DYNAMIC GENERAL EQUILIBRIUM TAX MODELLING: A STUDY OF THE UK IN THE 1980'S

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ABSTRACT

This study develops a dynamic general equilibrium tax model to gauge the incidence and growth effects of the 1980s major UK tax policy changes. The model focuses on forward-looking investment decisions and adjustment dynamics, on intertemporal consumption decisions, on endogenous financial capital decisions and on the influence of international financial capital flows. The model permits a satisfactory assessments of short-run effects of tax policy on assets values as well as long-term impacts on capital accumulation.

Simulation results suggest that the major UK tax policy changes would generate capital accumulation but yield large windfall to shareholders. It is observed that in the long run the reform would increase aggregate investment by about 7.6 per cent.

Simulation results indicate that the announcement of the UK tax reform hastens the gains to be achieved in terms of capital formation and real incomes. Results from this experiment reveal that in the short run total investment increases by around 9.2 per cent compared with an increase of approximately 5.5 per cent in the unannounced policy case in the corresponding period.

Simulation results also suggest that the endogenous adjustment of the financial structure will allow us to predict the response of investment to changes in the taxes that affect the relative attractiveness of debt finance and retention. Simulation results indicate significant changes in debt-equity ratios as a response to tax changes and thus changes in the cost of finance.

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CHAPTER 1 INTRODUCTION

The purpose of this study is to gauge the incidence and growth effects of the 1980s major UK tax policy changes. Major tax policy changes such as the recent UK tax reform can produce substantial alterations in the rate of accumulation and the allocation of capital among sectors and types of assets. To capture these alterations requires a comprehensive account of intra- and intertemporal aspects of decision-making. We therefore develop a dynamic model of the UK economy in order to evaluate the tax reform. The model focuses on forward-looking investment decisions and adjustment dynamics, on intertemporal consumption decisions, on endogenous financial decisions, and on the influence of international financial capital flows.

Economists long ago recognised that in order to evaluate the effects of changing a major tax, important economy-wide effects must be taken into account, and thus built models based on the well-known Arrow-Debreu (general equilibrium) model to provide quantitative measurement of general equilibrium impacts of taxes. General equilibrium analysis of taxation started with Harberger's model (Harberger 1962) and was implemented subsequently on a large scale by Shoven and Whalley (1972) and others. These traditional applied general equilibrium tax models shed light on the allocative and incidence effects of taxes. However, it has been recognised that the models' main purposes were limited to the allocation of a fixed stock of the capital factor with its perfect mobility across sectors. In other words, the traditional model does not incorporate time and adjustment dynamics. In these models, policy shocks cause the fixed economy-wide capital stock to be immediately reallocated across industries so that the rental rate of capital is equalized across all industries. This gives rise to a question of the relevance of the standard comparative static applied general equilibrium tax models in analyzing intertemporal distortions of taxes and the capitalization effects of tax changes.

Savings and investment are essentially intertemporal decisions and hence tax policy impacts on saving and investment cannot be properly assessed in essentially static standard tax models. Instantaneous adjustment makes it impossible to capture capitalization effects that are central to tax incidence. This is because immediate equalization of the rate of returns across industries implies that the tax reform might have the same effect on investors in the taxed sector and in other sectors. It would be argued that in reality capital is not perfectly mobile and thus increases in capital taxes in a given sector particularly reduce the prospective profitability of capital in that sector and disproportionately lower its market value. (See Goulder and Summers 1989).

More recent works incorporate the features to which the static models have paid little attention. The new models include forward-looking behaviour under the specification of perfect-foresight expectations. Following the work of Hayashi (1982) they in general tend to use q-theory type of investment functions. Q-theory offers several attractions for tax policy analysis. The first is that it links the real sector with the financial sector. Financial assets can be introduced and they can be interpreted as claims on physical capital. This permits us to estimate the effects of tax policies on investment by assessing their impact on firms' values. The second is to capture the capitalization effects of tax changes through asset valuations.

Hence, this approach provides a more satisfactory basis for estimating the short-run impacts, growth effects, incidence effects and welfare effects of tax policy. It has been shown that works that ignore the transition path and do not treat adjustment dynamics would overstate the welfare gains of tax reform. New studies found that capital immobilities would result in significant capitalization effects rather than efficiency effects. Hence, asset prices rather than intersectoral capital allocation absorb short-run adjustments to policy changes.

The new approach also enables us to make useful distinctions between savings incentives (for example, corporate income tax) and investment incentives (for example, changes in depreciation rules) and between announced policies and surprise policies. Auerbach and Kotlikoff (1987) and Goulder and Summers (1989) showed that investment incentives would yield significant increases in investment without conferring windfall gains to existing capital owners whereas savings incentives would yield large windfalls to shareholders while providing only modest investment stimulus. As for policy prediction effects, it was shown that announced policies would generate significant short-run effects without changing long-term impacts on capital accumulation.

However, it appears that new models tend to disregard the financial effects of tax policies. In the context of static models, work done by Slemrod (1983, 1985), Fullerton and Gordon (1983) and Galper, Lucke and Toder (1988) showed the importance of incorporating endogenous financial behaviour. However, difficulties encountered in incorporating uncertainty into intertemporal models led dynamic model builders to specify exogenous financial behaviour. Osterberg (1989) pointed out that debt-equity ratios can be optimally determined by agency cost of debt together with tax rates favouring debt. Osterberg also modified q-ratios so as to take account of financial structure. The endogenous adjustment of financial structure is shown to create real effects. Therefore we attempt to incorporate endogenous choice of debt-equity ratio, as suggested by Osterberg, to capture the financial effects of taxes. This permits us analyze adequately the effects of policies that introduce a wedge between debt finance and retained earnings. A tax-induced change in this wedge would then affect decisions as to how investment is financed. In turn, this would affect firms' cost of capital. As a result, the tax-induced change would result in real effects through changes in the cost of capital. Also, changes in debt-equity ratios imply wealth effects. The wealth effects represents distributional effects.

Although there is a growing interest in the mobility of capital across countries, dynamic applied general equilibrium models seem to be slow to respond to this interest. Theoretical analysis has demonstrated that international capital mobility may substantially influence the impact of tax policies. However, theoretical works have paid little attention to international taxation practice. Recently, Bovenberg (1986, 1989); Frenkel, Razin and Sadka (1991); Sinn (1987); Slemrod (1988) elaborated the influence of international capital flows under international taxation rules. Recently, Goulder and Eichengreen (1989) and Perrauddin and Pujol (1991) have included international financial capital flows in dynamic applied general equilibrium models. Goulder and Eichengreen's work showed that, in the presence of international capital mobility, saving- and investment-promoting policies differ significantly in the effects on net trade and on capital accumulation. Perrauddin and Pujol stressed the influence of the terms of trade effects on welfare and indicated the influence of international financial capital flows on growth. We also introduce endogenous international financial capital flows in our model.

Differences in after-tax interest rates between the United Kingdom and the rest of the world induce financial capital flows. Initial debt stock is taken as zero which has the effect of constraining long-run effects to zero. Hence we concentrate on the short-run effects of capital flows on the terms of trade, domestic saving and investment, and trade balance.

The study develops a dynamic general equilibrium model of the UK economy to study the incidence and growth effects of the 1980 major tax changes, by extending the dynamic general equilibrium tax model developed by Goulder and Summers (1989) in two ways; endogenous financial behaviour in the context of optimal debt-equity ratio choices is included; and a well-developed external sector is developed. The model, in essence, is based on commonly used intertemporal approach initiated by Brock and Turnovsky (1981) and Abel and Blanchard (1983). Economic behaviour of agents is derived from intertemporal optimization. Economic agents have forward-looking behaviour with perfect foresight. Households optimize intertemporal utility over an infinite horizon. Thus, saving behaviour is derived from standard microeconomic principles. Firms maximize the present value of its after-tax cash flow in a technology with adjustment costs of investment and agency costs of debt. Hence, investment demand functions are derived from the intertemporal optimizing behaviour of forward-looking firms. Also, the cost of capital is endogenously determined by optimal choices of debt-equity ratios which is determined by agency costs of debt together with tax rates favouring debt. Following the works of Hayashi (1982) and Osterberg (1989), q-theory type of investment functions are derived. Hence, our q ratios differ from those in Goulder and Summers (1989) and others; q ratios in the model are affected by the endogenous adjustment of financial structure.

Given that British product and capital markets are closely integrated with those of its neighbours, a well-developed external sector is considered to add realism to the model, which is absent in most applied dynamic general equilibrium tax models. The demand for exports and mobility of international financial capital are assumed to be imperfectly elastic.

In order to examine interindustry and intersectoral effects, the model allows for producer disaggregation. It distinguishes five industries, and take into account differences between corporate and noncorporate sectors. The model simplifies the household sector by specifying them as an aggregate household. The model incorporates each of the major taxes in the United Kingdom.

In this study we employ the model to simulate the effects of the major UK tax policy changes to have taken place during the 1980s. Our results reveal that saving-promoting policies (the personal and corporate income tax cuts) outweigh the negative effects of the write-off (first year and initial) depreciation allowances elimination. Our experiments with the UK major tax policy changes in the 1980s suggest that the increase in investment in the long run could be approximately 7.6 per cent above the base case steady-state value.

We observe that differences across industries appear to be negligible. All industries gain from the overall tax policy changes almost at the same extent. As residential sector, the housing sector, largely benefit from the VAT rate rise, non-residential sectors largely benefit from the personal and corporate tax cuts. When policies are considered separately, simulation results indicate significant differences across sectors in the effects of various tax policy changes. Industry effects are significant especially between residential and non-residential sectors. Policy changes, in general, cause adverse consequences for the housing sector, particularly in the short run. These different effects are largely attributable to the existence of costs of adjustment. Adjustment costs to investment greatly reduce the immediate sharing of policy benefits and losses. For example, while the elimination of write-off capital allowances decreases in investment in most sectors, investment in the housing sector rises by 8.2 per cent. But over the longer term investment in the housing sector declines by 0.4 per cent below the base case steady-state value.

Simulation results from the announced policy experiment cast light on the importance of incorporating forward-looking investment behaviour. In the short-run total investment increases by approximately 9.2 per cent as compared with 5.5 per cent in the announced policy scenario

Simulation results also suggest that models which ignore the endogenous adjustment of the financial structure will systematically err in predicting the response of investment to changes in the taxes that affect the relative attractiveness of debt finance and retention. In sensitivity analysis, we observe that alternative specification of agency costs of debt generates different investment levels, implying that opportunities in adjusting financial structure yield real effect. Simulation results indicate that companies respond to the reduced attractiveness of debt finance by shifting from debt finance to retention.

The results of the simulation experiments with international financial capital mobility suggest that the short run effects of tax policies from differ the long-run outcomes.

The remainder of this study is organized as follows. Chapter 2 discusses the major aspects of the UK tax system and the major tax policy changes to have taken place in the 1980s. Chapter 3 reviews the literature on applied dynamic general equilibrium tax models. Chapter 4 describe the structure of the model. Chapter 5 focuses on model implementation issues. The chapter describes the model's data sources, parameterization methods and solution methods. Chapter 6 reports and analyzes results from policy simulations. Finally, chapter 7 summarizes the results in the study and provides some concluding remarks.

CHAPTER 2 LITERATURE SURVEY

2.1 INTRODUCTION

The incidence and allocation effects of tax changes have long been a principal concern of both policy makers and public finance economists. They were first analyzed in the context of 'partial equilibrium'. Partial equilibrium allow for highly disaggregated analysis at the cost of not considering market interactions. The second approach is 'macroeconomics' which allows for market interactions in the context of aggregated models. As an alternative, the third approach is 'general equilibrium'. General equilibrium approach allows for both disaggregated analysis and full consideration of market interactions. However, unlike partial and macroeconomic analysis, general equilibrium fails, in general, to produce clear-cut quantitative and qualitative comparative statics results. This is due to the complexity and dimensionality added to afford full-market feedbacks in a disaggregated setting. In this chapter we will survey general equilibrium models, in particular, the applied model.

Since Arrow-Debreu proved the existence of the general equilibrium, formalised by Leon Walras a long time ago, 'applied general equilibrium, AGE, models' have been used by many economists. The AGE model for tax policy evaluation was first done by Arnold Harberger in the late 1950s. The Harberger approach enabled general equilibrium effects of taxes to be quantified in the structure of a series of differential equations with two sectors, two factors and two goods. However, Harberger's analyses have their own shortcomings. In particular, the Harberger model quickly becomes intractable in dealing with more than two sectors or two factors. Also, the model is not suitable for considering large policy changes.

The work of Scarf (1967) which develops a reliable algorithm to compute equilibrium prices for an Arrow-Debreu economy give rise to the emergence of 'computable general equilibrium, CGE, models'. CGE models that rely on computational techniques enable one to analyze economies with many more sectors, goods, and factors. Furthermore, with the computational approach, the modeller does not have to be confined to small changes in parameters as with an analytic approach. As CGE keeps the desirable features of analytic general equilibrium, it is based on the use of flexible numeric -as opposed to analytic- techniques to obtain clear unambiguous comparative results.

Shoven and Whalley (1972) and subsequently several others[1] used CGE models to investigate the medium-run effects (i.e., efficiency, allocation, income distribution and so on) of tax policy changes. Early examples of CGE models are static; they do not model time and the amount of production factors are taken as fixed. This is undesirable in the sense that taxes, in general, affect savings and investment decisions leading to effects on capital accumulation which, in turn, alter the marginal productivities of both capital and labour and, thus factor returns. Fullerton et al., FSW, (1981, 1984, 1985) first considered time in a recursive equilibrium context, which permits CGE tax models to be employed to explore long-run capital accumulation and growth effects. The FSW model is dynamic only on the consumer side in which consumers face a choice between current consumption and leisure versus future consumption. The dynamics of the model are limited, however, in that future consumption is collapsed into a composite commodity. The main weaknesses of this standard CGE tax models are instantaneous adjustment and the lack of forward-looking behaviour. If capital adjusts instantaneously to changes in tax policies so that the return to capital is equalised in all sectors, then it is impossible to capture the capitalization effects that are central to tax incidence. Recently, a new generation of CGE models that are fully dynamic and incorporate adjustments and forward-looking behaviour has emerged. The new generation of CGE models have made it possible to analyze the short-, medium- and long-run effects of tax policy changes in an integrated way. Also it can be employed to study a number of issues including adjustments and capitalization effects of tax policy, announcements effects and permanent-temporary policy issues. Major developments in dynamic computable general equilibrium (DCGE) tax models have been done by Auerbach and Kotlikoff (987); Goulder and Summers (1989); Pereira (988a, 1988b) and Perraudin and Pujol (1991).

[1]Whalley (1988) surveys recent CGE tax models. CGE model application is not confined to tax issues. Trade, development and other issues such as energy and environment have been analyzed in CGE models. De Melo and Robinson (1989) provides recent trade and development models for developing countries. Also, constructive financial CGE models recently gain importance. Robinson (1991) reviews this issue.

In this section, we will overview DCGE tax models in great detail. Since DCGE tax models keeps the features of the previous CGE models, literature survey opens with a brief overview of 'non-dynamic' CGE models.

2.1.1 Brief Overview of 'Non-dynamic' General Equilibrium Models

The history of developments in general equilibrium model can be started with the Leon Walras' formulation of a general equilibrium. In the 1950s Arrow-Debreu proved the existence of Walrasian general equilibrium. After Arrow-Debreu's proof it was possible to convert the Walrasian general equilibrium structure from an abstract representation of an economy into realistic models of actual economies. The idea of using these models is to evaluate policy options by specifying production and demand parameters and defining equilibrium conditions and incorporating data reflective of real economies.

Arnold Harberger (1962, 1966) first introduced a general equilibrium model of taxation three decades ago. Harberger's model was designed to examine the interindustry distortion from the corporate income tax. He assigned industries to the corporate and non-corporate sectors based on whether they were 'heavily' or 'lightly' taxed. Each sector produces a single output in perfect competition using homogeneous, perfectly mobile labour and capital, the supplies of which were fixed in the aggregate. Harberger's results on the burden of the corporate income tax depended on 'factor substitution effect', and 'output effect'. The first effect was due to the fact that the corporate income tax was viewed as a differential tax on capital income only. The second, referred to as the effect on the demand for the output of industry where a factor of production is being taxed, resulted from the fact that each sector's output could have a different price elasticity of demand, and each output could have different factor intensities. However, since there was only one consumer, using Mieszkowski's (1967) terminology there was no 'demand effect'. The solution technique involved total differentiation, so that, technically speaking, the model was appropriate only for small changes in the tax code.

The work of Herbert E. Scarf and Harold W. Kuhn in the middle to late 1960s provided a reliable algorithm for computing equilibrium prices for an Arrow-Debreu economy. The algorithm used simplicial subdivision techniques and can be shown to be the computational analog of the fixed point theorems previously used to prove the existence of equilibrium. With this computational technique that could solve much more disaggregated versions of the Harberger model, Shoven and Whalley (1972, 1973) first examined large changes in the corporate tax rate.

Their model has several industrial sector, in which fully mobile and homogeneous labour and capital are used in production in a cost minimising combination with a zero profit condition as a result of constant returns to scale assumption. There are several household groups, defined by income, that are endowed with labour and capital in varying amounts. These groups also derive income from government transfers. Households allocate their income across consumption goods according to principles of budget-constrained utility maximisation. There are usually ad valorem taxes on incomes, factors, and outputs, and these enter into the appropriate production and consumption decisions. Equilibrium is reached when demand and supply are equal for all goods and factors. The model is based on social accounting matrix, SAM, approach, in that data are arranged in a SAM. The model's specification and calibration are checked by solving it in the presence of the base set of taxes. The result should be exactly the initial SAM. Then the model was used to solve for a counterfactual equilibrium in the presence of a new tax design, which gives again a SAM. The equilibria were compared in order to assess the impact of the new tax plan.

Examples of this type of modelling, surveyed in Shoven and Whalley (1984) and Fullerton, Henderson and Shoven (1984), can be given as, with differences in many aspects, Keller (1980) for Holland, Piggott-Whalley (1985) for U.K., Serra-Punche (1984) for Mexico, Slemrod (1893) for U.S., and Whalley (1975) for U.K..

These models are static in that aggregate supplies of productive factors, especially capital, are taken as fixed. If the capital intensity of the economy is fixed, many tax reform issues, such as corporate tax integration, effects of investment tax credits, effects of accelerated depreciations, consumer or expenditure taxes and importance of saving subsidies, etc., can not be examined satisfactorily. In essence, the capital accumulation and capital reallocation take time and may involve adjustment costs. Because of these issues, FSW took the first steps towards developing a dynamic model. FSW built a model to solve for a time sequence.

The dynamic feature of the FSW model is that consumers face a choice between consumption and leisure future consumption (which can be purchased via savings). Saving is equivalent to the purchase of a fixed-weight bundle of capital goods. To simplify the computations, these models assume that the capital stock is augmented with a one-year lag. Thus, the FSW model computes a sequence of static equilibria rather than dynamic equilibria. The production side of the model is completely static.

2.1.2 Overview of Dynamic Applied General Equilibrium Models

2.1.2.1 Modelling Economic Decisions of Agents

In the non-dynamic models, on the producer side and government side, there is no attempt for dynamic setting. Likewise, on the consumer side, the dynamics of the models are limited in that future consumption is collapsed into a composite commodity. The lack of dynamic properties of the non-dynamic model was first elaborated on the consumer side by Ballard (1983), and Auerbach and Kotlikoff (1983, 1984). Household behaviour is determined by maximisation of an additively separable, time invariant intertemporal utility function under an intertemporal budget constraint which equalises the present value of consumers' income and expenditure. Hence, consumers have the flexibility to plan for varying amounts of consumption in different future periods. This is in contrast to the FSW model, where consumers must plan for a constant level of consumption in all future periods. These new models also allow each consumer's planned allocations of consumption over time to be based on expected lifetime income, rather than on current income alone. In the FSW model, tax policy affected consumption-savings choices by influencing the expected relative prices of present and future consumption and by influencing current income. With these new models, policy changes can influence the consumption-savings decision not only through these channels but also through effects on expected future incomes.

In general, the recent models adopt the main framework of dynamic specification of household behaviour done by Ballard (1983), and Auerbach and Kotlikoff (1983). Since the main motives to save are to finance future consumption, and inter-generational altruism, the consumer's behaviour is modelled in a way that the motives to save are captured. In these models, each generation decides on its consumption and saving allocation for its entire lifetime. Each of them has 55 age cohorts simultaneously alive. Also, in Ballard (1983) and Ballard and Goulder (1985), consumers derive utility directly from bequeathing part of their wealth. The difference between models lies on the specification of budget constraint, introduction of inter-generational setting whether or not with bequest motives and allocation of savings. In Bovenberg (1985, 1986, 1989), Goulder and Eichengreen (1989), Pereira (1988a, 1988b), and Perraudin and Pujol (1991), the intertemporal budget constraint is defined as a sequence of recursive equations of motion on wealth. The potential advantage of doing so is to accommodate liquidity constraints. Perraudin and Pujol introduces liquidity constraints in a way that poor households face liquidity constraints that prevent them from borrowing against their future labour income. However, it should be recognised that in the absence of liquidity constraints, the two specifications of the household intertemporal budget constraint are essentially equivalent.

Depending on whether financial assets are introduced or not, allocation of saving should be under consideration. If there is only one consumer and one financial asset besides physical capital, allocation of saving is a straightforward issue. This type of models, used by Auerbach and Kotlikoff, and Feltenstein (1984, 1986), enable one to analyze crowding-out effects of tax changes. Having financial assets such as private bonds and equity into model involves tying physical capital to firms, and thereby allocating savings into the financial assets. This allocation of savings has been done endogenously by Feltenstein, Goulder and Summers, and Pereira under exogenous financial behaviour. Obviously, this is not an optimal allocation. An exceptional work in this area is done by Goulder and Eichengreen. Under certainty conditions, they

Table 1

Dynamic applied general equilibrium models

CAPABILITIES

	Horizon	Efficiency Effects: Inter-generational	Efficiency Effects: Intertemporal Savings	Efficiency Effects: Intertemporal Inter-sectoral	Capital intensity decisions	Financial dec. Debt/ Equity
Auerbach-Kotlikoff (1987)	Infinite	Yes	Optimal	1 Sector	Optimal	No
Ballard-Goulder (1985)	Infinite	No	Optimal	19 Sectors	Not	No
Bovenberg (1985,1986)	Infinite	No	Optimal	2 Sectors	Optimal	No
Erlich et al. (1987)		No	Optimal	24 Sectors	Not	No
Feltenstein (1986)	Two years	No	Optimal	30 Sectors	Not	No
Goulder-Eichengreen (1989)	Infinite	No	Optimal	9 Sectors	Optimal	Exogenous
Goulder-Summers (1989)	Infinite	No	Optimal	5 Sectors	Optimal	Exogenous
Jorgenson-Yun (1990)	Infinite	No	Optimal	1 Sector	Optimal	No
Pereira (1988)	Finite	No	Optimal	4 Sectors	Optimal	Exogenous
Perraudin-Pujol (1991)	Infinite	Yes	Optimal	3 Sectors	Optimal	No

Table 1. (continued)

	CAPABILITIES					
	Financial Effects					
	Dividend/ Retention	Portfolio Selection	Liquidity constraint	Crowding-out effects	Capital flows	Private fin. Asset
Auerbach-Kotlikoff (1987)	No	No	No	Yes	Closed economy	No private fin. assets
Ballard-Goulder (1985)	No	No	No	No	No	No
Bovenberg (1985,1986)	No	Non-optimal	No	No	Yes	No private fin. assets
Erlich et al. (1987)	No	Non-optimal	No	No	Yes	No private fin. assets
Feltenstein (1986)	No	Non-optimal	No	Yes	No	No private fin. assets
Goulder-Eichengreen (1989)	Exogenous	Optimal	No	No	No	Domestic and foreign equities and bonds
Goulder-Summers (1989)	Exogenous	Non-optimal	No	No	No	Equity and bond
Jorgenson-Yun (1990)	No	No	No	No	Closed economy	No private fin. assets
Pereira (1988)	Exogenous	Non-optimal	No	Yes	Closed economy	Equity, and bond
Perraudin-Pujol (1991)	No	Non-optimal	Yes	Yes	Yes	No private fin. assets

Table 1. (continued)

	CAPABILITIES					FUNCTIONAL FORMS
	Labour supply decisions	Government expenditures	Product different. in imports	Endogenous terms of trade effect	Trade balance	Consumption function
Auerbach-Kotlikoff (1987)	Endogenous	Exogenous	Closed economy	Closed economy	Closed economy	CES
Ballard-Goulder (1985)	Endogenous	Exogenous	Yes	Yes	Balanced trade	Stone-Geary
Bovenberg (1985,1986)	Exogenous	Exogenous	Yes	Yes	Two country model	CES
Erlich et al. (1987)	Exogenous	Exogenous	No	No	Interna. trade welfare func.	Stone-Geary
Feltenstein (1986)	Endogenous	Exogenous	Yes	No	Foreign cons. specification	Two period
Goulder-Eichengreen (1989)	Exogenous	Endogenous Composition	Yes	Yes	Two country model	CES
Goulder -Summers (1989)	Exogenous	Endogenous composition	Yes	No	Balanced trade	CES
Jorgenson -Yun (1990)	Endogenous	Exogenous	Closed economy	Closed economy	Closed economy	CES
Pereira(1988)	Endogenous	Endo. level and comp.	Closed economy	Closed economy	Closed economy	CD
Perraudin-Pujol (1991)	Endogenous	Exogenous	Yes	Yes	Semi-small economy	CES

Table 1. (continued)

	FUNCTIONAL FORMS				IMPLEMENTATION	
	Budget constraints	Production functions	Investment specification	Adjustment cost func.	Country data/year	Computation Algorithm
Auerbach-Kotlikoff (1987)	Intertemporal	CES	q-theory	Quadratic in I/K	U.S. plausible/ hypothetical	Gauss-Seidel
Ballard-Goulder (1985)	Intertemporal	CES	Exogenous	No	U.S. 1973	Fair-Taylor method (int.) Tato. (sta.)
Bovenberg (1985,1986)	Dynamic	CD	q-theory	Quadratic in I/K	U.S. plausible/ hypothetical	Dynamic vers. Jorgenson's linearisation
Erlich et al. (1987)	Intertemporal	Leontief, CD in VA	Exogenous	No	Belgium	Negishi's optimisation
Feltenstein (1986)	Two yearly constraint	Leontief, CES in VA	Exogenous	No	Australia 1981-1982	Merrill's optimisation
Goulder-Eichengreen (1989)	Dynamic	Leontief, CES in VA	q-theory	Quadratic in I/K	U.S. 1973	Fair-Taylor method (int.) Powell alg.(sta.)
Goulder-Summers (1989)	Intertemporal	Leontief, CES in VA	q-theory	Quadratic in I/K	U.S. 1973	Fair-Taylor method (int.) Powell alg.(sta.)
Jorgenson-Yun (1990)	Intertemporal	Dual translog price func.	Neoclassical	No	U.S. 1955-1980	Econometric estimation
Pereira (1988)	Dynamic	Leontief, CD in VA	Neoclassical	Quadratic in I	U.S. 1973	NPSOL optimisation algorithm
Perraudin-Pujol (1991)	Dynamic	CES	q-theory	Quadratic in I/K	France plausible/ hypothetical	Gauss-Seidel

Table 1. (continued)

	IMPLEMENTATION **Policy issues**
Auerbach-Kotlikoff (1987)	Consumption tax, capital income versus wage income taxation, effects of taxation on capital formation, dynamic fiscal policy issues and effects of government deficits.
Ballard-Goulder (1985)	Effects of the adoptation of a pure consumption tax, importance of consumers' foresight in terms of welfare.
Bovenberg (1985,1986)	Effects of pure consumption taxation, capital income taxation in open economy.
Erlich et al. (1987)	Real wage policies in Belgium.
Feltenstein (1986)	Financial crowding-out in Australia.
Goulder-Eichengreen (1989)	Saving and investment incentives policies in open economy.
Goulder-Summers (1989)	Corporate tax cut, reduced investment tax credit and announcement effects of these policies.
Jorgenson-Yun (1990)	Effects of several programs of tax reform on the allocation of capital.
Pereira (1988)	Corporate tax integration, effects of re-introducing investment tax credit.
Perraudin-Pujol (1991)	Consumption tax, capital income versus wage income taxation, influential role of government debt stocks, terms of trade effects and tax evaluation, capital flows.

allocate savings between domestic and foreign assets. They posit a portfolio preference function that is consistent with the observed home-country preference can be embedded within a utility maximizing framework that allows households to adjust asset shares in accordance with differences in rates of return.

The framework of the standard general equilibrium models that capital is homogeneous mobile across industries, and fixed in total supply was less helpful in analyzing tax incidence, particularly over time. Because in the real world, capital is industry-specific factor and thereby becomes imperfectly mobile between industries. Capital could increase in an industry only as a result of investment being greater than depreciation and could not be physically moved from one industry to another. Fullerton (1983) analyzed the effects of imperfectly mobile capital in a model with constraints limiting the scope of capital adjustment in each industry within a given time interval.

Given the fact that in the real world investments are irreversible, and there are installation costs of capital when adjusting capital toward its optimal level, the shortcomings of the Fullerton's analysis are obvious in that forward-looking investment behaviour and adjustment costs are lacking. For example, the fact of irreversible investment decisions is clearly going to affect a firm's attitude to the future, taking great care to avoid mistakes. A profit-maximising firm will have to consider the expected profitability of potential new capital goods over the whole of their lifetime if, once purchased, they cannot be resold. A particular worry will be the possibility of a fall in demand at some future date leaving the firm with a lot of expensive new equipment and little demand for the potential product of this new capacity. Adjustment costs have also an importance on investment decisions, in that capital is a quasi-fixed factor; it can be changed but only if the firm is prepared to bear an adjustment cost. On the other hand, with adjustment costs, optimal profits will, in general, be non-zero even with constant returns to scale technology. Hence, the intertemporal output path for the firm is endogenously, optimally, and uniquely determined.

In the DCGE tax models firms maximise either their market value as the present discounted value of the future stream of dividends or the present discounted value of net cash flow. In the first specification, dynamic production and investment behaviour are linked to Tobin's q theory. This maximisation is constrained by the adjustment-cost technology and equation of motion describing the motion of the capital stock.

In most non-dynamic models, the authors have assumed that the government budget is in balance. In particular, a balanced budget is a necessary assumption in a model without paper assets, due to the fact that deficits must be financed by an increase in government securities or by money creation. On the other hand, even if paper assets exist, there is no need to specify government budget deficit. The reason is that general equilibrium models provide a solution for relative prices, and thus allocation of resources depends only on relative prices, and not on absolute prices. However, since the tax systems are generally non-neutral with respect to inflation, and policies that affect absolute prices have allocational impacts.

Hence, allowing government to run deficits that creates crowding-out effects would be considered as another area which causes non-optimality of resource allocation, to be modelled. Auerbach and Kotlikoff (1983, 1987), Feltenstein (1984, 1986) and Perraudin and Pujol (1991) modelled the economy with government budget deficits. In the Auerbach and Kotlikoff deficits are financed by an issuance of government bond. Feltenstein included money into his model and hence financed deficits with a mix of creation of money and issuance of bond. Clearly, the specification of government budget constraint with deficits requires a dynamic setting. Because at the end, government debt should be repaid to the household sector, and considerable by an increase in taxes and/or a reduction in spending but not again borrowing. With this fact, Auerbach and Kotlikoff, and Perraudin and Pujol specified an intertemporal government budget constraint. Feltenstein did not consider the future repayment of public debt, that is that government is not subject to any intertemporal constraint, which is, in a sense, an ad-hoc specification. In Pereira (1988a, 1988b), a sequence of recursive equations of motion reflecting the evolution of the public debt, allowing for government budget imbalances in which liquidity constraints on government borrowing can be implemented was used.

From the fact that government behaviour is constrained by balanced budget, either the level of government spending or tax revenues can be determined endogenously within the model as long as specifying one of them exogenously. In general, tax parameters are given, therefore the amount of government revenue can be calculated, in turn, the level of government spending is determined endogenously. However, in order to determine the level of government expenditure optimally, the model needs specifying a social welfare function which would be, as adopted in the literature, over indirect utility function of households, as more theoretical way. This type of treatment of government behaviour has been done in static CGE models by few modellers. In most of CGE tax models, the level of government expenditure are determined only endogenously but not optimally. However, the composition of public expenditures is often optimally determined, giving the government a utility function, and keeping utility as constant when replication analysis is done, in Ballard et al. (1985), Erlich et al. (1987), and Goulder and Summers (1989).

Only Pereira (1988a, 1988b) attempts to address both the incorporation of deficits and the determination of government expenditures. The path of government expenditures and deficits/surpluses (and therefore the path for debt) are endogenously and optimally determined, with a social welfare function over the domain of an aggregate public good. Such public good is assumed to be produced using capital, labour, and intermediate inputs according to a well behaved production function. Pereira states that this optimisation objective is consistent with a modelling of consumer behaviour in which the public good does not enter the set of budget constraints and is not a decision variable. He adds that this is equivalent to having the public good enter additively in time t to the private functions. Thus the marginal rates of substitution between private goods do not depend on the level of availability of public good. The government is then assumed to act emphatically with the private consumers according to a constrained social utility maximising problem.

In the tradition of CGE modelling, the emphasis on external side is given to commodity flows between countries rather than capital flows. No model include flows of international reserves or a role for monetary policy. Within the area of commodity flows, most of the open economy models (e.g.. Ballard (1983) and Ballard and Goulder (1985)) follow the assumptions of balanced trade, with import and export net demands characterised by constant elasticities along the lines of Ballard et al. (1985); hereafter, BFSW (1985). In the models, a common approach is to use the so-called 'Armington' formulation which treats similar products produced in different countries as different goods. Among other reasons, the Armington formulation is usually adopted in order to accommodate the phenomenon of countries both importing and exporting the same good (cross hauling).

Among the CGE tax models, Goulder et al. (1983) first attempted to incorporate the international capital flows, allowing a foreign consumer who is endowed with large quantities of those commodities that the United States imports, and with a large amount of capital services rent some of his endowment to be used in U.S. production if the U.S. rental price of capital increases above the benchmark level (capital inflow). On the other hand, if the U.S. rental price of capital were to fall below the benchmark level, the foreigner would rent U.S. capital for his foreign consumption (capital outflow). They also attempted to model direct foreign investment, allowing the foreigners to purchase capital goods instead of renting them.

In Feltenstein (1984, 1986), international financial flows are introduced by adding foreign bond. The rest of the world is treated as an additional consumer group endowed with financial assets, money and bonds. Both foreign and home consumer groups demand these financial assets. Bovenberg (1986, 1989) develops a model in which two economies are considered, each following intertemporal perfect-foresight paths. These economies meet in the international forum. His papers continue the work on two country model in Goulder et al. (1983) but differ from their study in several important respects. Most importantly on contrary to this previous study, his papers explicitly distinguish between the mobility of financial capital and the mobility of physical capital. The framework developed by Bovenberg also adds to Goulder et al. (1983) by modelling production both at home and abroad. This allows international capital flows to affect the productivity of capital in both parts of the world.

Among the new generation of DCGE tax models, only Erlich et al. (1987) incorporated the international capital flows in the context that foreign trade is generated according to an intertemporal trade welfare function with constant import and export elasticities. In the short run the model allows international trade imbalances, which generate capital flows to the domestic households. In the long run, however, trade balance is assumed.

The aspects of non-dynamic general equilibrium tax models have highlighted their use in studying intersectoral distortions. The new generation of dynamic CGE tax models added studying intertemporal distortions. Models with financial behaviour may be used for analyzing three additional distortions caused by personal and corporate income taxes. These are inefficiencies in portfolio allocation, in the choice between debt and equity finance, and in dividend payout rates. Given that countries experience large government deficits, current account trade imbalances, and sizeable accumulated foreign debt, the inclusion of these features in policy models requires an explicit treatment of financial assets.

Mainly the new generation of DCGE tax models devoted attention to the real side of the economy. Auerbach and Kotlikoff (1983, 1987) allow for government debt thereby introducing government budget deficit into their model. Feltenstein (1984, 1986) also allows for government debt, adding money in a way that it is demanded by consumers for transaction motives and exogenously given fraction as a store of value, as well. In these models savings finances changes in government debt and physical capital. Private and public assets are perceived by the households as perfect substitutes. The allocation of savings merely adjusts to the relative demands for funds.

Goulder and Summers (1989) and Pereira (1988a, 1988b) introduce a whole menu of financial assets as well as firm-specific equity capital. Pereira also allows for government bond. The treatment of the rate of return of assets are different, in that assets earn different rates of return in Goulder and Summers whereas Pereira model assets are seen as to be expected to yield the same rate of return and therefore are perceived as perfect substitutes. However, in Goulder and Summers, such rates are equal up to constant and exogenous sector-specific risk premiums. Hence, the different asset types allow consideration of debt/equity and dividend/retention rules and therefore several sources of investment financing; bonds, equity, and retained earnings.

Although a few of DCGE tax models, in particular, Goulder and Summers, and Pereira (1988a, 1988b) introduce endogenous financial behaviour, the decisions on financial assets, the allocation of savings, investment financing and government debt path, are not optimally determined. Only, Pereira(1988a, 1988b) determines government debt path optimally. In order to determine endogenous portfolio selection of households the model requires a treatment of uncertainty. Slemrod (1985) has attempted to incorporate modern portfolio behaviour on the part of consumers, while Fullerton and Gordon (1983) have capital intensity and optimal financial decisions jointly determined through a two-stage process.

As stated before, virtually all the surveyed models are based on Walrasian market-clearing assumptions, perfectly competitive markets and atomistic competition among agents. Almost, none of the surveyed models consider Keynesian economic issues, such as market disequilibria or price stickiness. The only exception is Erlich et al. (1987)'s treatment of rigidity of wage rate in the short-run leading to a disequilibrium in the labour market and thereby generating an endogenous unemployment in the short-run.

Since given the dynamic nature of the economy's behaviour, market-clearing prices in each period depend on expectations of future prices and tax variables, the importance of expectations in effecting policy outcomes turns out to be obvious. Expectations affect short-run stabilisation policy outcomes, as mostly have focused on, and also long-run policy outcomes, capital accumulation and welfare effects, as worked on by Ballard (1987). Moreover, expectations lead to implications on type of equilibrium and computation of models. In the surveyed models, modellers adopt three different approaches to expectations. With the first approach, the researcher assumes that it depends only on previous or current prices and not on any prices to be realised in the future. Both myopic expectations (where only current prices determine expectations and influence behaviour) and adaptive expectations (where previous prices also enter in) are consistent with this approach. CGE models adopting this approach include FSW (1983) with myopic expectation assumption and Ballard (1987) and Pereira (1988a, 1988b) as a comparison.

The second, popular, approach assumes perfect foresight on the part of key economic agents. Some of them are Auerbach and Kotlikoff (1987), and Goulder and Summers (1989). The third approach considers a flexible amount of foresight in terms of years over which price movements are foreseen. Pereira's model (1988a, 1988b) is an example of this approach, and also includes a wide range of expectation rules.

The choice of one of these approaches is ultimately made on philosophic grounds. In terms of equilibrium, these approaches imply two concepts of equilibrium, perfect-foresight and temporary equilibrium (in the case of non-perfect expectations). In what follows, the concepts of equilibrium have different implications. The dimensionality of the equilibrium solution algorithm with perfect-foresight grows and becomes the number of periods times the number of markets whereas a temporary equilibrium requires dimension as much as the number of markets, in each year.

2.1.2.2 Implementing Dynamic Applied General Equilibrium Tax Analysis

The technical aspects of operating applied general equilibrium models are parameterisation procedure, solution methods, and measurement of efficiency and distributional gains.

In order to find values of parameters, having the fact that the size of models and their integrated structure make it impossible to simultaneously estimate all parameter values using conventional simultaneous equation econometric techniques, pointed out by Mansur-Whalley (1984), the so-called, non-stochastic, 'calibration method' has been mainly used. With this fact, only one year's data suffice to carry out parameterisation procedure.

Two calibration approaches have been used in the literature. The first approach is referred to as 'quantitative approach`'. With this approach, calibration procedure must satisfy two sorts of requirements: first, replication of base-year data is required; second, in the base case, the model must generate an intertemporal balanced growth path. Accordingly, the parameterisation procedure involves selecting certain parameters, such as substitution elasticities, from outside sources and identifying remaining parameters and economic flows restrictions implied by the two requirements above, using a set data. In general, data are gathered from available sources for a particular year and are inconsistent, and therefore the data must be adjusted for consistency. In this way the model satisfy the strong assumption that the data represent an equilibrium of the economy. The consistent data set represents what is often referred to as the 'benchmark equilibrium'. The quantitative calibration approach has been adopted by Ballard (1983), Ballard and Goulder (1985), and Goulder and Summers (1989), following the practice of the FSW work.

The second approach, called as 'qualitative calibration', chooses the structural parameters exogenously so that the economy follows a reasonable path into the future. With this approach, given the recursive nature of the dynamic economy, only initial stock values are needed by the model. With initial conditions on the stocks of say, private wealth, capital and government debt, agents optimise and thereby generate a first round of net demands and equilibrium conditions. In turn, the equilibrium prices will determine the evolution of stock variables in the next period. The qualitative calibration approach has been followed by Auerbach and Kotlikoff (1983, 1987), Bovenberg (1985, 1986, 1989) and Pereira (1988a, 1988b).

Once the parameterisation procedure has been done and the data set available, the next job is to solve the model. Given the existing state of the art, there is no 'canned' program that one can use to solve all CGE models. The modeller must therefore exploit the mathematical (and economic) properties of the system in order to reduce the number of nonlinear equations that must eventually be solved. The modeller then must choose among existing algorithms of varying complexity and applicability, no one which dominates for all models. First a solution strategy should be adopted to establish numerically a set of simultaneous nonlinear functions (generally excess demand equations) whose solution will provide the equilibrium values of all the endogenous variables in the model. Then a solution algorithm (computational technique) is necessary to solve the set of simultaneous nonlinear equations numerically.

In dynamic models, there are sets of markets that must be cleared: factor markets, product markets, and asset markets. Although it is possible to attack all three sets of markets simultaneously, it is usually more efficient in computational terms to separate them. Depending on the assumptions made in the models, it would be possible to make dimensionality reduction and only some of the markets would matter. In the case of recursive dynamic general equilibrium models, with the assumptions that factors of production are fully mobile across industries, no profits occur in any of the available activities that have fixed input-output coefficients, and the demand functions are homogeneous of order zero, the product markets and asset markets are essentially substituted out and there is no need to compute excess demands for products. However, it cannot be used in such models in which some factor such as capital is fixed by sector ('putt-clay' model of capital), due to the fact that cost prices will not then be independent of production levels. It also cannot be used easily if the demands for products depends in any way on the sectoral structure of production (i.e. government tax revenues depend on the structure of production). Finally, if there are financial assets, we must take into account that asset markets generate wealth incomes to consumers.

Furthermore, in the case of perfect-foresight equilibrium, the solution strategy must extend to include intertemporal equilibrium condition. Besides within-period equilibrium, which requires that the overall demand for labour equal its supply that output demand equal supply for each sector, that firms' demands for funds (total borrowing exclusive of retained earnings) equal total household saving, and that government expenditures equal government revenues, intertemporal equilibrium condition under perfect foresight expectations requires a three-stage procedure, a base-case steady-state, a revised case steady-state, and a transition path for the economy between these two steady states.

Finally, there are a variety of solution algorithms that work directly with the various excess demand equations, using the kind of solution strategies described above. These algorithms can be divided into three types: (1) those based on fixed-point theorems (2) those based on a tatonnement process and (3) those exploiting information about the derivatives of the excess demand functions.

Algorithms based on fixed-point theorems (Scarf's simplicial search method and Merrill's grid search algorithm) are truly elegant mathematically and a major advantage of this approach is that convergence is guaranteed within a finite number of dimensions on the simplex. All the Shoven and Whalley type models and Feltenstein utilised this method.

