-4.19	-1726.07	447.53	-3.86			
East Lothian	-387.32	221.06	-1.75	137.13	148.67	0.92			
East Renfrewshire	-1228.42	209.58	-5.86	-1273.60	221.26	-5.76			
Edinburgh, City of	387.01	91.34	4.24	471.50	91.07	5.18			
Eilean Siar	112.18	411.69	0.27	(dropped)	0.00	0.00	2221.65	575.24	3.86
Falkirk	305.81	144.27	2.12	374.95	160.78	2.33			
Fife	-260.11	251.59	-1.03	-174.37	280.71	-0.62			
Glasgow City									
Highland	-245.83	245.76	-1.00	-338.52	317.50	-1.07	2811.13	1239.91	2.27
Inverclyde	145.60	142.71	1.02	267.42	141.35	1.89			
Midlothian	298.10	215.27	1.38	486.25	248.36	1.96			
Moray	544.25	108.03	5.04	677.55	153.99	4.40	2804.38	2275.05	1.23
North Ayrshire	561.52	137.34	4.09	629.98	141.42	4.45			
North Lanarkshire	76.20	143.31	0.53	164.29	162.72	1.01			
Orkney Islands	839.16	291.44	2.88	(dropped)	0.00	0.00	2921.47	966.32	3.02
Perth & Kinross	-1762.77	70.17	-25.12	-1746.81	82.01	-21.30	-461.25	1283.97	-0.36
Renfrewshire	-596.93	178.58	-3.34	-462.86	191.73	-2.41			
Scottish Borders	-431.19	170.33	-2.53	-93.84	204.63	-0.46	1211.34	1518.21	0.80
Shetland Islands	1582.47	246.17	6.43	(dropped)	0.00	0.00	4215.69	998.08	4.22
South Ayrshire	285.08	208.51	1.37	458.77	227.83	2.01			
South Lanarkshire	-157.10	214.64	-0.73	-197.63	224.40	-0.88			
Stirling	553.03	186.42	2.97	623.96	220.90	2.82			
West Dunbartonshire	-93.24	141.34	-0.66	-59.73	155.46	-0.38			
West Lothian	544.14	118.77	4.58	736.48	141.02	5.22			
Constant	9886.83	1034.70	9.56	8694.76	1173.99	7.41	13749.27	2016.55	6.82
Sample size		2520			2150			313	
R-squared		0.343			0.324			0.469	
Wu-Hausman test (p-value)		0.001			0.000			0.577	
Sargan test (p-value)		0.140			0.106			0.245	
Number of instruments		2			2			2	
1st stage regression									
R-squared		0.145			0.133			0.228	
F-statistic on instruments (F2,n)		10.70			11.31			11.23	

Notes: Dependent variable is annual earned income net of deductions (£). Robust standard errors reported in parentheses. Standard errors are adjusted for spatial correlation in the residuals by clustering on local authority of workplace. Red t-stat/F-stat indicates coefficient is significantly different from zero at <1%, blue at 5% level (two tailed t-test). Instruments are dummy variables for large urban areas (population>125,000) and urban areas except for Peripheral model where instruments are dummy variables for remote small town and very remote small town. Estimated using STATA9 econometric software. Constant relates to a male employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Glasgow City (except the Peripheral model where the constant relates to a workplace in Dumfries and Galloway).

Table E: Earnings Function IV Men (Contd)

	Men					
	Managers, professionals and technical occupations			Other occupations		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	15.67	6.01	2.61	8.95	9.14	0.98
Potential experience (yrs)	887.49	112.65	7.88	322.74	64.65	4.99
Potential experience squared (yrs^2/1000)	-14318.04	2319.63	-6.17	-5656.16	1305.25	-4.33
School certificate or no qualification (dummy variable)	-2371.05	1027.69	-2.31	-1330.40	367.28	-3.62
Other qualification						
Degree or higher (dummy variable)	2818.12	685.64	4.11	1803.28	1096.87	1.64
Temporary job	-2674.65	1544.35	-1.73	-2543.68	680.71	-3.74
Permanent job						
Works in a small workplace < 25people						
Work in a large workplace => 25 people	1868.23	681.95	2.74	888.84	286.04	3.11
Agriculture, hunting and forestry	-2545.56	3476.95	-0.73	-2496.24	918.02	-2.72
Fishing	-1435.69	2138.69	-0.67	-842.72	1182.21	-0.71
Mining and quarrying	6291.07	2718.20	2.31	2872.41	2064.60	1.39
Manufacturing						
Electricity, gas and water supply	5451.64	1582.27	3.45	1008.92	1030.16	0.98
Construction	-396.13	1258.07	-0.31	274.99	395.03	0.70
Wholesale and retail trade; repair trades	-2237.18	1008.55	-2.22	-2168.67	368.30	-5.89
Hotels and restaurants	-6181.28	1955.26	-3.16	-3722.09	768.87	-4.84
Transport, storage and communication	238.99	1102.37	0.22	-711.84	414.92	-1.72
Financial intermediation	4486.54	1457.71	3.08	-1144.66	1779.04	-0.64
Real estate, renting and business activities	-359.66	632.17	-0.57	-2758.19	579.65	-4.76
Public administration and defence; compulsory social security	-211.38	859.01	-0.25	568.57	688.55	0.83
Education	-1384.16	797.45	-1.74	-3367.13	778.50	-4.33
Health and social work	2024.71	1469.47	1.38	-3554.09	594.22	-5.98
Other community, social and personal service activities	-1103.15	872.95	-1.26	-2486.49	556.88	-4.47
Private households and extra-territorial	2350.77	2862.62	0.82	420.61	923.20	0.46
Managers and senior officials						
Professional occupations	-876.63	593.16	-1.48			
Associate professional and technical occupations	-3447.20	540.79	-6.37			
Administrative and secretarial occupations				-653.30	676.96	-0.97
Skilled trades occupations				1469.00	566.30	2.59
Personal service occupations				1569.22	579.26	2.71
Sales and customer service occupations				443.73	424.88	1.04
Process, plant and machine operatives				-271.75	509.64	-0.53
Elementary occupations						
Council area could not be derived	-251.16	533.24	-0.47	762.97	139.59	5.47
Aberdeen City	3425.41	495.76	6.91	776.86	69.81	11.13
Aberdeenshire	2200.61	439.57	5.01	1480.84	467.10	3.17
Angus	1940.11	218.80	8.87	-426.08	749.62	-0.57
Argyll & Bute	1052.06	382.53	2.75	768.36	519.32	1.48
Clackmannanshire	-205.74	670.94	-0.31	3056.56	995.80	3.07
Dumfries and Galloway	2190.81	783.26	2.80	-808.90	836.25	-0.97
Dundee City	-272.13	311.71	-0.87	-347.92	314.37	-1.11
East Ayrshire	308.39	260.28	1.18	-266.49	109.88	-2.43
East Dunbartonshire	-1421.15	939.74	-1.51	-1767.82	895.49	-1.97
East Lothian	-2763.38	433.49	-6.37	248.42	626.72	0.40
East Renfrewshire	-3313.24	567.51	-5.84	43.28	253.54	0.17
Edinburgh, City of	298.73	190.70	1.57	751.41	261.78	2.87
Eilean Siar	894.01	869.68	1.03	-679.06	1060.78	-0.64
Falkirk	1001.81	320.64	3.12	179.79	288.77	0.62
Fife	-138.43	515.89	-0.27	-276.04	612.77	-0.45
Glasgow City						
Highland	-23.12	642.13	-0.04	16.20	485.82	0.03
Inverclyde	2598.46	529.86	4.90	-1111.53	624.33	-1.78
Midlothian	-249.67	589.73	-0.42	398.52	425.82	0.94
Moray	223.27	244.89	0.91	489.13	251.36	1.95
North Ayrshire	-239.39	489.49	-0.49	948.74	677.70	1.40
North Lanarkshire	-1085.14	425.80	-2.55	842.54	228.09	3.69
Orkney Islands	3889.56	569.60	6.83	-1385.22	781.35	-1.77
Perth & Kinross	-1504.98	208.81	-7.21	-1667.12	168.25	-9.91
Renfrewshire	-250.45	221.12	-1.13	-457.00	394.77	-1.16
Scottish Borders	3042.94	457.95	6.64	-1973.61	186.68	-10.57
Shetland Islands	968.84	585.65	1.65	1804.87	580.50	3.11
South Ayrshire	-101.67	568.87	-0.18	706.68	272.68	2.59
South Lanarkshire	-1789.43	496.64	-3.60	550.00	448.75	1.23
Stirling	915.53	439.55	2.08	451.80	471.23	0.96
West Dunbartonshire	-3134.91	398.20	-7.87	450.08	240.99	1.87
West Lothian	583.17	482.66	1.21	567.78	382.21	1.49
Constant	2459.01	1855.55	1.33	7383.26	1850.58	3.99
Sample size		959			1561	
R-squared		0.205			0.171	
Wu-Hausman test (p-value)		0.002			0.814	
Sargan test (p-value)		0.370			0.273	
Number of instruments		2			2	
1st stage regression						
R-squared		0.154			0.119	
F-statistic on instruments (F2,n)		4.43			8.37	