Algorithms based on a tatonnement process simply adjust the price in each sector in response to that sector's excess demand. The Gauss-Seidel iteration procedure is a special version of tatonnoment process. In particular, in the case of Gauss-Seidel iteration, successful convergence to an equilibrium depends in principle upon judicial selection of starting values and step size. The costs of the Gauss-Seidel method depend on efficient ordering of equations into simultaneous and recursive blocks. Among the surveyed models, only Auerbach and Kotlikoff has used Gauss-Seidel method.

The third class of algorithms that deals directly with the set of algebraic excess demand equations is defined by their use of derivatives of the functions. In the case of Newton's method, the search involves a movement across the simplex in directions indicated by the local behaviour of excess demand functions at any point under consideration. Steps can be large or small and there is no guarantee that the search procedure will terminate with an equilibrium solution. A preferable algorithm has been considered by Powell as an extension of Newton. The Powell algorithm has mainly been chosen due to that it does not require the analytic specification of the derivatives of the excess demand functions. The Powell algorithm is employed by Goulder and Summers.

To solve intertemporal equilibrium, the following algorithms are used: a variant of Fair-Taylor (by Goulder and Summers), a variant of Negishi's linearisation method (by Erlich et al.) and dynamic version of Johanson's linearisation method (by Bovenberg). Fair-Taylor method is similar to Gauss-Seidel procedure in algorithmic terms. Therefore , Auerbach and Kotlikoff adopted Gauss-Seidel iteration procedure, with a different solution strategy than Goulder and Summers. With the Negishi's approach, the economic equilibrium can be generated as a solution of a mathematical program whose objective function is a weighted sum of utility functions of the various agents, while the constraint set consists of the market clearing conditions. The Johanson's linearisation method employed by Bovenberg is to reduce the CGE model to a set of log-linear equations (linear in growth rates) in all the endogenous variables. The system of linear equations can be solved by inverting the resulting matrix of coefficients, which is the simplest possible solution algorithm. Being essentially determined by the continuous time nature of the model, Bovenberg's linearisation method has the disadvantage of confining the analysis to infinitesimal changes around the base-case equilibrium. Pereira relies on an optimisation algorithm developed by Gill, et al. (1986). In this algorithm the equilibrium conditions are seen as nonlinear equality constraints in the minimisation of an artificial objective function.

Although it is the fact that without a social welfare function, it is impossible to state unambiguously that one equilibrium or a path of equilibria is better than an alternative, unless the improvement follows Pareto's law -that is, no-one is worse off. What the investigators do in the CGE models in measuring the change in economic efficiency of the welfare of a policy change is analogous to the measurement of costs and benefits in cost-benefit analysis. With a dynamic structure of the model, a dynamic path of prices and endowments is computed, and then this path is compared with the path of the economy when there is no policy change by using individual utility functions over future horizon.

For those infinite time models, with steady-state equilibrium condition, it is possible to approximate the contribution to discounted utility of these infinite streams using results from simulations over a finite time interval. To assess the welfare change implied by the adoption of a new policy, a welfare measure which is dynamic analog of the Hicksian compensating variation or equivalent variation is employed. When perfect foresight is assumed there are no difficulties associated with the use of the standard Hicksian indicators.

If expectations are not self-fulfilling, Ballard and Goulder take some steps in that direction by defining an indicator that accommodates periods in the future. However, the issue is more fundamental in the context of a general temporary equilibrium framework. In such circumstances, Pereira (1988a, 1988b) develops a dynamic generalisation of the Hicksian indicators obtained from the present discounted value of a sequence of short-run optimal expenditures functions consistent with a base-case expected future stream of utilities. No model enter the government's expenditures into this calculation. However, this is less serious owing to the equal revenue-equal expenditure constraint; that is the government has the same real resources available to it under both the old and new policy regimes. A related problem arises for the models that use an equal-yield strategy, the question is how to interpret the concept of equal-yield when the government is allowed to run deficits.

2.1.2.3 Empirical Evidence from Selected Policy Issues

Early quantitative public finance models emphasised the incidence effects of taxes in a general equilibrium framework which allows modellers to capture demand side (utility substitution and income) effects and supply side (factor substitution and output) effects of taxes, simultaneously. Recently CGE modellers incorporated other tax effects, such as capital accumulation, capitalization and financial effects. The emphasis has been extended so as to investigate the effects of taxes on savings and investment decisions of agents under closed economy assumption and open economy assumption with international capital flows as well, and with financial assets. In addition to tax effects, the new generation dynamic CGE tax models considered real and financial crowding-out effects of government debt policy.

Auerbach and Kotlikoff (1987) list key issues in the area of dynamic fiscal policy as follows: Effects of the choice of tax base on saving, welfare and efficiency gains, the impact of business tax and tax incentives on the investment behaviour, the impact of deficit finance on short- and long-term interest rates and thereby private investment (crowding out effect of government deficits), the efficiency costs of progressive taxation in comparison with the costs of proportional taxation, and announcement effects of policy changes and the role of expectations. These theoretical issues have been investigated in the examples of the integration of corporate and personal income tax, replacement of income with consumption tax, introduction of the investment tax credit, financial crowding-out effects of government deficits and announcement effects of policy changes and the role of consumer expectations.

The policy that has received the most attention from CGE modellers is the integration of the corporate and personal income tax, probably because Harberger originally examined the incidence and efficiency consequences of the corporate income tax with his two-sector model. It has long been recognised that the existence of separate taxes on corporate income and personal income may reduce the efficiency of the allocation of capital because this separate taxation is widely acknowledged to lead to a number of problems associated with the 'double' taxation of corporate income. BFSW (1985) and Pereira (1988b) provide some evidence on integration. Goulder and Summers also reports the effects of a corporate tax cut. They all use the same data of the U.S. economy for 1973. Such a complete elimination of the corporate tax and its replacement by increased personal income tax rates in the Pereira's work yields a very moderate long-run benefits which is never larger than 0.17% of the present value of future consumption and leisure. This is almost four times lower than the figure supplied by BFSW (1985) in the case of additive scaling of marginal personal income tax to maintain the assumption of equal revenue yield. It could be argued that the difference may be due to that Pereira (1988b) incorporates the distortions resulted from financial crowding-out effects of government deficits, and the existence of costs of adjustment reflecting an adjustment lag in the interindustry investment decisions and in turn restrict the mobility of capital across industries, and considers a whole set of different financial assets which allows the model to capture the fact that different assets are treated differently by the tax code both at the personal and corporate income levels and defines the financial behaviour of the firms.

However, Slemrod (1983, 1985), going further on the work of Pereira (1988a, 1988b), has modelled optimal household portfolio decisions but in a static environment and has obtained benefits from integration which are twice as large as those reported in BFSW (1985). Part of the difference has been attributed to the fact that Slemrod's model is static and labour supply is exogenous. On the other hand, by not letting the households optimally adjust their portfolio to the new conditions after integration, a source of efficiency is not accounted for. Therefore, the results in the works of BFSW and Pereira may be biased downwardly.

Fullerton and Gordon (1983) focused on financial decisions of firms, reporting efficiency gains of 0.6 per cent of GNP from the elimination of the tax distortions favouring debt. However, when they eliminate the corporate tax and replace it with increased personal income taxes, additional distortions are created in the optimal labour and leisure decisions.

The results reported in Slemrod (1983, 1985), Fullerton and Gordon (1983), and BFSW (1985) are important, but they may be severely biased. Several aspects of economic behaviour and modelling that are crucial for the study of income tax integration, such as the absence of government deficits (which creates financial crowding-out effects), the lack of forward-looking investment behaviour and the introduction of financial assets, have not been captured in any of these models.

Goulder and Summers (1989) does not provide efficiency effects of tax changes. Therefore it is not comparable to the other studies above. A corporate tax cut, from 0.46 to 0.34 in all industries, leads to simulate investment through higher q values and in turn results in steady increases in the capital stock. In the new steady state, the capital stock is above the base case value by 9.1 per cent in the case of manufacturing sector. However, short-run effects of policy changes are different depending on whether policy change is announced or surprise. In first year and fifth year, the rates of increases in the capital stock of manufacturing industry are 4.9 (9.3) per cent 6.0 (6.6) per cent respectively with surprise (announced) policy changes.

Auerbach and Kotlikoff (1987) analyses the impact on capital formation of tax reform. From their results, it could, for example, be said that the increase in the steady state value of the capital stock from switching to consumption taxation is about 25 per cent. They examine the financial crowding-out effects of government deficits on capital formation, unlike Goulder and Summers (1989). They concluded that deficit finance and government consumption can significantly crowd out capital formation. Tax cuts of short duration can lead to short-run crowding in, although substantial crowding out occurs in the long-run. Hence, short-term changes in capital formation may provide little or no guide to the ultimate impact of deficit finance. Crowding out from deficit finance is a very slow process because it results from increased consumption spending over potentially long horizons. Deficit policies that lead to a very sizeable increases in long-term interest rates may involve no change or even declines in short-term interest rates. The inclusion of adjustment costs to the life cycle model has only a trivial affect on time path of interest rates arising from a policy of deficit finance, despite its smoothing of the path of the capital stock.

Feltenstein (1986) also allows for crowding-out analysis and concludes that small increases in real government spending are found not to lead to crowding out, while an increase in the debt financed portion of the government's budget deficit does lead to crowding out.

A related topic to capital income taxation is the impact of business tax incentives on capital formation and investment. The term 'business tax incentives' is used to comprise saving incentives and investment incentives. The distinction is made such that investment incentives treat old and new capital equally. The emphasis is given to investment incentives. It may be due to the fact that saving incentives represent a shift from income to wage taxation, whereas investment incentives represent a shift from income to consumption tax which is more efficient than labour income taxes.

The well-known investment incentive, investment tax credit is addressed in Goulder and Summers (1989) and Pereira (1988b). Goulder and Summers show that eliminating the investment tax credit causes a reduction of about 12 per cent in the rate of investment in the new long-run steady state. With a previous policy announcement, the overall attractiveness of investment has declined leading to a downward shift in the investment profile. However, the reduction in investment is slight in years prior to implementation of the new policy. The steady-state effects of this policy change are the same as in the pre-announced policy case previously described. In the experiment of the elimination of the investment tax credit accompanied by a reduction of the corporate tax rate, which is 'revenue neutral' early years of policy change and then starts revenue losing as a result of behaviourial adjustment to the new tax regime, this combined policy reduces the aggregate capital stock by 3.5 percent. They conclude, after carrying out an opposite type of combined policy -a doubling of the investment tax credit combined with a revenue preserving increase in the corporate tax- increasing investment tax credit would be preferable in terms of capital formation.

CHAPTER 3 TAX REFORM

3.1 INTRODUCTION

The whole direction of tax policy in the United Kingdom in the 1980s has changed significantly, compared with the dominant approach of the 1960s and 1970s. In the 1960s and 1970s, tax policy was concerned with conjunctural policy (demand management), with the aim of achieving a "better" distribution of income, and devising incentives to correct market failures and intervene selectively to increase the growth of productive potential. Economic incentives are designed to stimulate the level of investment in order to achieve a desirable rate of growth of productive potential.

The changes in the economic environment that took place during the 1970s have led to a different approach to economic policy, which has been reflected in taxation policy. The almost universal recognition of the distortions and inequities created by high tax burden and rates, years of inflation, and ineffective tax preferences led many industrial countries of the world including the United Kingdom to reform their tax systems.

Analysts have recognized that despite their names, neither the "personal income tax" not the "corporate income tax" was a true income tax. The facts that unrealized capital gains and imputed income are not taxed, generous exemptions are provided, and savings are greatly sheltered in the tax system resemble the rules that would apply under a consumption tax, so the UK income tax system, like other countries is a mixed or a hybrid system that contain both income tax and consumption tax features.[2] Accordingly, as in other countries, the UK government faced a choice in deciding the elements of a comprehensive tax reform. They could have affirmed the principles of income taxation or they could have moved decisively to convert the hybrid tax to a true consumption tax. Although in the 1970s there was an interest in the consumption tax, which is reflected in the Meade Report (Meade 1978) - the same interest is reflected in Blueprints for Basic Tax Reform (1977) in the United States as well - in many respects the former "income taxation" was chosen, repealing a number of provisions that are inconsistent

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[2]For a comprehensive discussion see Aaron, Galper and Pechman (1988), and Bird and Cnossen (1990)

with income taxation, broadening both personal and corporation tax bases, and lowering and flattening marginal rates of the personal and corporate income taxes. The conviction behind this base-broadening/rate-flattening approach is that as a less distortionary tax system requires low marginal tax rates, a horizontally equitable tax system may be achieved with taxes levied on broad bases. The striking feature in the UK tax reform is to eliminate capital subsidies, in accordance with the belief that freely operating markets allocate resources much more effectively than those driven by tax incentives. To offset part of the revenue loss from these changes, the British government doubled the standard rate of value-added tax.

3.2 TAXATION THEORY

Taxes affect important macroeconomic aggregates such as investment, saving, the current account, the market value of firms, and the stock of net foreign assets. Microeconomic effects of taxation cause such impacts. These effects are brought about either directly (that corresponds to real economic effects of taxes) or indirectly through financial effects of taxes. To analyze these effects of taxes requires taking account of a large number of details in the tax code, including the rate of corporation tax, the nature and scope of depreciation allowances, investment subsidies, the system of corporation tax, personal income taxation, capital gains taxation, wealth taxation, the interaction of inflation with the tax system and indirect taxes such as value added taxes and specific excises.

In analyzing the effects of taxation on macroeconomic aggregates, public economists work with the saving-investment identity. To assess the impact of taxation on this identity, they increasingly tend to directly compute the tax "wedge" between the rate of return on investment and the rate of return on savings. The size of the tax wedge depends upon the system of corporation taxation, the tax treatment of depreciation, the personal income taxation, the capital gains taxation, the existence of wealth taxes, other taxes and issues, and the interaction of these taxes with inflation.

Corporate taxes reduce the marginal benefit from investing which discourages investment while the marginal cost of investing will also be reduced, to the extent that tax savings result from the grants and tax allowances given for the asset purchased via investment and the deductions of interest costs. Therefore, corporate taxes lead to a wedge between the rate of return on investment and the user cost of capital. Personal income taxes and capital gains taxes indirectly influence the investment decision of a firm through their impact upon the cost of finance to the firm, a determinant of the user cost of capital. Personal income taxation and capital gains taxation generate a further distortion on asset markets by driving the wedge between the cost of finance to the firm and the net (after-tax) return received by households on their savings. In addition to the distortion imposed on the financial structure of the firm by the interest deductibility provision of the corporate tax, the personal tax may also influence the relative costs of debt and equity finance. If interest is taxed less heavily under the personal tax than are dividends and capital gains, the relative cost of debt finance to the firm will decrease and thereby induce higher gearing in addition to the impact of corporate tax.

These points can be explored as follows. The system of corporation tax puts impacts upon the tax wedge through its treatment of double taxation of capital income. It has been recognised that the existence of separate taxes on corporate income and personal income may reduce the efficiency of the allocation of capital. A corporate tax that operates separately from the personal income tax is widely acknowledged to lead to a number of problems associated with the "double" taxation of corporate income. Dividends are paid out of corporate profits net of corporate taxes. Dividends are further taxed under the personal income tax. Given the existence of capital gains tax, retained earnings are also taxed twice, to the extent they are capitalized in higher share values.

One problem with this double taxation is that it may reduce overall rates of return and affect capital accumulation adversely. A second problem is that the deferral advantage given to retained earnings impairs the efficiency of capital markets. This is sometimes referred to as the "lock-in" effect. Firms can invest retained earnings in projects with a below-market yield, and their shareholders can still earn a higher net-of-tax return than if the funds were distributed as dividends and invested elsewhere. A third problem is that corporate financial policies might be distorted by the existence of the bias toward debt finance, since only equity returns are subjected to corporate taxes. A final problem is that the corporate tax introduces higher effective tax rates in some industries than others, due to special provisions in the corporate tax law and to the varying degrees to which industries are incorporated. These tax rate differentials further disrupt an efficient allocation of capital.

Finally, investment incentives and interest deductions on the part of the marginal investment financed by debt may greatly reduce or eliminate the corporate tax and effect the user cost of capital services. The user cost of capital will be affected in two ways: through the cost of finance because the firm's financial resources are locked up in fixed investment for a period, and through the physical cost of capital because part of the capital stock deteriorates during the period. To sum up, the cost of capital services is a function of the system of corporate taxation, the personal income tax code, the system of investment incentives, the rate of capital gains tax, the tax treatment of debt interest payments and the firm's financial policy.

Economists disagree on the importance and even the direction of these biases. For example, Stiglitz (1973) argued that, when a corporate tax is the only tax imposed, it has no impact on the investment decision if the firm chooses debt financing at the margin and debt interest is deductible from the corporate tax. For equity finance, Feldstein and Slemrod (1980) points out that the corporate tax system can shelter income for a high-bracket stockholder, in which the owners of corporations could have their total taxes reduced by paying only the corporate tax on retained earnings.

In defining the double taxation of dividends, there is a growing debate. Economists agree that dividend taxation at the individual level, when coupled with business taxation at the corporate level, results in double taxation of the income attributable to investments financed with new share issues. But they disagree on whether it also results in double taxation of the income attributable to investments financed with retained earnings. In traditional view of dividend taxation, it is argued that dividend taxation at individual level also results in double taxation of the income attributable to investments financed with retained earnings. Two key assumptions characterize the traditional view. The first is that shareholders derive a positive benefit from receiving dividend (as opposed to an increase in retained earnings) that affects the tax penalty implied by the case that personal income tax rate is greater than capital gains tax rate. These benefits may, for example, arise from the "signalling" value of dividend distributions characterized by asymmetric information. Another possible explanation is that dividend payments may be a partial solution to the "principal-agent" problem associated with the separation of ownership and control in the modern corporation; that is, such payments reduce managerial discretion over the use of profits by distributing earnings directly to shareholders. The second key assumption in models that adopt the traditional view is that marginal investments are effectively financed with new share issues.

In marked contrast to the traditional view, the new view of dividend taxation implies that such taxes have no effect on marginal investments financed with retained earnings. Since the vast majority of equity finance typically takes the form of retained earnings, this view has significant effects on estimate of the effects of taxation on investment decisions. Firstly, the primary rationale for corporate/personal tax integration -the elimination of double taxation of equity income- becomes significantly weaker, because the primary effect of integration would be to eliminate a significant tax disincentive against equity finance in the form of new share issues. Secondly, future dividend taxes are capitalized in share prices. This capitalization leaves investors indifferent at the margin between corporations paying out dividends and retaining earnings. The new view holds that while changes in the dividend tax rate will affect shareholder wealth, they will have minor impact on corporate investment decisions[3]. The latter in turn implies that any integration scheme that reduces or eliminates dividend taxes would results in huge windfall gains to existing shareholders. This new view of dividend taxation is based on the assumptions that earnings on equity-financed investments can ultimately be distributed to shareholders only in the form of taxable dividends. This means that alternative "distributions" such as share repurchases are

[3]However, the findings of Poterba and Summers (1983) suggest that dividend taxes have important effects on investment decisions.

precluded by assumption. This is a reasonable assumption, indeed; share repurchases are prohibited in the U.K.

Inflation interacts with the tax system in several ways can influence the size of the distortion on the capital market. In the case of corporate tax, the presence of inflation would influence the effective tax in two ways[4]: (i) depreciation deductions may be based upon the original value of the capital being depreciated or the historic cost. Thus, the real value of depreciation deduction falls with inflation (ii) firms are allowed to deduct nominal, rather than real, interest payments, inflation thus increases the value of interest deductions. In the case of personal taxes, the tax base is nominal capital income (interest and dividends). This means that households are being taxed partly on nominal returns, which represent only a maintenance of their real asset values, as well as on real interest payments. In the case of capital gains tax, then presence of inflation would influence the effective tax. Since the tax base is nominal capital gains, inflation increases the effective tax rate of capital gains.

In recent years, economists increasingly recognized that tax policy effects in an open economy might significantly differ from those in closed economy. In an open economy, the qualifications made above might need to be modified. The wedge between the rate of return on investment and the rate of return on savings caused by domestic tax policies leads to international financial flows and hence becomes less distortionary to the domestic economy. This can be better understood from the national income identity that the excess of domestic savings over investment must equal the trade balance. The identity implies that policies which increase national investment (savings) without increasing (affecting) national savings (investment) must necessarily lead to increases (decreases) in imports or decreases (increases) exports. Furthermore, Summers (1988) pointed out that policies aimed at stimulating saving and those targeted at promoting investment are likely to have opposite effects on capital flows, exchange rate and international competitiveness. However, the Summers' result is based on the assumption that capital income taxes are imposed according to residence principle. A

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[4]There is also a third way which is stock appreciation.

source-base capital income taxation, however, might reverse it; a lower capital income taxation, for example, induces capital inflows as opposed to neutral direct effects of the residence-base capital income taxation.

Given that q-ratio -defined as the ratio of the market value of firms to the replacement cost of their assets- summarises the ratio of the rate of return to capital to the cost of capital, the tax-adjusted q-ratios in our model sufficiently reflects the distortion and incentive effects of taxes on savings and investment, linking the saver and the companies through the rate of return the company pays on the saver's financial claims.

Finally, some taxes, such as national insurance contributions, make impacts on the demand for labour by industries. Commodity taxes differ from other taxes on causing less distortions. However, it depends on commodity taxes being general. Specific excise taxes, of course, are a disincentive to purchase the commodities on which they are levied. The amount by which the tax reduces purchases will depend upon the elasticity of demand for the commodity in question as well as the elasticity of supply of the commodity. It also depends on general income effects of taxes.

3.3 THE PRE-REFORM UK TAX SYSTEM

In this section the structure of the major UK pre-reform taxes is described, and their treatment in the model is outlined[5].

3.3.1 Income Taxation

The UK income tax is a tax on annual incomes of tax units, at progressive rates. The basic principle that defines household taxation is a unit one rather than an individual

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[5]Kay and King (1978), Meade (1978), King and Fullerton (1984), Piggott and Whalley (1985) and Pointon and Spratley (1988) outline many aspects of the pre-reform tax system. For the whole tax system Kay and King's and Piggott and Whalley's works can be referred. King and Fullerton's work deals with taxes that affect capital accumulation. Meade's work is primarily concerned with the direct tax system. Pointon and Spratley's work describes taxes that interest business.

one, so tax units are households with a limited amount of income splitting. Important features are large annual deductions, the non-taxation of imputed income of owner-occupied house, and a tax surcharge on investment income. Annual tax free allowances are given which vary both by family size and the working characteristics of the wife. They are a single person's allowance, an additional special 'married person's' allowance being given along with an allowance for each child depending on age and a wife's earned income allowance being given. Additional deductions besides the personal allowances are allowed for mortgage interest payments and one-half of life insurance premiums.

The rate structure of the tax is characterized by a basic rate of 33 per cent, a top marginal rate of 83 per cent on earned incomes and 98 per cent on investment income. Investment incomes are subject to an investment income surcharge of 10 per cent or 15 per cent depending on amounts. In addition, a dividend tax credit that the imputation feature of the UK corporate tax system provides since 1973, is structured such that an individual in the basic bracket pays no further income tax on dividends received. As with most countries, the imputed income from owner-occupied housing is not included in the tax base nor are gifts and inheritances received.

In the model, the income tax is treated as the dominant part of a model equivalent income tax system in which income tax and estate duty is considered to operate as a single system of personal taxation. Taxable personal income consists of labour income, dividend receipts incorporating tax credit and interest income. Lump-sum transfers from the government are considered tax exempt. We calculate an average income tax rate by using the data taken from the national account data set which provides us with both personal income and tax levels. We also calculate the income tax revenue according to the marginal tax rate. An income intercept can then be calculated to reflect the difference between marginal tax rate and average tax rate[6].

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[6]Under this treatment, households face a constant marginal tax rate. This weakens the progression of marginal rates from that in the true system as household will not be in a higher marginal rate bracket if its income rises.

3.3.2 Corporation Tax

Corporation tax was introduced as a separate tax on corporation profits in 1965. Corporation tax is a flat rate annual tax on the trading and other profits of the UK companies. Important features are deductibility of interest payments from the tax base and accelerated depreciation provisions. In terms of how distributed profits relative to undistributed profits are taxed, the UK corporation tax is an imputed system under which shareholders receiving dividends also get a fractional dividend tax credit. This imputes to shareholders a portion of the corporate tax paid. The credit is structured in such a way that shareholders in the basic income tax rate bracket pay no further tax. To prevent tax avoidance, companies must pay income tax at the basic rate to the Inland Revenue when dividends are distributed. Such payments are made in advance of the date when corporation tax would normally be paid, and since they are also part of corporate tax bill, they are termed advance corporation tax (ACT). Hence the total company taxes minus ACT is usually termed "mainstream" corporation tax. The aim of the introduction of advanced corporation tax in 1973 was to accelerate the payments of corporation tax.

The pre 1980 system of business taxation is characterized by a high rate of corporation tax combined with high initial allowances for some, but not all, investment. At the beginning of the 1980s the corporate tax rate was 52 per cent. During 1970s depreciation allowances in the UK have become progressively more generous in the acceleration relative to true economic depreciation. 100-per cent first year depreciation was allowed for investment expenditures on plant and machinery and 75-per cent initial allowances on industrial buildings. There are other investments incentives provided by the UK corporation tax. They are investment grants, regional assistance and national selective assistance; both are given to industrial investment. Grants are nontaxable receipts.

In the early 1970s under the stock appreciation provisions nominal capital gains on inventory holdings were taxes on an accrual basis. Piggott and Whalley (1985) cites from National Income and Expenditure 1964-74 (Table 34, p. 37) that in the calender year 1974 approximately 50 per cent trading profits of companies were accounted for by stock appreciation alone (p. 77). In 1974, following a corporate liquidity crisis in which the tax payments due in 1975 would have led to serious financial difficulties for a number of major firms, a temporary (but remained until 1981) 'stock relief' was introduced. A ceiling of 10 per cent was placed on the ratio of taxable profits from this source of total taxable profits.

In the model corporate taxes are treated as ad valorem taxes paid on profits. In the standard general equilibrium tax models, it is assumed that marginal tax rate is equal to the observed average tax rate on capital income. This involves the calculation of effective tax rates derived from tax payments by industry. Less incorporated industries pay smaller amounts of corporation tax and have low ad valorem tax rates on profits when compared to heavily incorporated industries.

This approach conveniently abstracts from the many detailed provisions of the United Kingdom tax law. However, it has many problems. Most crucial is the measured average tax rate which depends critically on the measure for true earnings to capital. This latter number is difficult to calculate appropriately in any year and varies greatly year to year. This variation implies that there is substantial measurement error in the calculated tax rates.

Instead, recent work models tax law directly and calculates the cost of capital implied by the prevailing market interest rate and the existing tax code[7]. While this procedure requires many new data in order to characterize the tax law by industry, it does not require capital income and tax payments figures, which can fluctuate sharply year to year. A more important reason for this type of modelling is that the explicit model of the effect of taxes on capital intensity decisions implies that marginal tax distortions differ from average tax rates even if all figures can be measured without error. In calculating the tax base, bond interest payments and depreciation allowances are deducted from the base. Investment grants are treated as ad valorem subsidy to

[7]In the standard general equilibrium tax models, capital is allocated such that the rate of return to capital net of taxes and depreciation is equated in all industries. It does not require an explicit calculation of the cost of capital.

investment by industry whereas nominal gains on inventory holdings and stock appreciation provisions are not modelled.

3.3.3 North Sea Oil and Gas Taxation

The profits accruing to the companies in the North Sea contain a supernormal component of rent on the right to exploit the oil and gas fields. In order to recover some of these profits the Government has imposed a special tax system on North Sea activities. This system contains three elements. The first tax is a royalty levied at 12.5 per cent of the value of oil. The second is a new tax (introduced in 1978) called petroleum revenue tax (PRT). It is charged at the rate of 45 per cent on the receipts from sales of oil and gas minus expenses incurred in finding it, extracting it, and bringing it ashore. Royalty payments are an allowable expense. But interest payments will not be an allowable deduction.

PRT is charged on each field separately, and the fact that interest deductibility applies to activities outside the North Sea arena means that the taxation of North Sea profits has to be isolated from the rest of the company's activities, the so-called 'ring-fence' approach. Secondly, capital expenditures is treated as an allowable cost, but companies may deduct not only the value of this expenditure but 1.75 times the expenditure (described as an 'uplift' of 75 per cent). In addition there is a special relief (to ensure that marginal fields are not discriminated against); an oil allowance per field of 1 million tons oil a year which will be exempt from PRT subject to a cumulative total of 10 million tons per field. The final tax charge is corporation tax which is charged on the usual basis with both royalties and PRT payments counting as allowable costs.

Since PRT is a tax on rent rather than on profits, we did not attempt to model it. It requires fundamental changes in the model.

3.3.4 National Insurance and Related Contributions

National insurance contributions (NICs) were contributed as a flat-rate tax, payable by all those in work and by their employers. Contributions are loosely tied to benefits paid to qualifying individuals (retired, unemployed, disadvantaged) for contributions to government operated funds which finance benefits.

Applied tax modellers agree that all these contributions can be treated as ad valorem taxes on use of labour services by industry. Public finance economists query this treatment as a tax by the argument that, unlike other taxes, there is a direct benefit involved with these contributions. Since contribution levels vary with no change in benefits and benefits levels change with no change in contributions, and payments are not benefit related such that any given individual is not actually guaranteed to get back the some of his contributions, the treatment as a tax seems to be justified.

The model treatment of these contributions as ad valorem taxes on the use of labour services by industry is based on a characterization of national insurance and related contributions as a payroll tax. The effect of these contributions (taxes) on saving through the substitution of private savings (i.e., intertemporal allocation effect) and anticipated future social security receipts, or the effect of social security on retirement decisions are not modelled.

Since age and sex characteristics affect contributions, and different contribution levels are set for self-employed persons, the ad valorem treatment is not wholly appropriate. As the composition of the labour force and degree of incorporation changes by industry, the tax rate by industry will also differ. These inter-industry distortions are not captured in the model.

3.3.5 Indirect Taxes

The structure of commodity taxes in the UK is characterized by one general sales tax - value-added tax (VAT) - and heavy duties on three products - tobacco, alcoholic drinks, and petrol. In the 1970s, in aggregate they accounted for a significant portion of total tax receipts.

The basic principle of VAT is that it is a sales tax chargeable to the sellers of all output, with the proviso that in computing their liabilities, firms may deduct any VAT that has been levied on inputs into their products. The main advantage of VAT is that it is a method of levying a tax on all commodities that enter consumption while effectively exempting all intermediate goods - those who buy goods for further processing receive a refund of the tax that they have been charged with, and only those who are the final consumers of the goods actually pay it[8].

Prior to the tax reform, there were two rates of tax, zero and the standard rate of 8 per cent. A 25 per cent luxury' rate was introduced in 1975 and reduced to 12.5 per cent in 1978. Additionally, some products - such as financial services, education, and funerals - are exempted.

In the model, VAT is treated as an ad valorem tax on final sales because of the complexities in explicitly modelling all of the features of the tax as it applies to intermediate transactions. Exports are free of tax, and the tax is applied to imports for final use (which corresponds to destination principle). The model applies the VAT law directly to 28 individual commodities modelled, instead of calculating effective tax rates. Since the model allows 28 commodities, applying the tax code directly is very much likely to reflect the effective tax rates on more aggregated products.

Specific excise taxes in the UK are heavily concentrated on three major groups of products - tobacco, drink, and hydro-carbon oils[9]. In the model specific excise taxes are all treated as ad valorem taxes paid on purchases of taxed products. Both intermediate and final purchases of goods are taxed. Identical rates are used for comparable domestically produced and imported items. A similar treatment is adopted for customs duties. Finally, local authority housing subsidies that cover the subsidization

[8]So exempting all intermediate goods does not cause the traditional problem of sales taxes, the cascading effect of the tax. Thus it seems an ideal tax with respect to the first of the principles of indirect taxation that there should be no taxes on intermediate goods.

[9]Taxing these commodities heavily underlies the 'Ramsey rules' which say that a heavier tax should be levied on commodities for which demand is inelastic in order to induce less distortionary effects.

of council tenancies, are treated as an ad valorem subsidy on purchases of the services of housing sector.

3.3.6 Capital Gains Tax

The taxation of gains realised on the disposal of assets was introduced in 1965. Capital gains (or losses) are generally calculated as the differences between the consideration received on the disposal of an asset and the aggregate cost of acquiring the asset, expenditure incurred on the asset to enhance its value and certain costs incidental to the disposal of the asset. Whereas the gains of individuals and trust are charged to capital gains tax, the gains made by companies are charged to corporation tax. A large variety of asset are exempt from the capital gains tax (CGT), including principal residences (but not second houses), National Savings instruments and so forth. Gains that are less than £1,000 were exempted from the tax. The tax rates for individuals were less than their income tax rates. But for trusts, rates were 30 per cent. In the model capital gain is treated as an ad valorem tax on accrued capital gains. The statutory tax rate is transformed into an equivalent rate applied on accrued capital gains.

3.3.7 Rates

Rates are the UK form of property tax levied by local government in order to meet their expenses. They are an annual tax on all property based on assessed annual letting values of property. Unlike the United Kingdom, in most countries, values of property are based on the capital markets values of assets. All properties are covered; exemption is given to churches and agricultural buildings. In the model rates are treated as ad valorem taxes paid by industries on capital stock.

3.4 PROBLEMS OF THE PRE-REFORM PERIOD

During the 1970s taxation emerged as a prime suspect in the explanation of disappointing long-term economic performance. In 1978 the Meade Committee was established on this ground and set out options for radical reform of the tax base, as did the US Treasury, publishing its Blueprints for Basic Tax Reform, in 1977.

In explaining the problems caused by the tax system in the 1970s, analysts emphasized the role of capital income taxation. The tax burden on income from capital are argued to distort the efficient allocation of capital, to the extent that the taxes on income from capital cause interasset, intersectoral and intertemporal distortions. Interasset distortions represent non-optimal allocation of saving. Intersectoral distortions imply misallocation of capital. Intertemporal distortions denote non-optimal consumption/saving choice. Studies done by King and Fullerton (1984), Meade (1978), Piggott and Whalley (1985), and Whalley (1973, 1975) revealed that the distortionary effects of UK capital income taxation would cause important allocation, welfare and incidence effects. Whalley (1973, 1975), using a general equilibrium model, showed that although the introduction of the imputation system improved the capital allocation efficiency, there is still efficiency lost due to misallocation of capital because of the differential taxation of capital in the corporate and incorporate sectors. Piggott and Whalley (1985) explored the effects of UK capital income taxation on the efficiency of capital allocation as well as saving decisions, using a large size general equilibrium model. They report that the intersectoral effects of the UK capital income taxation are significant. Using a simple recursive dynamic model they calculate that replacing personal income taxes with consumption taxes increase savings substantially in the region of 25-30 per cent.

Meade (1978) studies the UK direct taxation in a comprehensive way; the report pointed out that the UK direct tax system would create important inter-asset, intersectoral and intertemporal distortionary effects. In the report several proposals were suggested to repair these distortions. The central theme of the Meade Report (and of Blueprints in the US) was the wide disparity in the tax treatment of different assets. This was partly a matter of particular assets being deliberately tax-favoured. In the UK, this refers to principally owner-occupied housing (imputed rental income and capital gain on sale exempted, mortgage interest payments on loans up to a ceiling deductible against income tax), life insurance (half of premiums deductible) and occupational pensions (employee's and employer's contributions deductible against income tax, pension funds tax exempt and a tax-free lump-sum available at retirement)[10]. At corporate level, plant and equipment were favoured over other physical investments. Also there was a capriciousness in the differential treatment of alternative forms of capital income. Capital gains, in particular, were strongly favoured relative to interest income, which was taxable by addition to earned income and subject to an investment income surcharge: gains were taxed at 30 per cent (compared to a rate of up to 98 per cent on interest income) and enjoyed a separate exemption, liability could be deferred until realisation of the asset.

Such capriciousness has many unattractive consequences. It creates opportunities for pure tax arbitrage, transactions which reduce tax liability without affecting the stock of real assets. Capriciousness in capital income taxation can also lead to a misallocation of real resources. This means that the cost of capital might be affected by taxation through the nature of the underlying physical asset, the means by which it is financed, and the route through which it is held.

Such distortions generate excess burden. Under capricious treatment of alternative forms of capital income, capital stock is allocated so as to equalize the post-tax returns across activities: Otherwise the private return on capital could be increased by reallocating it towards activities yielding a higher post-tax return. But then if effective marginal rates of tax differ, so must pre-tax returns, implying that the social return on capital - the private return plus taxes - could be increased by reallocating it from activities in which pre-tax return is low to those in which it is high. The concern grew such that variations in effective marginal tax rates - deviations from 'fiscal neutrality' - were indeed considerable.

To summarize the impact of UK tax law that are applicable to income from capital, King and Fullerton (1984) employ the notion of an effective tax rate for each

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[10]Keen (1991) gives a figure of 53 per cent for the percentage of these assets relative to the personal sector's net worth in 1977, p. 53.

type of asset[11]. They consider other countries as well; namely, Germany, Sweden and the United States and compare the marginal effective tax rates in four countries for 1980. The effective tax rates are used to measure tax burden imposed on different forms of income; it reflects the tax wedge between the rate of return on investment and the rate of return on savings. Since with distortionary taxes the two rates of return can differ, the effective tax rate then is expected to move from zero. King and Fullerton's work takes account of a large number of details in the tax code to calculate the effective tax rates for three industries and physical and financial assets.

King and Fullerton's findings reveal that there is an insignificant tax burden on income from capital; the overall average marginal tax rate for the fixed-p case is only 6.6 per cent at a 10 per cent rate of inflation. This confirms widely the view that the UK tax system during the 1970s encouraged saving and investing rather than discouraging. Personal savings, indeed, hit new highs in the seventies and generous investment incentives and further piecemeal measures adopted to bolster capital accumulation. One important form of investment was strongly encouraged by the tax system, with deductibility against corporation tax of both interest payments and investment expenditures on plant and machinery. Therefore it is argued that the UK tax system approximates an expenditure tax as far as the corporate tax system as a whole is considered. But this average conceals a very wide dispersion of marginal tax rates; there is a striking contrast between the effective subsidy given to investment in machinery and the high tax rates levied on investment in buildings. The effective tax rates for these assets are -33.3 and 41.0 per cent, respectively (see King and Fullerton 1984, table 3.23 p. 74). Several works such as Byatt's work (1988) confirm King and Fullerton's findings; Byatt's corresponding effective tax rates, respectively, are -0.2 and 7.7 per cent[12]. King

[11]Effective tax rates are discussed by King and Fullerton (1984, especially chapters 2 and 7, pp 7-30 and 268-302). Papers by Jorgenson and Yun (1986b, 1990) extensively utilized the approach. It is based on the assumption that if capital internationally immobile, national savings and investment are the same thing. In principle, the tax incentive to save and invest can then be described by the single number: the wedge between pre- and post-tax returns on the marginal investment.

[12]The difference between Byatt's and King and Fullerton's figures lays in method chosen, rate of inflation taken and source of investment finance assumed. Byatt assumes a 10 per cent nominal return post-tax on capital, 5 per cent rate of inflation, 5 per cent real return, debt-financed investment in plant

(continued...)

and Fullerton note that the differences in the effective tax rates for physical assets, plant and machinery and building, are reflected in the relatively low tax rates of -6.9 in manufacturing and other industry (mainly services and construction) compared with the high tax rate of 39.5 in commerce. Interestingly, the overall tax rate declines with inflation. They explain this by the fact that the generous depreciation allowances for investment and the deductibility of nominal interest payments at the corporate level more than offset the failure to index the personal tax system.

In comparative country analysis, they found that the United Kingdom has the lowest overall effective tax rate, 3.7 per cent at the actual inflation rate of 13.6 per cent, compared to the highest overall rate of 48.1 per cent in Germany (see table 7.1 p. 269). Immediate expensing of machinery is seen to be a major reason for the low overall rate in the United Kingdom. The effective tax rate on machinery is minus 37 per cent, while other assets are taxed at over 39 per cent. Britain has the lowest total tax on machinery and the highest share of machinery in its capital stock. Machinery is 47 per cent of total capital in Britain whereas it is only 22 per cent in the United States. This difference is mainly explained by the tax advantages afforded machinery in Britain. In the breakdown by source of finance, the United Kingdom again provides the most striking contrast. Debt-financed investments are heavily subsidized, since assets receive accelerated or immediate depreciation and corporate interest payments are fully deductible from taxable income.

The sorry state of capital income taxation was most evident in the virtual collapse of corporation tax. Low profitability, stock relief, interest deductibility and the generosity of investment incentives had led to a substantial erosion of the corporate tax base. The share of mainstream corporation tax in the central government current receipts fell form about 12 per cent in the late sixties to around 4 per cent in the eighties, by when 40 per cent of industrial and commercial companies paid no mainstream

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[12](...continued)
and machinery, equity-financed investment in commercial building. In comparison, King and Fullerton assume 10 per cent pre-tax return on capital, 10 per cent inflation and a different source of investment finance.

corporation tax at all. Awareness grew that non-neutrality of the kind described above could have real costs in terms of both investment decisions and the public finances.

On the other hand, concentration centred on redistribution in the 1970s. More detailed studies suggested that the tax system was doing surprisingly little redistribution. Kay and King (1978) showed that all the complexities of the UK direct and indirect taxation seemed approach to something pretty close to a linear tax.

3.5 THE 1980S TAX REFORM

Economists argue that academic thinking did play an important role in persuading policy-makers that the solution to the growing problems of the UK tax system lay in moving toward fiscal neutrality. The objective of fiscal neutrality was recognized as desirable both to reduce distortions and to limit tax avoidance. In particular, fiscal neutrality is believed to be achieved to the extent that a tax system avoids high marginal tax rates and those rates do not differ for essentially similar activities. This tax system can be either a comprehensive income tax or an expenditure tax. It was believed that the measures required to move to comprehensive income tax involve less upheaval that those necessary for the transition to an expenditure tax[13]. Steps were taken in the direction to the comprehensive income tax; tax bases have been broadened, discrepancies in the tax treatment of different types of assets have been narrowed and a limited inflation indexation has been introduced. The base-broadening has let the British government to cut the high marginal tax rates.

Since 1979 major steps taken in this direction and in general changes in the UK tax system can be summarized as follows. In 1979 the British government made a sharp cut in marginal tax rates in income tax; the basic rate was reduced from 33 to 30 per cent and the top marginal tax rate on earned income was reduced from 83 to 60 per

[13]However, two members of the Meade committee whose report inspired policy-makers to reform the system, John Kay and Mervyn King do not share the view held by the government arguing that the transition to the expenditure tax would cause less problems that one might anticipate. See Kay and King (1990) p. 225.

cent. A long-term aim was announced; the basic rate will be reduced to 25 per cent. Over the years the basic rate in 1987 was lowered to a rate of 25 per cent. The number of bands in the personal income tax was cut from 12 to 6. Another marked change was made in the taxation of capital gains by allowing indexation of capital gains for tax purposes in 1982. To offset the revenue lost caused by this tax-cutting changes the government raised the value-added tax rate, the 8-percent of the standard rate almost doubled to 15 per cent. In subsequent years, the raise in the VAT was insufficient to balance the government budget and supplementary measures were needed. The revenue need was met by increases in the petroleum revenue tax, excise duties and by introducing a new tax called supplementary petroleum revenue tax.

In 1984 a major reform of corporation taxation took place; the government eliminated the 100-percent first-year write-off for plan and equipment and the 75-percent initial allowance for industrial building, using the revenue gain to reduce the corporate tax rate from 52 per cent to 35 per cent. As seen from table 3.1, the changes are put into effect over a time period. Other elements of the 1984 tax reform are that the partial deductibility of life assurance premiums was removed and that the investment surcharge and the composite rate were abolished.

In 1988, another market reform proposals were passed through the parliament. The reform's marked changes were reflected in personal income taxation. The top marginal tax rate was reduced from 60 per cent to 40 per cent. The British government cut the number of tax bands; only two bands remain to which a basic rate of 25 per cent and a higher rate of 40 per cent are applied. The reform aimed at reducing the

Table 3.1: Tax policy changes in the United Kingdom since 1979

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Personal income tax														
lower rate	25	25	-	-	-	-	-	-	-	-	-	-	-	-
basic rate	33	30				29		27	25					25
Top rate[a]	83	60									40			4
bands	12	7	6								2			2
Corporate tax														
Full rate[b]	52	52				50	45		35				34	33
ACT rate	3/7								29/71	27/73	25/75			25/75
Capital Allowances														
Plant and Machinery														
FYA	100						75	50	-	-	-	-	-	-
WDA	25													25
Industrial buildings														
IA	50		75				50	25	-	-	-	-	-	-
WDA	4													4
Capital gains tax[c]														
rate[d]	30										40			40

a: There was also an investment income surcharge which is applied at the rates of 10 or 15 per cent.
b: A lower rate of corporation tax is applied to small companies.
c: Capital gains were indexed for tax purposes in 1982. Since 1988 capital gains above a threshold are taxed as ordinary income.
d: Prior to 1980, there were bands in taxation of capital gains and different rates, the top rate was 30 per cent.

discrepancies in the tax treatment of income from capital. Since 1988 capital gains above a threshold are taxed as ordinary income - as the top slice of income.

Since 1988 there have been more changes in the UK tax system; the corporate tax was reduced to 33 per cent and the VAT standard rate raised to 17.5 per cent. Deductibility of pension contributions was limited in 1989. The real value of the ceiling for mortgage relief was allowed to decline substantially, and relief restricted to the basic rate in 1991. Local authority rates were replaced by community charge or poll tax but recently it is modified.

3.6 EVALUATING REFORM

It appears that the base-broadening feature of the tax reform outweighed the rate-flattening and lowering feature; over the years the tax burden on the economy, the share of taxes in GDP were raised from 34 in 1979 to 37.5 in 1989. The increase in the share of taxes in GDP allowed the government to keep the public sector borrowing requirement at a low level, even a negative value representing a surplus in the late 1980s. As for the breakdown of the sources of revenue, there is a salient shift from direct taxation to indirect taxation. The share of indirect taxes in central government tax revenue (including national insurance) increased from 34 per cent in the late 1970s to about 40 per cent in 1990 (see Keen 1991 p.58). Although corporation tax had dwindled almost to insignificance at the beginning of the decade, it recently become an important revenue-raiser once more.

It is hard to interpret this broad structure of the tax system. To assess the tax reform, individual tax burden should be examined. In order to evaluate the distortionary effects of taxes, one should look at marginal tax rates, in particular. As implied by changes in the personal income tax, empirical works tend to find lower marginal rates of income tax for certain income forms of capital. Robson (1988) estimates, for instance, that in 1978 the average marginal rates on dividend and interest income stood at about 54 and 49 per cent respectively; now both will be below 40 per cent. Devereux (1987) finds that the effective marginal rate of corporation tax rose by about 25 percentage points over the decade. This reflects that the reduction in capital allowances outweighed the cut in corporate tax rates. On the other hand, the effects of the tax cut and the reduction in capital subsidies require a closer look. The cut in corporate rate represents a saving incentive whereas the reduction in capital allowances implies investment incentives. As pointed out by the basic finance equivalence theorem in a closed economy, economically meaningful distinctions between saving and investment incentives do not arise. But there are meaningful distinctions between policies that affect savings; the sum of past and current saving, and those that directly affect only current saving, or, in equilibrium, current investment. Auerbach and Kotlikoff (1987) and Goulder and Summers (1989) show that although types of policies alter marginal incentives to accumulate new capital, investment incentives can generate significant infra-marginal redistribution from current holder of wealth to those with small or zero claims on the existing stock of capital. In other words, investment incentives are likely to hurt capital owners by causing substantial declines in stock market values while increasing investment.

Accordingly, while the cuts in (personal and corporate) income taxes would stimulate capital accumulation and lead to increases in stock market valuation, the reduction in capital allowances discourages investment and bolsters the increases in stock market valuation caused by the cuts in personal and corporate income taxes. Auerbach and Kotlikoff (1987) also notes that while savings incentives represent a shift from income to wage taxation, investment incentives represent a shift from income to consumption taxation. They found that consumption taxation stimulates considerably greater savings (i.e., capital accumulation) than does wage taxation. From this point it would be argued that the UK tax reform would mean a capital de-accumulation and hence a lower growth.

As far as open economy is concerned, economists such as Harberger and Summers increasingly recognized that there is another meaningful distinction between policies that affect savings and those that affect investment. While saving policies might result in capital outflows and thereby lessens domestic capital accumulation, investment incentives might attract capital inflows. This reverse capital effects in turn generate opposite effects on exchange rates and competitiveness. Given that the recent UK tax reform would lead to a positive saving incentives and negative investment incentives (investment disincentives), one would expect that the reform will result in capital outflows, depreciation in exchange rate and deterioration in competitiveness.

3.7 CONCLUSION

The 1980s UK tax reform offers an interesting case study. Changes in the various UK taxes are often discussed in the taxation theory. The reform includes a shift from income taxation to consumption taxation. On the other hand the reform represent a change in the treatment of old capital and new capital. Investment incentives that were targeted toward new capital were phased out. Instead, saving-promoting policies that treat new and old capital equally were adopted. These two policies have different effects on asset values as well as capital formation.

We take the 1980's major tax policy changes rather the reform as a whole to study. We concentrate on the cut in the personal income tax, the corporation tax, the write-off depreciation allowances elimination and the rise in the VAT rates. We left out several aspects of the UK taxation system. Tax exhaustion is one of them, public finance economists have been increasingly discussing this issue. The tax system interaction with inflation rate is also left out.

CHAPTER 4 STRUCTURE OF THE DYNAMIC APPLIED GENERAL EQUILIBRIUM TAX MODEL

4.1 OVERVIEW OF THE MODEL AND TREATMENT OF THE U.K. TAX SYSTEM

4.1.1 Overview of Structure of the Model

The model built in this study incorporates the behaviour of the production, household, government and foreign sectors. Households and firms derive their behaviour from intertemporal optimisation without direct co-ordination with other agents. The model contains not only real economic decisions, such as consumption, saving, production and investment, but also financial decisions, such as financing investment. All real economic decisions are optimally and endogenously determined while on the financial side only financing behaviour of investment is taken as an optimal and endogenous decision.

Accordingly, in the model there are physical commodities and financial assets, which is consistent with the modelling of real economic decisions as well as financial decisions of agents. Physical commodities are four types: (i) scarce factors, which include all non-produced goods, namely labour and capital stock; (ii) intermediate and final goods, which are the outputs of, and inputs to , production activities; (iii) imported goods, which may include both inputs to production and consumption goods, and (iv) investment goods. Financial assets are of two types: equity and bond.

The model distinguishes five industries: (1) agriculture; (2) energy; (3) manufacturing; (4) services, trade, and utilities; and (5) housing services. Each industry produces a single output using inputs of labour, capital, intermediate goods. In each industry at each point in time, the given stock of capital combines with a variable quantity of labour in a Cobb-Douglas production function to produce value added. Value added combines with composite intermediate inputs in fixed proportions to produce gross output. Labour supply is fixed in the aggregate within period while its aggregate force grows at a constant exogenous rate over time. But it is perfectly mobile across sectors. The capital stock of each sector, in contrast, is fixed at each point in time. Capital stocks at the industry level and in the aggregate, also change over time. But in contrast with labour, they evolve endogenously in a response to the investment decisions of firms in each industry. In the long run, tax-adjusted marginal value products of capital are equalized across sectors.

As for investment decisions, managers consider not just current profits but future profitability as well. In each industry, managers choose levels of investment to maximize the market value of the firm. Because of adjustment costs associated with the installation, firms find it optimal, in response to a change in economic conditions, to approach new long-run capital intensities gradually over time. So, investment decisions balance the costs of new capital (acquisition costs plus costs of installation) against the higher revenues made possible by large capital stock.

In financing investments, managers choose an optimal mix of bond issuance and retained earnings. Given the fact that taxes favour debt-finance for instance, interest payments are deductible from the corporate tax base, debt-equity ratios are optimally determined by agency costs of debt together with tax favouring debt. To find optimal debt-equity ratios, managers are assumed to maximize the market value of debt plus equity, instead of the market value of equity.

On the consumer side, the analysis is conducted for one aggregate household. The aggregate household derive total consumption and saving optimally in an intertemporal optimisation context. So, their current consumption and saving decisions depend not only on current income and interest rate but on the entire paths of these and other variables from the present onwards. The capital income of a household consists of dividends, interest earnings, and capital gains on existing company shares. Households also earn labour income for their labour supply to firms and receive transfer payments from the government.

In the study the government is engaged in three economic activities; collecting taxes, transferring discretionary lump-sum amounts to the private sector, purchasing consumption goods, and to accomplish general government activities. In the model, taxes are collected according to an exogenously given tax regime, and the tax system and tax policies are institutionally given as the outcome of a process is not captured by the model. The path of government expenditure and transfers to households are also exogenously given. Hence, the policy instrument of the government is tax policy or tax/debt policy.

Finally, the model trace foreign economic transactions in a semi-small open economy assumption. Foreign economic transactions consists of not only trade flows but also capital flows. However, neither labour nor physical (as distinct from financial) capital is mobile internationally. By the semi-small economy, we mean that the country can influence the world prices when exporting. Product differentiation in imported goods is made in order to add realism. This gives rise to the Armington (1969) assumption that domestic and foreign goods substitute imperfectly for one another. In each commodity, these are combined in a CES function to produce a composite commodity. These composite commodities are demanded in several different ways. Firstly, they serve as intermediate inputs for each of industries. Secondly, they meet the demands for final goods by the government. Thirdly, they combine, according to fixed coefficients, to produce a representative capital good; thus satisfy the total demand for new capital goods given by the aggregate level of investment. Finally, they combine, according to fixed coefficients, to create the 28 types of consumer goods demanded by households[14]. In modelling exports, we allow for inelastic demand for the country's exports, which create endogenous terms of trade effects. As for financial capital flows, the model considers that financial capital flows occur between the host (the home country) and the rest of the world when there is a net (after-tax) interest rate difference in the home country and the rest of the world. However, capital flows are assumed imperfect rather than perfect.

Since this is a perfect foresight model, equilibrium requires two sorts of conditions: intratemporal equilibrium requirements and intertemporal equilibrium requirements. The intratemporal requirements are that current supplies and demands

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[14]The transformation of producer goods into consumer goods is necessary. This is because the categories for outputs from production data differ from the categories for goods from consumer expenditure data. Also, consumer taxes are best applied if they are sufficiently categorised.

balance at each point in time given the expectations of future variables. The intertemporal requirements are that expected values must conform to the values realized in later periods.

Intratemporal equilibrium requires that each point in time: (1) the supply of each good equal the sum of home and foreign demands; (2) the aggregate labour supply equal its aggregate demand; (3) total national savings equal the aggregate demand for external funds by home firms; (4) the government budget constraint must be satisfied; and (5) balance of payments constraint must be satisfied. These equilibrium requirements are met through the adjustment of commodity prices, wage level, interest rate, lump-sum adjustments to personal income taxes to yield government budget balance, and the nominal exchange rate.

The whole menu of financial assets in the model are bonds and equities. In an endogenous international financial capital mobility, the model includes foreign bonds. In terms of equilibrium analysis, the consumer supplies funds and production sectors demand funds by issuing bonds. Depending on the interest rate differential between the home country and the rest of the world, the latter would either be fund supplier or fund demander. For instance, if interest rate at home is higher than the world interest rate, the rest of the world supplies funds to the home country. As a result, the current interest rates as well as the market availability of funds are endogenously determined by the equilibrium conditions.

The tax system of the economy consists of a consumption tax, personal income tax, corporate income tax, labour tax, and capital gain tax. Apart from personal income tax, which is considered to be a linear progressive tax, all other taxes in the economy are modelled in an ad valorem context. The consumption tax is an European value-added tax. The U.K. corporate tax is a partial imputation system. There is a tax credit, in the determination of personal income taxes on dividends, that relates to part of the underlying corporation tax. The labour tax is levied on labour services used by firms. And finally, the capital gains tax is considered as a tax on the appreciation of shares.

To sum up the analysis is conducted for one aggregate consumer and five different industries, namely, agriculture, energy, manufacturing, services and housing sectors. Firms produce consumption goods with the aid of labour, intermediate goods and capital and the latter can appear as equity and debt. The optimal short-run intensities for labour and long-run intensities for both capital and labour are determined from Cobb-Douglas (CD) value added functions. Intermediate and final production is represented by an input-output matrix. The intensities of intermediate goods are fixed. Goods produced by firms are demanded in several different ways. First, they serve as intermediate goods for each of the industries. In addition, they meet the demands for final goods by the household and government and the exports demands of the foreign sector. Finally, they combine, according to fixed coefficients, to produce a representative capital (investment) good.

The model is characterised by Walrasian market clearing assumptions and all markets are perfectly competitive, like most of CGE tax models. Market-clearing prices in each period depend on expectations of future prices and tax variables in the economy, and these expectations are self-fulfilling, that is perfect, Hence a perfect foresight equilibrium prevails. In this context, the factor price paths, interest rate and wage, and commodity prices that are exogenous to the individual planning problems are endogenous to the market equilibrium. It is assumed that the paths are determined such that the plans of all market agents are compatible with one another. The compatibility is assured if the individual optimisation condition of market agents are satisfied and if, in addition, at each period, the labour, the commodity, and the financial markets are clearing. Perfect capital and labour markets are sufficient for coordinating private plans in all markets of the model, hence forward markets are not necessary for an intertemporal general equilibrium. The reason for this result is what could be called the intertemporal linking function of the capital market[15]. Finally, plans of agents are mainly formulated in continuous time[16].

4.2 THE PRODUCTION SECTOR

In building an intertemporal model of producer behaviour, we make two fundamental assumptions: first, that managers seek to maximize the value of the firm, and second, that an arbitrage equation governs the relationship between returns on debt and returns to equities. The first assumption establishes the basis for both the firm's investment behaviour and its financial structure. The second is needed to define how the firm's market value is determined by asset holders.

Standard intertemporal models trace the market value of firm as the market value of its shares. In a departure from these models, the model in this paper, following the work of Jensen and Meckling (1976), assumes that managers seek to maximize the market value of debt plus equity. Jensen and Meckling viewed firms differently as a "contracting arena" in which the conflicting interests of bondholders, stockholders, and managers are negotiated. It is assumed that bond covenants and other constraints force stockholders to maximize the market value of debt plus equity. Accordingly, managers choose levels of investment to maximise the value of the firm in accordance with the optimal choice of its debt level that minimizes financial costs. Furthermore, we assume that investment incurs adjustment costs. This accounts for adjustments dynamics in the producer side of the model. With this adjustment costs associated with investment, firms find it optimal, in response to a change in economic conditions, to approach new long-run capital intensities gradually over time. The length of time necessary to attain the

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[15]See, Sinn (1987)

[16]Although discrete time analysis is often very useful in making explicit crucial roles of 'periods' in certain economic occurrences, in the literature 'continuous time analysis' is preferred to discrete time analysis by theoreticians because there are many more readily available theorem in the mathematical theory of differential equations associated with continuous time analysis than the theory of difference equations associated with discrete time analysis.

optimal capital intensity depends critically on the adjustment costs faced by the firm. Thus, in making investment decisions, firms balance the costs of new capital (acquisition costs plus adjustment costs) against the higher cash flows made possible by a large capital stock.

In what follows, the maximization of the market value of the firm subject to the adjustment technology gives rise to q-theory type investment functions. Q-theory, representing the ratio of the financial market value of capital and the production cost of capital, was introduced by Tobin (1969)[17]. The theory predicts that firms will invest when the stock market value of their assets exceeds the cost of replacement[18].

The theory behind this prediction can be summarised as follows: Given the assumption that managers seek to maximize the market value of the outstanding common shares and bonds, an investment project should be undertaken if and only if it increased the value of the shares and bonds. The securities markets apprise the project, its expected contributions to the future earnings of the company and its risks. If the value of the project as appraised by investors exceeds the cost, then the value of the company's shares will appreciate to the benefit of existing stockholders and bondholders. That is, the market will value the project more than the cash used to pay for it. If new debt or equity securities are issued to raise the cash, the prospectus leads to an increase of share prices. The essential insight underlying Tobin's theory is that in a tax-less world firms invest as long as each dollar spent purchasing capital raises the market value of the firm by more than one dollar. It follows from that, depending on the existence of the above type adjustment costs, the level of investment would be different were no such adjustment cost present, firms would find it optimal to invest so much in each year that

[17]The q theory of investment is one of the well-known two theories of investment. The other of which is the neoclassical theory developed by Jorgenson, the maximisation of the present discounted value of net cash flows. It is increasingly recognised that the modified neoclassical investment theory with instalment costs and the q theory are equivalent.

[18]By introducing independent industry investment, we alter the 'macro-closure' of general equilibrium tax models (for a recent discussion of the closure issue see Robinson 1991), investment in physical capital and household saving in no longer identically equal. A financial sector intermediates between decentralized households, storing their wealth in financial assets, and decentralized firms requiring financial capital to finance their investments in physical capital.

the gap between the market value and the replacement cost of capital goods would be driven to zero. With respect to adjustment costs, the high levels of investment that this policy would sometimes require would cause the firm to incur unacceptably large additional expenses. The firm would thus be motivated to "smooth" its investment over time. With this smoothing behaviour comes the possibility that a firm's market value will, from time to time, vary from the replacement costs of its assets, being higher in periods of strong investment and lower in periods of weak investment.

In fact, what Tobin suggested is that the rate of investment is a function of q. However, what we can observe is average q, namely the ratio of the market value of existing capital to its replacement cost. Hayashi (1982) showed that if the firm is a price-taker with constant returns to scale in both installation and production, then marginal q is equal to average q. Dixon et al. (1992) points out the existence of another condition: dividends should be a function of capital stock, investment, and a vector of short-run variables and it must be homogenous of degree one in capital and investment.

Although q-theory link real sector with the financial sector as explained above, most q models assume that neither the market value of a firm nor its cost of capital were affected by the decision as to how investment is financed. The assumption that managers are forced to maximise the market value of debt plus equity by the existence of financial constraints gives rise to an optimal determination of debt-equity ratios. Osterberg (1989) showed that the debt to equity ratio is optimally determined by agency costs of debt together with tax rates favouring debt. In modelling firms' behaviour based to the work of Jensen and Meckling, Osterberg considers only the conflict between bondholders and stockholders. An agency cost is associated with contractual restrictions intended to control the conflict between them. Agency costs of debt and taxes favouring debt (for instance, corporate income tax allowing interest payments to be deductible from the corporate tax base) combine to yield an interior solution for the endogenous debt-equity ratio. Now, financial structure affects q but only indirectly, through that the discount rate (cost of capital) varies with the debt-equity ratio since q is the present discounted value of after-tax marginal products of capital. However, this result is based on two more restrictions: first, that the number of shares of equity is assumed fixed, i.e., no equity issuance, second, that the firm pays out a constant fraction of the market value of its shares as dividends.

As for production technology, each of the five industries produces a single output using inputs of labour, capital, and intermediate goods. A multilevel structure governs the production of each industry output. Firms choose the input levels of labour and intermediate goods at each point in time to minimize real costs, given the current capital stock. In hierarchy, first labour and capital combine to produce a value-added composite, VA. Second, this composite is combined with intermediate inputs ($y_1, y_2, \ldots\ldots, y_J$) in fixed proportions to generate output Y. This sequence of decision making can be understood better in the light of the property of constant returns to scale (CRTS) of production function. Since production exhibit CRTS properties, we can find the optimal level of labour inputs and then supply functions and in turn the demand for intermediate goods, depending on the level of capital stock.

4.2.1 The Decision Problem of the Firm

In the model the firms are assumed to be domestically owned corporation. Their managers are assumed to maximize the market value of debt plus equity subject to a set of real economic and financial constraints. These constraints are production technology, profit identity, investment-finance identity, arbitrage condition, capital stock accumulation condition and initial conditions for stock variables (capital, equity and debt).

We adopt the adjustment cost investment framework developed in Lucas (1967) in which when incorporating investment goods into the production process, the firm incurs adjustment costs. These costs can be viewed as internal costs; in order to install new capital, currently available resources - labour, existing capital, and intermediate goods - must be diverted from the firm's output to the installation of new equipment. We can combine the production technology with the adjustment cost technology. Hence, the firm's technology possesses the relation ($\Phi[L,K,y,I]$) which depends positively on labour (L), capital (K), (vector of) intermediate inputs (y) and value of equity (E), and negatively on the remaining two arguments; namely, investment (I) and debt stock (B). To be more precise, the technology takes the following separable form:

$$\Phi[L,K,y,I]=\phi_p(L,K,y)-\phi_d(I/K)I \tag{1}$$

where ϕ's capture production and adjustment cost relationship, respectively. In particular, the production technology at every point in time is represented by a time-invariant Leontief structure in intermediate and final production, which is in the form:

$$\phi_p(L,K,y)=Min\{\frac{1}{a_0}VA(L,K),\frac{y_1}{a_1},..........\frac{y_J}{a_J}\}, \qquad j=1,....,J=5 \tag{1a}$$

where y_j represents the physical quantities of input j, a_0 is the requirements per unit of output, and $VA(.,.)$ is the value-added function. The value added function has the following usual neoclassical production function properties; it is twice continuously differentiable, strictly increasing in every input, and concave. The function also satisfies the Inada conditions: $VA'(0)=\infty$ and $VA'(\infty)=0$. The time invariant value added production function will be characterised by a linearly homogeneous Cobb-Douglas structure:

$$VA(L,K)=\epsilon_1 L^{\epsilon_0}K^{1-\epsilon_0} \tag{1b}$$

where ε_0 is the share parameter and ε_1 is the efficiency parameter. The adjustment cost function is assumed to be quadratic in I/K of the form:

$$\phi_d(I/K)=\frac{(\alpha_1^d/2)[I/K-\alpha_0^d]^2}{I/K} \tag{1c}$$

where α^d_0 and α^d_1 are parameters.

The second constraint is the profit accounting identity which states earnings before interest payments and taxes, *EBIT*, equal the sum of the total cost of debt finance (interest payments plus agency costs of debt), *TCD*, tax liabilities, *TAXF*, retained earnings, *RE*, and dividends, *DIV*:

$$EBIT=TCD+TAXF+RE+DIV \tag{2}$$

It means that the gross profits go to bondholders as interest, to government as taxes, to stockholders as dividends, into retained earning, or are absorbed by the agency cost.

The before tax and interest payments earnings (gross profits), *EBIT* can be defined as

$$EBIT=PY-P_L L-P_y y \tag{2a}$$

Where P is the price of output, Y represents the quantity of output by the firm (net of adjustment cost), P_L denotes the wage rate (gross of indirect tax on labour), P_y is the vector of intermediate input prices (gross of intermediate input taxes facing the industry).

In accordance with the firm behaviour of maximising the market value of debt plus equity so as to control the conflict between bondholder and stockholders, the cost of debt finance is the sum of interest payments and agency costs. We assume that there are bond covenants that are negotiated to restrict the level of debt for a given value of equity. The higher the debt-equity ratio, the more likely that the covenant will be violated, resulting in restrictions on investment activities and a decrease in firm value. Thus, the cost of issuing units of bond increases with the debt-equity ratio, γ. Accordingly, we postulate that agency cost function is quadratic in the debt-equity ratio and takes the following functional form:

$$\phi_g(\gamma)=\frac{(\alpha_1^g/2)[\gamma-\alpha_0^g]^2}{\gamma} \tag{2b}$$

$\alpha^g{}_0$ and $\alpha^g{}_1$ are agency cost parameters, and formally γ is equal to the ratio of the value of debt stocks (B) to the value of equity (E). As for the total cost of debt finance, agency cost of debt is added to interest payments to existing bond stocks:

$$TCD=r_B B+\phi_g(\gamma)B \tag{2c}$$

where, r_B denotes the nominal rate of return on bonds.

Firms must pay taxes on their output, use of labour inputs, use of intermediate inputs and profits. These taxes correspond with output tax, labour tax (National Insurance Contributions), indirect taxes (Specific Excises) and corporate income tax (Corporation Tax), respectively. Corporation tax, in contrast with other taxes, requires a detailed explanation because there are, broadly, three main aspects to corporation taxation and the interaction of these three elements determines the impact of taxation on companies. In defining the corporation tax, the model specifies the tax rate, the rules concerning the definition of "profits" for tax purposes and the system relating to the taxation of corporation profits. Corporation tax rate is a flat rate applied to annual trading and other profits of corporation. In determining taxable profit (tax base), corporation is allowed to deduct interest payments on existing bond stocks and capital allowances (depreciation allowances). Also, the corporation tax system affects the real economic and financial decisions of firms. At this stage, we can still define the firm's tax liabilities without referring to the corporation tax system as

$$TAXF=\tau_y PY+\tau_L P_L L+\tau_{vj} P_y y+\tau_c[\theta_y PY-\theta_L P_L L-\theta_{vj} P_y y-r_B B]-\tau_c DA \tag{2d}$$

In our notation, a tax rate will be indicated by the letter "τ" amended by a suitable subscript. Accordingly, τ_i are the various tax rates; $i=y,v,L,c$ are the output tax, indirect tax, labour and corporate tax rates, respectively. Expressions of the kind $1\text{-}\tau$, called tax factors, are denoted by a "θ" with the same subscript as the corresponding τ. A subscript j to differentiate firms is used in defining the indirect taxes on intermediate goods because tax rate on intermediate good for each firm consists of a vector of indirect taxes on particular intermediate goods. *DA* represents the value of currently allowable depreciation allowances. The calculation of *DA(t)* assumes that the rate of depreciation used for tax purposes reflects accelerated depreciation and that tax depreciation is based on historical cost. Depreciation allowances in a given period are calculated by

$$DA(t)=\delta_w^T K^T(t)+(\delta_a^T+\delta_f^T)P_K(t)I(t) \tag{2e}$$

where $\delta^T{}_w$, $\delta^T{}_a$ and $\delta^T{}_f$ describe the rates of writing down, initial and first year capital allowances and K^T is the capital stock basis for tax purposes. K^T is calculated on a historical rather than real cost basis. This permits the model to incorporate an important non-neutrality of the tax code with respect to the rate of inflation: the real value of K^T erodes more quickly the greater the inflation rate is.

The dividend policy of the firm is represented by a constant fraction, $\bar{d}$, of the market value of shares

$$DIV=\bar{d}E \tag{2f}$$

Here, E is the value of equity, and has a relation such that $E=P_E\bar{E}$ with P_E is the price of equity and $\bar{E}$ denotes number of equity.

As for the investment-finance identity, it is assumed that investment is financed through retained earnings and/or debt issue:

$$(1-z)P_K I = RE + \dot{B} \tag{3}$$

where (1-z) is the 'direct' costs of new capital (net of the investment tax credit), P_K is replacement price of capital goods and z represents the investment tax credit (in the case of UK, investment grants). In addition, one can notice that it is also assumed that there is no equity issue.

Shares and bonds are taken to be perfect substitutes and they must therefore yield the same expected return after tax. If $P_E\bar{E}$ is the market value of outstanding shares, τ_p is the personal tax rate on income, b is dividend tax credit rate since the U.K. corporate tax rate is assumed to be a partial imputation system, and τ_g is the effective personal tax rate on accrued capital gains on shares, perfect foresight on behalf of investors thus implies the arbitrage condition

$$\theta_p r_B P_E \bar{E} = \frac{\theta_p}{\theta_b} DIV + \theta_g \dot{P}_E \bar{E} \tag{4}$$

The term on the left-hand side of eq. (4) is the after-tax income which shareholders could earn if they sold their shares and invested the revenue in bonds, while the expression on the right-hand side represents the actual after-tax earnings on shares, being made up of after-tax dividends and after-tax capital gains. Using expression (2f) and dividing condition (4) by the term $P_E\bar{E}$, we get the following formula

$$\theta_p r_B = \frac{\theta_p}{\theta_b} \bar{d} + \theta_g \frac{\dot{P}_E}{P_E} \tag{4'}$$

Arbitrage condition gives rise that one can link households to firms. The link between them is the cost of capital, driven by the rates of return required by households.

Another constraint on the firm behaviour is the capital stock accumulation condition:

$$\dot{K}=I-\delta^R K \tag{5}$$

where δ^R is the economic depreciation rate[19].

Finally, firms take the initial values of capital stock, debt and equity as given at t=0:

$$K(0)=K_0,\ B(0)=B_0,\quad \text{and}\ \bar{E}(0)=\bar{E} \tag{6}$$

Hence, we can derive a closed form expression for the market value of the firm using expressions above because, as Osterberg showed, maximising the market value of debt plus equity is equivalent to maximising a particular present discounted value under the set of financial and production constraints explained above. This can be shown as follows: First, substitute equations for *EBIT*, *TCD*, *TAXF*, *RE* and *DIV* into equation (2), add $\dot{P}_E\bar{E}$ to the both sides of the resulting relation; and obtain the following relation:

$$NCF+\dot{P}_E\bar{E}=[\theta_c r_B+\frac{(\alpha_1^g/2)[\gamma-\alpha_0^g]^2}{\gamma}]B+\bar{d}P_E\bar{E}-\dot{B}+\dot{P}_E\bar{E} \tag{7}$$

where *NCF* is the cash flow of the firm, defined as

$$NCF=[P_NY-\theta_LP_LL]\theta_c+\tau_cDA-(1-z)P_KI \tag{8}$$

Here P_N is the net price or per-unit value added, defined as price $P_N=[P(1-\tau_y)-\sum_j a_j(1+\tau_v)p_v]$. Second, note that the market value of the firm relation, $V=B+P_E\bar{E}$, implies:

$$\dot{V}=\dot{B}+\dot{P}_E\bar{E} \tag{9}$$

now, using (4') and (9), expression (7) can be written as:

$$NCF+\dot{V}=\Gamma V \tag{10}$$

where Γ is the cost of capital, defined as:

[19]It is assumed that the capital stock declines exponentially at the rate of economic depreciation δ^R. It has been shown that exponential or geometric decline in the capital stock provides a satisfactory approximation to actual patterns of decline. See Jorgenson and Yun (1986b).

$$\Gamma=[\theta_c r_B+\frac{(\alpha_1^g/2)(\gamma-\alpha_0^g)^2}{\gamma}]\frac{\gamma}{1+\gamma}+\frac{\theta_p}{\theta_g}\{r_B+\bar{d}\frac{[\theta_g\theta_b-\theta_p]}{\theta_p\theta_b}\}\frac{1}{1+\gamma} \tag{11}$$

Expression (10) is a linear differential equation in V that can be integrated to show that Γ is the discount factor which maintains the equality between the integral of V_t and $B_t+P_{Et}\bar{E}$. Finally, integrating equation (10) yields the following expression for V[20]:

$$V(t)=\int_t^{\infty}\exp[\omega^c(t,s)]NCF(s)ds, \tag{12}$$

where $\omega^c(t,s)=-\int_t^s\Gamma(u)du$.

One of the objectives of the model is to capture tax effects on old capital stocks and new capital stocks of firms. Therefore we can separate the terms reflecting the value of depreciation allowances on existing capital, DE, and future acquisitions, DN, which yields new expression for market value of the firm at t:

$$V(t)=\int_t^{\infty}\exp[\omega^c(t,s)]NCF(s)ds+DE(t) \tag{12'}$$

Now, the net cash flow definition is modified as

$$NCF=[P_N Y-\theta_L P_L L]\theta_c+\tau_c DA-(1-z-DN)P_K I \tag{8'}$$

[20]Solution method is such that: rearranging (10) as $\dot{V}-\Gamma V=-NCF$ and multiplying it by integrating factor, $\exp[\omega^c(t,s)]$ converts the left side of the rearranged equation (10) into an exact differential. Thus, after multiplying the integrating factor, it can be integrated over $[t,\infty)$ to give

$$V(\infty)\exp[\omega^c(t,\infty)]-V(t)\exp[\omega^c(t,s)]=-\int_t^{\infty}\exp[\omega^c(t,s)]NCF(s)ds$$

At this point we assume that the left most of the above equation (which is formally a limit) is zero. This is known as a transversality condition, and it will be true as long as the value of firm grows more slowly than the cost of capital as time tends toward infinity. Hence after applying the transversality condition and rearranging slightly, we obtain the explicit equation for the value of the firm at any time t.

The values of depreciation allowances on existing capital and future acquisitions are defined respectively as[21]

$$DE(t)=\int_{t}^{\infty}\tau_c\delta_w^T\exp[\omega^c(t,s)]K^T(s)[\exp(-\delta_w^T)(s-t)]ds \tag{12a}$$

$$DN(s)=\tau_c(\delta_a^T+\delta_f^T)+\int_{s}^{\infty}\tau_c\delta_w^T\exp[\omega^c(s,u)]\exp[(-\delta_w^T)(u-s)]du. \tag{12b}$$

4.2.2 Derivation of Firm Behavioral Functions

Now, the firm's problem is to choose the sequence $\{L(t),y_j(t),I(t),\dot{B}(t)\}$ so as to

$$\max\int_{t}^{\infty}\exp[\omega^c(t,s)]NCF(s)+DE(t) \tag{13}$$

subject to the real and financial constraints, that is equations (1)-(6).

Note that *NCF* is solely a function of 'real' variables, *K* and *L*, whereas Γ is a function of only 'financial' variables summarised by $\gamma(t)$. Thus, the firm can optimise in the following sequence: first choose $L(t),y_j(t)$ and $I(t)$ to maximise $NCF(t)$, then choose $\gamma(t)$ to minimise $\Gamma(t)$.

[21]Discounting of depreciation allowances is an unresolved issue. The theory has clear implications. Because prospective depreciation allowances are very nearly riskless, they are more valuable than other prospective sources of cash flow. The appropriate discount rate for safe cash flows, like the stream of future deductions, is lower than the rate applicable to risky physical investments.

In fact future depreciation deductions are subject to some risks. Depreciation deductions will be useless for firms that make losses and become nontaxable and are unable to make use of carryback and carryforward provisions. There is also the possibility of changes in tax rates, this source of uncertainty may drive the appropriate discount rate down rather than up. Finally there is always the possibility that the depreciation rules will be changed with respect to assets already in place. (See Summers 1987)

Although this discussion suggests a lower discount rate for the discounting of depreciation allowances, as is commonly adopted, we discount the depreciation allowances at the rate which firms discount the stream of the future cash flows. The following argument might justify this: the Since depreciation allowances are not adjusted to inflation, one could argue that prospective depreciation allowances are not riskless.

This problem is solved using 'control theory techniques', in particular, 'Pontryagin's Maximum Principle', to obtain demand functions for investment and intermediate goods, and supply function of output and bond. With choice of functional forms the current value Hamiltonian associated at t with our problem becomes:

$$H(L,I,\dot{B};K;\lambda)=\exp(\omega^{c})[NCF-\lambda(I-\delta^{R}K)+\zeta(\dot{B})] \qquad (14)$$

The Hamiltonian can be thought of as measuring the total flow of cash flow is equal to the sum of the flow of cash flow form contemporary production activities plus the imputed (shadow) cash flow value of capital to be installed at s plus the cash flow yield from borrowing at s. λ and ζ are the costate variables associated with K and B, respectively. λ and ζ have the interpretation of the 'shadow price of an increment of capital and borrowing, respectively.

The necessary and sufficient conditions[22] for optimality are:

$$P_N VA_L=\theta_L P_L \qquad (14a)$$

$$[(1-z-DN)P_K+\theta_c P_N(I/K)\phi_d^{\prime}]=\lambda \qquad (14b)$$

$$\dot{\lambda}=(\Gamma+\delta^{R})\lambda-\theta_c P_N(VA_K-(I/K)^2\phi_d^{\prime}) \qquad (14c)$$

$$\frac{\theta_p}{\theta_g}[r_B+\bar{d}\frac{[\theta_g\theta_b-\theta_p]}{\theta_p\theta_b}]-\theta_c r_B=\frac{\alpha_1^g}{2}\gamma^2+\gamma-(1+\frac{\alpha_1^g}{2}\alpha_0^g)\alpha_0^g \qquad (14d)$$

$$\dot{\zeta}=0 \qquad (14e)$$

[22]The conditions below are necessary as well as sufficient because the equation (14b) satisfies the second order condition H_{II}<o. This can be seen from the property that (d/dI)[(I/K)ϕ_d']>0. Furthermore, the strict convexity of adjustment cost function guarantees the uniqueness of the solution for the above problem. Since production function is concave and satisfies the Inada conditions, and adjustment we can argue that the solution exists and we can reach this solution as long as the cost of capital, the discounting factor, is positive.

In formal terms, systems of this type are two-point boundary-value problems. In order to solve them uniquely, it is necessary to specify terminal conditions for the asset price variables as well as initial conditions for the variables. The terminal conditions simply involves specifying transversality conditions ensuring the model's convergence.

$$K(0)=K_0,\ B(0)=B_0 \quad \text{and} \quad \bar{E}(0)=\bar{E} \tag{14f}$$

$$TVC \lim_{s\to\infty} \exp[\omega^c(t,s)]\lambda(s)K(s)=0=\lim_{s\to\infty} \exp[\omega^c(t,s)]\zeta(s)B(s) \tag{14g}$$

The first order condition, equation (14a), implies that labour is hired until its value of marginal product and wage are equal. Expression (14b) states that marginal q differs from one by the after-tax decline in cash flow due to relative prices and installation costs, and implies that the investment rate is an increasing function of marginal q. The equation (14d) defines the optimal debt-equity ratio. Expression (14c) is the arbitrage condition that the shadow return from holding capital must equal to the required return on capital, $(\Gamma+\delta^R)q$. Expression (14c) can be integrated subject to the transversality condition (14f) to obtain:

$$\lambda(t)=\int_t^\infty \exp[-\int_t^s (\Gamma(u)+\delta^R)du]\theta_c P_N (VA_K-(I/K)^2\phi_d')ds \tag{15}$$

Expression (15) shows that $\lambda(t)$ equals the present discounted sum of after-tax marginal products of a unit of capital installed at time t. Thus, since Γ depends on the debt to equity ratio, so does λ. However, (14b) shows to be a 'sufficient statistic' for investment. In other words, the total of the market values of debt and equity captures the effect of financial structure on cost of capital.

In order to derive an investment function of the industry, following Summers (1981b) and Summers (1987) we will define the investment function as follows. The first-order condition, equation (14b), characterises the investment function; it implicitly defines a function linking investment to the real shadow price of capital, λ/P, the tax parameters, and the costs of adjustment. This equation has an intuitive explanation. The right-hand side is the shadow price of additional capital goods, which is equal to their marginal cost in after-tax corporate dollars on the left-hand side.

The equation (14c) describes the evolution of the shadow price, λ. It guarantees that the shadow price equals the present value of the future marginal products of a unit of capital. This equation is of no operational significance, Hence, we are trying to link the shadow price to the market valuation of existing capital.

PROPOSITION: In the presence of perfectly competitive output and factor markets,

$$q(0)=\frac{V(0)-DE(0)}{P_K(0)K(0)} \text{ with } q=\lambda/P_K \tag{16}$$

if and only if the installation function $\phi_d(I/K)$ in linearly homogenous in I/K, the production function $VA(K,L)$ is linearly homogenous in K and L and exponential rates govern the depreciation of K.

PROOF: First suppose VA and ϕ_d are linearly homogenous. Since the firm is a price-taker, we have, from (14a),

$$VA_L=\theta_L P_L/P_N \tag{17a}$$

Since VA is homogenous, (17a) implies

$$(NCF+(1-z-DN)P_K I+\theta_c P_N \phi_d)/K=(d/dK)\phi_p \tag{17b}$$

Now consider

$$\frac{d}{ds}\{\lambda(s)K(s)\exp[\omega^c(t,s)]\}=\{\dot{\lambda}K+\lambda\dot{K}-\Gamma\lambda K\}\exp[\omega^c(t,s)] \tag{17c}$$

along an optimal path. Using (17a), (17b), (14c), (14b), (16), we can easily establish

$$\frac{d}{ds}\{\lambda K\exp[\omega^c(t,s)]\}=-NCF\exp[\omega^c(t,s)] \tag{17d}$$

Integrating (17d) from t=0 to infinity and using the transversality condition (14f), we obtain

$$\lambda(0)K(0)=\int_{t=0}^{\infty} NCF(s)\exp[\omega^c(t,s)]ds \tag{17e}$$

which implies (16).

REMARK 1: The proposition holds at any point in time along the optimal path.

REMARK 2: Since the installation function is concave in I/K, the optimal path is unique if it exists[23].

Therefore, combining equations (14b) and (16) demonstrates that

$$\frac{I}{K}=h(Q) \tag{18}$$

where $h(.)=[(I/K)\phi_d']^{-1}$ and Q is the tax-adjusted q, defined as

$$Q=[\frac{V-DE}{P_K K}-1+z+DN][\frac{P_K}{\theta_c P_N}] \tag{19}$$

From the adjustment cost function, equation (1c), we can write the investment function, (18), as

$$\frac{I}{K}=\alpha_0^d+\frac{1}{\alpha_1^d}Q. \tag{18'}$$

Since we know the value of capital stock we can solve equation (14a) for L, using value added function, and obtain an equation for Y.

$$L(t)=K(t)\{\theta_L P_L/\epsilon_0\epsilon_1 P_N\}^{\frac{1}{\epsilon_0-1}} \tag{20a}$$

$$Y(t)=K(t)\{\theta_L P_L/\epsilon_0\epsilon_1 P_N\}^{\frac{\epsilon_0}{\epsilon_0-1}} \tag{20b}$$

Also, demand for intermediate inputs is obtained as:

$$y_j(t)=a_j K(t)\{\theta_L P_L/\epsilon_0\epsilon_1 P_N\}^{\frac{\epsilon_0}{\epsilon_0-1}} \tag{20c}$$

As is seen, demands for labour and intermediate inputs as well as output supply depend on all current prices and on the rate of returns. No future prices are relevant. However, investment demand is forward looking in the sense that it not only depends on the current prices of the investment good but also on next period's rate of returns and all the other future prices via the shadow price of capital.

[23]See Hayashi (1982) and Summers (1981b).

Since there is no equity issue, γ is adjusted by varying the B vs. RE financing mix. Hence, the equation (14d) can be numerically solved for finding the debt-equity ratio. Having chosen the path of the investment, labour demand, and the debt-equity ratio, the initial share price is determined by the condition $B(0)+P_E(0)\bar{E}=V(0)$.

4.3 THE MODEL OF HOUSEHOLD BEHAVIOUR

Households are represented as forward-looking and having perfect foresight. Since today's saving affects both current and future consumption (by affecting future income through asset accumulation), the determination of current optimal saving levels is a fundamentally intertemporal problem. Hence, an aggregate consumption and savings are derived from the utility maximising behaviour of a representative household that faces an infinite horizon[24]. Once households chose aggregate consumption level, they then choose specific consumers goods according to fixed expenditure shares.

Savings are used to accumulate assets (actually bonds). Households are allowed to buy foreign bonds as well and hence decide on holding domestic and foreign bonds. In the allocation of savings between domestic bonds and foreign bonds, a simple approach is adopted, in which asset preferences are left out of individuals' utility functions[25]. In the model, households' asset portfolio are passive: the actual

[24]Judd (1985) discusses the relevance of assuming that any person has an infinite life. In consistent with empirical evidence that indicates that substantial amounts of wealth are held for bequest purposes, in which case the true economic agent consists of several generations of a family, Judd argues that is not an absurd approximation.