Table F: Earnings Function IV Women

	Women								
	All			Central			Peripheral		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	-1.08	2.63	-0.41	0.04	2.58	0.02	-6.01	17.34	-0.35
Potential experience (yrs)	353.08	55.68	6.34	348.45	57.89	6.02	487.18	214.39	2.27
Potential experience squared (yrs^2/1000)	-5833.73	1078.16	-5.41	-5813.84	1119.06	-5.20	-7579.84	4389.18	-1.73
School certificate or no qualification (dummy variable)	-2202.90	213.66	-10.31	-2177.29	255.04	-8.54	-2034.53	595.59	-3.42
Other qualification									
Degree or higher (dummy variable)	2803.20	334.38	8.38	2898.62	359.61	8.06	2022.50	581.61	3.48
Temporary job	-317.91	576.57	-0.55	-264.67	604.75	-0.44	-921.21	2172.22	-0.42
Permanent job									
Works in a small workplace < 25people									
Work in a large workplace => 25 people	394.86	275.78	1.43	487.35	279.78	1.74	-381.75	1160.70	-0.33
Agriculture, hunting and forestry	-239.72	1424.91	-0.17	-499.28	1779.65	-0.28	2142.75	3689.68	0.58
Fishing	-847.58	647.25	-1.31	-767.82	875.59	-0.88	-830.15	2493.74	-0.33
Mining and quarrying	2932.84	389.09	7.54	2853.60	406.04	7.03	(dropped)	0.00	0.00
Manufacturing									
Electricity, gas and water supply	2327.19	1322.18	1.76	2115.99	1374.61	1.54	3116.52	3298.52	0.94
Construction	463.04	1042.93	0.44	963.02	1067.44	0.90	-4437.60	2587.99	-1.71
Wholesale and retail trade; repair trades	-2309.17	397.69	-5.81	-2354.65	445.87	-5.28	-1078.27	856.73	-1.26
Hotels and restaurants	-1850.23	410.28	-4.51	-2013.54	448.56	-4.49	-760.93	1247.15	-0.61
Transport, storage and communication	30.90	772.63	0.04	-34.93	784.13	-0.04	895.90	446.61	2.01
Financial intermediation	1466.27	1185.59	1.24	1409.75	1225.46	1.15	3149.35	3283.58	0.96
Real estate, renting and business activities	-941.72	578.04	-1.63	-837.58	579.10	-1.45	-1594.38	831.43	-1.92
Public administration and defence; compulsory social security	400.72	564.87	0.71	189.44	610.70	0.31	2671.20	1557.71	1.71
Education	-970.46	641.91	-1.51	-677.01	695.60	-0.97	-2245.13	2716.60	-0.83
Health and social work	-662.81	391.90	-1.69	-811.72	389.27	-2.09	1210.96	723.43	1.67
Other community, social and personal service activities	-1321.33	845.40	-1.56	-1513.76	952.89	-1.59	571.36	2286.24	0.25
Private households and extra-territorial	104.89	1120.19	0.09	420.60	1210.66	0.35	1041.92	2090.46	0.50
Managers and senior officials									
Professional occupations	1947.08	426.43	4.57	1745.72	446.64	3.91	2795.42	2071.35	1.35
Associate professional and technical occupations	324.27	458.98	0.71	514.58	465.31	1.11	-1511.78	1528.76	-0.99
Administrative and secretarial occupations	-3718.51	345.95	-10.75	-3687.77	372.65	-9.90	-4049.78	1122.62	-3.61
Skilled trades occupations	-3087.57	853.03	-3.62	-2968.37	1047.86	-2.83	-3452.84	615.97	-5.61
Personal service occupations	-3890.01	323.40	-12.03	-3816.55	328.66	-11.61	-5127.49	1372.02	-3.74
Sales and customer service occupations	-4376.58	545.78	-8.02	-4319.01	610.27	-7.08	-4318.73	1533.94	-2.82
Process, plant and machine operatives	-4468.51	521.38	-8.57	-4197.07	596.13	-7.04	-6624.98	1459.95	-4.54
Elementary occupations	-3314.87	841.36	-3.94	-3045.22	956.19	-3.18	-5711.15	3225.07	-1.77
Council area could not be derived	-791.31	235.87	-3.35	-801.55	245.91	-3.26			
Aberdeen City	-111.22	199.00	-0.56	-25.43	215.38	-0.12			
Aberdeenshire	-1529.45	325.27	-4.70	-1243.75	304.63	-4.08			
Angus	-1461.82	277.68	-5.26	-1353.82	264.34	-5.12			
Argyll & Bute	-1351.34	326.68	-4.14	-1013.56	365.24	-2.78	531.80	1488.60	0.36
Clackmannanshire	-1125.09	202.85	-5.55	-1088.43	197.19	-5.52			
Dumfries and Galloway	-1776.60	199.35	-8.91	-1517.57	209.37	-7.25			
Dundee City	-913.60	167.43	-5.46	-922.42	158.66	-5.81			
East Ayrshire	-687.46	189.06	-3.64	-553.85	168.93	-3.28			
East Dunbartonshire	-1260.46	367.62	-3.43	-1190.59	367.37	-3.24			
East Lothian	-187.17	316.14	-0.59	-458.22	318.60	-1.44			
East Renfrewshire	-235.36	195.28	-1.21	-286.34	207.99	-1.38			
Edinburgh, City of	509.20	156.67	3.25	496.08	166.95	2.97			
Eilean Siar	348.00	459.91	0.76	(dropped)	0.00	0.00	2107.29	2292.79	0.92
Falkirk	-690.51	380.24	-1.82	-524.01	350.77	-1.49			
Fife	-440.82	226.25	-1.95	-371.07	210.32	-1.76			
Glasgow City									
Highland	-1411.19	357.84	-3.94	-1022.57	408.48	-2.50	-171.35	1392.96	-0.12
Inverclyde	-1104.59	252.06	-4.38	-1009.79	250.45	-4.03			
Midlothian	-2214.85	357.90	-6.19	-2067.22	341.82	-6.05			
Moray	691.46	264.27	2.62	557.96	296.81	1.88	11498.50	4986.34	2.31
North Ayrshire	-556.28	300.55	-1.85	-490.99	285.73	-1.72			
North Lanarkshire	-617.13	301.39	-2.05	-505.60	278.19	-1.82			
Orkney Islands	-943.61	367.50	-2.57	(dropped)	0.00	0.00	985.36	1335.89	0.74
Perth & Kinross	-1714.50	241.53	-7.10	-1451.42	263.88	-5.50	-176.52	987.89	-0.18
Renfrewshire	-568.41	291.04	-1.95	-478.13	278.22	-1.72			
Scottish Borders	-3142.24	340.28	-9.23	-3175.53	331.57	-9.58	448.87	755.36	0.59
Shetland Islands	-468.36	316.87	-1.48	(dropped)	0.00	0.00	1824.04	1150.45	1.59
South Ayrshire	-1279.63	255.26	-5.01	-996.93	254.51	-3.92			
South Lanarkshire	-226.51	264.83	-0.86	-144.27	244.74	-0.59			
Stirling	314.24	169.00	1.86	381.40	152.33	2.50			
West Dunbartonshire	1712.21	241.96	7.08	1772.20	235.95	7.51			
West Lothian	-102.61	178.53	-0.57	-68.45	177.10	-0.39			
Constant	11077.00	1114.51	9.94	10783.79	1117.94	9.65	8120.69	5669.32	1.43
Sample size		1897			1655			215	
R-squared		0.445			0.441			0.576	
Wu-Hausman test (p-value)		0.246			0.454			0.441	
Sargan test (p-value)		0.549			0.700			0.691	
Number of instruments		2			2			2	
1st stage regression									
R-squared		0.147			0.150			0.204	
F-statistic on instruments (F2,n)		6.61			6.05			3.21	

Notes: Dependent variable is annual earned income net of deductions (£). Robust standard errors reported in parentheses. Standard errors are adjusted for spatial correlation in the residuals by clustering on local authority of workplace. Red t-stat/F-stat indicates coefficient is significantly different from zero at <1%, blue at 5% level (two tailed t-test). Instruments are dummy variables for large urban areas (population>125,000) and urban areas except for Peripheral model where instruments are dummy variables for remote small town and very remote small town. Estimated using STATA9 econometric software. Constant relates to a female employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Glasgow City (except the Peripheral model where the constant relates to a workplace in Dumfries and Galloway).

Table F: Earnings Function IV Women (Contd)

	Women					
	Managers, professionals and technical occupations			Other occupations		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Generalised cost of commute	-0.73	3.96	-0.18	-12.50	9.14	-1.37
Potential experience (yrs)	647.21	101.23	6.39	93.71	61.89	1.51
Potential experience squared ($yrs^2/1000$)	-10907.98	2037.75	-5.35	-1715.56	1243.22	-1.38
School certificate or no qualification (dummy variable)	-4452.77	672.79	-6.62	-1949.76	466.83	-4.18
Other qualification						
Degree or higher (dummy variable)	2864.56	546.86	5.24	3179.49	781.61	4.07
Temporary job	613.51	1005.62	0.61	-1274.23	541.49	-2.35
Permanent job						
Works in a small workplace < 25people						
Work in a large workplace => 25 people	690.38	441.57	1.56	90.48	296.37	0.31
Agriculture, hunting and forestry	-3764.63	743.00	-5.07	-519.21	1969.93	-0.26
Fishing	-2858.57	3038.41	-0.94	113.52	2896.81	0.04
Mining and quarrying	2130.09	640.19	3.33	5920.18	1016.08	5.83
Manufacturing						
Electricity, gas and water supply	1851.13	2177.12	0.85	1528.06	1757.43	0.87
Construction	1480.30	2300.70	0.64	-1493.49	928.08	-1.61
Wholesale and retail trade; repair trades	-2317.65	665.91	-3.48	-3091.15	615.95	-5.02
Hotels and restaurants	-1673.90	1258.37	-1.33	-2868.83	823.51	-3.48
Transport, storage and communication	-116.42	2525.10	-0.05	-1108.47	738.01	-1.50
Financial intermediation	1785.90	1436.53	1.24	539.30	1148.19	0.47
Real estate, renting and business activities	-1952.55	918.55	-2.13	-584.16	483.74	-1.21
Public administration and defence; compulsory social security	-46.88	984.62	-0.05	103.76	730.78	0.14
Education	-1192.23	880.08	-1.35	-3053.78	1066.62	-2.86
Health and social work	-807.48	777.82	-1.04	-1578.48	746.13	-2.12
Other community, social and personal service activities	-1711.48	1176.23	-1.46	-1992.70	657.20	-3.03
Private households and extra-territorial	1069.75	2517.00	0.43	-1134.22	1498.58	-0.76
Managers and senior officials						
Professional occupations	1694.40	433.33	3.91			
Associate professional and technical occupations	104.27	604.53	0.17			
Administrative and secretarial occupations				-190.04	952.32	-0.20
Skilled trades occupations				-462.40	1168.36	-0.40
Personal service occupations				-193.84	908.74	-0.21
Sales and customer service occupations				-1377.04	1049.06	-1.31
Process, plant and machine operatives				-1137.13	958.10	-1.19
Elementary occupations						
Council area could not be derived	-648.56	497.31	-1.30	-2235.91	801.06	-2.79
Aberdeen City	-235.88	382.72	-0.62	-217.14	198.76	-1.09
Aberdeenshire	-1475.77	412.34	-3.58	-2684.18	1055.08	-2.54
Angus	-2954.42	252.78	-11.69	-1501.38	775.72	-1.94
Argyll & Bute	-647.36	697.92	-0.93	-2197.59	532.17	-4.13
Clackmannanshire	-2596.69	253.25	-10.25	60.03	528.52	0.11
Dumfries and Galloway	-3043.28	189.15	-16.09	-1839.04	646.00	-2.85
Dundee City	-965.27	268.73	-3.59	-1691.74	208.86	-8.10
East Ayrshire	-490.85	231.69	-2.12	-1589.09	698.13	-2.28
East Dunbartonshire	-3621.99	791.96	-4.57	-1030.14	993.85	-1.04
East Lothian	-1086.78	477.32	-2.28	3095.07	639.79	4.84
East Renfrewshire	2946.80	418.01	7.05	-1363.04	383.09	-3.56
Edinburgh, City of	315.51	180.31	1.75	642.35	203.29	3.16
Eilean Siar	635.92	965.11	0.66	-526.04	683.55	-0.77
Falkirk	-993.61	590.21	-1.68	-1772.49	958.22	-1.85
Fife	-1401.96	210.07	-6.67	-757.82	830.07	-0.91
Glasgow City						
Highland	-2424.38	504.21	-4.81	-1804.93	871.53	-2.07
Inverclyde	-2101.72	392.00	-5.36	-1165.42	598.58	-1.95
Midlothian	-2077.91	345.80	-6.01	-3703.03	1251.02	-2.96
Moray	1721.51	442.93	3.89	-1613.99	730.02	-2.21
North Ayrshire	-1491.53	404.81	-3.68	-951.09	591.99	-1.61
North Lanarkshire	-936.51	323.85	-2.89	-2119.27	1149.58	-1.84
Orkney Islands	-1265.17	531.73	-2.38	-1022.41	671.18	-1.52
Perth & Kinross	-2311.60	244.28	-9.46	-1641.03	554.81	-2.96
Renfrewshire	-1600.76	504.23	-3.17	-696.39	653.04	-1.07
Scottish Borders	-5521.14	501.25	-11.01	-3014.57	958.57	-3.14
Shetland Islands	-1102.04	442.84	-2.49	-969.52	745.88	-1.30
South Ayrshire	-1368.39	497.18	-2.75	-1718.87	540.65	-3.18
South Lanarkshire	-1048.07	273.89	-3.83	-408.08	657.21	-0.62
Stirling	727.77	248.13	2.93	-1504.80	796.68	-1.89
West Dunbartonshire	1354.86	378.67	3.58	1394.23	428.93	3.25
West Lothian	-781.40	234.54	-3.33	-917.47	737.14	-1.24
Constant	7896.75	1425.29	5.54	14253.87	3082.89	4.62
Sample size		906			991	
R-squared		0.270			0.282	
Wu-Hausman test (p-value)		0.337			0.400	
Sargan test (p-value)		0.606			0.440	
Number of instruments		2			2	
1st stage regression						
R-squared		0.177			0.104	
F-statistic on instruments (F2,n)		5.38			8.43	