[25]However, when domestic and foreign assets are imperfect substitutes and offer different expected returns, portfolio and consumption choices need to be coordinated since the choice of portfolio affects the overall rate of return to the household. One approach to this problem would be to incorporate risk explicitly. But the integration of portfolio choice and consumption demands in the face of risk and uncertainty presents difficult, unresolved theoretical issues, particularly when there are many time periods and many consumption goods. Moreover, risk may only partly explain the main empirical fact of interest: that households hold diversified portfolios despite sustained differences in rates of return. Goulder and Eichengreen (1989) take an alternative approach in which they posit a portfolio preference function embedded within a utility-maximising framework that allows households to adjust asset shares in accordance with differences in rates of return. This approach is based on the observation that households exhibit strong home-country preference: assets from their own country often make up the bulk of their portfolios, even when rates of return on other-country assets are comparable or higher. However, Goulder and Eichengreen report that their complicated approach and our simple approach which is also used by them yield a very similar pattern of results. Hence, we choose the simple approach instead of Goulder and

composition of the portfolio holdings is driven by the equation that determines the supply of savings between the home country and the rest of the world. This point will be dealt with some length below.

4.3.1 The Decision Problem of the Household

The information structure underlying the economic problem of the consumer at each point in time t can be summarised as follows. At each point in time t, the consumer observes current commodity and labour prices and anticipates the parameters of future taxation policy. Accordingly, the value of current wealth is determined. These parameters are used to determine his intertemporal plans for consumption.

Consumer decisions can be divided into two stages. In the first stage, the consumer decides an intertemporal path of a composite consumption commodity (aggregate consumption). In the second stage, individuals divide the expenditures on the composite good among several consumer goods.

4.3.1.1 Composite Consumption and Saving

At any moment of time t the behaviour of the household is motivated by the objective of maximising its total lifetime utility for the remainder of its life. For simplicity, it is assumed that each household lives infinitely and that total lifetime utility U is the integral of the discounted flow of utility which the household expects to enjoy at each moment of time in the future

$$U(t)=\int_t^{\infty} u[\tilde{C}(s)]\exp(-\rho(s-t))ds \tag{21a}$$

where $u[\tilde{C}(s)]$ measures the flow of utility which the household enjoys at each point in time s; $\tilde{C}(s)$ is the composite consumption commodity at each point in time s. ρ is the pure rate of time preference -the rate at which the household discounts future utils in order to compare them with current utils.

Eichengreen approach.

For the instantaneous utility or 'felicity' function, *u(s)*, we choose a single iso-elastic form for all s

$$u(s)=\frac{\sigma_u}{\sigma_u-1}\tilde{C}(s)^{\frac{\sigma_u-1}{\sigma_u}} \quad \text{for } \sigma_u\neq 1 \qquad (21b)$$
$$u(s)=\ln\tilde{C}(s) \qquad \text{for } \sigma_u=1$$

where σ_u is the constant intertemporal elasticity of substitution.

Combining the two expressions above, above, we can rewrite the household's lifetime utility as:

$$U(t)=\int_t^{\infty}\frac{\sigma_u}{\sigma_u-1}\tilde{C}(s)^{\frac{\sigma_u-1}{\sigma_u}}\exp(-\rho(s-t))ds. \qquad (21)$$

The household's behaviour is constrained by a dynamic set of budget constraints relating the intertemporal patterns of income, spending and wealth accumulation. The consumer's income consists of labour income, government transfers received and capital income.

The consumer earns labour income $P_L L$. In the model labour is measured in efficiency terms, and is assumed to grow at a time-invariant rate, *g*. This rate reflects both population growth and labour productivity growth. The household is considered to receive lump-sum transfers from the government, *Tr*. Also, individuals receive capital income on their non-human wealth, which is composed of earnings on shares and interest earnings on bonds. Earnings on shares can be broken into two categories; dividends and capital gains. In addition, as a requirements of Walras' law, the model treats the agency costs of debt stocks of firms as households' income.

Labour income, dividends and interest earnings are taxable according to a linear progressive income tax schedule. Under a partial imputation system, which is the U.K. corporation tax system, there is a tax credit, in the determination of personal income taxes on dividends, that relates to part of the underlying corporation tax. Lump-sum transfers from the government and agency income are considered tax-exempt. Capital gains are taxed at a different rate τ_g. Accordingly, disposable income, *YD*, is given by:

$$YD=f+YH+YK \tag{22}$$

where f is negative to reflect that the fact that marginal tax rates exceed average tax rates, YH represents the sum of labour income (net of personal income taxes), transfer received from the government and agency income, and formally defined as

$$YH=\theta_p P_L L+Tr+\Sigma_j \phi_{gj}(\gamma_j)B_j \tag{22a}$$

and similarly, YK denotes the capital incomes, which is defined as

$$YK=\Sigma_j \frac{\theta_p}{\theta_b} DIV_j+\theta_p r_B^D \Sigma_j B_j+(r_B^w+\frac{\dot{e}}{e})eB_w-\tau_g \Sigma_j \dot{P}_{Ej} \bar{E}_j \tag{22b}$$

Some points need to be clarified here: first, that since foreign bonds, B_w, are denominated in foreign currency as opposed to domestic private bonds, B_j (j[th] firm's bond), exchange rate changes should be included in calculating returns on foreign bonds and second, that although capital gains are part of capital income on shares, they are not realized and therefore cannot be counted as disposable income. As before, τ_p is the marginal income tax and θ stands for the tax factor representing expressions of the kind 1-τ with the same subscript as corresponding (for example $\theta_p=1-\tau_p$); b denotes the rate of imputed tax credit on dividends, DIV; and e is the nominal exchange rate, the foreign currency price in terms of the domestic currency price.

The consumer's expenditures on consumption is represented by $\tilde{P}\tilde{C}$ where $\tilde{P}$ is the price index for composite consumption. Hence, the household's supply of savings into the fund market is now described by

$$S=YD-\tilde{P}\tilde{C} \tag{23}$$

Clearly, saving, S, is a flow variable, a surplus unit as a result of the difference between income and consumption/expenditure. Surplus units are stored in financial assets, i.e., savings are invested into assets. This implies that savings represent intertemporal transfers of wealth to finance future consumption. In accordance with demands for funds by firms and the rest of the world consist of only borrowing, savings are modelled to buy bonds:

$$S=e\dot{B}_w+\Sigma_j\dot{B}_j \tag{24}$$

We assume that domestic and foreign bonds are imperfect substitutes and offer different returns. This assumption, however, leads to an allocation problem of savings between bonds. It is solved by ensuring that the household's supply of savings are used to buy the mix of domestic and foreign bonds as determined by the equilibrium conditions. Suppose that Ω is the share of domestic bond accumulation in savings. Accordingly, the average return on bonds, r_B, is calculated by

$$r_B=\Omega\theta_p r_B^D+(1-\Omega)[r_B^w+\dot{e}/e] \tag{25}$$

Households pay personal income taxes only on interest earnings on domestic bonds; this reflects that source-base taxation is applied in taxing income obtained abroad. This issue will be discussed below at some length.

Combining equations (23) and (24) by using expression (25), the dynamic budget constraint of the household can be written as follows:

$$\dot{WB}=r_B WB+f+YK+YH-\tilde{P}\tilde{C} \tag{26}$$

where WB stands for the total bondholding (i.e., the sum of the total firms' bond and the rest of the world bond stocks) of the household and WE, similarly denotes the total equityholding of the household. Thus, we can define the household's nonhuman wealth as

$$WK=WB+WE \tag{27}$$

4.3.1.2 Consumption of specific commodities

The variable $\tilde{C}(t)$ above refers to overall consumption in each time t. This is a composite of consumption of several specific consumer goods. Thus, in the second stage, individuals maximise a Cobb-Douglas form for the sub-utility function

$$\tilde{C}=\Pi_i C_i^{\mu_i} \tag{28a}$$

subject to

$$\Sigma_i P_i(1+\tau_{vi})C_i = YD - S \tag{28b}$$

where P_i is the individual price of product i and τ_{vi} is the value added tax on commodity i purchase. The μ_i weighting parameters are the Cobb-Douglas expenditure shares[26].

4.3.2 Derivation of Household Behavioral Functions

The objective of household behaviour is to maximise total lifetime utility. As indicated above, the household's lifetime utility at time t=0 is equal to the discounted sum of the flow of utility which it will enjoy at every future moment of time. Without loss of generality, we may take the current moment of time t=0. The household's lifetime utility to be maximised is written as

$$U(t) = \int_t^{\infty} \frac{\sigma_u}{\sigma_u - 1} \tilde{C}(s)^{\frac{\sigma_u - 1}{\sigma_u}} \exp(-\rho s) ds \tag{29a}$$

The household seeks to maximise U by choice of the time paths of $\tilde{C}$. The household's choice of the time paths of $\tilde{C}$ subject to the dynamic budget constraint,

$$\dot{WB} = r_B WB + f + YK + YH - \tilde{P}\tilde{C} \tag{29b}$$

and the lifetime budget constraint, which the household's net borrowing at any future point of time, $WB(T)$, must not exceed the household's ability to repay these borrowing out of its non-asset income. The latter constraint is called 'No-Ponzi-game condition' stating that the consumer cannot indefinitely accumulate debt at a rate higher than or equal to the net interest rate.

$$-WB(T) \leq \int_s^{\infty} [f + YK + YH - \tilde{P}\tilde{C}] \exp[-\int_T^s r_B du] ds \quad \text{for} \quad all\ T \geq 0, \tag{29c}$$

One can also write the lifetime budget constraint[27] as

[26]Since we differentiate consumer goods from producer goods, the subscript i instead of j is used.

[27]For the equivalence of these conditions, see Mussa (1976) p. 60-62.

$$\int_{t=0}^{\infty} \tilde{P}(s)\tilde{C}(s)\exp[\omega^h(t,s)]ds \leq TW_{t=0}, \tag{29c'}$$

where $\omega^h(t,s)=-\int_t^s r_B(s)ds$ and $TW_{t=0}$, the sum of initial assets and the present discounted value of the household's non-asset income, is the household's initial wealth and is defined by

$$TW \equiv WK+WH \tag{30}$$

where WH represents the sum of the human wealth, the present value of labour income and the present value of transfers:

$$WH(t)=\int_{t}^{\infty} YH(s)\exp[\omega^h(t,s)]ds, \tag{30a}$$

As stated in section 2.2.2, in order to solve this problem, which is a two-point boundary-value problem, uniquely, it is necessary to specify initial conditions for the state variable and terminal conditions ensuring the model's convergence.

Initial conditions for the state variables are given as:

$$WK(0)=WK_0=e^*B_{w0}+\Sigma_j B_{j0}+\Sigma_j P_{Ej0}\bar{E}_j \tag{29d}$$

We characterise the solution using the control theory techniques, in particular, Pontryagrin's Maximum principle. The optimal solution is obtained by setting up the relevant Hamiltonian function at time s:

$$H[\tilde{C};WB;\lambda]=[\frac{\sigma_u}{\sigma_u-1}]\tilde{C}^{\frac{\sigma_u-1}{\sigma_u}}+\lambda[r_B WB+f+YK+YH-\tilde{P}\tilde{C}] \tag{31}$$

Here H can be thought of as measuring the total flow of utility (in terms of utils of time s) which arises out of the activities of the household at time s. This total flow of utility is equal to the sum of the flow of utility from consumption of commodities plus the current utility value of the flow of asset accumulation, $\lambda[YD\text{-}\tilde{P}\tilde{C}]$. $\lambda(s)$ has the interpretation of the 'shadow price of unit of consumption goods at time t, and is measured in utils of time t. In other words, λ is called the costate variable associated with the state variable *WB*. The value of $\lambda(t)$ is the marginal value, as of time s, of an additional unit of wealth at s.

In the solution of the household's intertemporal allocation problem, *WB(s)* and $\lambda(s)$ are treated as the 'state variables' of the problem and $\tilde{C}(t)$ is treated as the 'currently determined variables' of the problem. The solution of the intertemporal allocation problem proceeds in three steps. The first step is to determine the values of the currently determined variables, at each point of time s, so as to maximise *H(s)*, taking the values of the state variables at time s as given. This determines the values of the currently determined variables at each point of time as functions of the values of the state variables at that point of time. The second step is to solve the differential equations which represent the 'transition laws' for the state variables, making use of the results of step one. This determines the time paths of the state variable, and, hence, of the currently determined variables, up to the value of one parameter, the initial value of λ. The third step is to use the 'transversality conditions', together with the results of steps one and two, to determine the initial value of λ.

A rationale for this three-step procedure may be given as follows. Step one tells the household to maximise the total flow of utility arising out of its activities at any moment of time, taking appropriate account of the constraints which current activities will impose on future behaviour. The constraints which past decisions impose on current activities at time s are summarised in the state variable *WB(s)*. Current activities affect future behaviour only through $\tilde{C}(s)$. The value of state variable $\lambda(s)$ tells the household the value which it should assign to a unit of asset accumulation at time s. Steps two and three tell the household to select the time paths of the state variables in such a manner that they do appropriately reflect the constraints of past decisions on current activities and the implications of current activities for future behaviour.

i) <u>Step One</u>

The necessary conditions for the maximisation for the maximisation of the current value Hamiltonian with respect to the currently determined variables are given by

$$\tilde{C}^{-\frac{1}{\sigma_u}}-\lambda\tilde{P}=0 \tag{31a}$$

The properties of the flow of utility function insure that the solution will always result in the determination of unique, positive values of $\tilde{C}$, for any given, positive values of λ. Specifically, properties (smoothness, increasing marginal utility and concavity) insure that the relationship between $\tilde{C}$ and $\partial u/\partial\tilde{C}$ will be continuous, inverse, and single valued. The 'Inada conditions' insure that $\tilde{C}$ will be strictly positive.

The proofs of the propositions advanced in the last paragraph are, in general, both obvious and straightforward. Therefore we will not try to prove them.

Formally, the condition (31a) can be solved for $\tilde{C}$:

$$\tilde{C}=[\lambda\tilde{P}]^{-\sigma_u} \tag{31a'}$$

ii) <u>Step Two</u>

Having determined the values of the currently determined variable $\tilde{C}$ as function of the values of the state variable λ and of the exogenous variable $\tilde{P}$, the next step in the solution of the household's intertemporal allocation problem is to determine the time paths of the state variables up to the value of the constant $\lambda(0)$. This is accomplished by writing down and then solving the differential equations which characterize the 'transition laws' for the state variables. The transition law for bonds is given by

$$W\dot{B}=r_B WB+f+YK+YH-\tilde{P}\tilde{C} \tag{31b}$$

The transition law for the shadow price of consumption (in terms of utils of time s) is

$$\dot{\lambda}=[\rho-r_B]\lambda \tag{31c}$$

Equations (31a) and (31c) determine the path of the rate of change of marginal utility. The level of this path is determined by the wealth constraint.

The solution to the differential equation (31b) is given by

$$WB(s)=\exp[\omega^h(t,s)]\{WB(t)+\int_t^s[f+YK+YH-\tilde{P}\tilde{C}]\exp[\omega^h(t,s)]du\}, \tag{31b'}$$

where the solution to the differential equation (31c) is given by

$$\lambda(s)=\lambda(t)\exp[\rho(s)-\omega^h(t,s)] \tag{31c'}$$

The interpretation of the transition law for assets, eq.(31b), and of its solution, eq. (31b'), are both relatively straight forward. The rate of accumulation of assets is equal to the difference between disposable income and expenditure (consumption). Total assets at any moment of time s are equal to the sum of what initial assets would have been if they had been allowed to accumulate at compound interest plus the accumulated difference, including compound interest between past income non-asset sources and expenditure.

To interpret the transition law for the shadow price of consumption (in terms of utils of time t), eq. (31c), it is convenient to define 'subjective rate of time preference' by dividing the equation (31c) and rewriting it:

$$r_B=\rho-\dot{\lambda}/\lambda \tag{31c'}$$

Equation (31a) shows that, given utility function, the relative decline in marginal utility consists of two components. One is the subjective rate of discount ρ that reflects von Böhm-Bawerk's second reason for interest, the 'underestimation of future wants'. The other, $-\dot{\lambda}/\lambda$, is the decline in instantaneous felicity. This component reflects von Böhm-Bawerk's first reason which he calls the 'difference in the relationships between demand and supply'.

It is straightforward to find a term for $\dot{\lambda}/\lambda$ from eq.(31c). Now we can define the rate of return on consumption
where a '^' over variable denotes expressions such that $\hat{x}=\dot{x}/x$.

$$r_B - \hat{P} = \rho + \frac{1}{\sigma_u}\hat{C} \qquad (31c'')$$

From eq. (31c') and (31a), by introducing a new term for λ showing the shadow price of consumption at time s measured in terms of utils of time t, one can obtain the following equation

$$\exp(-\rho s)\frac{(u'[\tilde{C}(s)]/\tilde{P}(s))}{(u'[\tilde{C}(t)]/\tilde{P}(t))} = \omega^h(t,s), \qquad (31d)$$

The economic meaning of this equation is that the marginal rate of substitution between commodity consumption at time s and commodity consumption at time t must equal the market rate of transformation between commodities at time s and commodities at time t, ω^h(t,s).

Aside from the variables $\tilde{C}$ and $\tilde{P}$ which appears in eq. (31a'), the only variables which appear in the solutions for *WB* and λ given by eqs. (31b') and (31c') are λ(0) and the exogenously determined values of *WB(0)*, $\tilde{P}(s)$, $P_L(s)$ and $\tilde{r}_B(s)$, namely, the total bondholdings, price index for composite consumption, wage rate, and average return on bonds,

$$\tilde{C}(s) = \{\lambda(0)(\exp[\rho(s) + \omega^h(t,s)])\tilde{P}(s)\}^{-\sigma_u} \qquad (32)$$

Substituting this result into (31b') yields an expression for *WB(s)* written exclusively in terms of *λ(0)* and the values of the exogenous variables. It follows that the time paths of the state variables, *WB* and λ, and hence the time paths of the currently determined variable $\tilde{C}(t)$, will be completely determined once the value of *λ(0)* is determined.

iii) Step three

The final step in the solution of the household's intertemporal optimisation problem is to use the 'transversality conditions' to determine the value of λ_0. Transversality conditions are

$$\lim_{s\to\infty}\exp[-\rho(s)]\lambda(s)\geq 0 \tag{33a}$$

$$\lim_{s\to\infty}\exp[-\rho(s)]\lambda(s)WB(s)=0 \tag{33b}$$

substituting from (31c') for $\lambda(s)$ in condition (33a) yields the condition

$$\lim_{s\to\infty}\lambda(0)\exp[-\int_t^s r_B(u)du] \tag{33a'}$$

which will be satisfied provided that $\lambda(0)$ is chosen to be ≥ 0. If $\lambda(0)$ is equal to 0, then $\lambda(s)$ must equal 0 for all s, and under the assumptions that have been made concerning the properties of $u(\tilde{C})$, it must be true that $\tilde{C}(s)=+\infty$ for all s. Since this would violate the lifetime budget constraint, substituting from (31b') for $W(s)$ and from (31c') for $\lambda(s)$ into condition (33b) yields the condition.

$$\lim_{s\to\infty}\{WB(0)+\int_t^s[f+YK+YH-\tilde{P}\tilde{C}]\exp[\omega^h(t,s)]du\}=0 \tag{34}$$

Using eq. (32) for $\tilde{C}$ which appears in above condition (34), the condition (34) can be rewritten as

$$\int_t^\infty \tilde{P}(s)\{\lambda(0)(\exp[\rho(s)+\omega^h(t,s)])\tilde{P}(s)\}^{-\sigma_u}\exp[\omega^h(t,s)])ds=TW(0) \tag{34'}$$

where $TW(0)$, the total wealth, is given by (30). If the integral on the left-hand side of (34') converges for some positive value of $\lambda(0)$, then the assumptions which have been made concerning properties of the flow of utility function ensure that there is a unique value of $\lambda(0)$, for which the condition (34') is satisfied. This is so because the value of $\tilde{C}$ which appears under the integral sign on the left-hand side of (34') has been shown to be a monotonically decreasing, continuous function of $\lambda(0)$.

To find a solution of the optimal path of $\tilde{C}$: solve eq. (34') for $\lambda(0)$ and substitute it into eq. (32)

$$\tilde{C}(s)=\Lambda(s)TW(0)$$

$$\text{where } \Lambda(s)=\frac{\{\exp[\rho(s)+\omega^h(t,s)]\tilde{P}(s)\}^{-\sigma_u}}{\int_t^{\infty}\tilde{P}(s)^{1-\sigma_u}\exp[\rho(s)]^{-\sigma_u}\exp[\omega^h(t,s)]^{1-\sigma_u}ds} \tag{35}$$

At time t, we can write eq. (35) as

$$\tilde{P}(t)\tilde{C}(t)=\Lambda(t)TW(t)$$

$$\text{where } \Lambda(t)=[\int_t^{\infty}[\tilde{P}(s)/\tilde{P}(t)]^{1-\sigma_u}[\exp(\rho(s-t))]^{-\sigma_u}[\exp[\omega^h(t,s)]]^{1-\sigma_u}ds]^{-1} \tag{35'}$$

Hence, it is clear that the consumption is homogeneous of degree one in total wealth, and the ratio of consumption to wealth depends on the future interest rates. The parameter Λ is the propensity to consume out of wealth. It is generally a function of the expected path of interest rates. An increase in interest rates, given wealth, has two effects. The first is to make consumption more attractive later: this is the substitution effect. The second is to allow for higher consumption now and later: this is the income effect. In general, the net effect on the marginal propensity to consume is ambiguous. For the logarithmic utility function, however, σ_u=1, and the two effects cancelled; the propensity to consume is then exactly equal to the rate of time preference; ρ, and is independent of the path of interest rates.

In general, expectations of interest rates affect both the marginal propensity to consume out of wealth and the value of wealth itself, through the present discounted value of the household's non-asset income. Expectations of wages also affect $\tilde{C}$ through the present discounted value of the household's non-asset income. Given these expectations the consumer decides how much to consume and save. This in turn determines capital accumulation and the sequence of factor prices.

Finally, demand for individual consumer goods is obtained by solving equation (28a),which is subjected to equation (28b):

$$C_i = \mu_i \frac{(YD-S)}{P_i} \tag{36}$$

An important property of the nested Cobb-Douglas function is that we can derive the indirect utility functions and expenditure functions easily. The expenditure function can be in turn used to create a composite price index, $\tilde{P}$, from the individual prices, $P_i(1+\tau_{vi})$. An especially convenient property of this kind of price index for the Cobb-Douglas (and CES functions as well) is that the composite price index can be calculated without knowing the actual quantities, C_i.

$$\tilde{P} = \prod_i \left[\frac{\theta_{vi} P_i}{\mu_i}\right]^{\mu_i} \tag{37}$$

4.4 GOVERNMENT BEHAVIOUR

On the government side, we concentrate on tax while allowing no optimal government behaviour. The level of overall government spending (purchases plus transfers) is given exogenously. It grows at a steady-state rate of growth, g.

This model is consistent with two types of public consumption. First, the public consumption can be thought of as either public goods that do not affect the marginal rates of substitution among private goods or transfers to individuals. Both interpretations could be modelled formally by assuming that the private utility functional is additively separable in private and in such public expenditure[28]. Therefore, while there may be value to each taxpayer from public consumption or transfers to the poor, the level and path of such transfers do not affect the demand functions of the agents for their private goods. A second class of public expenditures consistent with this model are publicly provided private goods that are perfect substitutes for private consumption. Being perfect

[28]Brock-Turnovsky (1981) states that this corresponds to the assumption of "ultrarationality".

substitutes, their provision is equivalent to lump-sum transfers to taxpayers. Therefore, our model includes both classes of public goods. Let G be the public expenditures that are additively separable with respect to private consumption. Lump-sum transfers will represent those that are perfect substitutes for private consumption. With these formulation we can concentrate on purely fiscal policy issues while allowing two major classes of public expenditures[29].

We model the government sector such that it engages in three economic activities. Firstly, it collects taxes according to an exogenously given tax regime. Secondly, it transfers discretionary lump-sum amounts to the private sector. Finally, the government sector purchases consumption goods to accomplish general government activities.

4.4.1 The Government Sector Revenues

The tax system, which consists of seven classes of taxes, and tax policies are institutionally given as the outcome of a process not captured by the model. Direct taxes in the model are corporate income tax described by partial imputation system, personal income tax, capital gains tax and property tax. Indirect taxes are considered ad valorem labour and value-added taxes. The only subsidy in the model is ad valorem investment tax credit. The total revenues they generate at t are accumulated as follows:

1. Ad valorem labour tax on labour services used by the different industries, which generates revenue, T_L:

$$T_L = \tau_L P_L \Sigma_j L_j^D \tag{38a}$$

where L^D_j represents labour demand by industry j.

2. Ad valorem corporate income tax on industries generates revenue, T_C:

3. Ad valorem investment tax credits on industries generate revenue, T_Z:

[29] See, Judd (1985) p. 301.

$$T_C=\Sigma_j\tau_{cj}EARN_j$$
$$\text{where} \quad EARN=[P_N Y-\theta_L P_L L-r_B^D B-DA] \tag{38b}$$

$$T_Z=\Sigma_j z_j P_K I_j \tag{38c}$$

4. Ad valorem value-added tax generates revenue, T_V:

$$T_V=\Sigma_i\tau_{vi}P_iC_i+\Sigma_j\Sigma_i\tau_{vi}P_jy_{ji}+\Sigma_i\tau_{vi}P_iG_i \tag{38d}$$

where in y_{ji}, j denotes j^{th} intermediate good demanded by i, G_i denotes government expenditure on good i.

5. A linear progressive personal income tax represented by linear function generates revenue, T_P:

$$T_P \; = \; -f+\tau_p[P_LL+r_B^D(B_w+\Sigma_jB_j)+\Sigma_j\theta_b^{-1}Div_j]-\frac{b}{1-b}\Sigma_jDiv_j \tag{38e}$$

6. Capital gains tax generates revenue, T_g:

$$T_g=\Sigma_j\tau_g\dot{P}_{Ej}\bar{E}_j \tag{38f}$$

7. Property tax (Rates) generates revenue, T_w:

$$T_w=\Sigma_j\tau_wP_KK_j \tag{38g}$$

Accordingly, total taxes collected at time t are T:

$$T=T_L+T_C-T_Z+T_V+T_P+T_g+T_w \tag{39}$$

4.4.2 The Government Budget Constraint

In the model requires the government's budget to be in balance in any given year. This may be written as

$$\Sigma_i \theta_{vi} P_i G_i + Tr = T \tag{40}$$

where Tr is transfer payments, and T is tax collections. Total lump-sum redistributive transfer payments, i.e., transfers to households at t are exogenously given as Tr. Transfer payments grow at the steady-state growth rate.

4.5 THE REST OF THE WORLD

A substantial economic relations -commodity and capital flows- between countries necessitate modelling economies as to be opened up to the rest of the world. Because introducing these substantial commodity trade and capital flows could change the effects of taxes obtained under a closed economy assumption. For instance, in a closed economy, it is clear that there is no important difference between savings and investment taxes. But in open economies, where capital flows are possible, they will have quite different effects. This is apparent from the national income accounting.

We close the model by adopting a small open country assumption. However, the model includes two departures from the commonly adopted small open economy assumption[30]. On the real side, it appears quite unrealistic to assume that the medium-size industrialised countries can sell unlimited quantities of their exports at constant prices. On the financial side, international financial flows are not infinitely elastic. So the assumption is replaced by a semi-small economy assumption. Moreover, we assume product differentiation for imports along with the lines of Armington (1969) assumption.

However, even with the semi-small country assumption, closed-economy results might be significantly reversed. Perraudin and Pujol (1990) clarifies the role played by the terms of trade effects resulted from the inelastic demand for the country's exports. They showed that tax policies which stimulate production would cause deterioration in

[30]The small country assumption means that the economy can purchase or sell unlimited quantities of imports and exports at constant world prices on the real side and borrow and lend freely abroad at the constant world interest rate on the financial side. See, De Melo and Robinson (1989) for a careful examination of the treatment of the external sector in CGE models.

terms of trade, to extent that the export demand is inelastic. They also stress that changes in the terms of trade depends upon the elasticity of substitution between imports and exportable for domestic consumers; the larger the elasticity of substitution between imports and exportable, the less changes in the terms of trade. As for welfare effects, the deterioration in the terms of trade leads to welfare losses for domestic households. Moreover, economists further argued that changes in the terms of trade or changes in the exchange rate could also be lowered by the degree of international capital mobility. Hence, introducing commodity and capital flows between countries could change the effects of taxes obtained under closed economy assumption.

As Feldstein and Horioko (1980) asserted, one would expect that, with perfect capital mobility, there should be no relation between domestic savings and domestic investment: saving in each country respond to the worldwide opportunities for investment while investment in that country is financed by worldwide pool of capital. However, many empirical works found a positive correlation between national savings and domestic investment. Moreover, the correlation between savings and investment is both a short-run and very long-run phenomenon[31].

Bovenberg (1989) explores conditions that result in the correlation between national saving and investment rates that Feldstein and Horioko (1980) found. He shows that capital flows may cause changes in prices and wealth that affect savings. Whether the induced change in savings will suffice to finance the change in investment is shown to depend on the values of intertemporal and trade (intratemporal) substitution elasticities and of trade shares. If exports and imports are imperfect substitutes, domestic investment and the time profile of domestic consumption are closely linked -even if financial capital is perfectly mobile internationally. His results also reveal how the real exchange rate transmits shocks in domestic investment to domestic saving, even if financial capital is perfectly mobile internationally; if domestic and foreign goods become less substitutable in demand, the real exchange rate overshoots more, which

[31]It is argued that permanent, exogenous shifts in the rate of technological progress or population growth with imperfect labour mobility can explain the long-run co-movements between savings and investment.

implies a larger anticipated decline in the terms of trade. The anticipation of the fall in the terms of trade stimulates domestic saving because of both spending-smoothing behaviour due to anticipated income effects and intertemporal substitution due to real interest rate effects.

Turnovsky and Sen (1991) incorporate government budget imbalances. This might explain the correlation between domestic savings and investment by correlating government budget imbalances with international financial capital flows.

Our treatment of firms' financial behaviour might clarify the puzzle of the positive correlation between domestic savings and domestic investment with large financial capital flows internationally. Since with agency costs of debt, investment in our analysis is determined by availability of internal finance (retained earnings). Investment will be unaffected by financial capital flows. For example, a lower corporate tax will discourage borrowing but encourage retaining earnings because in the model the optimal debt-equity ratio is determined by agency costs of debt together with tax rates favouring debt.

Another way of looking at these issues is to use a theory of the determination of current account based on factors underlying saving and/or investment behaviour. This theory begins with the national income identity[32], S-I=Z-M that policies which increase national investment (savings) without increasing (effecting) national savings, S, (investment, I) must necessarily lead to increases (decreases) in imports, M, or decreases (increases) in exports, Z. In other words they will worsen (improve) the current account and lead the traded-goods sector to contract (expand).

Summers (1988) pointed out that policies aimed at stimulating saving and those targeted at promoting investment are likely to have opposite effects on capital flows, exchange rate and international competitiveness. However, the Summers' result is based on the assumption that capital income taxes are imposed according to residence

[32]The meaning of identity is that it holds that the trade balance (Z-M) must equal the excess of domestic savings over investment. Equivalently, as the balance of payments must, the current account (Z-M) must be just offset by capital account (S-I).

principle. A source-base capital income taxation might reverse it; a lower capital income taxation, for example, induces capital inflows as opposed to neutral direct effects of the residence-base capital income taxation.

To be more precise, international capital flows can be considered as financial or physical capital flows. In terms of behaviour that drives capital flows, there would be a distintion between portfolio investment and direct investment. However, we will not deal with foreign direct investment. Since asset portfolio choice is taken as passive in the model we will not treat foreign portfolio investment explicitly, either. It is assumed that physical capital flows are negligible, therefore we concentrate on financial capital flows. Since the number of equities has been assumed fixed, only bonds flow internationally.

4.5.1 Treatment of Imports and Exports

There is a variety of external closure rules referring to the various assumptions about export demand and import supply behaviour[33]. We adopt the one that incorporates product differentiation (i.e. the Armington assumption) for imports along with a downward-sloping foreign export demand curve with constant elasticity[34]. We then define for each tradable commodity category an aggregate or composite commodity $\tilde{Y}$ which is a CES function of commodities produced abroad (imports, M) and commodities produced domestically, Y. The aggregation is given by

$$\tilde{Y}=\beta_1[\beta_0 M^{\frac{\sigma_M-1}{\sigma_M}}+(1-\beta_0)Y^{D\frac{\sigma_M-1}{\sigma_M}}]^{\frac{\sigma_M}{\sigma_M-1}} \tag{41}$$

where β_0, β_1 and σ_M are parameters and M and Y^D are like inputs "producing" the aggregate output. The demands for imports and domestically produced commodities

[33]For these rules see, Whalley and Yeoung (1984) and De melo and Robinson (1989)

[34]The Armington assumption with price-taking behaviour for imports along with a downward-sloping foreign export demand curve with constant elasticity yields a model in which both domestic and foreign offer curves lie on top of one another. See, De Melo and Robinson (1989). They are able to derive normally shaped offer curves by making a symmetric product differentiation for imports and exports.

become derived demands, in just the same way as the demand for factor inputs in a derived demand in a traditional model.

Given the specified prices for the imported and domestic goods, the problem facing the user or buyer is mathematically equivalent to that faced by the firm wishes to produce a specified level of output at minimum cost. In mathematical terms, it means the optimisation is subjected to

$$\tilde{P}_j\tilde{Y}=P_M M+P^D Y^D \tag{42}$$

where $\tilde{P}_j$ is the composite commodity prices, P_M and P^D are the imported and domestic goods prices, respectively. Therefore, solving (41) subject to (42) yields:

$$m=\frac{M}{Y^D}=\left(\frac{P^D}{P_M}\right)^{\sigma_M}\left(\frac{\beta_0}{1-\beta_0}\right)^{\sigma_M} \tag{43}$$

$$M=\left(\frac{P^D}{P_M}\right)^{\sigma_M}\left(\frac{\beta_0}{1-\beta_0}\right)^{\sigma_M}Y^D \tag{44}$$

Since it is assumed that the economy can purchase unlimited quantities of imports at constant world prices a conversion factor, e, is used translate foreign prices into domestic prices such that

$$P_M=P^w_M(1+\tau_m)e \tag{45}$$

where $P^w{}_M$ is the world price of imports in foreign currency, and τ_m is the tariff rate.

The export good, which is consumed by domestic households and used as inputs to intermediate goods and investment by firms, is assumed to be demanded by the rest of the world. In defining the foreign demand for exported goods, similar to domestic consumer behaviour, an intertemporal utility optimisation approach is used

$$U_w(t)=\int_t^{\infty} u_w[\tilde{Z}(s)]\exp(-\rho_w(s-t))ds \tag{46a}$$

where $u_w[\tilde{Z}(s)]$ measures the flow of utility which the foreign consumer enjoys at each point in time s; $\tilde{Z}(s)$ is the composite exported commodities at each point in time s. ρ_w is the pure rate of time preference -the rate at which the household discounts future utils in order to compare them with current utils.

Similarly, for the instantaneous utility function, $u_w(s)$, we choose a single iso-elastic form for all s

$$u_w(s)=\frac{\sigma_z}{\sigma_z-1}\tilde{Z}(s)^{\frac{\sigma_z-1}{\sigma_z}} \quad \text{for } \sigma_z\neq 1$$
$$u_w(s)=\ln\tilde{Z}(s) \qquad \text{for } \sigma_z=1 \tag{46b}$$

where σ_z is the constant intertemporal elasticity of substitution. This is actually the price elasticity of export demand.

Combining the above two expressions, we can rewrite the household's lifetime utility as:

$$U_w(t)=\int_t^{\infty}\frac{\sigma_z}{\sigma_z-1}\tilde{Z}(s)^{\frac{\sigma_z-1}{\sigma_z}}\exp(-\rho(s-t))ds. \tag{46}$$

The foreign household's behaviour is also constrained by a dynamic set of budget constraints, the balance of payments constraint, relating the intertemporal patterns of interest income, imports, exports and wealth accumulation. The foreign consumer's income consists of the revenue of the sales of imported goods to the home country, and interest income. The balance of payments constraint requires that

$$\dot{B}^w(t)=[1+(1-\tau_p^w)]r_B^w B^w(t)+\Sigma_j P_{Mj}^w(t)M_j(t)-\tilde{P}_Z(t)\tilde{Z}(t) \tag{47}$$

where

P_Z = composite domestic export goods price,

B^w = foreign bond,

τ_p^w = marginal rate of personal income tax in the rest of the world.

Individual exports prices P_{Zj} are defined such that

$$P_{Zj}=\frac{P_j^D}{(1+\tau_{Zj})e} \tag{48}$$

where τ_Z is the rate of export subsidy.

One dash of economic theory to equation (47) requires that one must rule out Ponzi games in international borrowing, and the result is

$$B^w(t)=\int_t^{\infty}[\Sigma_j P_{Mj}^w(s)M_j(s)-\tilde{P}_Z(s)\tilde{Z}(s)]\exp[\omega^w(t,s)]ds \tag{47'}$$

where $\omega^w(t,s) = \int_t^s r^w{}_B(s)ds$. In the model, it is assumed that $B^w{}_{t=0} = 0$. Roughly speaking, equation (47') then tells us that today's trade surplus is tomorrow's trade deficit. Note that, because of the discounting, the absolute size of today's trade surplus is smaller than the absolute size of tomorrow's trade deficit. This means that the absolute size of today's real exchange rate appreciation has to be smaller than tomorrow's exchange rate depreciation.

Accordingly, one can define real exchange rate (e_r), $e_r=e/\bar{P}$ Here $\bar{P}$ denotes the domestic price index. Clearly, a choice must be made with respect to the weights entering the aggregator for domestic price index. It is appropriate to choose CPI deflator.

4.5.2 International Capital Flows

In the modelling of international capital flows, only international portfolio investments are considered and international direct investment are left out. Since the allocation of domestic savings is made in the forms of bond accumulation, international portfolio investments accordingly take place in bond issuance. The supply of savings from the rest of the world (the home country) to the home country (the rest of the world) is taken to depend positively on the net (after-tax) interest rate. So any net interest rate differential will lead to the supply of savings from one country to another. If the net interest rate at home is greater than that at abroad, the rest of the world will supply savings to the home country (capital inflows). If the net interest rate at home is less than that at abroad, there will be supply of savings from the home country to the rest of the world (capital outflows). When flexible exchange rate system is considered, changes in exchange rates must be taken into account.

In defining taxation principle of international capital income, source principle is employed in the model. For example, capital income obtained abroad by domestic citizens is taxed abroad. Sinn (1987) shows that because it equalizes the post-tax market rates of interest, taxation at source has the advantage of implying equality of marginal rates of time preference of households at home and abroad and hence of satisfying an important condition for an intertemporal optimum in the exchange of credit contracts between households. Mclure (1992) also argue that inter-nation equity requires that host countries are entitled to a substantial portion of the tax levied on income originating within their borders. The principle of source entitlement naturally leads to taxation at source. Mclure, after defining efficient international capital allocations in terms of capital import neutrality and capital export neutrality, discusses whether and under what circumstances the source principle and the residence principle are compatible with capital import neutrality and capital export neutrality. Capital import neutrality requires that everyone doing business in a particular country face the same tax regime. It is consistent with source-based taxation. For it to be realized under residence-based taxation, all nations would need to apply identical taxes to income from business and capital. However, this form of neutrality is seen not necessary to achieve an efficient location of the world's investment. Capital export neutrality requires that income from capital be taxed equally, no matter where it is earned. This requirement is most usefully interpreted in terms of equality of marginal effective tax rates, though this is not made clear usually. If this requirement is not met, the world's capital will be misallocated to those jurisdictions where it is taxed least heavily.

It is assumed that the U.K. tax system advocates source principle of taxation. The supply of savings between the home country and the rest of the world is finally defined by the following expression

$$\dot{B}^{w}(t)=\bar{B}^{w}[(1-\tau_p^D)r_B^D(t)-(1-\tau_p^w)r_B^w-\dot{e}/e] \qquad (49)$$

Here $\bar{B}$ is parameter. We choose a value for $\bar{B}$ in which it will indicate the degree of liberisation of capital flows.

4.6 ECONOMIC EQUILIBRIUM OF THE MODEL

Atomistic competition in every market is assumed. Even though the number of agents on each side of the market is finite, it is assumed that enough agents are involved to render their actions negligible in terms of the overall equilibrium outcomes. Also, Kehoe and Levine (1985) points out that when there is a finite number of infinitely lived agents, perfect foresight equilibria are determinate. The concept of Perfect Foresight Equilibrium is adopted to capture the self-fulfilling behaviour of economic agents price expectations. The model is calculated to exhibit steady-state growth in the base-case (or benchmark) equilibrium. Following a policy shock, temporary equilibria (in the sense employed by Grandmont (1977) with market-clearing are generated in every period. These temporary equilibria form a transition path on which the economy gradually approaches a new long-run steady-state equilibrium. Since agents in the model are forward-looking with perfect foresight, solution of the model requires that expectations conform to actual future values. Hence equilibrium of the model must satisfy two set of conditions. The intratemporal requirements are that, given expectations of future variables, current supplies and demands balance at each point in time. The intertemporal conditions are those of perfect foresight: Expectations must conform to the values realized in later periods.

Intratemporal equilibrium requires only that current markets for current goods and assets clear at current market prices. Since household demands for goods and assets depend on their expectations concerning the future behaviour of prices, wages, taxes, exchange rates and rates of return, it is clear that the intratemporal equilibrium position of the economy is influenced by these expectations. Intertemporal equilibrium is a state in which not only are current markets for current goods and assets cleared at every instant of time, but also the movement of the economy from one intratemporal equilibrium to the next is such that expectations are continuously fulfilled and that previously made plans are always carried out.

Clearly, under the assumption that all prices (hereafter prices will be used such that they includes product prices, wages, taxes, exchange rates and rates of return) are flexible, and accordingly all perfectly competitive markets clear, market-clearing prices at every point at time depend on expectations of future prices and on tax variables in the economy. There are essentially two ways of interpreting the economic equilibrium in such a dynamic context. If future prices are perfectly anticipated (i.e. expectations are self-fulfilling), a perfect foresight equilibrium prevails. However, if price expectations are not perfect, (i.e. agents make mistakes with respect to future prices), then a temporary or short-run equilibrium prevails. In the case of perfect foresight equilibrium, current plans for the future are precisely implemented while not in the case of temporary equilibrium because they will be revised as more or better information become available to the economic agents.

4.6.1 Intratemporal Equilibrium

The concept of 'equilibrium' has a different meaning in the case of intratemporal equilibrium. The conditions of intratemporal equilibrium determine the position of the economy, not where the economy is going. They provide a complete description of where the economy is at any moment of time. At intratemporal equilibrium, every agent is doing exactly what it wants to do, given the constraints which past decisions and current prices impose on its behaviour, and conditional on the expectations which it holds concerning the future behaviour of prices and other variables which are relevant to its current decisions but not observable in any current market. From this definition it is clear that there are two forces which affect the conditions of intratemporal equilibrium. The position of intratemporal equilibrium is conditional on the stocks of assets which the economy inherits from the past and on the expectations which economic agents hold concerning the future behaviour of prices, wages, interest rates, exchange rates, taxes and transfers. Current prices must be such that all economic agents choose to behave in a manner which is consistent with the clearing at all markets for current goods and assets. This does not imply that the expectations upon which various agents base their current decisions will be fulfilled, nor does it imply that these agents do not regret some of the past decisions which have imposed constraints on their current behaviour.

Intratemporal equilibrium of the model is an extension to the general equilibrium described by Leon Walras and developed by Arrow and Debrue (1954). Walras first constructed the model in which prices and quantities were simultaneously and interdependently determined, which is often referred to as "the Walrasian model". Walras used a tatonnement process to show that the economy reaches to an equilibrium with an auctioneer, whose job is to find out equilibrium price vector by changing prices, according to the adopted any price adjustment rule, up to the point the excess demand is zero with equality of demand and supply with this process. Although Walras did not prove the existence of general equilibria formally, his significant achievement, which is known as "Walras' Law" is usually expressed as "the value of excess demand equals zero" is the corner-stone of general equilibrium analysis.