Table G: 1st Regression Results for IV Earnings Function Men and Women

	Men and women								
	All			Central			Peripheral		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Large urban areas	-121.00	37.00	-3.27	-114.47	34.61	-3.31			
Other urban areas	-52.93	13.53	-3.91	-49.52	13.33	-3.71			
Small town accessible areas									
Small town remote areas							-16.51	25.87	-0.64
Small town very remote areas							-62.30	13.83	-4.50
Rural Accessible areas									
Rural remote areas									
Rural very remote areas									
Potential experience (yrs)	1.73	1.25	1.39	0.87	1.37	0.63	3.06	4.58	0.67
Potential experience squared (yrs2/1000)	-39.09	24.62	-1.59	-25.82	28.54	-0.90	-46.93	88.93	-0.53
School certificate or no qualification (dummy variable)	-26.55	6.48	-4.10	-22.37	7.30	-3.07	-29.81	20.37	-1.46
Other qualification									
Degree or higher (dummy variable)	55.78	9.40	5.93	53.75	11.00	4.89	42.20	27.05	1.56
Female (dummy variable)	-12.31	11.77	-1.05	-15.59	13.25	-1.18	-0.22	27.25	-0.01
Temporary job	24.82	15.38	1.61	22.13	15.78	1.40	64.91	53.46	1.21
Permanent job									
Works in a small workplace < 25people									
Work in a large workplace => 25 people	3.95	5.95	0.66	0.04	6.49	0.01	28.64	9.45	3.03
Agriculture, hunting and forestry	17.32	31.23	0.55	0.72	35.54	0.02	154.43	146.06	1.06
Fishing	44.64	51.25	0.87	317.87	140.18	2.27	42.35	36.74	1.15
Mining and quarrying	13.42	25.96	0.52	-3.34	26.06	-0.13	193.99	29.80	6.51
Manufacturing									
Electricity, gas and water supply	-13.65	19.86	-0.69	-22.52	20.68	-1.09	39.86	97.84	0.41
Construction	3.34	11.72	0.29	-1.65	13.89	-0.12	13.87	30.95	0.45
Wholesale and retail trade; repair trades	-6.63	10.19	-0.65	-13.86	12.22	-1.13	37.58	21.54	1.74
Hotels and restaurants	-29.30	14.95	-1.96	-23.13	18.25	-1.27	-21.82	33.32	-0.66
Transport, storage and communication	6.92	9.70	0.71	-0.14	9.74	-0.01	35.16	19.45	1.81
Financial intermediation	8.06	18.24	0.44	3.20	18.57	0.17	45.73	82.97	0.55
Real estate, renting and business activities	-2.37	10.58	-0.22	-4.28	12.61	-0.34	0.44	19.53	0.02
Public administration and defence; compulsory social security	0.96	9.22	0.10	-4.63	8.45	-0.55	24.10	30.60	0.79
Education	-42.79	11.31	-3.78	-40.87	12.39	-3.30	-43.01	60.54	-0.71
Health and social work	-18.56	13.32	-1.39	-24.08	14.85	-1.62	21.03	41.21	0.51
Other community, social and personal service activities	-19.28	8.73	-2.21	-28.20	10.15	-2.78	33.98	22.41	1.52
Private households and extra-territorial	-29.54	24.76	-1.19	-27.31	26.93	-1.01	12.70	25.87	0.49
Managers and senior officials									
Professional occupations	3.22	11.47	0.28	-5.92	11.14	-0.53	57.61	35.34	1.63
Associate professional and technical occupations	10.57	12.81	0.83	3.96	14.20	0.28	-1.27	18.90	-0.07
Administrative and secretarial occupations	-31.54	14.02	-2.25	-39.08	15.77	-2.48	9.42	40.88	0.23
Skilled trades occupations	-22.29	9.89	-2.25	-30.77	10.25	-3.00	20.84	19.76	1.05
Personal service occupations	-39.01	12.59	-3.10	-44.42	12.35	-3.60	-6.64	32.04	-0.21
Sales and customer service occupations	-54.75	11.27	-4.86	-66.13	12.33	-5.37	-15.17	37.92	-0.40
Process, plant and machine operatives	-47.05	12.56	-3.75	-52.64	14.87	-3.54	-9.09	26.08	-0.35
Elementary occupations	-35.32	21.52	-1.64	-45.28	22.43	-2.02	23.41	40.16	0.58
Female Managers and senior officials									
Female Professional occupations	-20.61	14.22	-1.45	-19.17	12.61	-1.52	7.70	62.16	0.12
Female Associate professional and technical occupations	-29.41	22.30	-1.32	-25.07	24.78	-1.01	0.04	46.83	0.00
Female Administrative and secretarial occupations	-7.22	20.67	-0.35	-8.14	23.83	-0.34	17.46	28.81	0.61
Female Skilled trades occupations	-46.86	22.09	-2.12	-66.30	22.60	-2.93	9.04	29.65	0.30
Female Personal service occupations	8.03	13.80	0.58	11.01	14.96	0.74	-8.17	34.94	-0.23
Female Sales and customer service occupations	-15.42	17.90	-0.86	-8.98	20.98	-0.43	-15.42	67.23	-0.23
Female Process, plant and machine operatives	20.10	22.45	0.90	19.84	25.07	0.79	36.42	56.96	0.64
Female Elementary occupations	-19.57	35.79	-0.55	-14.68	37.57	-0.39	-43.37	65.77	-0.66
Council area could not be derived	-85.87	12.47	-6.89	-84.45	10.91	-7.74			
Aberdeen City	-46.88	3.23	-14.51	-56.46	2.91	-19.38			
Aberdeenshire	-132.83	19.81	-6.70	-130.35	16.50	-7.90			
Angus	-124.46	23.60	-5.27	-120.02	22.44	-5.35			
Argyll & Bute	-163.27	25.29	-6.46	-70.43	20.04	-3.51	-52.59	21.66	-2.43
Clackmannanshire	-160.32	23.71	-6.76	-155.06	22.08	-7.02			
Dumfries and Galloway	-147.78	26.66	-5.54	-145.81	25.26	-5.77			
Dundee City	-48.85	2.11	-23.17	-47.47	2.16	-21.97			
East Ayrshire	-105.29	25.65	-4.10	-100.27	24.46	-4.10			
East Dunbartonshire	-23.15	10.26	-2.26	-20.86	9.90	-2.11			
East Lothian	-52.83	13.93	-3.79	-3.18	8.39	-0.38			
East Renfrewshire	-26.77	3.48	-7.68	-24.31	3.66	-6.64			
Edinburgh, City of	-13.38	2.82	-4.75	-14.97	2.16	-6.93			
Eilean Siar	-230.74	26.44	-8.73				-92.39	25.53	-3.62
Falkirk	-124.85	25.42	-4.91	-120.28	24.82	-4.85			
Fife	-126.41	24.48	-5.16	-122.56	23.48	-5.22			
Glasgow City									
Highland	-166.38	26.04	-6.39	-162.91	23.59	-6.91	-41.18	23.35	-1.76
Inverclyde	-89.28	21.81	-4.09	-85.19	21.57	-3.95			
Midlothian	-121.21	17.81	-6.81	-121.66	16.69	-7.29			
Moray	-127.84	25.12	-5.09	-134.83	23.81	-5.66	153.30	30.30	5.06
North Ayrshire	-103.76	25.75	-4.03	-101.65	25.00	-4.07			
North Lanarkshire	-88.35	10.67	-8.28	-85.66	10.49	-8.16			
Orkney Islands	-195.28	27.29	-7.16				-48.67	26.88	-1.81
Perth & Kinross	-97.14	22.81	-4.26	-88.28	21.31	-4.14	-17.10	20.45	-0.84
Renfrewshire	-27.80	2.28	-12.21	-28.71	2.21	-13.00			
Scottish Borders	-125.97	25.56	-4.93	-123.43	23.83	-5.18	15.37	24.62	0.62
Shetland Islands	-177.60	26.30	-6.75				-35.30	27.46	-1.29
South Ayrshire	-121.91	25.42	-4.80	-115.03	24.62	-4.67			
South Lanarkshire	-100.86	16.63	-6.07	-96.87	16.10	-6.02			
Stirling	-109.28	24.80	-4.41	-104.14	23.84	-4.37			
West Dunbartonshire	-47.05	8.48	-5.55	-44.89	8.40	-5.35			
West Lothian	-78.67	22.22	-3.54	-80.01	21.43	-3.73			
Constant	365.08	29.07	12.56	383.80	25.41	15.11	148.05	70.74	2.09
Sample size		4417			3805			528	
R-squared		0.129			0.123			0.165	
F-statistic on instruments (F2,n)		10.42			10.78			11.32	

Notes: Dependent variable is commuting cost. Robust standard errors reported in parentheses. Standard errors are adjusted for spatial correlation in the residuals by clustering on local authority of workplace. Red t-stat/F-stat indicates coefficient is significantly different from zero at <1%, blue at 5% level (two tailed t-test). Estimated using STATA9 econometric software. Constant relates to a male employee (except for female model) with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Glasgow City (except the Peripheral model where the constant relates to a workplace in Dumfries and Galloway).

Table G: 1st Regression Results for IV Earnings Function Men and Women (Contd)

	Men and women					
	Managers, professionals and technical occupations			Other occupations		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Large urban areas	-142.34	44.76	-3.18	-105.04	34.60	-3.04
Other urban areas	-65.82	23.01	-2.86	-40.11	12.57	-3.19
Small town accessible areas						
Small town remote areas						
Small town very remote areas						
Rural Accessible areas						
Rural remote areas						
Rural very remote areas						
Potential experience (yrs)	4.43	2.32	1.91	-0.16	1.48	-0.11
Potential experience squared (yrs2/1000)	-108.65	45.10	-2.41	6.70	31.67	0.21
School certificate or no qualification (dummy variable)	-15.64	20.92	-0.75	-28.38	6.95	-4.08
Other qualification						
Degree or higher (dummy variable)	54.37	9.63	5.65	62.39	21.18	2.95
Female (dummy variable)	-9.70	11.23	-0.86	8.16	21.47	0.38
Temporary job	41.25	26.71	1.54	17.83	21.87	0.82
Permanent job						
Works in a small workplace < 25people						
Work in a large workplace => 25 people	3.08	14.06	0.22	6.21	6.68	0.93
Agriculture, hunting and forestry	-78.52	60.07	-1.31	34.60	34.38	1.01
Fishing	9.73	122.58	0.08	49.88	43.17	1.16
Mining and quarrying	-3.39	19.84	-0.17	69.29	56.66	1.22
Manufacturing						
Electricity, gas and water supply	-68.45	30.84	-2.22	13.24	30.06	0.44
Construction	-29.89	34.38	-0.87	11.98	13.75	0.87
Wholesale and retail trade; repair trades	-21.10	25.19	-0.84	-5.22	10.15	-0.51
Hotels and restaurants	-56.94	30.29	-1.88	-25.14	16.83	-1.49
Transport, storage and communication	37.70	27.09	1.39	-3.26	11.74	-0.28
Financial intermediation	-12.22	18.86	-0.65	31.00	25.75	1.20
Real estate, renting and business activities	-13.30	15.37	-0.87	4.27	16.34	0.26
Public administration and defence; compulsory social security	-1.76	19.14	-0.09	-0.85	14.30	-0.06
Education	-46.02	14.98	-3.07	-34.68	17.95	-1.93
Health and social work	-11.83	21.08	-0.56	-31.49	13.81	-2.28
Other community, social and personal service activities	-22.96	16.73	-1.37	-22.11	15.85	-1.40
Private households and extra-territorial	-34.78	40.86	-0.85	-43.67	42.68	-1.02
Managers and senior officials						
Professional occupations	7.63	12.22	0.62			
Associate professional and technical occupations	7.31	14.91	0.49			
Administrative and secretarial occupations				11.09	15.04	0.74
Skilled trades occupations				21.64	12.55	1.72
Personal service occupations				4.48	17.44	0.26
Sales and customer service occupations				-6.75	11.63	-0.58
Process, plant and machine operatives						
Elementary occupations				6.19	23.81	0.26
Female Managers and senior officials						
Female Professional occupations	-28.21	14.24	-1.98			
Female Associate professional and technical occupations	-38.30	21.75	-1.76			
Female Administrative and secretarial occupations				-25.31	26.68	-0.95
Female Skilled trades occupations				-66.39	27.71	-2.40
Female Personal service occupations				-7.00	22.58	-0.31
Female Sales and customer service occupations				-34.02	26.03	-1.31
Female Process, plant and machine operatives						
Female Elementary occupations				-29.91	36.85	-0.81
Council area could not be derived	-106.25	7.41	-14.33	-73.51	15.07	-4.88
Aberdeen City	-76.42	5.98	-12.77	-19.50	4.37	-4.46
Aberdeenshire	-120.00	18.00	-6.67	-136.95	22.17	-6.18
Angus	-100.00	25.03	-3.99	-133.84	24.84	-5.39
Argyll & Bute	-215.71	31.26	-6.90	-132.40	25.24	-5.25
Clackmannanshire	-159.30	26.88	-5.93	-158.08	24.27	-6.51
Dumfries and Galloway	-147.36	27.56	-5.35	-143.81	26.38	-5.45
Dundee City	-74.35	4.57	-16.29	-30.27	3.78	-8.02
East Ayrshire	-115.73	27.03	-4.28	-97.35	25.50	-3.82
East Dunbartonshire	10.02	16.28	0.62	-49.27	8.37	-5.89
East Lothian	35.57	13.57	2.62	-119.67	16.90	-7.08
East Renfrewshire	-17.88	11.00	-1.63	-29.37	3.72	-7.89
Edinburgh, City of	-24.80	3.25	-7.63	0.83	7.21	0.12
Eilean Siar				-189.71	26.29	-7.22
Falkirk	-153.91	25.46	-6.04	-105.54	26.12	-4.04
Fife	-119.63	24.38	-4.91	-131.29	25.87	-5.08
Glasgow City						
Highland	-198.74	27.70	-7.17	-143.82	25.51	-5.64
Inverclyde	-65.60	19.17	-3.42	-110.16	22.54	-4.89
Midlothian	-103.24	17.16	-6.02	-126.19	20.10	-6.28
Moray	-144.20	28.28	-5.10	-114.41	25.13	-4.55
North Ayrshire	-67.66	26.96	-2.51	-122.33	27.32	-4.48
North Lanarkshire	-78.07	5.23	-14.94	-93.15	13.77	-6.76
Orkney Islands				-159.60	26.03	-6.13
Perth & Kinross	-91.19	24.11	-3.78	-101.28	23.13	-4.38
Renfrewshire	-62.23	2.86	-21.75	-8.13	3.54	-2.29
Scottish Borders	-160.03	30.39	-5.27	-99.84	25.19	-3.96
Shetland Islands				-155.98	25.42	-6.14
South Ayrshire	-166.25	25.20	-6.60	-94.57	26.10	-3.62
South Lanarkshire	-108.59	14.73	-7.37	-94.56	18.68	-5.06
Stirling	-93.56	26.65	-3.51	-118.63	26.66	-4.45
West Dunbartonshire	-46.25	11.11	-4.16	-46.39	8.15	-5.69
West Lothian	-37.55	19.74	-1.90	-103.09	23.43	-4.40
Constant	373.28	46.91	7.96	316.05	33.11	9.55
Sample size		1865			2552	
R-squared		0.146			0.104	
F-statistic on instruments (F2,n)		6.27			8.43	