Arrow and Debreu (1954) first proved the existence of general equilibria considering a precise logical model of the interaction of consumers and producers, and using the Brouwer's (Kakutani's) 'fixed point theorem' (FPT) that did not exist at the time of Walras. The Arrow-Debreu model (ADM) makes a number of assumptions and uses axioms regarding consumer behaviour, producer behaviour and production technology[35]. According to the ADM, with m=number of producers, n=number of consumers, and l=number of commodities, all finite, a competitive economy must be specified with (1) the endowment of consumers, (2) their preferences, (3) the production technology, and (4) the conditions of equilibrium (i.e., Walras' Law). The existence of general equilibria can thus be proved with using the FPT in the sense that normalised

[35]There are numerous works on the ADM. Among them a good description and discussion of the ADM can be found in Cornwall (1984) p. 1-91.

relative prices implied by the property of homogeneous degree zero of excess demand functions which is on a bounded price set gives us a general equilibria.

The model in this paper adds three new sectors, namely; financial sector, government and foreign sector in a detailed way, to those of Arrow and Debreu. With these new markets, the model's intratemporal equilibrium requires that at each point in time: (1) The demand for the output of each industry equal its supply; (2) the demand for labour equal its supply; (3) total external borrowing by firms equal total saving by domestic households plus the net capital inflows; and (4) total government revenue equal total government spending; and (5) foreign exchange receipts equal foreign exchange payments.

Our model differs from the Arrow and Debreu model in the tying up of capital stocks to firms. So it is not necessary to define explicitly physical capital market. Values of physical capital stocks are reflected in financial claims, firm bonds and equities. Assets market equilibrium is also implicitly defined, the loanable funds market equilibrium thus remains only relevant flow equilibrium condition in the model. These five types of requirements yields nine equilibrium conditions (since there are five industry outputs). Equilibrium is established by (1) the prices of industry outputs and (2) labour, (3) the interest rate, (4) the nominal exchange rate, and (5) the lump-sum component of personal income tax rate to yield government budget balance.

In the model product market equilibrium at each point in time is formally defined by

$$Y_j^D - Y_j^S = 0 \tag{50}$$

Here, Y^S_j denotes the net supply of product j obtained as deducting adjustment costs form gross supply. Equation (50) represents domestic product market equilibrium and so Y^S_j is the domestic production by sector j. Accordingly, Y^D_j indicates total demand for domestically produced good j and is defined as:

$$Y_j^D = D_j + Z_j \tag{50a}$$

where Z_j is the export demand for good j and D_j is the total demand for domestic use of good j. In turn, the total demand for domestic use of good j is obtained as

$$D_j = d_j[C_j + G_j + \alpha_{Ij}\Sigma_j I_j + \Sigma_j \alpha_{ji} Y_j^S] \tag{50b}$$

where C_j, G_j and y_{ji} are the demand for good j by the household, the government and he firms, respectively, α_{Ij} is the fixed coefficient good j of investment good (I_j) and d_j, the domestic use ratio, is given by.

$$d_j = \frac{1}{m_j(M_j/D_j, 1)} \tag{50c}$$

where m_j is the CES trade aggregation function.

The condition for labour market equilibrium is that the flow of efficiency units of labour that is inelastically supplied by the household sector is demanded by the sector of firms:

$$\Sigma_j L_j^D - L^S = 0 \tag{51}$$

where L^D_j and L^S are the demand by the j^{th} firm and supply of labour, respectively.

The condition for an equilibrium in the loanable funds market is

$$\Sigma_j \dot{B}_j + \dot{B}^w - S = 0 \tag{52}$$

Finally, the government budget constraint and balance of payments condition are given:

$$T - G - Tr = 0 \tag{53}$$

$$\Sigma_j P_{Mj} M_j + r_B^D B^w - \tilde{P}_Z \tilde{Z} - \dot{B}^w = 0 \tag{54}$$

At first glance it might be expected that, because of Walras' law, one of the five type of equilibrium conditions is redundant, that it is already implied by the other four.

It is important to realise that conditions (50)-(54) do not refer to five type markets in the usual sense but since they apply to all points in time to five continua of markets. In other words, it this way, one should expect that one of the five type of equilibrium conditions is redundant for just one single point in time but not the total continuum.

Since such a general equilibrium defines only relative prices, one use a price-normalization rule that provides a benchmark against which all price changes are relative price changes. The normalization rule can be seen as no more than the choice of a numeriare. Either aggregate price index or setting a variable such as a wage rate, the exchange rate, or the price of any particular commodity equal to one can be used. The consumer price index in the first period is chosen as the normalisation rule in this paper. Prices are scaled in subsequent periods so as to produce the specified rate of inflation π.

The model developed above is based on the assumption that there is a sufficient number of markets for a perfect coordination of economic plans or a perfect foresight of the development of all market data. While intertemporal contract with a certain, sometimes significant, depth are settled in the labour and especially in the capital markets, the commodity markets are typically organised as spot markets. Future markets for commodities are more an exception than a rule. In the light of this fact, forward markets are not necessary for an intertemporal general equilibrium. Perfect capital and labour markets are sufficient for coordinating private plans in all markets of the model. The reason for this result is what could be called the intertemporal linking function of the capital market.

In the short run, policy shocks give rise to divergences in marginal products of capital across industries and in returns to domestic and foreign bonds. Over time, long-run equilibrium is re-established as firms' investment decisions equalize after-tax products of capital across industries and households' savings behaviour equalize returns to domestic and foreign bonds.

4.6.2 Intertemporal Equilibrium

In intertemporal equilibrium the distinction between planned (expected) and actual magnitudes no longer applies. Intertemporal equilibrium is a state in which not only are current markets for current goods and assets cleared at every instant of time, but also the movement of the economy from one intratemporal equilibrium to the next is such that expectations are continuously fulfilled and previously made plans are always carried out. When the economy is in intertemporal equilibrium there are no incipient disequilibria. The rates at which households plan to add to their holdings of each asset equal the rates at which these assets are issued. The planned (expected) rate of change of consumption is equal to the rate of change of output of consumption goods at expected prices. Actual income is equal to expected income and actual asset accumulation is equal to planned asset accumulation. Since actual capital gains are equal to expected capital gains.

When agents have perfect foresight, the economy will follow a path which satisfies the present requirements for an intertemporal equilibrium which is also a steady-state (a balanced growth path). The steady-state equilibrium has the following properties: (1) under the assumption that the economy grows at a constant rate[36], g, real consumption and capital grow at constant rate g; (2) the real average rate of return $\tilde{r}_B$ equals the pure rate of time preference ρ plus the inverse of intertemporal substitution elasticity multiplied by the steady-state growth rate; (3) the economy's stock of capital is constant; and (d) all relative prices remain constant.

These properties imply that since the planned rate of asset accumulation must equal the actual rate of asset accumulation in intertemporal equilibrium, it follows that the planned rate of asset accumulation in the intertemporal must be equal to the steady state growth rate.

The analysis in this section has continually emphasized the crucial role which expectations play in determining the equilibrium position of the economy at any moment of time. Also, expectations play an important role in determining how the economy

[36]This growth rate is the growth rate of effective units of labour which has two components: population growth rate and Harrod-neutral technical change.

moves over time[37]. In order to conduct such analysis described above, it is necessary to make an assumption about how expectations are formed and revised. All assumptions about expectations are ad hoc in the sense that they are something additional which is put into the model. Many ways of forming expectations suffer from defects. For example, static expectations that arbitrarily assume that current prices, wages, taxes, rates of return and exchange rates will persist into the indefinite future suffer from the defect that expectations are consistently wrong, unless the economy has reached its intertemporal equilibrium position. The only assumption about expectations which does not suffer from this defect is the assumption of perfect foresight. By definition, if expectations are characterised by perfect foresight, expectations are never wrong. Further, perfect foresight is the only assumption about expectations which takes full account of the structure of the underlying model and, in the sense flows naturally form the model itself.

Loosely speaking, the concept of 'perfect foresight' can be defined by the requirement that 'the expected time paths of all prices are precisely those time paths which are fully consistent with maintaining equilibrium in the economy at every instant of time in the future'. Then, future actions are merely the implementation of current decisions for future periods. This implies that the prices of all periods must be solved for simultaneously. Although perfect foresight may, at first, be seen as an extreme assumption, it appears useful benchmark for analyzing behaviour, just as the assumption that consumers optimally choose among commodities appears useful in elementary demand analysis. The assumption of fully rational perfect foresight provides a useful benchmark because deviations from full rationality are not likely to be systematic. [Auerbach and Kotlikoff (1987) p. 10] They argued that less than perfect expectations imply that agents are irrational in some way.

[37]Recent evidence of many of applied dynamic general equilibrium tax models suggests that the choice in modelling expectations is an important one. Ballard (1987) examines the effects of moving from current income tax system to a consumption tax in the United States in the FSW model with "variable expectations" and tested the sensitivity of the results to changes in the specifications of expectations. He concludes that static expectations and perfect foresight yield rather similar results, and the value of additional foresight leads to a lower level of welfare.

To see important aspects of perfect foresight a more precise definition is needed, which is the following:

Given the initial conditions on real (capital) and financial assets (bonds and equities), a perfect foresight path for the economy is a combination of time paths for the endogenous 'price' variables and the endogenous quantity variables, which jointly satisfy the following conditions:

(1) the implications of optimal behaviours of firms, namely that the time path of L from equation (20a), I/K from equation (18'), X from equation (20b), y_j from equation (20c), γ from equation (14d) and $\dot{K}$ from equation (5) are derived from the maximisation problem in section 2 of this chapter; using the time paths of the endogenous 'price' variables as the basis for firms' expectations;

(2) the implications of optimal household behaviour, namely that the time paths of C_j, B_j, B_w and E_j are derived from the maximisation problem of section 3, using the paths of the endogenous 'price' variables as the basis for household expectations;

(3) the government budget constraint;

(4) the balance of payments condition with the implications of treatment of foreign trade and financial capital flows; and

(5) the requirement of intratemporal equilibrium at every moment of time.

Since the fact that transversality conditions ensure that the model converges steady state values of variables, it is necessary to show that perfect foresight paths lead to the steady state point found in solving optimal growth maximisation problem satisfy the transversality conditions of the individual decision problems of the representative household and representative firm. This has been done in similar models by Sinn (1987) and Mussa (1977) to the model in this study.

4.7 USING THE MODEL IN ANALYZING TAX POLICY CHANGES

If the model is described by the movement of changes in the rate of investment, I/K, and the capital stock, K, we assume that K is a 'slow moving' variable while I/K is a 'jump' variable. Thus, $K(t)$ is given at the time of the unanticipated change in the tax rate, i.e., predetermined variable. The initial steady state values of I/K and K, together with new steady state values and the adjustment cost technology, determine the amount by which I/K must 'jump' in order that new steady state be reached. Since the policy change affects capital accumulation through changes both in marginal benefits from investment and in marginal cost of investment, the movements of I/K and K require particular adjustments in Q, the cost of capital (cost of finance), and the debt to equity ratio.

In the light of this discussion, we can inspect the q-investment theory, in particular q-ratios, in reflecting the points made above. To do this let us reproduce the tax adjusted ratios, Q:

$$Q=[\frac{V-DE}{P_K K}-1+z+DN][\frac{P_K}{P_N(1-\tau_c)}] \tag{55}$$

Since, in equilibrium, firms choose investment level so as to equate the present value of the future products of a unit of capital with the effective cost of a unit capital (new investment) good. Since new and old capital goods must be of equal future profitability, the market value of firm equals the present value of the future products of a unit capital. (Hayashi, 1982). In the presence of taxation, on the other hand, one should subtract investment subsidies that reduce the firm's out-pocket cost. The investment tax credit directly reduces the real acquisition cost of new capital goods; the purchase of new capital good carries with it a stream of future tax-deductible depreciation allowances has a similar effect. These two factor reduce the effective price of capital goods from *1* to *(1-z-DN)*, where z is the investment tax credit and DN is the write-off depreciation allowances and the present value of the tax savings from the depreciation deductions arising on a new investment of one pound. This cost must be compared with the increase in the market value that results from the purchase. Under the assumption stated above that capital is homogeneous, the increase in the stock market value of a firm brought about by an extra pound of investment is $(V-DE)/P_K K$, where DE is the present value of the tax savings due to depreciation on existing capital. These must be subtracted because they are not related to new capital; DN already takes account of the depreciation allowances expected on new capital. Finally, since adjustment costs are expensed, firms invest until the market value of the additional capital minus its acquisition cost equals the after-tax cost of installation. When the corporate tax rate rises, marginal installation costs decline on an after-tax basis so investment increases, other, ceteris paribus. The term, $(1-\tau_c)$, is used in calculation Q-ratios to reflect that adjustment costs are expensed.

The effects of taxation on Q-ratios can be inspected from the market value of firm, V, the effective price of capital good, $(1-z-DN)$. Since the market value of the firm equals the present value of future cash flows, NCF, discounted at the nominal, after-tax cost of capital, Γ, taxes affect the market value of the firm directly through changes in NCF and indirectly through changes in Γ. While only business taxes can affect directly NCF, both business and personal taxes generate changes in Γ.

These effects can be clarified as follows. First, changes in the corporate tax rate, τ_c, the investment tax credit, z, and the depreciation allowances on new capital, DN, drive a wedge between the movements of Q and I/K. However, there might be windfall effects to the extent that taxes are targeted to old capital. Second, changes in taxes on marginal revenue of capital at corporate level allowing higher earnings and dividends and thereby increases the market value of firms and thus investment. Third, changes in taxes that affect the relative cost of debt finance to retention finance drives a wedge between the movements of the debt-equity ratio, γ, and the interest rate, r_B. The changes in the taxes that induce movements in γ affect the cost of capital, Γ by making adjustments in γ's optimal value. In turn the movements in Γ lead to changes in investment level. To see the last point clearly, let us reproduce the cost of capital expression:

$$\Gamma=[\theta_c r_B^D+\frac{\phi_g(\gamma)}{\gamma}]\frac{\gamma}{1+\gamma}+[\bar{d}+\frac{\dot{P}_E}{P_E}]\frac{1}{1+\gamma} \tag{56}$$

with the (arbitrage) condition that

$$\theta_p r_B^D = \frac{\theta_p}{\theta_b}\bar{d} + \theta_g \frac{\dot{P}_E}{P_E} \tag{56a}$$

where θ is the various tax factor such that subscript p denotes the personal income tax, b is the dividend tax credit, g represents the capital gains tax. What it implies is that in the steady state the model determines the dividend pay-out ratio, $\bar{d}$ and in transition the growth rate of shares prices $\dot{P}_E/P_E$ is determined by the arbitrage condition. Changes in τ_p, b and τ_g require adjustments in $\bar{d}$ in the steady state. In the steady state, the change in $r^D{}_B$ can only be generated by a change in τ_p. This can be seen from the relation on the consumer side.

$$r_B - \pi = \rho + \frac{1}{\sigma_u} g \tag{57}$$

where $r_B=\Omega_0(1-\tau_p)r^D{}_B+(1-\Omega_0)r^w{}_B$ with $\dot{e}/e=0$ in the steady state. Since π, ρ, g, σ_u, and $r^w{}_B$ are exogenously specified to be constant and Ω_0 is constant in the steady state, the change in τ_p must be absorbed by the change in $r^D{}_B$ so as to satisfy the condition. This is also consistent with the interest parity condition:

$$(1-\tau_p)r_B^D = r_B^w + \dot{e}/e \tag{57a}$$

Because the world interest rate remains constant as the requirement of small country assumption associated with the financial market and the steady state equilibrium condition requires that $\dot{e}/e$ equals zero, the change in τ_p must be adjusted in $r^D{}_B$ so as to satisfy the condition.

To see dominant effects let us review the possible effects of the particular policy change. The corporate tax cut, on the one hand, stimulates investment by raising the after-tax marginal product of capital, on the other hand reduces investment via declines in the value of tax depreciation allowances and via increases in the cost of capital. The latter effect stems from the fact that the tax cut reduces the tax advantage of debt finance, deductibility of interest payment from corporate tax base, and in response to this firms lower the debt-to-equity ratios to balance the agency costs of debt which in turn mitigate increases in the cost of capital. Dismantling partially first year and initial capital allowances directly reduces the marginal cost of investment, which makes capital factor relatively expensive to labour factor and leads to substitution between capital and labour factors. The marginal rate cut in personal income tax changes the relative cost of bond finance and retention finance by raising the net return to interest-bearing assets more than equity assets and makes ownership of bonds more attractive relative to ownership of real capital. If there is no change in capital gains taxes, the personal income tax cut, and accompanied by a similar cut in dividend tax credit surely will favour interest-bearing assets in terms of net returns. Increases in savings of the households derives interest rate down and stimulate investment.

In closed economies, saving and investment represent, respectively, the supply and demand for new domestic capital. Saving incentives shift the supply curve for new domestic capital, while investment incentives shift the demand curve. Hence, in closed economies, from the basic public finance equivalence theorem -that the real effects of a tax (subsidy) are independent of who nominally pays the tax (receives the subsidy)- one can conclude that saving and investment incentives do not represent conceptually distinct policies and that the real effects of taxes or subsidies are the same whether applied to saving or the demand for new capital, investment. However, there are meaningful distinctions between policies that affect savings incentives and investment incentives. the latter treats newly produced capital more favourably than existing capital, whereas saving incentives do not distinguish them. This distinction provides a useful starting point for the discussion of the effects of tax policy changes on capital accumulation, growth and the asset values of capital because although both types of policies alter marginal incentives to accumulate new capital[38].

Note that costly adjustment of investment to desired changes in long-run capital intensity constrains the supply of new capital goods. Adjustment costs add dynamics on the one hand and provide another reason for a difference in the pre-tax value of new capital and the value of old capital on the other hand. We discussed adjustment

[38]As for tax reform concerns, public economists point out that investment incentives represent a shift from income to consumption taxation, while savings incentives represent a shift from income to wage taxation. For a good discussion, Auerbach and Kotlikoff (1987) ch. 9.

dynamics before, now let us discuss the latter. The difference in the pre-tax value of new capital and the value of old capital, caused by adjustment costs, leads that the impact of an investment incentive on the market value of the firm is no longer clear. If the firm is attempting to expand its stock of capital, old (installed) capital gets a premium relative to new (non-installed) capital because of the adjustment costs required to install new capital. If the firm is trying to reduce its stock of capital, it values a unit of noninstalled capital more highly than installed capital because of the installation costs it is paying to disinstall capital. Hence, investment incentives will directly lower the value of existing assets whereas adjustment costs will drive it up. Which affect dominates depends on the magnitude of adjustment costs.

CHAPTER 5 MODEL IMPLEMENTATION

5.1 INTRODUCTION

Applying the model described in chapter 4 requires data collection, parametrization, and solution method. Data collection and parametrization are simplified on the adoption of deterministic calibration rather than stochastic estimation. The use of this sort of calibration approach is necessary because the number of exogenous variables is small, and extensive use of excluded variables as identifying restrictions is not possible because of the general equilibrium interdependence which the model captures. If single equation estimation is used, parameter estimates will be obtained which do not necessarily generate an equilibrium consist with observed data. To achieve this consistency, parameter values for equations are calculated from observed data using the equilibrium conditions of the model. Hence, data are structured for a single and particular year, which we choose the year 1980, and parameter values are obtained from these data in a way that will be explained below.

Given that there is an accounting system corresponding to every economic model, it is useful to make the accounts explicit in the form of a social accounting matrix (SAM) and more importantly such a matrix can be used as the framework for a consistent set of data[39]. The SAM provides a consistent picture of the flow-of-funds accounts of the separate institutions or "actors" in the economy that one may wish to distinguish. However, the widely-used standard SAM is not sufficient to capture main aspects of the model at hand in which a variety of different assets including domestic bonds, foreign bonds, equity and real capital are incorporated. To illustrate how the loanable funds market works in the model, we constitute a financial SAM, (or FSAM) which includes a subset of the assets, expressed in flow terms, indicating the changes in the assets and liabilities of the various actors during a period.

The remainder of this chapter is organised as follows. Section 5.2 describes data sources and consistency adjustments in constructing the benchmark equilibrium data set.

[39]There is a considerable body of literature showing how SAMs can be used to provide a framework for collating, reconciling, and presenting a detailed quantitative picture of an economy. Special Issue (SAM-based models) of Journal of Policy Modelling, Fall 1988 presents a range of studies on this area.

Section 5.3 focuses on parameterization issues. Section 5.4 discusses 'equal yield equilibria'. Section 5.5 discusses welfare measurement. Finally, section 5.6 explains solution method.

5.2 CONSTRUCTING THE SAM OF THE UK ECONOMY

A SAM is a simple and efficient way of representing the fundamental law of economics that for every income there is a corresponding outlay or expenditure. It provides the workings of an economy. So, one can use it as an organising framework with its device presented in one unified set of accounts a picture of the "circular flow" of a market economy. Therefore, we will use the SAM as the framework for a consistent data set.

Table 5.1
Social accounting matrix.

	Expenditures							
Receipts	Commodities (1)	Activities (2)	Factors (3)	Households (4)	Government (5)	Capital (6)	Rest of world (7)	Totals (8)
Commodities (1)		y		C	G	I	Z	Aggregate Demand
Activities (2)	Y							Value of output
Factors (3)		$P_L L$ $P_K K$						Aggregate factor income
Households (4)			$P_L L$ $r^D{}_B B$ DIV		Tr		$r^w{}_B B_w$	Household income
Government (5)	T_v	T_{vy}	T_L T_C	T_P T_g T_w			T_M	Government revenues
Capital (6)			RE	S	PSBR		BOC	Investment funds
Rest of world (7)	M		$r^D{}_B B$					foreign exchange payment
Totals (8)	Aggregate supply	Total costs	Aggregate factor income	Household expenditure	Government expenditure	Aggregate investment	Foreign exchange receipts	

Equilibrium conditions

1) flow equilibrium in product and factor markets

a) product market

$$Y+M = y+C+G+I+Z \tag{58}$$

b) factor market

$$L^S = L^D \tag{59}$$

2) flow equilibrium in loanable funds market

$$S+RE+PSBR+BOC = I \tag{60}$$

3) equilibrium in assets markets

a) equity

$$P_E E^S = P_E E^D \tag{61}$$

b) bonds

$$B^S+B^S+B_w^S = B^D+B_g^D+B_w^D \tag{62}$$

4) intertemporal equilibrium

Previous equilibrium conditions, i.e., intratemporal equilibrium conditions, must be satisfied for all time simultaneously.

In constructing a SAM, the first thing to be noticed is that it is a square matrix and corresponding row and column sums are equal. The defining characteristic of a SAM is then that each row and column reflects a separate account for which expenditures and receipts must balance. First, table 5.1 includes a set of accounts (numbers 1 to 3) for production. Second, there are accounts (numbers 4 and 5) for institutions, that is for households and government. Third, table 5.1 incorporates a capital account (number 6)[40]. Finally, table 5.1 shows a distinction between the home economy (accounts 1 to 6) and the rest of the world (account 7).

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[40]Although the SAM includes government budget deficit or surplus, the model does not treat unbalanced government budget. For the sake of completeness, we also describe government budget balance. Also, the model assumes a balanced trade account in the base case.

The "commodity" account keeps track of products market equilibrium; the supply of the commodity, which equals the domestic gross output plus imports from the rest of the world, equals the demands for the commodity by households, government, firms -demands for intermediate inputs- and the rest of the world -exports. The account is the net of output tax and indirect taxes -value added tax and specific excise duties. The "activities" account represents producers. As a requirements of the basic conceptualization that activities buy raw materials and hire factor services in order to produce commodities, producers pay out total revenue from sales of their output to commodity market to intermediate inputs suppliers as material costs, factors of production as factor costs and government as indirect taxes (row 2 and column 2). The factors accounts reflect the property that the model possesses that capital is tied to firms and accordingly factor incomes are paid as labour income, interest payments to households and/or to the rest of the world and as dividend payments. Producers also pay taxes on labour and profits. Firms also retain some of their earnings in order to finance investment.

Along with producers, the "institutions" (households and government) are represented by accounts 4 and 5, respectively. Households receive their income from firms as labour income, interest payments and transfer payments and from the rest of the world as interest payments. Households pay income taxes, capital gains taxes and then divide their disposable income between consumption and savings. Government receives income from direct and indirect taxes purchases commodities directly, pays transfers to households and also saves, in other words runs deficits.

The "capital" account in the sixth row and column summarizes the "loanable funds" market, collecting savings along the row and purchasing capital goods in the column. This account is further elaborated below in a financial SAM. Finally, the last account shows the relationship between the home country and the rest of the world. Accordingly, foreign exchange receipts for the home country come from exports and interest payments on domestic households foreign bond holdings. The home country makes foreign exchange payments to imports and to interest payments on the rest of the world's domestic bond holdings. A difference between foreign exchange receipts and payments is represented by a balancing item, either surplus or deficit, of current accounts.

From the accounts portrayed in table 5.1 one can notice the three basic macro balances: balance of current account, saving-investment, and government deficit. Depending on the macro closure rules chosen, the model can become either static or dynamic with endogenous macroeconomic behaviour. Specifying endogenous equilibrating feature to the basic macro balances, the model expand the notion of equilibrium to incorporate the loanable funds market, asset, and expectations. Saving-investment, government budget deficits and international financial flows as a whole are not only elements of a flow equilibrium condition but also require stock market equilibrium conditions. Therefore there are four equilibrium concepts that form the raw material of a dynamic model with endogenous macro behaviour.

To illustrate how the loanable funds market works in the model, table 5.2 shows a financial SAM (FSAM) which includes a subset of the assets. The FSAM is expressed in flow terms, indicating the changes in the assets and liabilities of the various actors

Table 5.2
Financial social accounting matrix.

		Capital accounts				Change in assets			
Current accounts		Firms	House-holds	Govern-ment	Rest of World	Capital goods	Firm bonds	Public bonds	Foreign bonds
Current accounts	SAM					I			
Capital accounts									
Firms	RE						ΔB		
House.	S								
Govern.	PSBR							ΔB_g	
World	BOC								ΔB_w
Change in liabilities									
Capital goods		ΔK				δK			
Firm bonds			ΔB^h		ΔB^w				
Public bonds			ΔB_g						
Foreign bonds			ΔB_w						
	SAM + Savings	Change in net worth				New capital	New firm bonds	New Public bonds	New foreign bonds

Equilibrium conditions

$$I = \Delta K - \delta^R K \tag{63}$$

$$I = RE + \Delta B \tag{64}$$

$$S = \Delta B^h + \Delta B_g + \Delta B_w \tag{65}$$

$$\Delta B = \Delta B^h + \Delta B^w \tag{66}$$

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during a period. The FSAM can be seen as a simplified presentation of the major financial linkages in the model.

Like all SAMs, the FSAM is square, with each column sum equal to the corresponding row sum. The standard SAM of the table 5.1 is collapsed into the first column and row of the FSAM, while the capital account is expressed to include the capital accounts of four agents: firms, households, the government and the rest of the wold. There are two types of assets; namely, physical capital goods and bonds, and the latter is further differentiated: firm specific bonds, government bonds and foreign bonds. The columns indicate the change in assets, while the rows indicate changes in liabilities. The last row and column sets out the change in the balance sheets of the actors with respect to the assets.

The savings entries in the first column (which represent flows from current accounts to capital accounts) represent the injections of savings into the loanable funds market. This account, as an equilibrium condition, must equal investment account. Firms are assumed to finance their investment by the mix of retained earnings and bond issuance. So firms issue bonds by the amount of investment minus retained earnings. The government and the rest of the world also issue bonds to finance government budget deficit and to take advantage of interest rate differentials, respectively. However, if domestic interest rate is greater than foreign interest rate, the rest of the world is then assumed to have saving and use it to purchase domestic firm bonds. Thus, household savings are used to purchase a mix of these bonds issued by domestic firms, the government and the rest of the world. A final point to note, capital stocks depreciate and net increase in capital stocks is equal to gross investment minus depreciation.

The FSAM is constructed so as to satisfy four equilibrium concepts. The first is flow equilibrium in product and factor markets. Since firms buy raw materials, hire labour services and use capital factors owned by these firms in order to produce commodities, in this process they generate revenues out of sales of their products to commodity markets and make payments to production factors. This revenue is partially offset by purchases of raw materials. The remainder is, by definition, a tax on activity (value added tax). Since capital factors are tied up to firms, as a balancing item on liabilities side firms must have bond stocks and common stocks. Hence after payments to labour factor, P_LL, i.e., profits, EARN, go to interest payments. Column 2 shows these payments. In column 1, Y^D represents the value of domestic products sold on the domestic market and M, imports. The column sum plus tariffs equals aggregate supply[41]. Row 1 details domestic demand items, household consumption, government expenditure and investment expenditure. Balance in the first two accounts yields the standard absorption identity: absorption=C+I+G=GDP+M-Z. In column 3, factor payments are broken down, as explained above. Similarly row 3 shows before tax factor payments,that is wages plus profits. Government collects taxes on the use of labour factor and company profits.

A second equilibrium is that of flow equilibrium in the market for loanable funds. Households supply the fund to loanable market as savings and this fund is demanded by firms to finance investment, the government to finance deficit. Another source of fund comes from the rest of the world as foreign financial capital flows. Achieving Savings-investment equilibrium is equivalent to specifying how equilibrium is achieved between the supply and demand of loanable funds. Row 6 of table 5.1 reveals sources of savings. As a condition that total savings is equal to investment shown in column 7.

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[41]Obviously, production activities and commodities can be disaggregated as has been done in the paper.

Third, there is equilibrium in asset markets. Equilibrium is defined in terms of firms achieving a desired debt-equity ratio and of household passively accommodating their demands for assets supplied by other agents. Two condition can be expressed as an equilibrium in $I=RE+\dot{B}^c$.

Finally, there is a notion of intertemporal equilibrium. Intertemporal equilibrium consists of two sorts of equilibrium notions: instantaneous equilibrium and long-run equilibrium. Firstly these equilibrium conditions altogether gives a notion of instantaneous equilibrium. However, actors are assumed to change their current behaviour based on their expectations about the future course the economy will take. In the long-run, it is assumed that the economy is on the steady-state equilibrium. Given that the balanced growth theory holds, it is written that capital stocks of firms and consumption of the household grow at the steady-state rate.

5.3 THE BENCHMARK EQUILIBRIUM DATA SET

Data requirements for the model are extensive. These include capital stock and its financial structure by industry, labour usage by industry, an input/output table, consumer expenditures by commodity and incomes by source, government expenditures and tax collections, and foreign trade. In addition, allowing for depreciation of capital stocks requires data on rates of depreciation for economic purposes and tax purposes. The model integrates data from several sources to form a 1980 benchmark data set.

5.3.1 Production Data

The information available in the National Accounts is primarily macro and value-added, hence an input/output table is needed to obtain data on surplus of industries and their intermediate demands. We used the data on input-output given in the book "Input-output tables for the United Kingdom 1984" (HMSO 1988). Data in the book are disaggregated for eight industries. In the model since we consider five industries, that is J=5; namely, (i) agriculture; (ii) energy; (iii) manufacturing sector; (iv) services, trade and utilities; and (v) housing services, we make necessary adjustments to reduce them to five industries. Data needed on the production side are required to be disaggregated for five industries (that is, J=5). The industries are classified as follows:

Agriculture: agriculture, forestry and fishing.

Energy: coal mining, other mining, quarrying and gas

Manufacturing: food, drink, tobacco, mineral oils, other coal, petroleum products, chemicals, metals, textiles, clothing, leather and fur, timber, furniture, paper, printing, publishing, instrumental engineering, shipbuilding and vehicles.

Services, trade and utilities: communication, retail trade, wholesale trade, transport, banking, insurance and construction.

Housing services: housing services

To calculate Leontief parameters a_{ij}, data on input use of industries and supply of them are taken from the book "Input-output tables for the United Kingdom 1984" (HMSO 1988). The CSO Blue Book (United Kingdom National Accounts) provides data on labour use by industry for the year 1980.

As for data on capital stocks of industries, a difficulty arises with the availability of data: Neither the Blue Book nor Input-Output Tables publish disaggregated figures of capital stock. One source of information is the Blue Book where gross capital stocks are broken down by industries. We use this information to convert aggregate data on net fixed capital stocks into disaggregated data. A further breakdown of capital stocks by asset is required for calculating depreciation rates for both economic and tax purposes. The breakdown of capital stocks by asset is made as follows: we calculate average values of the data on the capital formation made on assets (vehicles, machinery, buildings) over ten years. The data are taken from the Blue Book. For economic depreciation rates we use the data given in King and Fullerton (1984). However, King and Fullerton's work does not cover some of industries which are modelled in this paper: agriculture, energy, financial services, utilities and housing services. For these industries we calculate economic depreciation rates from the data on capital consumption by industry published in the Blue Book. As for tax depreciation rates, we compile the tax code and the sample data given in the Inland Revenue Book. We take investment values from the data on capital formation across industries and capital allowances from the sample data given in the Inland Revenue Book. Given these data we run a simple calculation to find actual rates of tax depreciation - the rate of first year depreciation allowances, the rate of the initial depreciation and the rate of annual depreciation allowances - accordingly calculate. In order to reflect actual figures we did not use the tax code. Table 5.3 reports benchmark values for certain variables and parameters calculated from the data defined above.

In many applied general equilibrium models, marginal corporate tax rates are set equal to the observed average tax rate on capital income, calculated separately by industry. This approach conveniently abstracts from the many detailed provisions of the specific country tax law. However, it possesses many problems. Most immediately, the measured average tax rate depends critically on the measure for true earnings to capital. This latter number is difficult to calculate appropriately in any year and varies greatly from year to year. This variation implies that there is substantial measurement error in the calculated tax rates. In this paper, we instead model the tax law directly while this procedure requires many new data in order to characterize the tax law by industry, it does not require capital income and tax payment figures, which can fluctuate sharply from year to year. However, we further simplify and assume that industries except housing services industry are corporate firms. Housing services sector is represented by corporate housing, tenant-occupied noncorporate housing and owner-occupied housing. Their shares in housing sector are calculated from the data supplied in Black and Stanford (1988); they are 10 percent, 30 percent and 60 percent, respectively. Accordingly, the effective tax rate on earnings is calculated as the share of (tenant-occupied) corporate housing in all housing times the statutory tax rate. A more important reason for our remodelling, however, is that the explicit model of the effect of taxes on economic decisions implies that marginal tax distortions differ dramatically from average tax rates, even if all figures can be measured without error.

The Data for labour use by industry are taken from the National Accounts. As it is noticed, Data taken from the Input-output Tables for the year 1984, therefore we adjust them for to year 1980.

Table 5.3
Benchmark values for industry tax and behaviourial parameters and capital stocks

Parameter or stock variable	Agriculture	Energy	Manufac-turing	Services, trade and utilities	Housing services
Capital stock	15.8	90.6	136.7	263.1	246.0
% Machinery	0.400	0.495	0.692	0.307	0.000
% Building	0.508	0.492	0.232	0.539	1.000
% Vechiles	0.092	0.013	0.076	0.154	0.000
Rate of economic depreciation (δ^R)	0.070	0.050	0.045	0.057	0.016
First year depreciation rate ($\delta^T{}_f$)	0.250	0.400	0.600	0.350	0.000
Initial depreciation rate ($\delta^T{}_a$)	0.010	0.015	0.060	0.010	0.000
Annual depreciation rate ($\delta^T{}_w$)	0.050	0.055	0.020	0.040	0.040
Import substitution elasticity	0.8	1.6	3.2	0.8	-
Export demand elasticity	0.6	1.2	2.4	1.8	-
Production efficiency factor	0.612	0.581	1.081	1.115	0.118
Labour/Capital ratio	0.082	0.072	0.316	0.355	0.000
Debt-equity ratio (γ)	0.190	0.224	0.251	0.363	0.500

Scalars:	
Corporate tax rate (τ)	0.52
Capital gains tax rate (τ_g)	0.075
Marginal income tax rate (τ_p)	0.35
Dividend credit rate (b)	0.30

To calculate agency cost parameters we need data on debt-equity ratios by industry. Debt-equity ratios are derived from The Extel Limited Data Set. However, the source does not provide information for all industries. The literature enables us to use sensible values for the debt-equity ratios cannot be calculated from the Extel Limited

Data Set. We take a value of 0.190 for the debt-equity ratio in the agriculture sector. Studies on housing market such as Black and Stanford (1988) indicate that debt-equity ratio in the housing sector is a value of around 0.5.

The adjustment cost parameters have been estimated in several works; Jenkinson (1981), Poterba and Summers (1983) and Bond and Devereux (1988). Sensible values for parameters are chosen in a way that those that are chosen are not necessarily reported in these works.

5.3.2 Data on Demand

The categories for goods from consumer expenditure data differ from the categories for outputs from production data. The consumer expenditure data are classified for 28 categories in the input-output Tables. Accordingly, we transform five producer goods to 28 consumer goods through the fixed-coefficient matrix. Each coefficient gives the amount of a particular producer goods needed to produce one unit of a particular consumer good. The data for the demand for commodities by the household, and government and foreign trade are derived from the Input-output Tables. The difficulty lies in finding indirect tax rates on commodity purchases. We tackled the difficulty by applying the tax law tax to calculate indirect tax rates for five commodities. This can be done without any loss of relativity because the advantage of the detailed consumer expenditure categorization allows us correctly define indirect rates on each consumer goods. In order to calculate average personal income tax rate, the data on income taxes paid and household disposable income that are available in the National Accounts are used. However, calculation of marginal rate requires additional data and work. This has been done in Fullerton and King (1984). Finally, we employ a value of 0.075 for the effective tax rate on capital gains. The tax rate differs for capital gains on residential capital. It is assumed that the half of residential capital gains are subjected to capital gains tax.

The model simplifies certain aspects of modelling issues. Firstly, unbalanced government budget is not allowed. Secondly, although capital flows are allowed, in the base case we assume a balanced trade account. Thirdly, the marginal income tax rate is taken as a rate of 35 per cent. A distinction between marginal tax rates on capital incomes and labour income would be beneficial. However, we simplify such tax treatment by taking one single marginal tax rate applied to all incomes. Studies done by Fullerton and King (1984) others suggest that personal income tax rate on dividend and interest income is above 40 per cent. We take into account of personal income tax rate on labour income and thus adopt a rate of 35 per cent. Similarly, we choose a rate of 30 per cent for the dividend tax credit rate. The model captures that the personal income tax is not levied on imputed income from owner-occupied housing services.

5.4 PARAMETERIZATION

Calibrating the model involves deriving values for parameters. However, values for two sort of parameters cannot be found in any calibration procedure because the benchmark data only give price and quantity observations, associated with a single equilibrium. They are (i) elasticity parameters defining certain degree of substitution between opposing choices such as consumption today or tomorrow, investing today or tomorrow, domestic consumption or import, issuing bonds or retaining earnings and demanding domestic goods or not (ii) certain parameters which define the steady-state property of the model such as the balanced growth rate, nominal interest rate and the inflation rate. Hence we specify values for intertemporal elasticity of substitution between consumption at different periods, elasticity parameters of adjustment cost, elasticity parameters of agency cost, price elasticity of export demands, trade substitution elasticities, certain intertemporal defining parameters such as the balanced growth rate, nominal interest rate and the inflation rate, and a parameter which controls international financial capital flows, based outside estimates. These values serve to identify uniquely the other parameters of the model along with the equilibrium observation. Given exogenously determined substitution elasticity parameters, a technique of "backwards solution" has been used to determine the remaining parameters.

The adjustment cost parameters have been estimated in several works: Jenkinson (1981), Oulton (1981), Poterba and Summers (1983), and Bond and Devereux (1988). However, these works use data of manufacturing industry, industries such as housing which holds a considerable amount of capital stocks are not taken into account. One then could argue that without other industries such as housing with low depreciation rates one could argue that they tend to estimate parameter values biased upward. It implies that they do not reflect the adjustment cost behaviour of industries as a whole correctly. Instead, we take low values for adjustment cost parameters. In the paper the estimated values of adjustment cost parameter are lowered down taking into account other industries and chosen as a value of 0.035 for α^d_0 and 15 for α^d_1. As for agency cost parameters, we guesstimate a value of 0.5 for α^g_1 and derive α^g_0 from the debt-equity ratios in the calibration.

Econometric estimates of the intertemporal elasticity of substitution (σ_u) vary considerably. We employ a value of 0.8 for σ_u. This value is consistent with the value for the saving elasticity parameter used in Piggott and Whalley (1985). We consider a range of plausible estimates in the sensitivity analysis.

For the parameters of price elasticity of export demands, trade substitution elasticity Piggott and Whalley provide information. They take a value of 1.25 for all product categories. We disaggregate this common value across industries in way that we increase the value for the export-oriented industries such as manufacturing and decrease it for other industries.

Finally, for the parameter that controls international capital mobility, we adopt a value of 10^7 for the parameter ($\bar{B}$). We scale this value across time to bring them in line with the levels implied by balanced growth rate and inflation.

Since the fundamental assumption made in calibrating the model is that the economy is in equilibrium in a particular year, the technique of backwards solution must satisfy certain equilibrium conditions. In a dynamic context, there are two sorts of requirements:

(a) Replication requirement. In the base case the model must generate an equilibrium solution with values matching those of the benchmark data set. In particular the levels of inputs in each sector, the levels of factor incomes, and the magnitudes of various tax payments must be identified to those of the benchmark data set.

(b) Balanced growth requirement. The model must simulate a balanced (steady-state) growth path, when the base policy is maintained.

The first requirement indicates intratemporal equilibrium condition as the second requirement is associated with the intertemporal equilibrium condition.

Intertemporal aspects of the parametrization can be explained as follows: First of all it is assumed that initially economy is on a balanced growth path. Hence, first we need to specify exogenously, the steady-state growth path, **g**. It takes the value .0275 that is the average value of the growth rate of the last two decade GDP, in our simulations. Accordingly, in the steady state, in discrete time, $\Delta K/K=\mathbf{g}$ and $\Delta C/C=\mathbf{g}$. Also, in the steady-state, financial variables grow at a combined rate of the rate of balanced growth and the rate of inflation such that $(1+\pi)(1+g)-1$.

The first condition, form the equation of motion for capital, implies that the rate of gross investment, I/K, in each sector must satisfy

$$\frac{I}{K}=g+\delta^{R} \tag{67}$$

Since we have the benchmark data on K and δ^R, we can obtain the initial level of investment in each industry. Having the value of the rate of gross investment, I/K, and given the parameters of the adjustment cost function, we invert equation (19) to solve for the steady-state value of Q.

The nominal depreciable capital stock, K^T, can be derived from the relationship

$$K^T(t+1) = (1-\delta_w^T)K^T+(1-z)(1-\delta_f^T)P_K(t)I(t) \tag{68}$$

In the steady-state, the relation between capital stock basis for tax purposes and capital stocks is then given by

$$\frac{K}{K^T}=\frac{(1+\pi)(1+g)-(1-\delta_w^T)}{(g+\delta^R)(1-z)(1-\delta_f^T)} \tag{69}$$

Given the values of the variables appearing in (69), we solve equation (69) for K^T in each sector.

In order to calculate V we use the relationship (7). It is rewritten in discrete time as:

$$\frac{NCF}{V}+\frac{\Delta V}{V}=\Gamma \tag{70}$$

It requires a long process to calculate the net cash flow, NCF. Data on the gross production levels and the use of intermediate goods and labour are used to obtain gross earnings of firms. But we must use net production levels, that is values after deducting agency and adjustment costs. With the extraneous values of adjustment cost parameters and the derived value from the calibration procedure, as explained above, a correct value for gross earnings can be calculated. When deductions of debt interest payments and taxes paid by firms, such as corporation tax, are made from gross earnings, it yields net earnings.

Since the link between households and firms is the cost of capital, driven by the rates of return required by households, now it is time to show how to obtain the cost of capital depending on the rates of return required by households. The first condition implies that investment is financed with retained earnings and bond issues, and that the debt-equity ratio must be constant. In turn, this implies that borrowing at steady-state is defined as

$$\Delta B=[(1+g)(1+\pi)-1]B \tag{71}$$

We can derive the dividend payout ratio, $\bar{d}$, from the arbitrage condition (4').

Once we have a value for the dividend payout ratio and given the benchmark data on debt-equity ratios and tax parameters, it is straightforward to obtain a value for agency cost parameter, α^{g}_{0}, by solving the equation (14d) and ruling out one of the roots. Finally, with the values of agency cost parameter, debt-equity ratios and tax parameters the equation (11) calculates the cost of capital.