Table H: 1st Regression Results for IV Earnings Function Men

	Men								
	All			Central			Peripheral		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Large urban areas	-133.14	41.62	-3.20	-127.78	38.99	-3.28			
Other urban areas	-66.95	17.70	-3.78	-65.90	18.09	-3.64			
Small town accessible areas									
Small town remote areas							-69.81	46.98	-1.49
Small town very remote areas							-78.15	16.50	-4.74
Rural Accessible areas									
Rural remote areas									
Rural very remote areas									
Potential experience (yrs)	1.82	2.14	0.85	0.39	2.32	0.17	6.03	6.27	0.96
Potential experience squared (yrs2/1000)	-24.68	40.17	-0.61	-0.39	45.76	-0.01	-92.74	116.82	-0.79
School certificate or no qualification (dummy variable)	-26.70	9.64	-2.77	-21.90	11.24	-1.95	-41.28	21.01	-1.97
Other qualification									
Degree or higher (dummy variable)	56.49	14.57	3.88	50.32	16.15	3.12	50.71	30.11	1.68
Temporary job	49.38	23.71	2.08	40.41	25.22	1.60	95.08	66.44	1.43
Permanent job									
Works in a small workplace < 25people									
Work in a large workplace => 25 people	9.14	6.23	1.47	2.56	6.42	0.40	44.18	7.54	5.86
Agriculture, hunting and forestry	21.37	35.89	0.60	-2.67	41.01	-0.07	261.56	171.55	1.52
Fishing	48.63	44.94	1.08	284.08	188.31	1.51	62.74	36.05	1.74
Mining and quarrying	33.05	30.36	1.09	12.60	34.29	0.37	180.90	37.44	4.83
Manufacturing									
Electricity, gas and water supply	-10.20	26.36	-0.39	-27.66	24.75	-1.12	63.23	116.14	0.54
Construction	16.60	13.22	1.26	11.35	15.63	0.73	29.72	32.02	0.93
Wholesale and retail trade; repair trades	12.28	12.92	0.95	3.49	14.18	0.25	61.29	30.09	2.04
Hotels and restaurants	-7.12	21.85	-0.33	12.95	24.33	0.53	-50.98	40.83	-1.25
Transport, storage and communication	10.84	13.17	0.82	6.66	14.01	0.48	33.23	20.39	1.63
Financial intermediation	33.70	22.20	1.52	23.28	22.70	1.03	267.07	48.49	5.51
Real estate, renting and business activities	11.78	11.14	1.06	13.76	14.39	0.96	-8.79	26.65	-0.33
Public administration and defence; compulsory social security	1.27	12.88	0.10	-4.89	11.11	-0.44	16.59	52.28	0.32
Education	-14.67	15.96	-0.92	-15.16	17.17	-0.88	-5.57	81.48	-0.07
Health and social work	-12.66	16.62	-0.76	-16.14	17.53	-0.92	3.58	69.27	0.05
Other community, social and personal service activities	-29.94	11.73	-2.55	-38.38	13.31	-2.88	-0.14	18.66	-0.01
Private households and extra-territorial	-28.08	36.84	-0.76	-27.85	39.95	-0.70	4.68	33.32	0.14
Managers and senior officials									
Professional occupations	-5.19	12.73	-0.41	-10.48	13.26	-0.79	40.84	37.23	1.10
Associate professional and technical occupations	12.74	13.21	0.96	7.37	14.45	0.51	5.29	21.29	0.25
Administrative and secretarial occupations	-32.07	13.29	-2.41	-38.56	15.35	-2.51	-0.68	46.24	-0.01
Skilled trades occupations	-18.49	9.47	-1.95	-27.88	9.26	-3.01	15.34	17.81	0.86
Personal service occupations	-33.74	12.76	-2.64	-40.38	12.23	-3.30	-1.60	33.85	-0.05
Sales and customer service occupations	-50.98	10.80	-4.72	-62.73	11.33	-5.54	-16.48	30.92	-0.53
Process, plant and machine operatives	-42.54	11.95	-3.56	-48.65	13.23	-3.68	-14.96	21.50	-0.70
Elementary occupations	-39.08	21.62	-1.81	-50.56	22.44	-2.25	30.07	39.81	0.76
Council area could not be derived	-73.43	13.58	-5.41	-65.87	12.04	-5.47			
Aberdeen City	-30.37	5.06	-6.01	-44.46	4.18	-10.63			
Aberdeenshire	-107.23	21.20	-5.06	-107.51	16.88	-6.37			
Angus	-115.61	26.05	-4.44	-114.21	24.99	-4.57			
Argyll & Bute	-144.76	28.38	-5.10	-55.80	25.62	-2.18	83.87	19.53	4.29
Clackmannanshire	-188.01	27.63	-6.81	-182.42	26.43	-6.90			
Dumfries and Galloway	-181.19	28.41	-6.38	-170.17	27.51	-6.18			
Dundee City	-43.46	3.89	-11.17	-42.57	4.09	-10.42			
East Ayrshire	-87.87	27.60	-3.18	-85.51	26.71	-3.20			
East Dunbartonshire	87.50	10.49	8.34	87.51	9.92	8.82			
East Lothian	-111.55	18.64	-5.98	-57.35	13.09	-4.38			
East Renfrewshire	-27.44	4.58	-5.99	-24.40	5.01	-4.87			
Edinburgh, City of	-1.28	3.95	-0.32	-6.44	3.36	-1.92			
Eilean Siar	-235.75	29.34	-8.04	(dropped)	0.00	0.00	0.72	34.27	0.02
Falkirk	-86.38	29.39	-2.94	-82.15	29.18	-2.82			
Fife	-122.19	27.59	-4.43	-118.84	26.51	-4.48			
Glasgow City									
Highland	-160.02	28.97	-5.52	-151.68	27.32	-5.55	72.33	27.58	2.62
Inverclyde	-85.70	26.17	-3.28	-82.30	26.07	-3.16			
Midlothian	-101.39	18.48	-5.49	-105.39	16.91	-6.23			
Moray	-111.23	29.04	-3.83	-117.03	28.21	-4.15	198.29	32.57	6.09
North Ayrshire	-82.66	28.60	-2.89	-81.23	28.15	-2.89			
North Lanarkshire	-59.23	11.59	-5.11	-57.94	11.53	-5.03			
Orkney Islands	-203.51	30.54	-6.66	(dropped)	0.00	0.00	32.33	35.96	0.90
Perth & Kinross	-63.70	24.44	-2.61	-50.47	22.96	-2.20	47.21	25.67	1.84
Renfrewshire	19.21	4.19	4.59	16.55	3.29	5.03			
Scottish Borders	-100.78	29.02	-3.47	-94.23	27.30	-3.45	139.57	17.56	7.95
Shetland Islands	-181.63	29.47	-6.16	(dropped)	0.00	0.00	54.55	37.90	1.44
South Ayrshire	-114.53	28.67	-3.99	-107.45	28.49	-3.77			
South Lanarkshire	-92.35	18.39	-5.02	-88.36	17.67	-5.00			
Stirling	-107.18	28.97	-3.70	-106.44	27.98	-3.80			
West Dunbartonshire	-30.25	8.12	-3.72	-29.27	9.09	-3.22			
West Lothian	-60.41	24.22	-2.49	-63.84	23.51	-2.72			
Constant	336.62	38.69	8.70	365.70	36.50	10.02	12.79	93.56	0.14
Sample size		2520			2150			313	
R-squared		0.145			0.133			0.228	
F-statistic on instruments (F2,n)		10.70			11.31			11.23	

Notes: Dependent variable is commuting cost. Robust standard errors reported in parentheses. Standard errors are adjusted for spatial correlation in the residuals by clustering on local authority of workplace. Red t-stat/F-stat indicates coefficient is significantly different from zero at <1%, blue at 5% level (two tailed t-test). Estimated using STATA9 econometric software. Constant relates to a male employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Glasgow City (except the Peripheral model where the constant relates to a workplace in Dumfries and Galloway).

Table H: 1st Regression Results for IV Earnings Function Men (Contd)

	Men					
	Managers, professionals and technical occupations			Other occupations		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Large urban areas	-153.23	55.60	-2.76	-123.90	40.94	-3.03
Other urban areas	-82.99	36.08	-2.30	-51.94	17.53	-2.96
Small town accessible areas						
Small town remote areas						
Small town very remote areas						
Rural Accessible areas						
Rural remote areas						
Rural very remote areas						
Potential experience (yrs)	3.42	4.46	0.77	0.91	2.63	0.35
Potential experience squared (yrs2/1000)	-67.63	84.93	-0.80	-0.53	52.02	-0.01
School certificate or no qualification (dummy variable)	-13.60	33.09	-0.41	-27.35	9.81	-2.79
Other qualification						
Degree or higher (dummy variable)	55.19	15.76	3.50	62.22	28.75	2.16
Temporary job	77.24	47.63	1.62	36.32	33.55	1.08
Permanent job						
Works in a small workplace < 25people						
Work in a large workplace => 25 people	3.51	16.35	0.21	12.82	10.68	1.20
Agriculture, hunting and forestry	-104.66	81.89	-1.28	47.29	40.57	1.17
Fishing	-27.52	101.91	-0.27	90.86	36.89	2.46
Mining and quarrying	18.39	25.72	0.72	72.05	68.91	1.05
Manufacturing						
Electricity, gas and water supply	-96.11	44.77	-2.15	35.15	36.86	0.95
Construction	-6.85	40.32	-0.17	23.58	15.78	1.49
Wholesale and retail trade; repair trades	2.87	36.76	0.08	14.34	13.03	1.10
Hotels and restaurants	-16.81	64.28	-0.26	-4.12	29.75	-0.14
Transport, storage and communication	40.11	33.71	1.19	3.96	17.45	0.23
Financial intermediation	13.49	30.49	0.44	81.76	43.76	1.87
Real estate, renting and business activities	3.86	16.49	0.23	12.89	19.40	0.66
Public administration and defence; compulsory social security	-10.93	23.02	-0.47	8.39	16.26	0.52
Education	-22.36	17.10	-1.31	22.04	42.17	0.52
Health and social work	-8.95	20.30	-0.44	-25.98	25.52	-1.02
Other community, social and personal service activities	-33.50	27.96	-1.20	-26.26	19.15	-1.37
Private households and extra-territorial	-13.90	73.30	-0.19	-67.93	23.51	-2.89
Managers and senior officials						
Professional occupations	-0.02	15.23	0.00			
Associate professional and technical occupations	10.58	16.89	0.63			
Administrative and secretarial occupations						
Skilled trades occupations				17.44	14.55	1.20
Personal service occupations				0.39	18.73	0.02
Sales and customer service occupations				-12.09	14.64	-0.83
Process, plant and machine operatives				-5.64	15.19	-0.37
Elementary occupations				-3.75	26.84	-0.14
Council area could not be derived	-114.88	10.87	-10.57	-50.47	17.02	-2.97
Aberdeen City	-60.40	12.68	-4.76	-11.60	4.52	-2.57
Aberdeenshire	-72.59	20.58	-3.53	-122.07	26.49	-4.61
Angus	-82.07	29.05	-2.83	-135.13	30.06	-4.49
Argyll & Bute	-174.11	41.63	-4.18	-133.05	30.37	-4.38
Clackmannanshire	-198.25	35.34	-5.61	-182.44	27.74	-6.58
Dumfries and Galloway	-217.38	33.50	-6.49	-167.38	30.11	-5.56
Dundee City	-78.25	5.79	-13.51	-26.84	5.12	-5.24
East Ayrshire	-123.40	32.65	-3.78	-76.27	28.02	-2.72
East Dunbartonshire	63.69	26.65	2.39	118.70	12.67	9.37
East Lothian	-32.68	20.66	-1.58	-130.97	19.81	-6.61
East Renfrewshire	-34.27	13.03	-2.63	-25.04	5.89	-4.25
Edinburgh, City of	-13.01	6.69	-1.94	5.66	8.28	0.68
Eilean Siar	-294.30	37.15	-7.92	-212.92	29.96	-7.11
Falkirk	-106.99	32.01	-3.34	-80.60	30.50	-2.64
Fife	-125.80	28.23	-4.46	-124.27	31.05	-4.00
Glasgow City						
Highland	-202.86	34.12	-5.95	-136.59	29.59	-4.62
Inverclyde	-34.31	29.52	-1.16	-112.26	28.82	-3.90
Midlothian	-94.78	18.89	-5.02	-102.46	21.03	-4.87
Moray	-132.08	39.03	-3.38	-103.60	29.52	-3.51
North Ayrshire	-14.06	31.56	-0.45	-133.50	32.52	-4.11
North Lanarkshire	-80.79	6.10	-13.24	-50.84	15.62	-3.25
Orkney Islands	-241.55	42.00	-5.75	-186.91	30.15	-6.20
Perth & Kinross	-54.40	29.58	-1.84	-80.76	24.71	-3.27
Renfrewshire	-9.32	8.05	-1.16	31.74	6.07	5.23
Scottish Borders	-171.67	39.72	-4.32	-65.18	30.18	-2.16
Shetland Islands	-225.45	39.61	-5.69	-160.01	30.70	-5.21
South Ayrshire	-170.29	29.55	-5.76	-88.98	31.54	-2.82
South Lanarkshire	-108.66	19.30	-5.63	-87.62	20.36	-4.30
Stirling	-94.42	35.12	-2.69	-112.83	33.24	-3.39
West Dunbartonshire	-35.06	26.44	-1.33	-27.51	7.51	-3.66
West Lothian	10.70	21.42	0.50	-93.61	27.85	-3.36
Constant	361.72	75.97	4.76	287.28	49.05	5.86
Sample size	959			1561		
R-squared	0.154			0.119		
F-statistic on instruments (F2,n)	4.43			8.37		

Table I: 1st Regression Results for IV Earnings Function Women

	Women								
	All			Central			Peripheral		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Large urban areas	-104.46	32.29	-3.24	-98.09	31.00	-3.16			
Other urban areas	-35.06	12.57	-2.79	-29.96	12.48	-2.40			
Small town accessible areas									
Small town remote areas							46.96	40.00	1.17
Small town very remote areas							-45.96	21.92	-2.10
Rural Accessible areas									
Rural remote areas									
Rural very remote areas									
Potential experience (yrs)	3.12	1.63	1.91	2.85	1.68	1.69	1.43	6.51	0.22
Potential experience squared (yrs2/1000)	-89.17	32.40	-2.75	-87.35	33.10	-2.64	-28.33	113.16	-0.25
School certificate or no qualification (dummy variable)	-27.48	11.36	-2.42	-27.82	14.27	-1.95	0.97	34.07	0.03
Other qualification									
Degree or higher (dummy variable)	50.26	9.73	5.16	50.35	11.77	4.28	52.96	27.90	1.90
Temporary job	0.85	18.98	0.04	4.57	18.84	0.24	12.79	46.21	0.28
Permanent job									
Works in a small workplace < 25people									
Work in a large workplace => 25 people	-5.82	8.58	-0.68	-7.23	9.20	-0.79	10.67	26.09	0.41
Agriculture, hunting and forestry	-23.46	53.72	-0.44	0.21	61.30	0.00	-103.89	98.54	-1.05
Fishing	73.41	83.51	0.88	378.70	36.88	10.27	-41.26	101.80	-0.41
Mining and quarrying	-48.84	12.98	-3.76	-42.02	14.63	-2.87	(dropped)	0.00	0.00
Manufacturing									
Electricity, gas and water supply	-9.03	40.05	-0.23	-0.58	41.91	-0.01	-151.36	52.67	-2.87
Construction	-96.17	33.63	-2.86	-99.95	38.10	-2.62	-118.52	47.43	-2.50
Wholesale and retail trade; repair trades	-43.30	18.14	-2.39	-49.61	20.82	-2.38	4.64	67.97	0.07
Hotels and restaurants	-62.30	22.20	-2.81	-61.03	25.52	-2.39	-30.03	65.77	-0.46
Transport, storage and communication	-19.05	25.72	-0.74	-36.37	24.10	-1.51	89.72	90.40	0.99
Financial intermediation	-30.40	23.47	-1.30	-30.49	25.62	-1.19	-58.95	91.99	-0.64
Real estate, renting and business activities	-34.71	17.36	-2.00	-39.03	18.64	-2.09	-11.08	32.74	-0.34
Public administration and defence; compulsory social security	-13.28	15.41	-0.86	-17.95	18.61	-0.96	8.78	58.15	0.15
Education	-84.06	18.61	-4.52	-80.33	20.61	-3.90	-88.72	69.45	-1.28
Health and social work	-44.37	20.60	-2.15	-49.48	22.44	-2.21	6.75	56.89	0.12
Other community, social and personal service activities	-27.66	20.38	-1.36	-37.43	20.32	-1.84	49.83	62.50	0.80
Private households and extra-territorial	-27.07	37.05	-0.73	-22.56	41.47	-0.54	81.46	43.56	1.87
Managers and senior officials									
Professional occupations	2.34	13.88	0.17	-8.81	12.76	-0.69	86.10	69.35	1.24
Associate professional and technical occupations	-18.03	14.43	-1.25	-22.59	16.65	-1.36	12.66	43.11	0.29
Administrative and secretarial occupations	-36.67	13.53	-2.71	-44.64	14.84	-3.01	45.35	27.18	1.67
Skilled trades occupations	-80.87	23.57	-3.43	-107.40	21.83	-4.92	43.77	21.95	1.99
Personal service occupations	-26.13	10.42	-2.51	-28.30	10.86	-2.60	-3.91	47.04	-0.08
Sales and customer service occupations	-80.59	14.43	-5.59	-85.30	15.30	-5.58	-57.89	64.44	-0.90
Process, plant and machine operatives	-18.10	22.58	-0.80	-21.47	26.22	-0.82	9.70	83.74	0.12
Elementary occupations	-50.01	21.35	-2.34	-52.64	23.81	-2.21	-63.90	77.82	-0.82
Council area could not be derived	-103.63	12.03	-8.62	-108.65	11.79	-9.21			
Aberdeen City	-62.93	3.29	-19.13	-67.58	3.47	-19.47			
Aberdeenshire	-163.62	19.05	-8.59	-158.70	19.19	-8.27			
Angus	-133.56	22.30	-5.99	-127.55	21.91	-5.82			
Argyll & Bute	-183.25	23.24	-7.89	-92.20	25.30	-3.64	-102.08	45.90	-2.22
Clackmannanshire	-115.46	20.33	-5.68	-110.12	19.32	-5.70			
Dumfries and Galloway	-120.39	24.12	-4.99	-121.09	22.80	-5.31			
Dundee City	-46.89	3.62	-12.94	-44.50	3.22	-13.80			
East Ayrshire	-123.75	23.26	-5.32	-112.35	22.25	-5.05			
East Dunbartonshire	-129.18	12.24	-10.56	-125.18	12.38	-10.11			
East Lothian	66.77	10.91	6.12	92.04	9.30	9.89			
East Renfrewshire	-28.43	5.38	-5.28	-25.47	5.18	-4.92			
Edinburgh, City of	-26.75	3.87	-6.91	-24.34	3.97	-6.13			
Eilean Siar	-220.34	24.50	-9.00	(dropped)	0.00	0.00	-118.06	33.61	-3.51
Falkirk	-175.28	21.84	-8.03	-169.66	21.47	-7.90			
Fife	-129.85	21.61	-6.01	-125.09	21.44	-5.84			
Glasgow City									
Highland	-174.18	23.31	-7.47	-179.83	21.03	-8.55	-85.34	41.03	-2.08
Inverclyde	-101.41	18.70	-5.42	-97.26	18.92	-5.14			
Midlothian	-157.63	18.03	-8.74	-151.51	17.64	-8.59			
Moray	-148.54	22.50	-6.60	-155.92	22.10	-7.05	299.63	41.93	7.15
North Ayrshire	-129.18	22.61	-5.71	-123.68	22.33	-5.54			
North Lanarkshire	-125.85	10.17	-12.38	-121.46	10.26	-11.83			
Orkney Islands	-190.43	25.33	-7.52	(dropped)	0.00	0.00	-66.70	44.37	-1.50
Perth & Kinross	-135.34	21.86	-6.19	-137.71	21.29	-6.47	3.81	46.75	0.08
Renfrewshire	-88.31	2.94	-30.07	-85.65	3.04	-28.17			
Scottish Borders	-159.36	22.94	-6.95	-156.37	22.15	-7.06	-29.81	46.66	-0.64
Shetland Islands	-170.15	23.68	-7.18	(dropped)	0.00	0.00	-57.07	33.26	-1.72
South Ayrshire	-130.23	22.61	-5.76	-125.58	22.61	-5.55			
South Lanarkshire	-117.06	14.78	-7.92	-112.07	14.85	-7.55			
Stirling	-113.15	22.19	-5.10	-103.13	21.81	-4.73			
West Dunbartonshire	-66.34	10.23	-6.48	-61.75	10.54	-5.86			
West Lothian	-104.09	20.88	-4.98	-99.35	20.65	-4.81			
Constant	386.55	36.16	10.69	392.84	34.49	11.39	204.59	110.31	1.85
Sample size	1897			1655			215		
R-squared	0.147			0.150			0.204		
F-statistic on instruments (F2,n)	6.61			6.05			3.21		