When the values for NCF and Γ are obtained, we substitute the steady-state condition of the growth rate of the market value of the firm for $\Delta V/V$, into (70) which can now be solved for V.

The last job regarding intertemporal aspect is to obtain the tax-adjusted q-ratios, appeared in equation (19). First, we calculate the present values of writing down depreciation allowances on existing capital, DE and new capital, DN. DE and DN in discrete time can be expressed as:

$$DN_w(t)=\frac{1}{1+\Gamma}[(1-\delta^T_w)DN_w(t+1)+\tau_c\delta^T_w] \tag{72}$$

$$DE(t)=(1-\delta^T)K^T(t)[DN_w(t)+\frac{\tau_c\delta^T_w}{1-\delta^T_w}] \tag{73}$$

Accordingly, the present value of first, initial and writing down depreciation allowances on new capital can be written as:

$$DN(t)\ =\ \tau_c(\delta^T_a+\delta^T_f)+DN_w(t) \tag{74}$$

Then, these values with together V, K and tax parameters are substituted to provide Q-ratios. However, these Q-ratios might not match the steady-state ones. We adjust the data so as to produce the Q ratio implied by the balanced growth requirement and the values of adjustment cost parameters (see eq. 18' of the model). From the equation of motion for capital, eq. 5, given the economic depreciation rates and the values of capital stocks, one can calculate the level of investment. The relationship between the rate of investment and Q, with exogenously chosen the values for adjustment cost parameters, then corresponds to a particular value for the Q ratio. The data supplied in official statistics do not generate this q ratio. For this reason, we adjust production level.

The subroutine PCALIB takes care of this adjustment procedure in production level. The algorithm used in PCALIB is a NAG subroutine called C05NCF. The algorithm is an improved hybrid POWELL method that is written to solve non-linear equations system. PCALIB works with the subroutine BPROD, in which the producer's demand functions are located.

Once the program adjusted production levels, we are able to calculate the consumer's income level and wealth (human and non-human wealth). To determine savings and consumption a pure rate of time preference rate is required. Once a value for time preference has been specified, we can identify initial consumption. Since the value of aggregate household savings must equal total external borrowing by firms, the subroutine DISRAT is written to calculate the rate of time preference[42]. From the intertemporal equilibrium condition for the consumer, it is required that the pure rate of time preference must be consistent with the nominal market rate of interest (see eq. 75). Since the calculation on the producer side is based on a specified rate of interest, on the consumer side we calculate a value for the pure rate of time preference. This is done in the subroutine BDMND. BDMND also calculates consumer spending on specific goods. The subroutine GVREV, accordingly, calculates various tax revenues, transfer payments and government spending on goods.

The second and third conditions together with the condition (31c''), the rate of return on consumption, can be used to find a value for the pure rate of time preference, ρ. In discrete time, a formula to obtain the pure rate of time preference is written as:

[42]Actually, there is no need such a subroutine. This is because from the intertemporal equilibrium condition for the consumer, eq. 75, one can calculate the pure rate of time preference.

$$\rho = \frac{(1+\tilde{r})}{[(1+\pi)(1+g)]^{\sigma}} - 1 \tag{75}$$

Given the values of the intertemporal elasticity of substitution, σ_u, the gross of tax nominal interest rate, r_B, and the rate of inflation, π, we can find a numerical value for ρ. Note that from the arbitrage condition the portfolio rate of return is equal to the after-tax interest rate. We specify exogenously the rate of inflation and the gross of tax nominal interest rate, whose values take 0.075 and 0.175 in our standard simulations.

We determine total nonhuman wealth (*WK*) by adding up debt and equity ownership across sectors. We take a zero value for the foreign bonds in the base case. From initial labour income and transfer, the household discount rate r_p, and the steady state growth rate, we calculate the present value of labour, transfer and income tax intercept. The solution of the household utility maximisation problem requires that

$$\tilde{P}\tilde{C} = \{1 - [(1+\pi)(1+\rho)]^{\sigma}(1+\tilde{r})^{\sigma-1}]\}TW \tag{76}$$

where TW=WK+WH. Since in the benchmark $\tilde{P}$=1, equation (76) yields initial consumption. Consumption is subtracted from initial income to obtain the initial value of household savings.

So far we have dealt with intertemporal aspect of calibration. Static aspect of calibration is much more straightforward to perform: it simply involves finding share values of production factors and expenditure on commodities.

5.5 EQUAL YIELD EQUILIBRIA

In applied general equilibrium tax models it is commonly used tradition to use an equal-tax-yield equilibrium concept in order to undertake "differential" analysis. Such analysis allows an existing tax to be replaced by an alternative tax system that raises equivalent revenue. This change in procedure allows us to maintain the size of government when the effects of changes in the structure rather than the level of taxes, we would not be able to interpret our results without worrying about changes in the pattern of total demands that are caused by changes in the amount of government spending.

In defining equal-tax-yield a question arises: what price index is suitable to correct the price changes occurred as a result of the adoptation of a new tax regime so as to preserve equal "real" revenue? Shoven and Whalley (1977) discuss a variety of price indexes. However, the concept of equal tax revenues is confined to cases when government activities is confined to taxation and transfers. On the other hand, when government activities include purchases of private goods in addition to taxation and discretionary transfers, equal yield is interpreted to mean "constant public utility". In this case, government base utility is maintained in the counterfactual experiments.

In this paper equal yield is also assumed to mean equal government public utility in both the base case and revised case equilibria. We give the government a utility function, and then use the corresponding expenditure function to calculate the revenue required for the government to achieve constant utility at any set of prices. The expenditure function expresses the amount of money necessary to attain a given level of utility at any given set of prices. When calculating a base-case equilibrium, we also calculate the government's utility. In equilibrium calculations for changes regime, we give the government enough revenue so that it reaches the same level of utility.

5.6 WELFARE COMPARISONS

There are several ways of associating a scalar welfare measure to the array of which defines an economic equilibrium[43]. Perfect foresight equilibrium models, in general, tend to use dynamic analogues of the standard money matric measures - Hicksian compensating and equivalent variations. In this study, a dynamic analogue of the Hicksian equivalent variations is used to measure changes in welfare.

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[43]Pereira (1988a, 1988b) discusses the commonly used welfare evaluations approaches.

Since consumer groups are regarded as infinitely-lived, to make welfare assessments it is necessary to calculate the utility derived from an infinite stream of consumption of goods. However, because of the steady-state properties of the model, it is possible to approximate the contribution to discounted utility of these infinite streams using results from simulations over a finite time interval. Under a revised case simulation, the economy departs from its initial steady-state path immediately following the policy change; however, the growth path of the economy converges to a new steady-state within about 50 years. Since simulations which calculate equilibria are generally run a period of 75 years, which is along enough interval to allow one to observe the feature of the new steady state, we can calculate to a very close approximation the welfare value of the infinite stream of consumption in the new steady state.

5.7 SOLUTION METHOD

We will explain solution method in two subsections: solution strategy and solution algorithm.

5.7.1 Solution Strategy

The approach to solving intertemporal models that is generally adopted consists of, first, solving for the initial steady state (the benchmark case: calibration); second, coputing the new steady state after policy changes; and, last, solving the transition path between the two steady states. Since our model assumes perfect foresight and rational expectations on the part of agents, current behaviour will depend on variables in future periods. Therefore, it will not in general be possible to solve the model recursively over the transition path. To obtain perfect foresight expectations, we repeatly solve the model forward, each time generating a path of equilibria under a given set of expectations. After each path of equilibria is abtained, we revise the expectaions and we solve for a new path. Hence, the solution of the model satisfies two sorts of equilibrium conditions. "Within period" equilibrium conditions require that, in any period, given any set of expectations for future variables current supplies and demands are in balance.

Intertemporal equilibrium conditions require that expectations conform to the values eventually realised in later periods.

In solving intertemporal allocation problems for finding the path of state and control variables over infinite time span, it is necessary to specify initial conditions for the state variables (stock variables such as capital stock) and terminal conditions (transversality conditions) for costate variables (asset price variables such as firm values) ensuring the model's convergence. In mathematical terms, the intertemporal equilibrium system is a two-point boundary-value problem.

In order to solve this kind of problem we make two alterations: approximation with difference equations for numerical solution of differential equations and replacement of the infinite time transversality condition with a finite condition[44]. The second alteration implies that a natural condition is that by time T, when T is large, the terminal values will converge to the steady state value. We take 75 year of T.

Once approximations have done, the strategy proceeds on expectations about the future. At any given point in time, t, these expectations are embedded within the current period values of the variables V_t, Q_t, DE_t, DN_{wt}, WH_t and N_t, where $N_t = \tilde{P}^{\sigma}/\tilde{\Lambda}$ and $\tilde{\Lambda}$ is the discrete analogue of Λ in equation (36')[45]. Using certain relationships we can reduce dimensions of these expectaions: from expression (19), we can express V_t in terms of Q_t, DE_t, DN_{wt} and prices and parameters from period t. In addition DE_t can be written in terms of DN_{wt} and current values. Thus, expectations hold in period t are fully summarised by the period t values of V_t, DE_t, DN_{wt}, WH_t and N_t. The time paths of such of these variables have certain characteristics that can be exploited: it is possible to derive explicit relationships of the form:

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[44]This corresponds to a transformation from continuous time analysis to discrete time analysis. As implicitly assumed in the previous chapters in which the model presented in continuous time, it is assumed that all transactions occur at the end of each period.

[45]When the endogenous financial capital mobility is considered, we add the exchange rate to these variables.

$$V_t = \frac{V^*_{t+1} + NCF_t}{1 + \Gamma_t} \tag{77}$$

where V^*_{t+1} denotes the period t expectation for the value of the firm in period t+1. Evaluating DN_w, WH, and N_t over successive periods yields:

$$DN_{wt} = \frac{1}{1+\Gamma}[(1-\delta^T)DN^*_{wt+1} + \tau\delta^T] \tag{78}$$

$$WH_t = YH_t + \frac{WH^*_{t+1}}{1+\tilde{r}} \tag{79}$$

$$N_t = \tilde{P}_t^{1-\sigma} + (1+\rho)^{-\sigma}(1+\tilde{r})^{\sigma-1}N^*_{t+1} \tag{80}$$

where $DN^*_{w\ t+1}$, WH^*_{t+1}, and N^*_{t+1} also denote the period t expectations for values in period t+1, YH_t is current labour and transfer income, and $\tilde{r}$ incorporates the risk premium associated with future labour and transfer income. We refer to the variables with asterisks as 'lead' variables.

Solution of the model proceeds on two steps. first solution step is to assign values to the lead variables for t=2,3,.....,T+1. Conditional on these guesses, we calculate a general equilibrium solution for every period; this is the whithin-period equilibrum problem. On the next step, we solve for the correct values for the lead variables; this is the intertemporal equilibrum solution problem.

5.7.1.1 Within Period Equilibrium

We assign an initial guess to current (product and labour) prices, interest rate and the exchange rate. We also specify tax policy. The strategy then works on the labour market. Given sectoral production technology and current capital stock one solves for the demand for labour in each sector.

An initial guess I^* is necessary to move on defining the demand for products and assets. The guess of investment allows us to calculate net cash flows in the current period based on current bond stocks. Solving equation (14d) for industrial debt-equity ratios and in turn using them in obtaining cost of capital, given the lead values for V, we can calculate current values for V. The next stage now is to calculate current values for Q. Since it can be defined in terms of V, DN_w, and DE, we then need to obtain values for DN_w and DE. Given the lead value for DN_w, we calculate current values for DN_w. Given the nominal depreciable capital stock, K^T, for the current period, since the values of DE and DN_w for a given period can be related, it is possible to determine DE from this relation. Finally, using the derived values for V_t, DN_{wt}, and DE_t, we calculate the current value of Q using (19). This value of Q implies a certain level of investment. If this value does not match the initial guess of investment which helped to generate it, the initial guess is updated and the entire sequence of derivations is performed again. This procedure is repeated until the initial investment guess matches the derived investment level.

From the optimal debt-equity ratio and the current Q we then derive investment, adjustment costs, and agency costs. Once adjustment costs and agency costs are known, we can calculate each sector's output from the desired input level and the current capital stock.

Given the lead value for WH, we calculate the current value for expected human and transfer wealth, WH according to equation (79). We sum the values of firms' bonds and firms' equities. We calculate non-human wealth, WK summing the values firms' bonds and firms' equities plus foreign bond stocks. The variables WH and WK allow the calculation of total wealth, consumption, and saving.

The demands for commodities by the government can be calculated from current prices and tax rates, given that the level of overall government spending (transfers plus purchases) is exogenous in every period.

Once the demands for commodities by households and the government and the demand for composite intermediate inputs derived from sectoral production levels and the input-output coefficients are known, using the domestic use ratio, we calculate total demand for domestic use. Exports are derived from the export demand functions. Total demand for domestically produced goods is therefore given as the sum of total demand for domestic use and exports.

The import demand functions derived from the trade aggregation function subject to that the value of composite good is equal to the value of import plus the value of commodity produced domestically yields imports.

Debt-equity ratios yield us desired bond and equity stocks. The difference between desired bond stocks and current bond stocks gives borrowing for each sector.

As stated in Chapter 4, within-period equilibrium requires that at each period: (1) the total (domestic and foreign) demand for the output of each industry equal its (domestic) supply; (2) the demand for labour equal its supply; (3) total borrowing by firms equal total saving by households plus foreign savings; (4) government revenue (taxes) equal government spending; and (5) the demand for foreign exchange equal its supply. Accordingly, a solution to the general equilibrium model is given by a price vector ($PD_1,\ldots,PD_j,P_L,r^D{}_B,ER,f$) such that excess demands equal zero in all markets[46]:

$$X_j^D - X_j^S = 0 \tag{81}$$

$$\Sigma_j L_j^D + L_g^D - L^S = 0 \tag{82}$$

$$\Sigma_j \dot{B}_j + \dot{B}_w - S = 0 \tag{83}$$

$$\Sigma_j P_{Mj} M_j + \dot{B}_w - \Sigma_j P_{Zj} Z_j - r_B^D B_w = 0 \tag{84}$$

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[46]Equal yield equilibrium requires another dimension and a parameter to be adjusted. We adjust the income tax lump-sum factor to preserve the equal yield equilibria.

$$\Sigma_i P_i(1+\tau_{vi})G_i+Tr-T=0 \tag{85}$$

The excess demand function have a number of important properties. First, they are homogenous of degree zero in all prices. It means that neither supplies nor demands are affected by proportional price changes. This implies that if a vector $(PD_1,...,PD_j,P_L,r^D{}_B,ER,f)$ constitutes a solution to the system of J+4 excess demand equations, any vector λ(PD1,...,PDj,PL,$r^D{}_B$,ER,f) proportional to it ($\lambda>0$) will also constitute a solution. There seems to be an infinite number of solutions. In fact, the second important property of the excess demand equations is that they are not independent. This property is deduced from Walras's law: because each agent's demands are subject to a budget constraint, it is clear that such a budget constraint also holds in the aggregate not only at equilibrium but for all allowable price vectors. There are thus only (J+3) independent excess demand equations to determine (J+3) relative price ratios.

Accordingly, we normalise prices to sum to a constant, which using such models as tools of policy analysis and formulation, it is best to use a price-normalisation rule that provides a "no-inflation" benchmark against which all prices changes are relative price changes. The equation used will be of the form

$$\Sigma_j P_j \mu_j = \bar{P} \tag{86}$$

where the μj are weights defining the index $\bar{P}$. The numeraire chose is the consumer price index in the first period. The index will updated over time to reflect the specified rate of inflation π.

However, normalising prices is not sufficient to solve the set of excess demand equations. It is crucial to attain that the set of excess demand equations is functionally independent and that the Jacobian is non-zero. The obvious solution if one wishes to work with an algorithm requiring a nonzero Jacobian is to drop one of the excess demand equations and replace it with price-normalisation rule.

5.7.1.2 Intertemporal Equilibrium

Perfect foresight requires that the values of the lead variables conform to realized values. Fair and Taylor (1983) and S. G. Hall in several papers (for instance, see Hall 1985) developed a method achieving this conformity[47]. Although there does not yet exist a general proof of convergence, the method has been used successfully in many application, such as Goulder and Summers (1989). The method is very simple: First, we calculate the new-steady values for V, DN_w, WH, and N which ultimately preveil after a policy change. The steady-state values are obtained by simulating the policy change under consideration in a general equilibrium system under steady-state constraints. Second, we assign an initial path for the lead variables. For the lead variable, V_t, for example, the path is represented $V^*_2, V^*_3, \ldots\ldots\ldots, V^*_{T+1}$.

Conditional on the values of lead variables, we solve successively for the market-clearing prices of each period from 1 to T. The general equilibrium solution provides a path of 'derived' values for V, DN_w, WH and N stemming from the relationships indicated by eqs. (77)-(80). Thus, the lead variables generate the time paths from 1 to T of V, DN_w, WH and Z.

We then compare the values for lead variables with contemporaneous derived values; if the lead and derived values are not sufficiently close to one another, we revise the lead values in a Gauss-Seidel fashion. For example, we adjust the V^* path accordingly to

$$V_t^{*(k+1)} = \lambda V_t^{(k)} + (1-\lambda) V_t^{*(k)}, \quad t=2,T \tag{87}$$

where k represents the iteration number and λ is a parameter between 0 and 1. When lead and derived values agree, a perfect foresight equilibrium sequence has been attained. This is the case because (1) the equilibrium paths for V, DN_w, WH and N are have the appropriate slope across any two consecutive periods, as assured by when lead values correspond to derived values for period t+1, and (2) the equilibrium paths have the appropriate level, since they lead to the desired steady-state values.

[47]A clear description of the method can be found in Blanchard (1985), Dixon et al. (1992) and for an implementation see Goulder and Summers (1989).

5.7.2 SOLUTION ALGORITHM

There are a variety of solution algorithms that work directly with the various excess demand equations, using the kind of solution strategies described above. These algorithms can be divided into three types: (1) those based on fixed-point theorems (2) those based on a tatonnement process and (3) those exploiting information about the derivatives of the excess demand functions.

Algorithms (Scarf's simplicial search method and Merrill's grid search algorithm) based on fixed-point theorems are truly elegant mathematically and a major advantage of this approach is that convergence is guaranteed within a finite number of dimensions on the simplex. However, Scarf's original fixed point algorithm has been extended to allow for continued refinement of approximations until an answer of desired accuracy is achieved, allow initiation of solution procedures on the face simplex rather than in a corner and make simplicial subdivision methods more competitive with Newton methods in terms of computational time.

Algorithms based on a tatonnement process simply adjust the price in each sector in response to that sector's excess demand. The Gauss-Seidel iteration procedure is a special version of tatonnoment process. In particular, in the case of Gauss-Seidel iteration, successful convergence to an equilibrium depends in principle upon judicial selection of starting values and step size. The costs of the Gauss-Seidel method depend on efficient ordering of equations into simultaneous and recursive blocks.

We use an algorithm which exploits information about the derivatives of the excess demand functions. This type of algorithms is called 'Jacobian algorithms' because their performance is sensitive to the determination of the matrix of numerical derivatives -the Jacobian. The algorithm solves a set of nonlinear functions, fi(P1,.....,Pn) which is in matrix terms:

$$f(P)=0 \tag{88}$$

where P is the vector of variables and f is the vector of functions. In general, any iteration procedure for solving this set of equations can be written as

$$P^{(k+1)}=P^{(k)}+\alpha^{(k)}d^{(k)} \tag{89}$$

where the superscript k refers to iteration, d(k) is a direction vector, and α is a scalar giving the size of the step to be taken in direction $d^{(k)}$. The iteration vector depends on the matrix of derivatives of the functions f(P). Define this matrix as D:

$$D_{ij}=\frac{\partial f_i}{\partial P_j} \tag{90}$$

Different approaches to solving eq. (88) lead to different methods which differ in the direction vector and the step size. A classic approach is to use the linear Taylor series expansion for f(P). It yields the following iteration procedure:

$$P^{(k+1)}=P^{(k)}-D^{-1}f(P^{(k)}) \tag{91}$$

This is the Newton or Newton-Raphson method with the direction vector d given by $D^{-1}f$ and the step size α equal to 1. Clearly, search involves a movement across the simplex in directions indicated by the local behaviour of excess demand functions at any point under consideration. Steps can be large or small and there is no guarantee that the search procedure will terminate with an equilibrium solution.

Another approach is to set up the solution problem as minimization problem of a special kind. Let

$$\Phi(P)=\Sigma_i[f_i(P)]^2=[f(P)]'f(P) \tag{92}$$

where the prime (') indicates the transpose. Φ(P) is a scalar function that has a minimum when f(P)=0. Thus, minimising the function Φ will yield a solution to f(P)=0. In seeking a P will minimise Φ(P), it makes sense to search in the direction in which the function decreases the fastest, that is, the steepest. Applying Taylor series expansion to Φ(P) and using the method of steepest descent yields the iteration formula

$$P^{(k+1)}=P^{(k)}-2\alpha^{(k)}D'f(P^{(k)}) \tag{93}$$

In general, the Newton-Raphson method has quadratic convergence properties provided that the initial guess is sufficiently close to the solution. The method of steepest descent is preferred when the initial guess of P is far from the solution, but it is slower to converge. A number of algorithms have been developed directions. These algorithms differ in how they do the interpolation, how they choose the step size $\alpha^{(k)}$, and how they compute the derivatives of f(P). We choose the Powell algorithm[48] that does not require the analytic specification of the derivatives of f(P). The Powell algorithm has mainly been chosen due to that it does not require the analytic specification of the derivatives of the excess demand functions. In the program written in fortran, we call one of the routines that are designed to solve a set of nonlinear equations in Nag Fortran Library. The routine called C05NCF is selected, in which the correction is made at each step as a convex combination of Newton and scaled gradient directions. Under reasonable conditions this guarantees global convergence for starting points far from the solution and a fast rate convergence. The jacobian approximated by forward differences, but these are not used again until the rank-1 method fails to produce satisfactory progress.

[48]The method and the associated computer algorithm are described in Powell (1970a, 1970b). For general information about the algorithm see Derviş, et al. (1982), in particular Appendix B.

CHAPTER 6 SIMULATION RESULTS

6.1 INTRODUCTION

In this chapter, we will attempt to evaluate the impact of the major tax policy changes to have taken place during the 1980s on U.K. growth using the model developed in chapter 4. The focus will be on their effects on the rate of capital accumulation and the allocation of capital among sectors and types of assets over time. We will examine the announcement effects of the tax reform. Since the model includes international financial capital flows and endogenous export demand feature, we analyze the tax reform effects on capital flows, exports and the terms of trade. In evaluating the results, we also pay attention to the efficiency effects in terms of changes in welfare level and functional distributional effects - capital owners versus labour suppliers, existing capital owners versus new capital owners, bond holders versus equity holders.

Major tax changes to be analyzed are the reductions in the corporate and personal income tax rates, the elimination of the write-off (first year and initial) depreciation allowances and the rise in the value-added tax rate. Changes in the tax code are directly applied to corporate, capital allowances and value-added tax, while those in personal income tax is assumed. During the 1980s the corporate tax rate was reduced from 52 to 33 per cent. The 100-percent first year and 75-percent initial depreciation allowances were replaced by a 25 per cent and 4 percent writing down allowances, respectively. We employ the tax code directly to the manufacturing sector while for other sector we apply the half rates of writing down allowances in order to reflect differences across industry. The VAT standard rate was raised from 8 to 17.5 per cent. The change in personal income tax rate, as suggested by empirical work[49] and changes in the tax code, is assumed to amount to a cut in average marginal rate from 35 to 25 per cent[50]. Similarly the reduction in dividend tax credit is taken as a reduction from 30 to 22.5 per cent.

[49]For example, Robson (1988) estimates that average marginal tax rates on dividend and interest income would be reduced from 54 and 49 respectively to 40 per cent.

[50]A 10 percentage point rate cut might seem to be too high as compared to Robson's findings. However, taking into account changes in the marginal income tax rate on labour income might justify it.

Simulation results are analyzed as follows. The 'base case' sequence of equilibria is the standard against which each of the alternative tax policies is measured. As discussed in chapter 5, the economy achieves steady-state growth in the base case at an annual rate of 2.75 per cent. Simulations are performed over an interval of 75 years, with the equilibria spaced one year apart. In most simulations, the economy almost completes convergence to the new steady state within 50 years. It is found that simulating over a longer time interval does not significantly affect the simulation results.

In all simulations, a balanced government budget is assumed. The path of real government spending is kept the same as in the base case. This means that all tax policies considered involve no changes in the timing and the level of the government's direct absorption of resources. It leaves unchanged, in the aggregate, the private sector's intertemporal consumption possibility frontier. To maintain government budget balance in each period we adjust the personal income tax intercept, f. Personal income revenue is calculated from the linear progressive income tax structure, $T_p=\tau_p(YT)-f$, where YT is the taxable income. Adjusting f, the tax intercept, thus, means that we use a non-distortionary replacement tax scheme to obtain equal yield equilibria. In this replacement scheme, increases (reductions) in government revenues caused by a tax change are absorbed (recovered) by lump-sum transfers (taxes) received (paid) by households. This amounts to changes in the personal income tax intercept. Although such changes in the personal income tax intercept does not create distortionary (substitution) effects since marginal personal income tax rate is not affected by the replacement scheme. However, the replacement scheme generates income effects.

Although this replacement scheme can be seen unrealistic because it abstracts from the efficiency effects of the replacement tax, One can justify this replacement scheme on several grounds. First, since it does not change effective tax rates, we can see a clear picture of the effects of tax policy changes on the economy. Second, since our tax policy issues do not include trade-off between the effects of alternative tax policies, there would be no need to adjust distortionary replacement tax scheme. For example, switching to consumption tax from income taxation would creates trade-off between no intertemporal distortionary effects of the consumption taxation and distortionary effects on labour supply of higher tax rates.

One can see the personal income tax intercept as personal allowances. So increases in government revenues caused by a tax change are absorbed by increases in personal allowances. Similarly, reductions in government revenues caused by a tax change are recovered by reductions in personal allowances.

In order to reach a cohesive conclusion we first simulate major tax policy changes individually. This might help one to identify the effects of individual taxes. We evaluate in sequence the reduction in the personal income tax and dividend tax credit rate, the reduction in the corporate tax rate, the elimination of the write off depreciation allowances, and the rise in VAT rate.

6.2 THE CUT IN THE PERSONAL INCOME TAX RATE AND DIVIDEND TAX CREDIT RATE.

In this experiment we evaluate the effects of the reductions in the personal income tax rate and dividend tax credit rate, as assumed, from 35 and 30 per cent to 25 and 20 per cent, respectively. As stated above, they are cut in marginal tax rates. The policy change is treated as unanticipated and takes effect in the first period. It encourages saving by raising the after-tax rate of return. We examine the effects of this policy change in the absence of internationally mobile financial capital.

Simulation results from the cuts in the personal tax rate and dividend credit tax rate are reported in tables 6.1, 6.2 and 6.3. Table 6.1 reports the effective tax rates in both the new steady state and the base case steady state. Table 6.2 reports the effects of the policy change on nominal interest rate, exchange rate, investment, nominal savings, exports volume, the terms of trade, revenue effect of the policy, total production, efficiency and distributional effects of the policy for period 1 and 5 and the new steady state. Figures are in percentage change as compared to the base case levels. Interest rate and exchange rate are in level terms. These rates as well as saving figures denote nominal level. The efficiency effect of the policy is measured in equivalent variation change in total wealth. Distributional effects indicates the ratio of discounted present value of labour earnings to that of capital earnings. Table 6.3 reports variables across industries.

The immediate impact of this policy change is to raise the after-tax return for households. The rise in the after-tax return at which households' incomes are discounted will reduce consumption and increase savings. Also, substitution effect will lower the propensity to consume wealth. As a consequence, savings will rise further. In the initial period, households's savings in nominal terms increase by approximately 8.5 per cent relative to the base case in the same period, as indicated in table 6.2. The table shows that this rise in households' savings will lower the equilibrium gross interest rate to a rate of 15.4 per cent from 17.5 in the base case. The lower interest rate and also lower taxes implies a drop in the cost of finance. The drop in the cost of finance across industries is between 0.5 and 1.5 per cent. The lower the cost of capital is the higher the market value of the firm and thus the higher the Q ratio. As indicated in table 6.2 this results in an increase in fixed investment of approximately 4.0 per cent relative to the base case in the first period. Over time, the rise in the capital intensity of the economy implies a lower marginal product of capital and a lower value of Q for any given interest rate; thus, the rate of investment falls, although the level of investment remains higher than in the base case because of the higher capital stock. In the new steady state, the rate of investment in each industry returns to its long-run value, while aggregate investment exceeds that of the base case for corresponding years by about 5.7 per cent[51].

The effects of this policy on imports and exports are also reported in table 6.2. The effects on exports and imports are minor in both the short and long run. Table 6.2 reveals that total export volume does not show any significant change; in the initial

[51]Our results are comparable to those of Goulder and Eichengreen (1989); In a two country model they find an increase in the US investment of 1.00 and 1.43 per cent in the initial and in the new steady state under no capital mobility, respectively, corresponding to a 4 percentage point in increase in taxes consumption with a compensating reduction in US households' marginal income tax rates from 0.285 to 0.256.

period, total export volume declines only by about 0.1 per cent relative to the base case. Over the longer term, the higher capital intensity and productiveness leads to an increase in demands for both foreign intermediate and final goods. To balance trade account in the new steady state total export volume increases by approximately 1.2 per cent over the base case steady state. However, in the new steady state the United Kingdom faces a worsening of approximately 4.2 per cent in the terms of trade. Since the demand for British exports is imperfectly elastic; to sell additional product in international markets necessitates a reduction in the exported good prices in foreign currency term.

As far as the incidence and welfare effects of the policy are concerned, as shown by Bovenberg (1989), amongst others, the welfare effects of the policy depends upon two competing effects: (i) capital accumulation is welfare improving and (ii) any deterioration in the terms of trade induces a negative welfare effect. In our experiment, the positive welfare effect associated with capital accumulation outweighs the welfare loss caused by worsening the terms of trade. British consumers enjoy with an improvement in welfare; the gain is in the region of 0.264 per cent of the base case total wealth level, as indicated table 6.2.

Turning to the distributional effects, it can be seen that wage earners gain from the policy change. The relative functional distribution of income shifts approximately 11 per cent in favour of human wealth (wage earners). Over the longer term, as the marginal product of capital falls the wage rate increases. Table 6.2 indicates that in the new steady state wage level is 1.01 as compared with the level of slightly over 1.00 in the first year. As indicated in table 6.3, the increases in the debt-equity ratios shift the relative distribution approximately 4 per cent in favour of bondholders from shareholders. Finally, the reductions in the personal tax and dividend credit rates amount to a loss of 27-25 per cent of the total government tax revenues, which is balanced by increases in lump-sum factor of the personal income tax.

Table 6.3 displays the policy effects across industries. The table shows the effects of the policy change on after-tax earnings, deb-equity ratios, cost of finance, firm values, investment-capital ratios, investment, and capital stocks in each industry. Since differences in investment in each industry underlie differences across industries, we concentrate on investment. In the new steady state, investment in the manufacturing sector rises by 9.6 per cent above the base case as the agriculture sector manages only an increase of 2.2 per cent. Differences across industries can be attributed to their differences in financial behaviour, and general equilibrium and trade effects.

Table 6.3 reveals that changes in the cost of finance are not the same across industries. This reflects the role of the endogenous adjustment of financial structure specified in the model. the policy reduces the relative cost of debt finance as compared with retention. Firms minimize the cost of finance by moving to debt finance. But agency costs of debt constrain firms in doing so. The table shows that industries, such as agriculture and energy, with lower initial debt stocks raise optimal debt-equity ratio more than other industries. However, industries namely manufacturing and services, with higher initial debt stocks, reduce the cost of finance, more than the agriculture and energy sectors despite a relatively lower rise in the optimal debt-equity ratio. As a result differences in investment can be partly attributed to differences in the industry's ability to reduce the cost of finance. For instance, as the agriculture industry reduces the cost of finance in the new steady state by 2.1 per cent and in turn investment in agriculture increases by 2.2 per cent, the services sector reduces the cost of finance by 3.2 per cent and in turn investment in services rises by almost 6.0 per cent. The situation differs for the housing sector. Since most interest payments in the housing sector are deducted at the personal income tax rate, the reduction in the personal income tax rate reduces the relative advantages of debt finance in this industry. The size of decline in the cost of finance in this industry despite its higher initial debt stock is lower than that of the services sector.

In table 6.1, we also presents the effective tax rates across industries as well as overall rate[52]. The overall effective tax rate in the new steady state declines to a rate of 11.1 per cent from 13.35 per cent, as indicated in the table. This decline in the overall

[52]They are on the r-based calculations. See Appendix C for the methodology of calculation.

rate is reflected in industries' effective tax rate or tax wedge but in varying degrees due to the endogenous adjustment of financial structure. Variations in changes in industries' effective tax rate measure tax distortions on capital allocation. Standard deviation measures this distortion after the policy change. Standard deviation declines a value to 0.559 from 0.648, representing a less distortionary tax system on capital allocation.

As for general equilibrium and trade effects, in general, the policy boosts capital goods industries (manufacturing and services because services include construction sector). Over the longer term, the relative advantage of capital goods industries declines as the capital intensity of the UK economy rises and after-tax rates of return and rates of accumulation fall. Trade effects play a role such that a deterioration in the terms of trade results in a demand shift towards home goods (housing services) by reducing home goods prices. The new steady state value of housing sector's investment rises by 3.2 per cent over the level of the base case steady state, as indicated in table 6.3.

6.3 PERSONAL TAX CUT AND VAT RATE RISE

As did the UK government in early 1980s, in addition to the previous policy, - the personal income and dividend credit rate reductions - we also double the standard rate of the value-added tax. The standard rate, in general, covers all commodities except housing services. Hence an important difference arises between this policy and the previous policy, in which the tax cuts are financed by lump-sum tax (i.e., lump-sum factor of the personal income tax): The VAT rate rise distorts the wedge between housing services and other goods, to the extent that housing services are exempted from the VAT. In the United Kingdom, as in other countries, housing services is favoured with no taxes on its services.

The increased relative attractiveness of housing sector combined with lower interest rate generated by the personal tax cut, results in a substantial increases in investment in this sector. In the initial period, investment in the housing sector increases by approximately 9.1 per cent over the base case. As for other industries, they also raise investment as a response to the decline in the cost of finance that encourage firms to invest, as explained above. Overall investment in the new steady state thus increases by 6.8 per cent over the base case steady-state. In contrast, this increase in aggregate investment is greater than the increase of 5.7 per cent scored in the previous policy experiment. This seems to reflect that since housing services are home goods and do not require imported intermediate goods in production process, the expansion of the housing industry incurs less deteriorations in the terms of trade associated with increases in economy's production power. Table 6.4 indicates that deterioration in the terms of trade caused by the VAT rate rise policy is relatively lower than in the previous policy. In the new steady state, the terms of trade deteriorates by 4.422 per cent, despite greater growth, as compared with 4.190 per cent in the previous policy case. Relatively, lower deterioration in the terms of trade implies a higher purchasing power of the UK consumers.

As is expected, the welfare gain is greater under the VAT rate rise policy than in the lump-sum tax finance. The welfare gain is in the region of 0.363 as compared to the gain of 0.264 in the previous case. Table 6.5 reveals that the policy leads to different incidence effects across sectors. The policy causes investors to reallocate assets: residential sector offers highest returns compared to other sectors. The value of the residential capital stocks rises by 5.6 per cent in the short run (in year 5). Over longer term, the changes in the sectoral allocation of capital brings about changes in output prices and cause asset values toward the same line with the other sectors. The table reveals that over the longer term capital owners of the manufacturing sector gain. In the new steady state the market value of manufacturing rises by 10.5 per cent relative to that of the base case steady-date. This seems to reflect the fact that the manufacturing industry is a capital-goods producing industry.

The table shows that the VAT rate rise fell short in offsetting the revenue loss faced by the personal tax rate reduction. The policy still gives rise to a deficit in the government budget which is balanced by nondistortionary component of the personal income tax namely lump-sum tax factor. In the first year of the policy implementation, the policy causes a 15 per cent deficit in the government budget. Over the longer term, it declines to approximately 12.7 per cent as the economy grows.

6.4 THE REDUCTION IN THE CORPORATE TAX RATE

In this experiment we evaluate the effects of the reduction in the UK corporate tax rate from 0.52 to 0.33 in all industries. Given that the housing sector in less incorporated, the tax cut effect on this sector is relatively smaller than the other sectors. We present results from this experiment in tables 6.6 and 6.7. The former table reports aggregate results and the latter reports industry effects.

Table 6.6 reveals that this policy encourage investments and thus generates increases in production. The table indicates that in the new steady state aggregate investment rises by approximately 7.1 per cent above the base case steady-state level. the higher the capital accumulation is the higher the production level, as indicated in table 6.6. In the new steady state aggregate production level increases by 2.1 per cent. The increased production level implies a gain in welfare level. The welfare gain in equivalent variations is in the region of 0.275 per cent. The previous discussion indicates that the increased production, causes a deterioration in the terms of trade. In the new steady state the deterioration in the terms of trade is almost 10 per cent. Such a level of deterioration in the terms of trade, results in the rest of the world having to share the benefits of the reduced corporate taxes with the domestic consumers. The corporate tax cut, on the other hand, creates significant distributional effects. The relative wealth distribution shifts by 16 per cent in favour of non-human wealth. Also, the relative distribution of assets shifts by around 13 per cent in favour of shares. This reflects the reduced attractiveness of debt finance caused by the corporate tax cut.

The tax cut policy effects across sectors and time can be summarized as follows. A corporate tax cut, on the one hand, stimulates investment by raising the after-tax marginal product of capital, and on the other hand, reduces investment via declines in the value of tax depreciation allowances and increases in the cost of capital. Table 6.7 reveals that the former effect predominates, and the corporate tax cut policy results in substantial increases in investment in all sectors. Table 6.7 sheds light on how to analyze the effects of the tax cut. The table reveals that the cut in the corporate tax raises the after-tax marginal product of capital, allowing higher earnings and dividends in every period. The market values of the firms rise immediately to reflect the increases in the stream of earnings. In the initial period, for instance, earnings in the services sector increases by almost 20 per cent over the base case. The market value of the services sector rises by 25 per cent reflecting the increases in the stream of earnings in this sector. The increase in the market values is sustained over time, and in the new steady state the market value of this sector exceeds the base case steady-state value by almost 32 per cent.

The higher asset values imply larger values for Q, and stimulate investment. In the first period investment in this sector rises by almost 7.0 per cent over the level of the base case. Sustained higher rate investment leads to steady increases in the capital stock. The increases in the capital stock in this sector over time, generate an increase of 9.0 per cent in this investment sector in the new steady state.

The results are similar for the other sectors except for housing, as indicated by table 6.7. The table demonstrates that investment in all sectors is higher than in the base case. For example, investment in the manufacturing sector is 9.7 per cent above the base case steady-state level.

The corporate tax cut policy implies differences across residential and non-residential sectors as well, to the extent that residential sectors are lightly incorporated. The housing sector is less directly affected by the corporate tax rate reduction policy since only a small fraction (approximately 10 per cent) of housing capital is employed by private corporations. The corporate tax cut implies a much smaller reduction in the overall rate of capital taxation in the housing sector than in other sector. In the first year earnings after taxes decrease by 2.4 per cent relative to the base case. The reduced attractiveness of the housing sector combined with higher interest rates generated by the higher investment of the non-residential sectors, causes the market value of this sector to decline initially by 3.2 per cent. The lower market values discourage investment, which initially declines by 6.0 per cent relative to the base case. However, as the capacity intensity of the economy improves productiveness, and raises incomes and demands, the housing sector ultimately benefits, and it offsets reductions in housing demands. In the long run the housing sector actually manages a slight increase in investment.

It can be seen that since the corporate tax rate reduction reduces the tax advantages of debt finance, deductibility of interest payments from corporate tax base, industries face a loss in their earnings after-tax. In our model, firms are able to choose an optimal debt-equity ratio, and thus they can mitigate the loss in tax advantage of debt finance by lowering their debt-equity ratios. As indicated in table 6.7, the debt-equity ratios in each industry decline in a considerable rate. For example, in the first year the manufacturing industry lowers the debt-equity ratio by 19.1 per cent relative to the base case in the first year. Table 6.7 shows differences across industries in changes in debt-equity ratios. This reflects that industries with a low debt-equity ratio in the base case incurs less agency costs, and hence can afford large changes in debt-equity ratios. In the base case, the debt-equity ratio of the agriculture sector is 0.190 and that of the services sector is 0.363. While in the first year the debt-equity ratio in agriculture declines by 25.6 per cent relative to the base case, that of the services, trade and utilities sector declines by only 12.1 per cent in the same period relative to the base case. Therefore, to the extent that industries can lower optimal debt-equity ratios, industries face less increases in their cost of finance. Otherwise they would incur much larger costs in financing investments. Table 6.7 reveals that the increase in the cost of finance is in the region of between 5 and 8 per cent (apart from housing), in the initial period, relative to the base case. As explained above, agriculture faces the lowest increase in the cost of capital, which is 5.4 per cent, while the services sector faces the highest increases in the cost of finance, which is 8.4 per cent. With an exogenous financial behaviour, such increases in the cost of finance would be much more larger than in our model.

Our results are consistent with Goulder and Summers's (1989) results from a similar model. They found that a reduction in corporate income tax rate from 0.46 to 0.34 in all American industries would stimulate capital accumulation in U.S. nonresidential industries, a striking rate between 3.5 per cent and 7.5 per cent in the new steady state.

In the short run the revenue effect of the tax reform is approximately 7 per cent deficit in the government budget. But in the long run as the economy grows the deficit becomes smaller. In the new steady state, the budget deficit is only 3.0 per cent.

6.5 THE REDUCTION IN THE WRITE-OFF CAPITAL DEPRECIATION ALLOWANCES

In this experiment, we replace the 100-percent first year depreciation allowances given to plant and machinery, and the 75-percent initial depreciation allowance given to industrial buildings, with 25 per cent and 4 per cent of writing-down depreciation rate, respectively. The writing down rates differ across industries. We apply the tax law directly to capital in the manufacturing industry. These rates are halved for other industries. The policy implies that this policy will curb the tax saving from the capital allowances. Industries will face a higher cost of investment project, and thus investment will be discouraged.

We report the results from this simulation in table 6.8 and 6.9. The tables report figures on aggregate variables and industrial variables, respectively. Both tables reveal marked effects on capital accumulation. Table 6.8 shows significant differences across industries and time. Our effective tax rates, reported in table 6.1, reiterate this point. The effective tax rate in manufacturing because of the policy change rises sharply to a rate of 62 per cent from a previous rate of 21 per cent because of the policy change. Effective tax rates in other sectors (apart from the housing sector whose effective rate remains unchanged) increases but at a lesser extent. As a whole, the overall effective tax rate jumps to a rate of 24 per cent from about 13 per cent. The effect of this rise in the overall effective tax rate can be seen from table 6.8: in the new steady state, total investment declines substantially by 9.3 per cent below the base case steady-state value.

As revealed in our Q ratio, the policy, - lowering tax depreciation allowances - lowers Q directly and causes an immediate reduction in the rate of investment. In the short run, investment in the manufacturing sector for instance, falls substantially by approximately 11 per cent. Over the longer term, the capital stock declines relative to the base case, as does the productiveness of capital. Thus, over the long term, both the earnings, and the market value of the firm fall. In the long run, the rate of investment (I/K) returns to the steady-state value, but both the capital stock and the level of investment are markedly lower than in the base case (about 15 per cent lower).