Notes: Dependent variable is commuting cost. Robust standard errors reported in parentheses. Standard errors are adjusted for spatial correlation in the residuals by clustering on local authority of workplace. Red t-stat/F-stat indicates coefficient is significantly different from zero at <1%, blue at 5% level (two tailed t-test). Estimated using STATA9 econometric software. Constant relates to a female employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Glasgow City (except the Peripheral model where the constant relates to a workplace in Dumfries and Galloway).

Table I: 1st Regression Results for IV Earnings Function Women (Contd)

	Women					
	Managers, professionals and technical occupations			Other occupations		
	Co-efficient	Std Error	T-stat	Co-efficient	Std Error	T-stat
Large urban areas	-128.36	40.63	-3.16	-77.75	27.56	-2.82
Other urban areas	-51.50	22.31	-2.31	-18.49	12.85	-1.44
Small town accessible areas						
Small town remote areas						
Small town very remote areas						
Rural Accessible areas						
Rural remote areas						
Rural very remote areas						
Potential experience (yrs)	6.68	2.82	2.37	-1.12	2.36	-0.48
Potential experience squared (yrs2/1000)	-176.82	54.60	-3.24	0.92	48.24	0.02
School certificate or no qualification (dummy variable)	-24.03	28.78	-0.84	-31.33	12.36	-2.54
Other qualification						
Degree or higher (dummy variable)	54.57	11.19	4.88	50.81	26.18	1.94
Temporary job	22.29	25.14	0.89	-10.44	21.40	-0.49
Permanent job						
Works in a small workplace < 25people						
Work in a large workplace => 25 people	-4.40	16.46	-0.27	-4.15	8.62	-0.48
Agriculture, hunting and forestry	14.98	30.73	0.49	-50.27	71.61	-0.70
Fishing	183.20	169.52	1.08	-36.20	67.47	-0.54
Mining and quarrying	-83.29	22.69	-3.67	82.47	13.00	6.34
Manufacturing						
Electricity, gas and water supply	64.05	81.82	0.78	-72.56	38.08	-1.91
Construction	-142.86	46.60	-3.07	-58.99	50.61	-1.17
Wholesale and retail trade; repair trades	-49.22	31.16	-1.58	-48.43	22.25	-2.18
Hotels and restaurants	-95.63	37.18	-2.57	-60.62	23.61	-2.57
Transport, storage and communication	45.63	55.30	0.83	-51.41	25.58	-2.01
Financial intermediation	-44.63	30.14	-1.48	-19.28	32.32	-0.60
Real estate, renting and business activities	-47.62	26.76	-1.78	-22.83	21.62	-1.06
Public administration and defence; compulsory social security	5.19	28.64	0.18	-26.34	24.20	-1.09
Education	-81.38	29.06	-2.80	-89.42	19.71	-4.54
Health and social work	-25.45	33.26	-0.77	-59.05	19.63	-3.01
Other community, social and personal service activities	-17.96	39.95	-0.45	-49.18	20.72	-2.37
Private households and extra-territorial	-53.41	42.36	-1.26	-39.80	66.30	-0.60
Managers and senior officials						
Professional occupations	-1.66	14.02	-0.12			
Associate professional and technical occupations	-32.87	17.58	-1.87			
Administrative and secretarial occupations				-17.28	25.34	-0.68
Skilled trades occupations				-61.26	29.39	-2.08
Personal service occupations				-4.86	24.77	-0.20
Sales and customer service occupations				-54.21	25.86	-2.10
Process, plant and machine operatives						
Elementary occupations				-29.33	27.31	-1.07
Council area could not be derived	-94.32	14.82	-6.36	-123.16	14.70	-8.38
Aberdeen City	-83.59	5.05	-16.57	-28.32	6.58	-4.30
Aberdeenshire	-155.53	21.86	-7.11	-166.29	18.42	-9.03
Angus	-115.88	25.34	-4.57	-132.13	19.65	-6.72
Argyll & Bute	-257.04	30.80	-8.35	-117.77	21.70	-5.43
Clackmannanshire	-94.24	21.09	-4.47	-114.39	21.49	-5.32
Dumfries and Galloway	-88.78	24.88	-3.57	-129.31	21.11	-6.12
Dundee City	-58.64	7.54	-7.78	-18.63	7.52	-2.48
East Ayrshire	-98.05	26.81	-3.66	-132.85	22.23	-5.98
East Dunbartonshire	-91.07	14.22	-6.40	-144.84	12.69	-11.41
East Lothian	75.45	14.84	5.08	2.72	20.74	0.13
East Renfrewshire	13.81	19.36	0.71	-43.94	9.41	-4.67
Edinburgh, City of	-34.29	4.99	-6.87	-11.03	6.22	-1.77
Eilean Siar	-304.65	27.06	-11.26	-147.69	22.20	-6.65
Falkirk	-200.58	25.48	-7.87	-154.45	21.09	-7.32
Fife	-111.35	24.30	-4.58	-144.48	21.08	-6.86
Glasgow City						
Highland	-189.73	26.82	-7.07	-155.30	20.86	-7.44
Inverclyde	-98.13	17.67	-5.55	-108.76	18.98	-5.73
Midlothian	-113.52	21.85	-5.20	-186.95	21.24	-8.80
Moray	-154.93	25.78	-6.01	-140.41	23.37	-6.01
North Ayrshire	-137.06	23.37	-5.86	-121.65	20.74	-5.87
North Lanarkshire	-65.69	7.82	-8.40	-158.25	11.25	-14.06
Orkney Islands	-247.37	34.43	-7.19	-129.29	21.74	-5.95
Perth & Kinross	-145.36	24.33	-5.98	-121.53	22.18	-5.48
Renfrewshire	-112.90	5.65	-20.00	-72.55	6.07	-11.94
Scottish Borders	-151.46	27.92	-5.43	-162.22	22.60	-7.18
Shetland Islands	-188.25	28.99	-6.49	-151.14	22.31	-6.78
South Ayrshire	-148.21	25.66	-5.78	-111.46	21.36	-5.22
South Lanarkshire	-108.68	13.95	-7.79	-112.96	16.30	-6.93
Stirling	-78.47	27.15	-2.89	-144.67	21.17	-6.83
West Dunbartonshire	-54.06	10.67	-5.06	-75.18	14.91	-5.04
West Lothian	-77.90	25.32	-3.08	-129.30	20.89	-6.19
Constant	370.77	57.27	6.47	396.61	45.35	8.75
Sample size		906			991	
R-squared		0.177			0.104	
F-statistic on instruments (F2,n)		5.38			8.43	