Table 6.9 reveals the effect of this policy change across the five industries. Repealing the write-off depreciation allowances, discourages investment in all industries. Once again the situation differs for the housing sector, since the initial writing-off depreciation allowances were zero, and thus repealing them has no direct impact. Investment in housing actually increases somewhat relative to the base case in the short term, after the write-off capital allowances are eliminated. This reflects the increased relative attractiveness of investment in the housing and the decline in interest rates associated with the reduction in aggregate investment demand. In the first year, nominal interest rates fall to a value of 16.85 per cent, as compared with 17.50 per cent in the base case. Similarly, in the short term the market value of the housing sector rises; in the first year it increases by about 5.2 per cent. This reflects the general equilibrium price effects associated with the relative attractiveness of industries. In the long run, investment in housing sector slows down and is below the base case steady-state value by some 0.4 per cent. This seems to be as a result of the fact that the overall capital intensity of the economy is lower, implying lower capital productiveness, lower real incomes, and a diminished demand for the output from the housing services sector.

It is worth noting that changes in the cost of capital over time suggest that the short term effects of this policy would be somewhat sharper than otherwise. In our model, firms exploit declines in the nominal interest rate by increasing optimal debt-equity ratios.

As a result of the reduced capital intensity in the new steady state, total production, declines by approximately 3 per cent. Reduced production level implies lower imports. The lower the imports and production level are, the lower the export volume will be. In the new steady state, the export volume drops by 2.8 per cent relative to the base case. Lower export volume induces improvements in the terms of trade. The new steady-state terms of trade is almost 10 per cent higher than the base case. Table 6.8 reveals that as the wage rate varies from the base case level, the ratio of the human wealth to non-human wealth change as well. The wealth distribution shifts in favour of non-human wealth. Since the policy does not change the relative attractiveness of debt finance and retention, the relative distribution of wealth between bondholders and stockholders remains the same as in the base. The revenue effect of the policy is in the region of 8.5 per cent in the short run. Over the longer term, as the economy contracts, the tax revenue declines, reflecting the reduced incomes, profits and expenditures.

Our results confirm the view that investment incentives are more efficient than any other policies such as savings incentives that aim at boosting investment. Auerbach and Kotlikoff (1987) and Goulder and Summers (1989) find substantial reductions in U.S capital accumulation after repealing investment tax credits. Goulder and Summers calculates the decline in capital accumulation in US manufacturing to be in the region of 11 per cent.

6.6 THE CORPORATE TAX CUT AND WRITE-OFF CAPITAL DEPRECIATION ALLOWANCES ELIMINATION

Two key features of the tax reform of 1984 are the elimination of the writing-off depreciation allowances and reduction in corporate income taxes. Here we consider the effects of a combined policy of this kind, the elimination of the writing-off capital allowances accompanied by a reduction of the corporate tax rate to 33 per cent.

The previous discussion indicates that eliminating the write-off capital allowances and cutting the corporate tax have the opposing effects on Q and investment; both in aggregate capital intensity. Our simulation results indicate that this combined policy does not result in any clear effect on capital accumulation. In the new steady state, the combined policy results in a minor effect on aggregate investment, which increases investment by only 0.7 per cent above the base case steady-state value. In the model, this combined policy is almost 'revenue neutral' over time. This suggests that this combined policy is not favourable in terms of growth and capital accumulation.

As indicated in table 6.11, this policy combination generates windfalls to capital owners (higher asset values) in both the short run and long run. It is especially worth noting that the windfall to capital owners is not accompanied by any increase in capital accumulation. The market values of industries except the residential sector increase in the region of 30 per cent - 40 per cent in both the short run and long run. The relative distribution of wealth shifts accordingly in favour of non-human wealth. Table 6.10 reveals that the shift in the welfare distribution is the region of 18 per cent. This policy combination, as discussed above, shifts the relative distribution of wealth in favour of equity assets because of the corporate tax cut.

The UK corporate tax reform of 1984 have been studied by several researchers (Kay and King (1989), Devereux (1987a, 1987b and 1988)). Kay and King's work finds that the effective average marginal tax rates on corporate investment has risen from a negative value to a zero from a level of over 40 per cent. However, Devereux's works imply a lower increase in overall effective tax rate. They mark that the government achieved the gains in terms of greater fiscal neutrality at the expense of an increase in the overall marginal tax rate on new investment in the corporate sector. They stress the substantial reduction in the write-off depreciation allowances in explaining the rise in the overall effective tax rate. Our effective tax rates reported in table 6.1 remains almost unchanged. The results from our simulation show that the standard deviation declined from 0.648 to 0.639. It can be argued that our results are consistent with the mentioned works above. We observe a slight increase in total investment in the long run. In the manufacturing sector, which they mainly study, we also found a decline of almost 0.8 per cent in investment in this sector in the long run. One should stress that our preliminary results take into account several issues: we take into account general equilibrium effects of taxes, endogenous adjustment of financial structure and adjustment dynamics. The works mentioned above are mainly concentrated on corporate industries and they are not taking into account any behaviourial issues.

6.7 THE OVERALL EFFECTS OF THE RECENT UK MAJOR TAX REFORM

In this experiment we allow all the UK major tax policy changes to have taken place during the 1980s to be in effect. Table 6.12 and 6.13 report aggregate and industry effects, respectively. Also, figure 6.1 displays the effects of the policy change on after-tax earnings, the cost of the capital, the market value of the firm and investment in each industry.

The previous discussion indicates that cutting the personal and corporate income taxes stimulates investment. Eliminating the write-off depreciation allowances causes the capital stock to decline. The previous section shows that the corporate tax cut outweighs the negative effects of the depreciation allowances elimination. As a consequence it will be expected that the overall tax policy will greatly stimulate investment and production. Table 6.12 indeed exhibits that the overall policy effect is growth accelerating. As can be seen from the table, in the new steady state, aggregate investment increases by approximately 7.6 per cent below the base case steady-state value. In the new steady state total production rises by around 2.1 per cent. The increased productiveness result in a rise in the performance of exporting industries and export volume increases by around 1.8 per cent.

Table 6.13 demonstrates that the rise in the cost of finance associated with the corporate tax cut outweighs the reduction in the cost of finance associated with the personal income tax cut. All industries apart from the housing sector face higher financial cost. As explained above, this reflects the fact that the corporate tax cut implies a much smaller reduction in the overall rate of capital taxation in the housing sector than in other sectors.

Our results show that differences across industries appear to be not important. All industries gain from this overall policy almost at the same extent. As residential sector, the housing sector, largely benefit from the VAT rate rise, non-residential sectors largely benefit from the personal and corporate tax cuts.

Both table 6.12 and table 6.13 indicate that there are differences across time, reflecting the adjustment costs of investment. In the initial period, total investment increases by 5.5 per cent relative to the base case, over time the increase in total investment reaches to a 7.6 per cent.

Table 6.13 reveals that the recent major UK policy changes generate windfalls to capital owners. Asset values increase significantly in both the short and long run. This reflects that the policy change raises the relative rate of return to existing capital to the rate of return to new capital. The previous discussion indicates that previously considered policies treated new and old capital differently. Since cutting the personal income tax does not affect the relative attractiveness of old capital and new capital, the tax cut resulted in higher asset prices accompanied by increases in capital accumulation. Cutting the corporate tax has changed the relative attractiveness of old and new capital since adjustment costs are deducted from the tax base - when the corporate tax rate is lowered, marginal installation costs increases on an after-tax basis. Hence, the corporate tax cut changes the relative attractiveness of capital in favour of old capital. In this instance, the increased attractiveness of old capital is reflected in increases in asset prices (the market values of the firms). The elimination of the write-off capital allowances produces two opposing effects on the market value of a firm. On the one hand, cutting tax savings given to new investment make existing capital attractive relative to new capital thereby resulting in a positive influence on the value of the firm in the short run. On the other hand, infra-marginal losses associated with existing capital tends to cause reductions in the value of the firm.

Our simulation results indicate that the tax policy changes favour old capital when all the changes are combined. Figure 6.1 and table 6.12 reveal that the overall policy generates windfalls to capital owners in both the short run and long run. The market values of industries increase by 30-55 per cent. However these increases in asset values are not accompanied by substantial increases in capital accumulation. The tables also indicates that relatively, residential capital owners realize much lower windfall gains.

As would be expected, this policy implies an efficiency gain in terms of welfare effect. The welfare gain in equivalent variations is in the region of 0.428 per cent of the base case total wealth. Although the terms of trade deteriorated, implying an deterioration in British citizens' living standards, capital accumulation resulted in welfare gain. Functional distribution changes in favour of capital income receivers. Table 6.12 indicates the relative distribution between wage earners and capital income receivers. The relative distribution between wage earners and capital income receivers changes by around 11 per cent in favour of capital income receivers. As for the relative distribution of wealth between bondholders and stockholders, the reduced attractiveness of debt finance because of cuts in corporate rate leads to capitalization effects; share prices increase while bond prices declines. This implies gains for the stockholders but loss for the bondholders. Table 6.12 indicates that the relative wealth distribution between the two assets changed by around 7.5 per cent in favour of the stockholders.

The revenue effect of the tax reform is negative. Our results discussed above have already indicated that both the personal tax cut combined with VAT rate rise and the corporate tax cut combined with capital allowances elimination cause budget deficit. Hence the revenue effect of this policy is multiplied, when these policies are combined. The budget deficit amounts to be 14 per cent in the short run and almost 12 per cent in the long run, as indicated in table 6.12.

6.8 ANNOUNCEMENT EFFECTS OF THE U.K. TAX REFORM

The 1980s tax reform is, to great extent, a preannounced reform; in the late 1970s and early 1980s, the U.K. government lowered personal and corporate income tax rates, reduced capital allowances and raised consumption tax rates. The government announced in advance further tax cuts in personal and corporate income taxes and capital allowances. This section analyses the announcement effects of the tax policies on capital accumulation. We consider the implications of the policy when the policy change is announced five years prior to its implementation (the tax policy takes effect in year 6).

While it is expected that the announcement of the tax policy change in advance of their implementation significantly affects the short-run results, the steady-state consequences of this pre-announced policy change are the same as those in the unannounced case previously considered. In the long run, the capital intensity of each sector changes by that amount necessary to bring the after-tax marginal product of capital into its appropriate relationship with the cost of new capital.

However, the short-run effects of this pre-announced policy change differ significantly from those in the unannounced policy change. This indicates the following points: Firstly, the cut in corporate taxes will reduce DN, the present value of depreciation allowances on a pound of investment, once the policy change takes effect. This induces firms to invest more prior to the policy change than the pre-announced corporate tax rate effect on DN. Secondly, although the reductions in capital allowances lowers the overall attractiveness of investment and leads to a downward shift in the investment profile, the reduction in investment is slight in the years prior to full implementation of the new policy, as firms continue to take advantage of the original investment subsidies right up to the time of the change. Thus, the rate of investment is expected to be higher prior to anticipated policy change than the rate after the change. As Judd (1985) points out, in anticipation of lowered future investment subsidies, households may step up current savings, particularly in 'fast-adjusting' economies with high intertemporal elasticities of substitution in consumption, which further induces investment prior to the policy change. Thirdly, the cut in personal income taxes raises the after-tax capital income, reducing the effective rate of tax on savings, and increases savings. Thus, up to the time of the policy change households speed up the rate of growth of savings, in order to meet the income required to consume more at cheaper prices in future. This leads to a decline in interest rate and in turn stimulates investment.

The simulation results of the unannounced effects of the 1980s tax reform are reported in table 6 and displayed in figure 2. As predicted by the theory, in the short run the announcement effects of the tax reform differ from those in the long run as well as those in the unannounced policy change. The combined effects of the announced changes in these taxes induce firms to invest as much as adjustment technology allows and encourage households to save after the tax reform is fully put into effect. For example, for manufacturing, investment in this sector prior to the policy change increases the base case level by around 15 percent while in the new steady state case investment in this sector increase by 8.2 per cent. The value of firm equity rises immediately following the announcement, but much lesser in the case where the tax cut is immediately enacted. This manifests that windfall effects do not occur prior to the policy implementation. But after the policy change is put into effect existing capital owners benefit windfall gains.

The pattern is similar for the other industries except for housing as indicated by table 6. The situation differs for the housing sector. Since the housing sector is considerably less subjective to taxation in the United Kingdom, the tax policy changes produce a negligible direct impact on the behaviour of the housing sector. While asset values rise in the other sectors, the reduced relative attractiveness of housing capital, combined with higher interest rates generated by the higher investment of the nonresidential sectors, cause equity values to decline initially. The lower stock values discourage investment. However, after the tax policy implementation, the situation is reversed for the housing sector and the other sectors, while investments in residential sectors begin to slow down. Investment in the residential sector initiates a marked rise.

These simulations indicates that the announcement of tax policy changes in advance would generate reverse effects in the short run and in the long run. Thus, for this policy change, the prior announcement of the policy seem preferable to maintaining uncertainty as to whether the policy will be implemented. This result is consistent with the analysis of Goulder and Summers (1989). Their analysis shows that the announcement of a prospective cut in corporate taxes hastens the gains to be achieved in terms of capital formation, productivity, and real incomes. We also observe their prediction; in the short run investment can be significantly increased by an announced policy. On the other hand, the result obtained here contradicts with the conventional belief that only surprise policies generate real outcomes.

Our results are consistent with other works. Devereux (1988) stresses these transitional effects caused by policy announcement in advance. Devereux quantifies the transitional effects and finds that they were extremely important in stimulating investment right after the 1984 corporate tax reform. Devereux reports an increase of about 25 per cent in investment in 1984 and 1985 which is induced by a decline of around 10 percentage points in the pre-tax cost of capital.

6.9 FINANCIAL CAPITAL MOBILITY AND THE RECENT TAX REFORM

In this experiment we allow for international financial capital mobility. We assume that the 1980s UK tax reform encourage foreign investors to supply their savings funds into Britain by cutting marginal rates of the personal income tax. The cut in the personal income tax rates causes the after-tax returns to interest payments to rise and therefore induces foreign savers to supply funds for the United Kingdom. However, the rise in the after-tax return depends on the market rate of interest as well. As in the no-mobility scenario, the initial effect of the recent UK tax policy changes is to increase investment demands and raises the domestic interest rate. The rise in the domestic interest rate further increases the domestic after-tax interest rate relative to the foreign after-tax interest rate. The higher is the domestic after-tax rates of return relative to the foreign one induces capital inflows. Table 6.18 reveals that in the initial year, domestic aggregate investment increases by 7.3 per cent as compared with the increase of 5.5 per cent with no-mobility case. This reflects that foreign savers supply their funds into the United Kingdom because of the tax advantage and increased interest rate after the growth accelerating tax policy change in the United Kingdom.

These capital inflows imply a surplus on the UK capital account, which puts upward pressure on the pound, making U.K. exports more expensive and decreasing demand for U.K exports by approximately 1.5 per cent in the initial period relative to the base case. This represents a significant difference between the no-mobility case and the mobility case. The decline in UK exports in the mobility case is 1.5 per cent as compared with the rise of 0.12 per cent in the no-mobility case. Higher funds supplies into the United Kingdom imply interest rate, implying a higher domestic investment level.

Over time the situation differs, as the foreign residents accumulate domestic assets and receive interest income from the United Kingdom. This implies an deterioration in the UK balance of payments, which puts downward pressure on the pound, making U.K exports cheaper and increasing demand for U.K exports. On the other hand, as the domestic economy grows because of increased capital intensity, U.K. households' incomes and savings rise, implying a decline in the domestic interest rate. This decline in the domestic interest rate implies a lower capital inflows and eventually zero capital flows in the new steady state. As a consequence, the long run result remain unchanged even though we allowed for international capital flows.

We also compare the above results with different cases, such as low capital mobility and high capital mobility. We take a value of 10^8 for the mobility parameter in the high mobility case and 10^6 in the low mobility case. We report results from this experiment in table 6.17. Figure 6.3 displays the effects of the policy change on exports, capital flows, the terms of trade and domestic investment. With low capital mobility, the effects of imports and exports are minor in the short. Since capital is internationally less mobile, there are less changes in capital account - a potentially important channel for transmitting effects on merchandise trade through its effect on the exchange rate. In the short run, real exports are not significantly affected by the policy change. In the initial year, exports volume declines by 1.5 per cent. Over the long term, the higher capital intensity and productiveness of the U.K. economy imply higher real output and incomes; this yields somewhat higher demands for foreign intermediate and final goods and a increased volume of international trade. In the new steady state, real exports are approximately 1.8 percent higher than in the base case.

Similarly, if capital mobility is high, the effects on imports and exports are higher than in the low mobility case in the short run. In the short run real exports are significantly affected by the policy change. With high mobility of financial capital internationally, capital outflow reaches to 5.395 billion pound (almost 20 per cent of domestic household savings) as compared to 1.563 billion of the central mobility case. This capital inflow is coupled with a 9.5 per cent in the terms of trade, reflecting an appreciation in the pound value. The appreciated pound in turn causes real exports to decline by 5.3 percent in the initial period than in the base case. Capital inflows lower the domestic interest rate. Lower domestic interest rate induces investment in the United Kingdom, in the first year total investment rises by 11 per cent as compared with a rise of 7.3 per cent with low mobility case.

6.10 SENSITIVITY

In this section we first describe sensitivity analysis and then test the robustness of results from the 1980s major tax policy changes with respect to parameters that govern major intertemporal aspects of decision-makings. The model's parameters that govern intertemporal aspects of decision-makings are the parameters of the adjustment cost function, the agency cost function, and the intertemporal elasticity substitution in consumption. They govern investment, cost of finance and savings, respectively. We vary the base case values of these parameters.

One of the feature of our model is to include endogenous financial behaviour; namely, optimal choice of debt-equity ratios. We explore the sensitivity of the model's results to parameters that govern debt-equity choice: namely α^g_0 and α^g_1 of the agency cost function, $\phi^g(B/P_E E)$. In a low agency cost case, we reduce the value of α^g_1 to 0.1 from 0.5 in the base case. Accordingly the value of α^g_0 is adjusted so as to leave the value of the ϕ^g function unchanged. Similarly, in a high agency cost case, we raise the value of α^g_1 to 1.5 and adjust the value of α^g_0 to leave the value of ϕ^g unchanged. In the low agency cost case we obtain a lower slope of the agency cost function and the high agency cost case the slope is raised.

Table 6.18 presents results from the sensitivity of the model with respect to agency cost parameters. The results suggest that endogenous financial behaviour generate real effects as well as financial effects. The high agency cost case resembles the model of Goulder and Summers (1989) and indeed others such as Auerbach and Kotlikoff (1987), Bovenberg (1986, 1989). Our results show that the exogenous financial structure (high agency cost) exacerbates the negative impact of the 1980s UK tax reform on the cost of finance, to the extent that industries are unable to exploit declines in cost of the alternative sources. The table reveals that in the new steady state total investment in the high agency cost case (i.e., exogenous financial structure assumption) increases by approximately 7.5 per cent above the base case steady-state value. In the low agency cost case, the rise in total investment in the same period is approximately 8.2 per cent. Clearly, these alternative cases produce a systematic difference endogenous financial structure and exogenous financial structure. However, we can state that simulation results are rather robust to the parameters of agency cost function.

As seen from table 6.18, in the low agency cost case, firms can afford large changes in debt-equity ratio and hence curb increases in the cost of finance in the high agency cost case. The manufacturing industry, for instance, in the new steady state, lowers its optimal debt-equity ratio by about 50 per cent below the base case steady-state value. This enables the industry to reduce its cost of capital and thus lower the declines in capital intensity. Table 6.18 indicates that in the high agency cost case the manufacturing lowers increases in the cost of finance. As a result of this ability, the new steady state investment in this sector in the low agency cost case increases by 8.5 per cent when compared with 7.8 per cent in the high agency cost case.

However, changes in debt-equity ratios in the high agency cost case are substantial thus, require attention with regards to incidence effects of tax policy. Policies like cut in corporate tax rate create important incidence effects. It would then be argued that the 1980s tax reform that reduced the attractiveness of bond finance through cut in corporate tax rate would cause substantial incidence effects if British firms were incurring less agency cost; bondholders would loose while stockholders would gain.

As pointed out by Chamley (1987), the elasticity of demand for capital is greatly determined by the adjustment cost of investment. The adjustment cost reduce the possibilities for intra- and intertemporal distortions, and the potential welfare gains of tax reform. Therefore, the parametrization of the adjustment cost functions gains crucial relevance. To understand the robustness of our results under the parameters chosen for adjustment cost function, we run a sensitivity analysis on the model's results to these parameters.

We take two alternative cases to the central case modelled in this paper. The two cases are represented by a low adjustment cost and a high adjustment cost. In low adjustment cost case, we halve the value of α^d_1 of the adjustment cost function, $\phi^d(I/K)$. Accordingly, the value of α^d_0 is adjusted so as to leave the value of the ϕ^d function unchanged. In the high adjustment cost case, we double the value of α^d_1 and adjust the value of α^d_0 to leave the value of ϕ^d unchanged. Hence, in the low adjustment cost case we halved the slope of the agency cost function and in the high adjustment cost case the slope is doubled.

As indicated by Summers (1981b) and Bovenberg (1985), the specification of adjustment cost function would create significant transitional, efficiency and distributional effect. Our results, reported in table 6.18, confirm this view. The table reveal that although the long-term effects of the tax reform are not substantially different across alternative adjustment cost specifications, the short-term effects can differ significantly - especially with respect to investment. In the case of low adjustment cost, total investment in the initial year substantially increases by approximately 7.5 per cent, while in the high adjustment cost case it rises by about 3.6 per cent.

An important difference introduced by changing the adjustment cost parameters is in differences across industries. The table shows that in the short run capital is reallocated through investment under the low adjustment cost case. Investment in the housing sector increases sharply in the first year under the low cost as compared with the slow increase in the high cost case.

In sensitivity analysis with respect to the intertemporal elasticity substitution in consumption we take a lower value of 0.4 and a higher value of 1.2. Results from this simulation are reported in table 6.18. As indicated in the table, the model's result is quite robust to the intertemporal elasticity substitution. Since the requirement that the model replicate the observed benchmark equilibrium that implies a relationship between the intertemporal elasticity of substitution and the subjective rate of time preference, a higher value of intertemporal elasticity of substitution corresponds to higher values of subjective rate of time preference. Similarly, a lower value of intertemporal elasticity of substitution corresponds to lower values of the subjective rate of time preference. Therefore the steady-state values under alternative cases would not be expected to differ[53]. (See Ballard and Goulder 1985).

As for short-run results, it would be expected that a higher value of intertemporal elasticity of substitution yield a greater saving response, faster transition, and larger welfare gain, our results shows that the offsetting effect of the rise in the subjective rate of time preference is not substantial. In the first year, total investment under the high value, for instance, increases by approximately 6.2 per cent as compared with 4.3 per cent under the low value.

[53]Goulder and Summers (1989) and overlapping generation models, such as Auerbach and Kotlikoff (1987) and Perraudin and Pujol (1991), find differences in steady-state results across alternative values of the parameter. As overlapping generation models' findings reflects differences between old and young generations, Goulder and Summers' result can attributed to the inclusion of risk premium in discounting households' incomes.

Table 6.1: Effective tax rates

	0	1	2	3	4	5	6
Agriculture							
r_I	9.62	9.20	9.20	7.50	11.87	8.67	8.27
t_w	5.75	5.32	5.32	3.63	3.87	4.79	4.40
t_e	148.37	137.36	137.36	93.64	79.90	123.67	113.47
Energy							
r_I	6.79	6.88	6.88	6.08	10.01	7.77	7.34
t_w	2.92	2.52	2.52	2.21	6.13	3.90	3.47
t_e	75.29	65.00	65.00	56.97	158.30	100.60	89.53
Manufacturing							
r_I	4.70	4.37	4.37	4.69	6.29	5.55	5.16
t_w	0.83	0.49	0.49	0.82	2.41	1.68	1.29
t_e	21.14	12.66	12.66	21.04	62.31	43.31	33.19
Services							
r_I	7.66	7.10	7.10	6.69	10.50	8.22	7.59
t_w	3.79	3.22	3.22	2.81	6.62	4.35	3.72
t_e	97.75	83.22	83.22	72.62	170.89	121.17	95.97
Housing services							
r_I	4.92	4.63	4.63	4.94	4.92	4.94	4.64
t_w	1.05	0.76	0.76	1.06	1.05	1.06	0.76
t_e	27.04	19.50	19.50	27.44	27.04	27.44	19.69
Overall ef. rate	66.75	55.30	54.85	52.10	117.90	80.35	67.35
St. dev.	0.648	0.559	0.556	0.478	1.140	0.743	0.639

Polices: 0 = Base case; 1 = Personal income tax cut and dividend credit cut; 2 = Policy 1 combined with VAT rate rise; 3 = Corporate tax cut; 4 = Write-off capital allowances elimination; 5 = Policy 4 combined with policy 3; and 6 = The 1980s overall tax reform.
Key: r_s = rate of return to savings, r_I = rate of return to investment, t_w = tax wedge, t_e = effective tax rate.

Table 6.2

Results from the Personal income tax and dividend tax credit rates reduction

	Periods		
	1	5	INF
Nominal interest rate	15.421	15.374	15.167
Nominal exchange rate	1.001	1.002	1.010
Investment	4.003	4.439	5.704
Nominal savings[a]	8.482	7.591	8.106
Total production	-0.262	0.087	1.345
Exports volume	-0.086	0.215	1.166
Terms of trade effect	-0.282	-1.749	-4.190
Wage rate	1.001	1.004	1.014
WH/WK	11.254	11.104	11.099
WB/WE	3.949	3.866	3.623
Revenue effect[b]	-26.617	-26.459	-24.528
Efficiency effect[c]	0.264		

Key: WH = total human wealth, WK = total non-human wealth, WB = Value of total bonds, and WE = value of total equities.

Note: All values express percentage changes from base case, except in the row corresponding to the interest rate, and wage rate.

[a]investment percentage may differ from personal saving percentage because of retained earnings and investment grants used to finance investment.

[b]Percentage change in personal income tax intercept to total tax revenues.
i.e. 100 * (change in tax intercept) / total tax revenues.

[c]Efficiency effect is measured as the equivalent variation

Table 6.3. Results from the Personal income tax and dividend tax credit rates reduction

Year	EARN	B/P_EE	Γ	V	I/K	I	K
Agriculture							
1	-1.350	9.568	-0.509	0.568	1.084	1.084	0.000
5	-0.787	9.433	-0.820	1.027	1.042	1.461	0.414
INF	-0.480	8.858	-2.145	2.358	0.000	2.208	2.208
Energy							
1	-0.566	8.183	-0.693	1.459	2.711	2.711	0.000
5	0.020	8.068	-1.005	2.068	2.279	3.068	0.772
INF	0.916	7.576	-2.327	4.004	0.000	3.971	3.971
Manufacturing							
1	0.500	7.148	-0.866	4.430	6.592	6.592	0.000
5	2.582	7.047	-1.177	5.834	5.506	7.356	1.754
INF	6.719	6.617	-2.498	10.122	0.000	9.630	9.630
Services							
1	-0.835	4.541	-1.530	2.754	5.078	5.078	0.000
5	0.049	4.477	-1.840	3.638	3.645	5.187	1.488
INF	1.596	4.204	-3.155	6.278	0.000	5.974	5.974
Housing Services							
1	-3.892	2.081	-0.646	0.150	0.640	0.640	0.000
5	-3.286	2.083	-0.960	0.736	1.350	1.512	0.160
INF	-1.766	2.093	-2.295	3.110	0.000	3.149	3.149

Key: EARN = Earnings after-tax before interest payments, B/P_EE = Debt to equity ratio, Γ = Cost of capital, V = Market value of firm, I/K = rate of investment, I = Investment, K = Capital stock.
Note: All values express percentage changes from base case.

Table 6.4

Results from the Personal income tax and dividend tax credit rates reduction and the value-added tax rates rise.

	Periods		
	1	5	INF
Nominal interest rate	15.439	15.383	15.167
Nominal exchange rate	1.002	1.003	1.010
Investment	5.516	5.836	6.817
Nominal savings[a]	10.377	9.620	11.070
Total production	-0.203	0.173	1.581
Exports volume	0.167	0.423	1.308
Terms of trade effect	-0.815	-1.525	-4.422
Wage rate	1.001	1.004	1.014
WH/WK	9.165	9.056	9.046
WB/WE	4.570	4.492	4.346
Revenue effect[b]	-15.269	-15.002	-12.662
Efficiency effect[c]	0.363		

Key: WH = total human wealth, WK = total non-human wealth, WB = Value of total bonds, and WE = value of total equities.

Note: All values express percentage changes from base case, except in the row corresponding to the interest rate, and wage rate.

[a]investment percentage may differ from personal saving percentage because of retained earnings and investment grants used to finance investment.

[b]Percentage change in personal income tax intercept to total tax revenues.
i.e. 100 * (change in tax intercept) / total tax revenues.

[c]Efficiency effect is measured as the equivalent variation

Table 6.5. Results from the Personal income tax and dividend tax credit rates reduction and the value-added tax rates rise.

Year	EARN	B/P_EE	Γ	V	I/K	I	K
Agriculture							
1	-0.890	9.599	-0.437	0.698	1.239	1.239	0.000
5	-0.542	9.455	-0.769	1.103	1.071	1.526	0.450
INF	-0.412	8.858	-2.145	2.429	0.000	2.284	2.284
Energy							
1	-0.906	8.210	-0.621	1.074	2.085	2.085	0.000
5	-0.371	8.087	-0.953	1.655	1.891	2.514	0.611
INF	0.589	7.576	-2.327	3.666	0.000	3.639	3.639
Manufacturing							
1	0.941	7.171	-0.794	4.716	7.008	7.008	0.000
5	3.018	7.063	-1.126	6.117	5.744	7.702	1.852
INF	7.089	6.617	-2.498	10.501	0.000	10.017	10.017
Services							
1	-1.069	4.556	-1.459	2.418	4.488	4.488	0.000
5	-0.265	4.488	-1.789	3.254	3.289	4.657	1.324
INF	1.271	4.204	-3.155	5.935	0.000	5.641	5.641
Housing Services							
1	3.277	2.081	-0.573	5.585	9.069	9.069	0.000
5	3.537	2.083	-0.908	6.247	7.785	9.360	1.461
INF	3.870	2.093	-2.295	9.026	0.000	9.073	9.073

Key: EARN = Earnings after-tax before interest payments, B/P_EE = Debt to equity ratio, Γ = Cost of capital, V = Market value of firm, I/K = rate of investment, I = Investment, K = Capital stock.
Note: All values express percentage changes from base case.

Table 6.6

Results from the corporate tax rate cut

	Periods		
	1	5	INF
Nominal interest rate	18.155	17.943	17.500
Nominal exchange rate	0.998	1.007	1.022
Investment	3.642	4.466	7.074
Nominal savings[a]	8.162	8.311	10.316
Total production	-0.336	0.176	2.145
Exports volume	-0.192	0.369	2.130
Terms of trade effect	0.589	-2.942	-9.919
Wage rate	0.999	1.008	1.030
WH/WK	-16.455	-16.344	-16.091
WB/WE	-13.279	-13.318	-13.426
Revenue effect[b]	-6.888	-5.977	-2.820
Efficiency effect[c]	0.275		

Key: WH = total human wealth, WK = total non-human wealth, WB = Value of total bonds, and WE = value of total equities.

Note: All values express percentage changes from base case, except in the row corresponding to the interest rate, and wage rate.

[a]investment percentage may differ from personal saving percentage because of retained earnings and investment grants used to finance investment.

[b]Percentage change in personal income tax intercept to total tax revenues.
i.e. 100 * (change in tax intercept) / total tax revenues.

[c]Efficiency effect is measured as the equivalent variation.

Table 6.7. Results from the corporate tax rate cut

Year	EARN	B/P_EE	Γ	V	I/K	I	K
Agriculture							
1	21.146	-25.629	7.527	22.764	5.555	5.555	0.000
5	17.057	-25.729	6.275	22.596	2.960	4.694	1.685
INF	15.058	-25.933	3.691	24.702	0.000	5.265	5.265
Energy							
1	18.773	-21.891	8.093	28.149	7.382	7.382	0.000
5	19.332	-21.976	6.834	29.431	5.455	7.573	2.009
INF	20.171	-22.150	4.236	32.949	0.000	8.562	8.562
Manufacturing							
1	11.816	-19.098	8.620	31.916	3.919	3.919	0.000
5	15.282	-19.171	7.355	34.639	4.364	5.595	1.179
INF	23.124	-19.324	4.744	43.026	0.000	9.742	9.742
Services							
1	19.900	-12.082	10.630	25.065	6.845	6.845	0.000
5	20.972	-12.129	9.341	26.734	5.049	7.180	2.029
INF	24.047	-12.225	6.682	31.867	0.000	8.935	8.935
Housing services							
1	-2.306	-0.910	4.560	-3.246	-5.998	-5.998	0.000
5	-0.744	-0.866	3.340	-2.069	-3.479	-4.289	-0.840
INF	3.225	0.297	-0.074	0.049	0.000	0.016	0.016

Key: EARN = Earnings after-tax before interest payments, B/P_EE = Debt to equity ratio, Γ = Cost of capital, V = Market value of firm, I/K = rate of investment, I = Investment, K = Capital stock.
Note: All values express percentage changes from base case.

Table 6.8

Results from the write-off capital allowances elimination

	Periods		
	1	5	INF
Nominal interest rate	16.852	16.971	17.500
Nominal exchange rate	0.999	0.995	0.979
Investment	-5.643	-6.481	-9.342
Nominal savings[a]	7.993	6.004	1.386
Total production	0.385	-0.303	-2.979
Exports volume	0.172	-0.512	-2.723
Terms of trade effect[b]	0.106	2.234	9.756
Wage rate	0.999	0.992	0.964
WH/WK	-4.610	-4.701	4.966
WB/WE	-1.081	-1.022	0.000
Revenue effect[c]	8.469	6.752	1.280
Efficiency effect[c]	-0.367		

Key: WH = total human wealth, WK = total non-human wealth, WB = Value of total bonds, and WE = value of total equities.

Note: All values express percentage changes from base case, except in the row corresponding to the interest rate, and wage rate.

[a]investment percentage may differ from personal saving percentage because of retained earnings and investment grants used to finance investment.

[b]Percentage change in personal income tax intercept to total tax revenues.

i.e. 100 * (change in tax intercept) / total tax revenues.

[c]Efficiency effect is measured as the equivalent variation.

Table 6.9. Results from the write-off capital allowances elimination

Year	EARN	B/P_EE	Γ	V	I/K	I	K
Agriculture							
1	-4.778	-1.230	-3.668	7.990	-2.307	-2.307	0.000
5	-4.574	-1.007	-3.004	7.550	-2.288	-3.155	-0.887
INF	-4.509	0.000	0.000	4.641	0.000	-5.029	-5.029
Energy							
1	-12.148	-1.051	-3.669	13.050	-9.387	-9.387	0.000
5	-9.907	-0.861	-3.006	12.928	-7.046	-9.395	-2.527
INF	-8.450	0.000	0.000	9.384	0.000	-10.240	-10.240
Manufacturing							
1	-3.398	-0.918	-3.671	11.071	-10.994	-10.994	0.000
5	-7.230	-0.752	-3.007	8.144	-12.141	-12.141	-2.912
INF	-14.469	0.000	0.000	-0.691	0.000	-15.447	-15.447
Services							
1	-10.095	-0.582	-3.676	9.544	-8.968	-8.968	0.000
5	-9.162	-0.477	-3.011	8.730	-6.773	-9.230	-2.636
INF	-10.316	0.000	0.000	3.584	0.000	-10.938	-10.938
Housing services							
1	5.861	0.105	-3.701	5.211	8.200	8.200	0.000
5	3.984	0.086	-3.032	3.865	4.700	5.908	1.154
INF	-1.443	0.000	0.000	-1.452	0.000	-0.407	-0.407

Key: EARN = Earnings after-tax before interest payments, B/P_EE = Debt to equity ratio, Γ = Cost of capital, V = Market value of firm, I/K = rate of investment, I = Investment, K = Capital stock.
Note: All values express percentage changes from base case.

Table 6.10

Results from the corporate tax cut and write-off capital allowances elimination

	Periods		
	1	5	INF
Nominal interest rate	17.782	17.671	17.500
Nominal exchange rate	0.998	1.003	1.008
Investment	0.379	0.484	0.721
Nominal savings[a]	15.597	13.315	11.049
Total production	-0.059	0.036	0.027
Exports volume	-0.062	0.085	0.367
Terms of trade effect[b]	0.590	-1.666	-3.801
Wage rate	0.999	1.003	1.007
WH/WK	-18.266	-18.705	-18.950
WB/WE	-13.698	-13.594	-13.757
Revenue effect[c]	-0.888	-1.217	-1.454
Efficiency effect[c]	0.025		

Key: WH = total human wealth, WK = total non-human wealth, WB = Value of total bonds, and WE = value of total equities.

Note: All values express percentage changes from base case, except in the row corresponding to the interest rate, and wage rate.

[a]investment percentage may differ from personal saving percentage because of retained earnings and investment grants used to finance investment.

[b]Percentage change in personal income tax intercept to total tax revenues.
i.e. 100 * (change in tax intercept) / total tax revenues.

[c]Efficiency effect is measured as the equivalent variation.

Table 6.11. Results from the corporate tax cut and write-off capital allowances elimination

Year	EARN	B/P_EE	Γ	V	I/K	I	K
Agriculture							
1	18.031	-25.801	5.361	28.127	4.223	4.223	0.000
5	14.158	-25.871	4.471	27.765	1.613	2.793	1.161
INF	12.344	-25.933	3.691	28.024	0.000	2.057	2.057
Energy							
1	10.115	-22.037	5.915	36.425	1.928	1.928	0.000
5	12.632	-22.098	5.020	38.078	1.265	1.772	0.500
INF	14.787	-22.150	4.236	39.753	0.000	1.618	1.618
Manufacturing							
1	9.259	-19.225	6.431	38.817	-2.689	-2.689	0.000
5	10.813	-19.278	5.532	39.809	-1.251	-1.822	-0.582
INF	12.850	-19.324	4.744	41.196	0.000	-0.794	-0.794
Services							
1	13.011	-12.163	8.400	30.946	1.504	1.504	0.000
5	14.891	-12.196	7.485	32.326	0.967	1.393	0.422
INF	16.960	-12.225	6.682	33.989	0.000	1.349	1.349
Housing services							
1	1.435	-0.834	2.449	-0.085	-0.687	-0.687	0.000
5	1.967	-0.803	1.583	0.440	-0.351	-0.443	-0.093
INF	2.604	-0.776	0.823	1.113	0.000	0.038	0.038

Key: EARN = Earnings after-tax before interest payments, B/P_EE = Debt to equity ratio, Γ = Cost of capital, V = Market value of firm, I/K = rate of investment, I = Investment, K = Capital stock.
Note: All values express percentage changes from base case.

Table 6.12

Results from the overall tax policy change

	Periods		
	1	5	INF
Nominal interest rate	15.681	15.503	15.167
Nominal exchange rate	1.000	1.001	1.018
Investment	5.534	6.022	7.621
Nominal savings[a]	27.451	25.224	25.104
Total production	-0.233	0.246	2.141
Exports volume	0.120	0.514	1.833
Terms of trade effect[b]	-0.259	-3.122	-8.377
Wage rate	1.000	1.006	1.023
WH/WK	-10.820	-11.001	-11.039
WB/WE	-7.407	-7.550	-7.766
Revenue effect[c]	-13.920	-13.867	-11.675
Efficiency effect[c]	0.428		

Key: WH = total human wealth, WK = total non-human wealth, WB = Value of total bonds, and WE = value of total equities.

Note: All values express percentage changes from base case, except in the row corresponding to the interest rate, and wage rate.

[a]investment percentage may differ from personal saving percentage because of retained earnings and investment grants used to finance investment.

[b]Percentage change in personal income tax intercept to total tax revenues.
i.e. 100 * (change in tax intercept) / total tax revenues.

[c]Efficiency effect is measured as the equivalent variation.

Table 6.13. Results from the overall tax policy change

Year	EARN	B/P_EE	Γ	V	I/K	I	K
Agriculture							
1	16.679	-12.502	4.813	29.041	5.393	5.393	0.000
5	13.255	-12.749	3.635	29.212	2.723	4.374	1.607
INF	11.692	-13.219	1.387	31.424	0.000	4.732	4.732
Energy							
1	8.421	-10.684	5.092	37.733	3.747	3.747	0.000
5	11.322	-10.895	3.911	40.089	2.994	4.071	1.046
INF	14.478	-11.296	1.656	44.680	0.000	1.751	1.751
Manufacturing							
1	8.567	-9.325	5.351	44.080	3.197	3.197	0.000
5	11.767	-9.509	4.167	46.661	3.655	4.665	0.975
INF	18.106	-9.859	1.907	54.315	0.000	8.165	8.165
Services							
1	10.746	-5.909	6.345	34.013	5.567	5.567	0.000
5	13.051	-6.025	5.150	36.312	4.062	5.769	1.641
INF	16.951	-6.247	2.867	41.878	0.000	7.222	7.222
Housing Services							
1	5.106	1.379	1.754	5.905	8.826	8.826	0.000
5	5.889	1.395	0.610	7.093	7.778	9.325	1.436
INF	7.127	1.426	-1.572	10.916	0.000	9.855	9.855

Key: EARN = Earnings after-tax before interest payments, B/P_EE = Debt to equity ratio, Γ = Cost of capital, V = Market value of firm, I/K = rate of investment, I = Investment, K = Capital stock.
Note: All values express percentage changes from base case.

Table 6.14

Results from the announced overall tax policy change

	Periods		
	1	5	INF
Nominal interest rate	15.370	155.370	15.176
Nominal exchange rate	0.994	1.011	1.018
Investment	9.174	6.778	7.621
Nominal savings[a]	66.265	24.645	25.104
Total production	-0.486	0.708	2.141
Exports volume	0.061	0.910	1.833
Terms of trade effect[b]	-0.419	-5.153	-8.377
Wage rate	0.994	1.013	1.023
WH/WK	-9.794	-11.0244	-11.039
WB/WE	2.575	-7.650	-7.766
Revenue effect[c]	9.097	-13.326	-11.675
Efficiency effect[c]	0.445		

Key: WH = total human wealth, WK = total non-human wealth, WB = Value of total bonds, and WE = value of total equities.

Note: All values express percentage changes from base case, except in the row corresponding to the interest rate, and wage rate.

[a]investment percentage may differ from personal saving percentage because of retained earnings and investment grants used to finance investment.

[b]Percentage change in personal income tax intercept to total tax revenues.
i.e. 100 * (change in tax intercept) / total tax revenues.

[c]Efficiency effect is measured as the equivalent variation.

Table 6.15. Results from the announced overall tax policy change

Year	EARN	B/P_EE	Γ	V	I/K	I	K
Agriculture							
1	-11.699	9.428	-0.831	14.766	6.881	6.881	0.000
5	10.870	-12.937	2.734	29.422	0.887	3.943	3.029
INF	11.692	-13.219	1.387	31.424	0.000	4.732	4.732
Energy							
1	-18.521	8.064	-1.016	24.856	6.254	6.254	0.000
5	12.074	-11.056	3.007	41.396	2.327	4.531	2.154
INF	14.478	-11.296	1.656	44.680	0.000	5.346	5.346
Manufacturing							
1	-12.829	7.043	-1.188	32.343	15.946	15.946	0.000
5	15.289	-9.649	3.261	49.621	1.743	5.571	3.762
INF	18.106	-9.859	1.907	54.315	0.000	8.165	8.165
Services							
1	-18.285	4.475	-1.851	22.003	9.457	9.457	0.000
5	14.144	-6.114	4.235	37.988	2.760	6.223	3.371
INF	16.951	-6.247	2.867	41.878	0.000	7.222	7.222
Housing Services							
1	-1.323	4.470	-3.560	2.657	4.563	4.563	0.000
5	7.399	1.407	-0.265	8.235	10.303	10.934	0.573
INF	7.127	1.426	-1.572	10.916	0.000	9.855	9.855

Key: EARN = Earnings after-tax before interest payments, B/P_EE = Debt to equity ratio, Γ = Cost of capital, V = Market value of firm, I/K = rate of investment, I = Investment, K = Capital stock.
Note: All values express percentage changes from base case.

Table 6.16

Results from the overall tax policy change with financial capital mobility

	Periods		
	1	5	INF
Nominal interest rate	15.770	15.553	15.176
Nominal exchange rate	0.992	1.005	1.018
Investment	10.509	11.001	7.621
Nominal savings[a]	37.030	30.202	25.104
Total production	-0.864	0.160	2.141
Capital flows[b]	-4.658	-3.839	0.000
Exports volume	-4.619	-3.051	1.833
Terms of trade effect[c]	8.128	2.953	-8.377
Wage rate	1.017	1.028	1.023
WH/WK	-12.165	-11.296	-11.066
WB/WE	-7.643	-12.650	-7.766
Revenue effect[d]	-11.595	-11.397	-11.675
Efficiency effect[e]	0.069		

Key: WH = total human wealth, WK = total non-human wealth, WB = Value of total bonds, and WE = value of total equities.

Note: All values express percentage changes from base case, except in the row corresponding to the interest rate, and wage rate.

[a]investment percentage may differ from personal saving percentage because of retained earnings and investment grants used to finance investment.

[b]Minus sign denotes capital inflows and plus sign represents capital outflow

[c]Percentage change in personal income tax intercept to total tax revenues.
i.e. 100 * (change in tax intercept) / total tax revenues.

[c]Efficiency effect is measured as the equivalent variation.

Table 6.17: Overall tax policy change with different financial capital mobility

	High mobility		Low mobility	
	1	5	1	5
Interest rate	15.778	15.544	15.730	15.555
Exchange rate	0.990	1.005	0.997	1.006
Investment	11.252	11.640	7.277	7.841
Nominal savings[a]	38.266	30.569	31.034	27.202
Total production	-0.963	0.152	-0.446	0.215
Exports volume	-5.346	-3.509	-1.499	-0.761
Capital account[b]	-5.395	-4.353	-1.563	-1.301
Terms of trade[c]	9.471	3.732	2.537	-0.954
Revenue effect[d]	-11.225	-11.056	-13.595	-13.097

Key: WH = total human wealth, WK = total non-human wealth, WB = Value of total bonds, and WE = value of total equities.

Note: All values express percentage changes from base case, except in the row corresponding to the interest rate, and wage rate.

[a]investment percentage may differ from personal saving percentage because of retained earnings and investment grants used to finance investment.

[b]Minus sign denotes capital inflow and plus sign represents outflow.

[c]Percentage change in personal income tax intercept to total tax revenues.
i.e. 100 * (change in tax intercept) / total tax revenues.

[d]Specified periods are replaced with 10, 20 and 50, respectively.

Table 6.18: Sensitivity Analysis

	Low values			High values		
	1	5	INF	1	5	INF
Elasticity substitution in consumption						
Total Investment	4.360	4.914	7.621	6.201	6.614	7.621
Housing investment	7.814	8.304	9.855	9.428	9.893	9.855
Manufacturing sector value	42.646	44.949	54.315	44.864	47.558	54.315
Housing sector value	5.421	6.484	10.916	6.192	7.433	10.916
Adjustment cost of investment						
Total Investment	7.519	7.954	8.493	3.557	3.967	6.149
Housing investment	9.526	10.496	9.618	7.538	8.001	10.251
Manufacturing sector values	45.197	48.712	57.780	41.588	43.264	49.122
Housing sector value	3.462	5.276	10.872	9.357	9.879	10.924
Agency costs of debt						
Total Investment	5.754	6.307	8.182	5.496	5.974	7.532
Housing investment	8.601	9.212	10.149	8.867	9.349	9.819
Manufacturing sector values	44.402	47.402	55.578	44.018	46.562	54.100
Housing sector value	5.749	7.045	11.303	5.934	7.106	10.866
Debt-equity ratios[a]	-48.281	-49.375	-51.465	-3.091	-3.151	-3.265
Cost of finance[a]	5.068	3.799	1.384	1.740	5.393	4.222

Note: All values express percentage changes from base case.

[a]Manufacturing industry.

Figure 6.1 : Effects on industries of the major UK tax policy changes

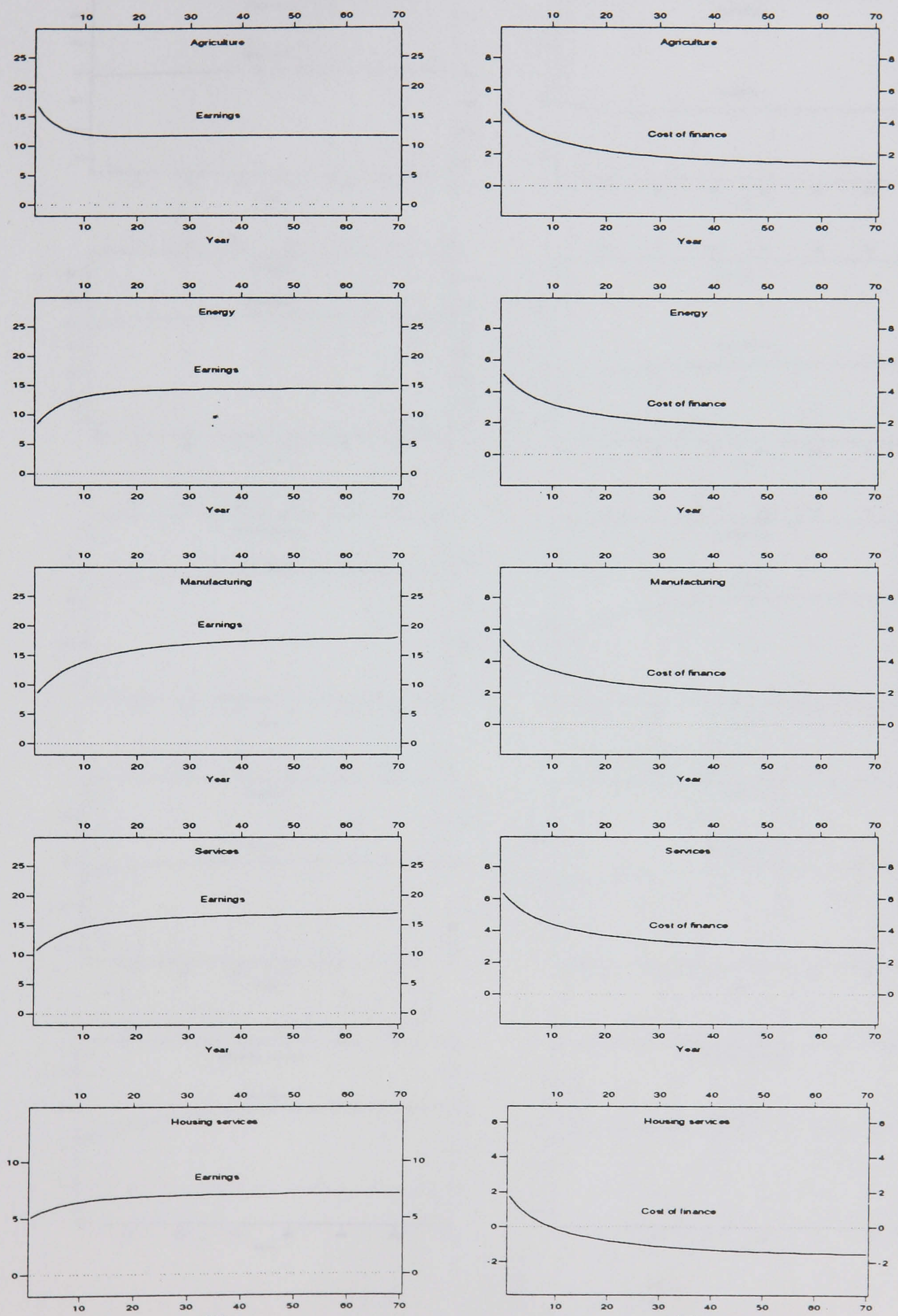


Figure 6.1 (Continued)

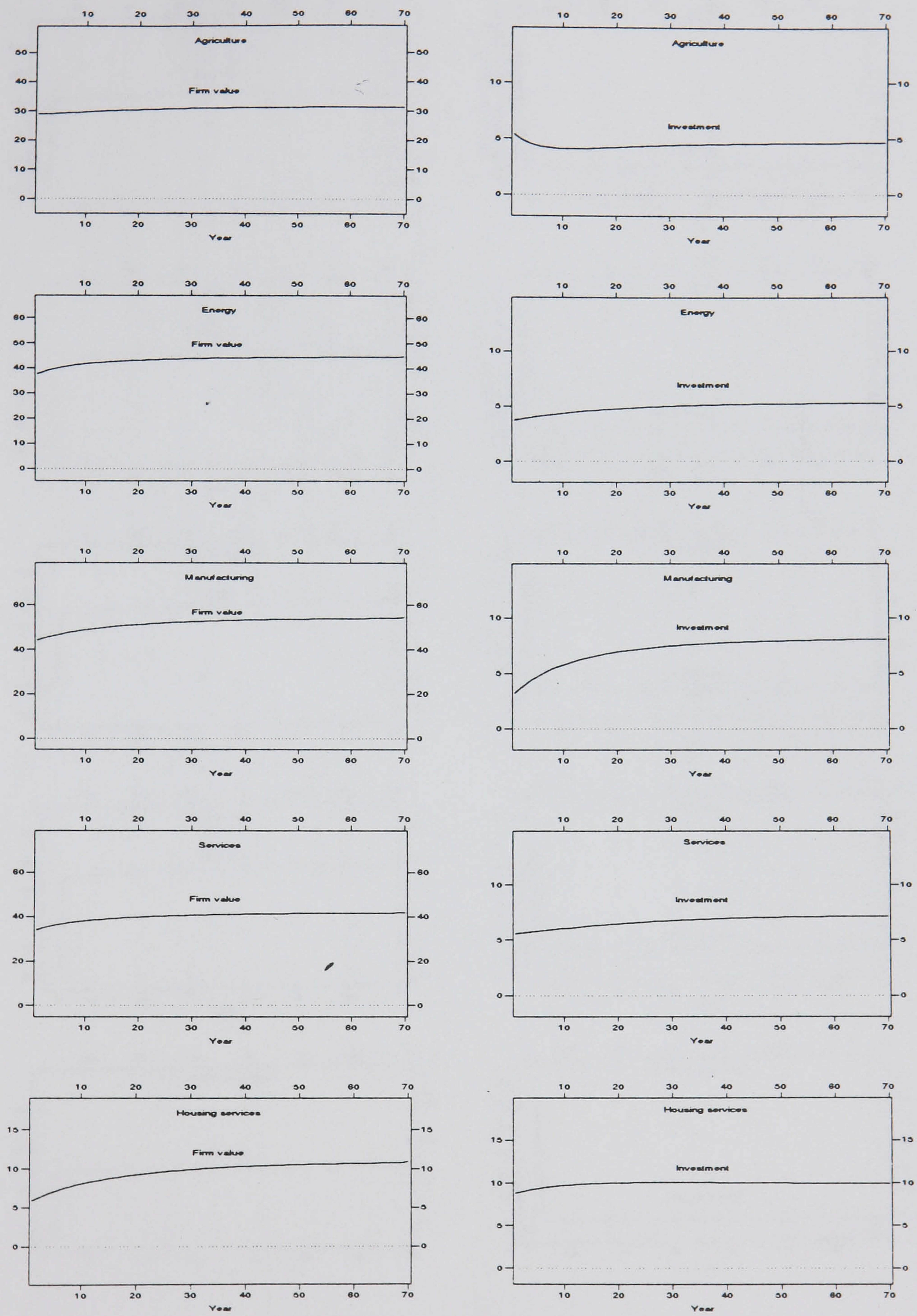


Figure 6.2 : Announcement effects of the major UK tax policy changes

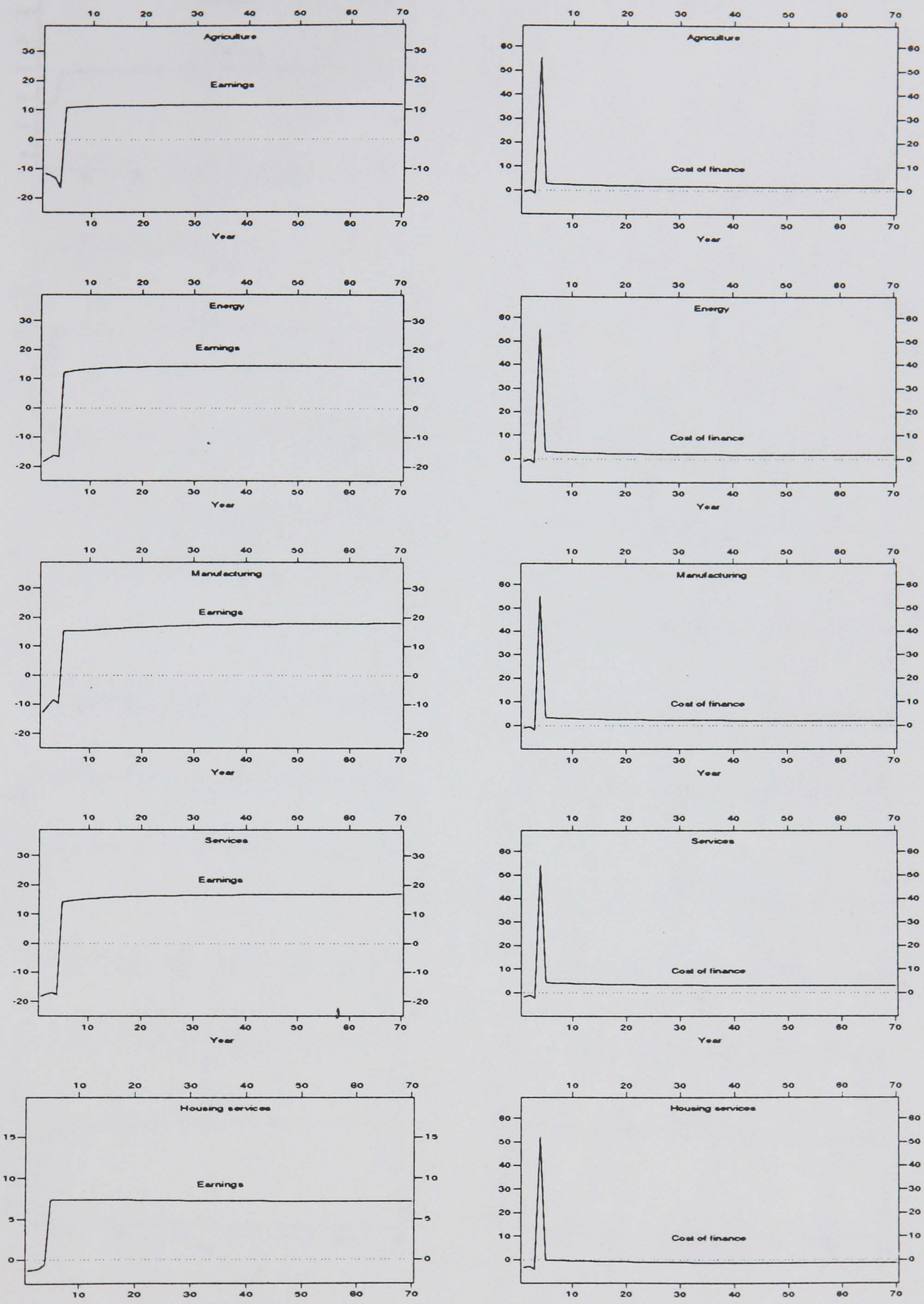


Figure 6.2 : (Continued)

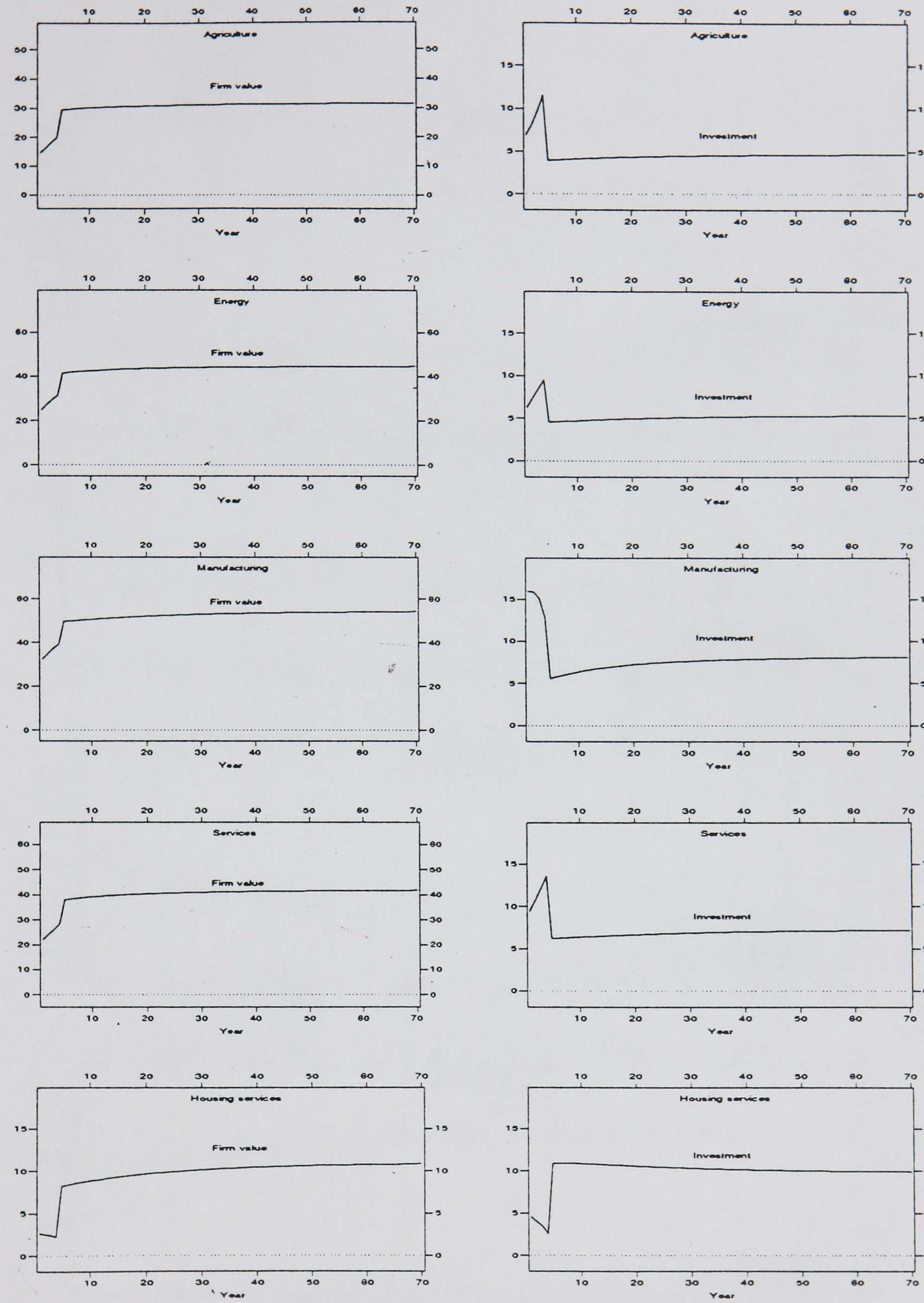
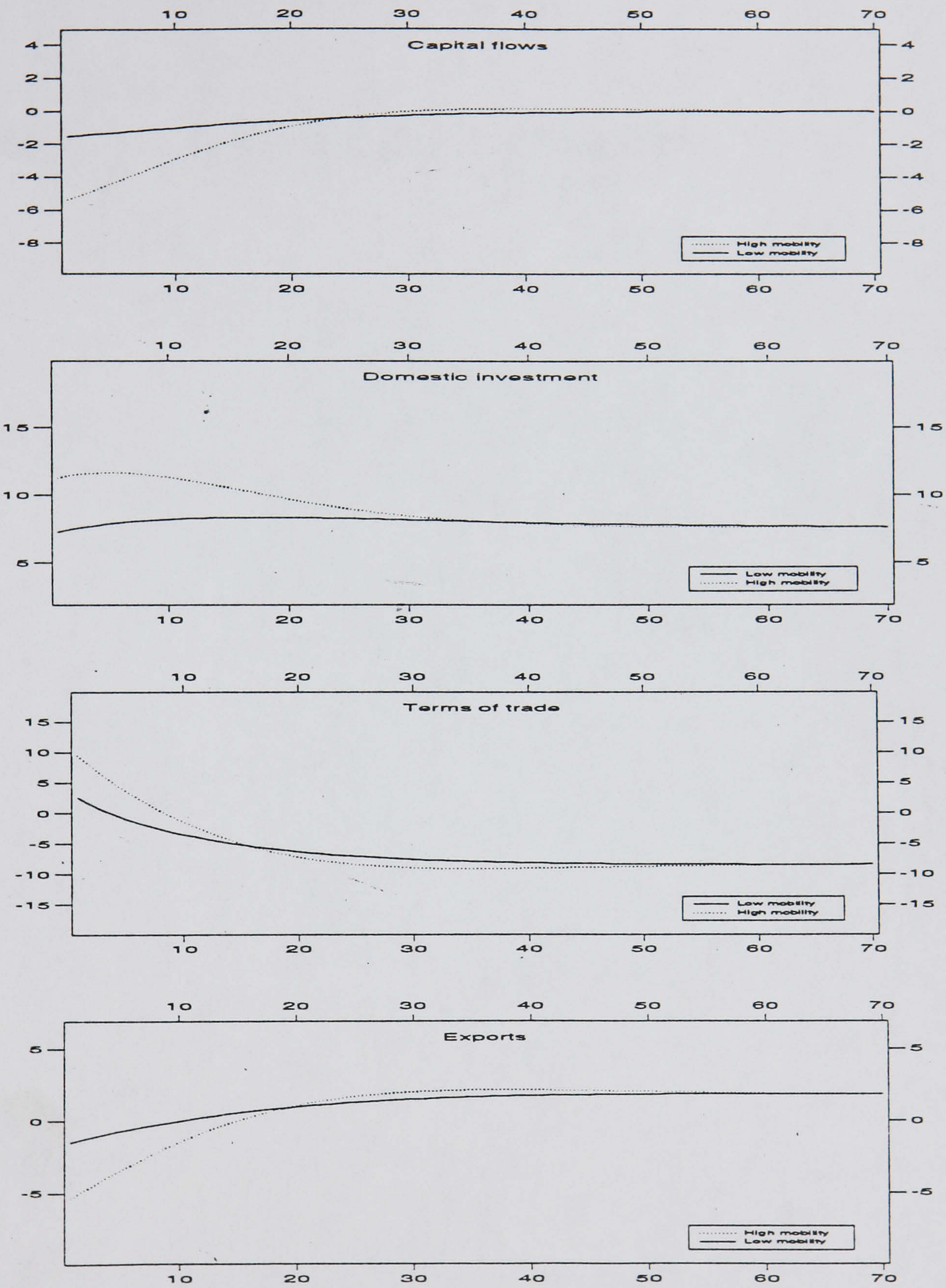


Figure 6.3 Capital mobility and the UK tax reform



CHAPTER 7 SUMMARY AND CONCLUSION

In this study, we developed a dynamic computable general equilibrium tax model to gauge the incidence and growth effects of tax policy changes. The model attempts to provide a comprehensive account of both the short-run impacts of the tax policy changes on asset values and their long-run effects on capital accumulation, by focusing on forward-looking investment decisions, on endogenous financial decisions, and on the influence of international financial capital flows. The model also allows for disaggregate industry effects by considering business sectors as well as housing services sector.

We have applied the model to the major tax policy changes to have taken place during the 1980s in the United Kingdom. Our preliminary results cast light on the importance of incorporating forward-looking investment behaviour, adjustment dynamics, endogenous financial behaviour and international financial mobility in general equilibrium policy evaluation models. The incidence and growth effects of the tax policy changes obtained in this study are consistent with economic theory and other works by Auerbach and Kotlikoff (1987), Dixon et al (1992) and Goulder and Summers (1989).

We observe that saving-promoting policies (the personal and corporate income tax cuts) outweigh the negative effects of the write-off (first year and initial) depreciation allowances elimination. Our experiments with the UK major tax policy changes in the 1980s suggest that the increase in investment in the long run could be approximately 7.6 per cent above the base case steady-state value.

The results of the simulation experiments indicate the UK corporate tax reform of 1984 (the corporation tax cut and capital elimination) would not produce any significant impact on capital accumulation. When these policies are considered separately, the corporate tax cut policy increases investment by 7.1 per cent in the long run, whereas the capital allowances elimination lowers the new steady-sate investment by 9.3 per cent above the base case steady-state value. When they are combined the corporate tax cut policy slightly predominates the other policy. However, it is worth noting that this combined policy generates significant windfall effects to capital owners. Our results indicates that the windfall effects of the policy could be in the region of 30 per cent to 40 per cent.

We observe that differences across industries appear to be negligible. All industries gain from the overall tax policy almost at the same extent. As residential sector, the housing sector, largely benefit from the VAT rate rise, non-residential sectors largely benefit from the personal and corporate tax cuts. When policies are considered separately, simulation results indicate significant differences across sectors in the effects of various tax policy changes. Industry effects are significant especially between residential and non-residential sectors. Policy changes, in general, cause adverse consequences for the housing sector, particularly in the short run. These different effects are largely attributable to the existence of costs of adjustment. Adjustment costs to investment greatly reduce the immediate sharing of policy benefits and losses. For example, while the elimination of write-off capital allowances decreases in investment in most sectors, investment in the housing sector rises by 8.2 per cent. But over the longer term investment in the housing sector declines by 0.4 per cent below the base case steady-state value.

Simulation results from the announced policy experiment cast light on the importance of incorporating forward-looking investment behaviour. Prior to the investment incentives elimination and the cuts in the personal and corporate tax rates, firms invest substantially to take advantage of the original investment incentives and lower tax rates to be applied to on their future profits right up to the time of the change. In the short-run total investment incentives increases by approximately 9.2 per cent as compared with 5.5 per cent in the announced policy scenario

Simulation results also suggest that models which ignore the endogenous adjustment of the financial structure will systematically err in predicting the response of investment to changes in the taxes that affect the relative attractiveness of debt finance and retention. In sensitivity analysis, we observe that alternative specification of agency costs of debt generates different investment levels, implying that opportunities in adjusting financial structure yield real effect. Simulation results indicate that companies respond to the reduced attractiveness of debt finance by shifting from debt finance to retention.

The results of the simulation experiments with international financial capital mobility suggest that the short run effects of tax policies from differ the long-run outcomes. We observe that increases in the UK domestic rate of return generated by both tax provisions and higher investment induces capital inflows. Such capital inflows greatly affect domestic investment in the short run. the increase in aggregate investment with financial capital mobility is double the increase in investment with no-mobility case.

There are undoubtedly weakness in this model. There are two groups of factor that should be taken into consideration when evaluating policies are under consideration. These are technical problems and fundamental conceptual problems. Technical problems are restrictive functional forms and inconsistent data set. Fundamental problems arise from those commonly used assumption; certainty, market-clearing and no technological progress.

Despite these limitations, our dynamic general equilibrium model represent a step forward to include more actual features of a complicated economic world in tax models. The model provides more realistic description of the dynamics of an economic system, and therefore, a more useful tool for fiscal policy evaluation.

The current model can be extended in several directions. Firstly, it would be useful to include different types of capital goods. Distinguishing structures from equipment would be particularly worthwhile, allowing for analysis of the effects of tax policy on the asset composition, as well as the industry composition, of investment.

Secondly, it would be useful to categorize households. Categorizing households makes it possible to address redistributional issues in a more realistic way.

Thirdly, incorporating liquidity constraints in the treatment of household behaviour also seems a worthwhile enterprise. Without these constraints, the current model may overstate the importance of wealth effects on consumption and understate the potential effects of policy changes on interest rate.

Finally, the current model adopts primitively 'source principle' in taxing capital income. The United Kingdom applies the residence principle for several capital income categories. Thus one profitable investment in a model development might be to expand the current model to capture the residence principle.

Apart from these modelling efforts, there are many other important issues associated with dynamic tax reform which the model presented here is capable of in addressing. These include the effects of policies which involve changing tax rates over time. An important area which few numerical general equilibrium models have entered so far is the analysis of government debt. Since it is widely believed that the structure of expectations about future tax liabilities can have a large effect when government bonds are issued, a model of this nature can be very useful in evaluating alternative tax and deficit plans.

APPENDIX A: A GLOSSARY OF NOTATION

1. Scalars

ρ	:	subjective rate of discount
σ	:	intertemporal elasticity of substitution
g	:	steady-state growth rate
π	:	inflation rate
r_B	:	nominal interest rate
f	:	income tax rate intercept
τ_p	:	marginal income tax rate
θ_p	:	marginal income tax factor
$\bar{\tau}_p$	:	average income tax rate
b	:	dividend tax credit rate
θ_b	:	dividend tax credit factor
τ_g	:	capital gains tax rate
θ_g	:	capital gains tax factor
τ_L	:	labour tax rate
$\alpha_0{}^d$	:	adjustment cost parameter considered to represent capital depreciation rate
$\alpha_1{}^d$	:	adjustment cost parameter
e	:	nominal exchange rate
e_R	:	real exchange rate
Tr	:	transfer payments

2. Behavioral and Tax Parameters

2.1 Firms

a_0	:	coefficient of requirement of value added
a_j	:	coefficient of requirement of intermediate input j
Φ	:	production technology
ϕ_p	:	Leontief production function
$VA(L,K)$	:	value added production function
ε_1	:	Cobb-Douglas normalisation parameter
ε_0	:	Cobb-Douglas weighting parameter
ϕ_d	:	adjustment cost function
ϕ_g	:	agency cost function
$\alpha_0{}^d$	:	agency cost parameter
$\alpha_0{}^d$	:	agency cost parameter
$\bar{d}$	:	dividend payout parameter
δ^R	:	capital economic depreciation rate
δ^T	:	tax depreciation rate
τ_c	:	corporate tax rate
θ_c	:	corporate tax factor
z	:	investment tax credit rate
$\bar{E}$	:	number of equity

2.2 Household and Rest of the World

μ	:	Cobb-Douglas utility weighting parameter
τ_v	:	value-added tax rate
σ_M	:	elasticity of substitution between domestic and imported goods
β_0	:	trade aggregation function weighting parameter

β_1 : trade aggregation function normalisation parameter
$P^w{}_M$: world price of import in foreign currency
τ_m : tariff rate
σ_Z : price elasticity of export demand
Z^0 : export demand in base case
$P^w{}_Z$: world price of export in foreign currency
τ_z : rate of export subsidy

3. Variables

3.1 Commodities and prices

$\tilde{C}$: composite consumer good
$\tilde{P}$: price of composite consumer good
C_i : consumer good i
Y_j : composite producer good j
P_j : price of composite producer good j
$Y^D{}_j$: domestic supply of good j
$P^D{}_j$: price of domestic good j
M_j : imported good j
P_{Mj} : price of imported good j
Z_j : exported good j
P_{Zj} : domestic export price of good j
P_{Nj} : net price of supply of good j
y_{ji} : demand for intermediate good j by industry i
y_j : intermediate good j
y : vector of intermediate inputs
P_y : vector of intermediate input prices
P_{Ej} : price of equity j
P_K : price of composite capital good
P_L : price of labour
L : labour

3.2 Assets

K_j : capital stock of firm j
V_j : market value of firm j
B_j : j^{th} industry bond
E_j : value of equity
B_g : government bond
B_w : foreign bond
TW : total wealth
WH : human wealth
WK : non-human wealth
WE : total value of equities
WB : total bond stocks
DA : value of currently allowable depreciation allowances
DE : value of depreciation allowances on existing capital
DN : value of depreciation allowances on future acquisition (unit investment)

3.3 Rate of Returns and Flow Variables

EARN : before tax earnings
NCF : net cash flow
DIV : dividends

RE	:	retained earnings
$\dot{B}_j$	:	debt issue by firm j
$\dot{P}_E$	:	increase in equity price (capital gains)
I	:	investment
$\dot{K}$	:	net investment (net increase in capital stock)
Γ	:	cost of capital
γ	:	debt-equity ratio
ω^c	:	discounting factor used by firms
λ	:	shadow price of additional capital goods
q	:	market valuation of existing capital (Tobin's q-ratio)
Q	:	tax adjusted q-ratio
U	:	lifetime utility level
u	:	instantaneous utility level
YD	:	disposable income
YH	:	labour income and transfers
YK	:	capital income
Tr	:	transfers
S	:	savings
$\dot{W}K$	:	capital asset accumulation
$\tilde{r}$	:	average after-tax return on the portfolio held by household
ω^h	:	discounting factor used by household
Λ	:	propensity to consume out of wealth
T_L	:	labour tax revenue
T_C	:	corporate tax revenue
T_Z	:	total investment tax credits paid by government
T_V	:	value-added tax revenue
T_P	:	personal income tax revenue
T_g	:	capital gains tax revenue
T_w	:	wealth tax revenue
T	:	total tax revenue
G_j	:	government expenditure on good j

APPENDIX B: STRUCTURAL EQUATIONS OF THE MODEL

1. Producer Behaviour

1.1 Production

-Production Technology

$$\Phi[L,K,y,I]=\phi_p(L,K,y)-\phi_d(I/K)I \qquad \text{(B.1)}$$

-Leontief structure

$$\phi_p(L,K,y) = Min\{\frac{1}{a_0}VA(L,K),\frac{y_1}{a_1},..........\frac{y_J}{a_J}\}, \qquad j=1,....,J=5 \qquad \text{(B.2)}$$

-Value added production function

$$VA(L,K) = \epsilon_1 L^{\epsilon_0}K^{1-\epsilon_0} \qquad \text{(B.3)}$$

1.2 Financial constraints, definitions and behaviour

-Gross profits (earnings before tax and interest payments) identity

$$EBIT = r_B+\phi_g(\gamma)B+RE+DIV+TAXF \qquad \text{(B.4)}$$

-Gross profits definition

$$EBIT = PY-P_L L-P_y y \qquad \text{(B.5)}$$

-Investment expenditure-finance identity

$$(1-z)P_K I=RE+\dot{B} \qquad \text{(B.6)}$$

-Dividend payout rule

$$DIV = \bar{d}E \qquad \text{(B.7)}$$

-Arbitrage condition

$$(1-\tau_p)r_B=\frac{(1-\tau_p)}{(1-b)}\bar{d}+(1-\tau_g)\frac{\dot{P}_E}{P_E} \qquad \text{(B.8)}$$

-Market value of firm

$$V(t)=\int_t^{\infty}\exp[-\int_t^s\Gamma(u)du]NCF(s)ds, \qquad \text{(B.9)}$$

-Net cash flow

$$NCF=[P_N Y-(1-\tau_L)P_L L]+\tau_c DA-(1-z)P_K I \tag{B.10}$$

-Cost of finance

$$\Gamma = [(1-\tau_c)r_B+\phi_g(\gamma)]\frac{\gamma}{1+\gamma}+[\bar{d}+\frac{\dot{P}_E}{P_E}]\frac{1}{1+\gamma} \tag{B.11}$$

1.3 Taxes on the producer

-Taxes paid by firms

$$TAXF = \tau_y PY+\tau_L P_L L+\tau_{vj}P_y y+\tau_c[\theta_y PY-\theta_L P_L-\theta_{vj}P_y y-r_B B]-\tau_c DA \tag{B.12}$$

-Depreciation allowances

$$DA(t) = \delta_w^T K^T(t)+(\delta_a^T+\delta_f^T)P_K(t)I(t) \tag{B.13}$$

-Value of depreciation allowances on existing capital

$$DE(t) = \int_t^{\infty}\tau_c\delta_w^T\exp[-\int_t^s\Gamma(u)du]K^T(s)[\exp(-\delta_w^T)(s-t)ds \tag{B.14}$$

-Value of depreciation allowances on new investment

$$DN(s) = \tau_c(\delta_a^T+\delta_f^T)+\int_s^{\infty}\tau_c\delta_w^T\exp[-\int_s^u\Gamma(v)dv]K^T(u)[\exp(-\delta_w^T)(u-s)du \tag{B.15}$$

1.4 Capital stock accumulation condition

$$\dot{K}=I-\delta^R K \tag{B.16}$$

1.5 Other conditions and functions

-Initial conditions for assets

$$K(0)=K_0,\ B(0)=B_0,\ \text{ and } \bar{E}(0)=\bar{E} \tag{B.17}$$

-Adjustment cost function

$$\phi_d(I/K) = \frac{(\alpha_1^d/2)[I/K-\alpha_0^d]^2}{I/K} \tag{B.18}$$

-Agency cost function

$$\phi_g(\gamma) = \frac{(\alpha_1^g/2)[\gamma - \alpha_0^g]^2}{\gamma} \tag{B.19}$$

1.6 Demand for investment

$$\frac{I}{K} = \alpha_0^d + \frac{1}{\alpha_1^d} Q. \tag{B.20}$$

1.7 Tax-adjusted q ratio

$$Q = [\frac{V-DE}{P_K K} - 1 + z + DN][\frac{P_K}{\theta_c P_N}] \tag{B.21}$$

2. Consumer Behaviour

2.1 Utility functions

-Intertemporal utility function

$$U(t) = \int_t^\infty \frac{\sigma}{\sigma-1} \tilde{C}(s)^{\frac{\sigma-1}{\sigma}} \exp(-\rho(s-t))ds, \tag{B.22}$$

-Sub-utility function

$$\tilde{C} = \Pi_i C_i^{\mu_i} \tag{B.23}$$

2.2 Budget constraint, income and conditions

-Intertemporal budget constraint

$$\int_t^\infty \tilde{P}(s)\tilde{C}(s)\exp[-\int_t^s (1-\tau_p) r_B(u)du]ds = TW(t) \tag{B.24}$$

-Total wealth

$$TW = WK + WH \tag{B.25}$$

-Non-human wealth

$$WK = eB_w + \Sigma_j B_j + \Sigma_j P_{Ej} \bar{E}_j \tag{B.26}$$

-Human wealth

$$WH(t) = \int_t^\infty YH(s)\exp[-\int_t^s (1-\tau_p) r_B(u)du]ds \tag{B.27}$$

-Dynamic budget constraint

$$\dot{B}_w+\Sigma_j\dot{B}_j = YD-\tilde{P}\tilde{C} \tag{B.28}$$

-Disposable fincome

$$YD = f+YH+YK \tag{B.29}$$

-Non-capital income

$$YH = (1-\tau_p)P_L L+Tr+\Sigma_j\phi_g(\gamma_j)B_j \tag{B.30}$$

-Capital income

$$YK = \Sigma_j\frac{1-\tau_p}{1-b}\div_j+(r_B^w+\frac{\dot{e}}{e})eB_w+(1-\tau_p)r_B^D Sigam_j B_j-\tau_g\Sigma_j\dot{P}_{Ej}\bar{E}_j \tag{B.31}$$

-Saving flow identity

$$S = e\dot{B}_w+\Sigma_j\dot{B}_j \tag{B.32}$$

-Average rate of return

$$r_B = \Omega(1-\tau_p)r_B^D+(1-\Omega)[r_B^w+\dot{e}/e] \tag{B.33}$$

2.3 Aggregate consumption and demand for commodities

-Demand for aggregate consumption

$$\tilde{P}(t)\tilde{C}(t) = \Lambda(t)TW(t)$$

$$\Lambda(t) = [\int_t^\infty[\tilde{P}(s)/\tilde{P}(t)]^{1-\sigma_u}[\exp(\rho(s-t)]^{\sigma_u}[\exp[-\int_t^s r_B(u)du]]^{1-\sigma_u}ds]^{-1} \tag{B.34}$$

-Demand for commodities

$$C_i = \mu_i\frac{[YD-S]}{P_i} \tag{B.35}$$

3. Government Sector Behaviour

3.1 Expenditures on commodities

$$G_i(t) = (1+g)^{t-1}\bar{G}_i \tag{B.36}$$

3.2 Goverment Sector Revenue

$$T = T_L+T_C-T_Z+T_V+T_P+T_g+T_w \tag{B.37}$$

-Labour tax on labour services

$$T_L = \tau_L \Sigma_j P_L L_j^D \tag{B.38}$$

-Corporate income tax

$$T_C = \Sigma_j \tau_{cj} [P_{Nj} Y_j (1-\tau_L) P_L L - r_B B_j - DA] \tag{B.39}$$

-Investment grants

$$T_Z = \Sigma_j z_j P_K I_j \tag{B.40}$$

-Value-added tax

$$T_V = \Sigma_i \tau_{vi} P_i C_i + \Sigma_j \Sigma_i \tau_{vi} P_j y_{ji} + \Sigma_i \tau_{vi} P_i G_i \tag{B.41}$$

-Personal income tax

$$T_P = \tau_p [P_L L + r_B^D \Sigma_j B_j + \Sigma_j \theta_b^{-1} DIV_j] - \frac{b}{1-b} \Sigma_j DIV_j - f \tag{B.42}$$

-Capital gains tax

$$T_g = \tau_g \Sigma_j \dot{P}_{Ej} \bar{E}_j \tag{B.43}$$

-Property tax

$$T_w = \Sigma_j \tau_w P_K K_j \tag{B.44}$$

3.3 <u>Government Budget Constraint</u>

$$\Sigma_j (1+\tau_{vi}) P_i G_i + TR = T \tag{B.45}$$

4. <u>Rest of World Behaviour</u>

4.1 <u>Trade</u>

-Production differentiation

$$Y = \beta_1 [\beta_0 M^{\frac{\sigma_M - 1}{\sigma_M}} + (1-\beta_0) Y^{D\frac{\sigma_M - 1}{\sigma_M}}]^{\frac{\sigma_M}{\sigma_M - 1}} \tag{B.46}$$

-Foreign consumer utility (function of export)

$$U_w(t) = \int_t^\infty \frac{\sigma_z}{\sigma_z - 1} \tilde{Z}(s)^{\frac{\sigma_z - 1}{\sigma_z}} \exp[-\rho(s-t)] ds \tag{B.47}$$

4.2 <u>International capital flows</u>

$$\dot{B}_w(t) = \bar{B}[(1-\tau_p^D)r_B^D-(1-\tau_p^w)-\dot{e}/e] \tag{B.48}$$

4.3 Balance of payment condition

$$\dot{B}_w(t) = [1+(1-\tau_p^w)]r_B^w B_w(t)+\Sigma_j P_{Mj}^w-\tilde{P}_z(t)\tilde{Z}(t) \tag{B.49}$$

5. Prices

-Composite consumer good price

$$\tilde{P} = \Pi_i[\frac{(1+\tau_{vi})P_i}{\mu_i}]^{\mu_i} \tag{B.50}$$

-Import price

$$P_M = P_M^w(1+\tau_m)e \tag{B.51}$$

-Export price

$$P_z = \frac{P_j^D}{(1+\tau_z)e} \tag{B.52}$$

6. Equilibrium Conditions

6.1 Product market

$$Y_j^D-Y_j^S = 0 \tag{B.53}$$

-Total demands

$$Y_j^D = D_j+Z_j \tag{B.54}$$

-Total demands for the goods produced in the domestic country

$$D_j = d_j[C_j+G_j+\alpha_{Ij}\Sigma_j I_j+\Sigma_i y_{ji}] \tag{B.55}$$

6.2 Labour market

$$\Sigma_j L_j^D-\bar{L} = 0 \tag{B.56}$$

6.3 Funds market

$$\dot{B}_w+\Sigma_j B_j = 0 \tag{B.57}$$

$$\Sigma_j(1+\tau_{vi})P_iG_i+TR = T \tag{B.58}$$

$$\dot{B}_w(t) = [1+(1-\tau_p^w)]r_B^w B_w(t)+\Sigma_j P_{Mj}^w-\tilde{P}_z(t)\tilde{Z}(t) \tag{B.59}$$

APPENDIX C: BASE CASE PARAMETER VALUES

Benchmark values for industry tax and behaviourial parameters

Parameter	Agriculture	Energy	Manufac-turing	Services, trade and utilities	Housing services
General Parameters					
Production efficiency factor (source: calibration)	0.612	0.581	1.081	1.115	0.118
Cobb-Douglas labour share (source: calibration)	0.082	0.072	0.316	0.355	0.001
Dividend payout rate (source: calibration)	0.029	0.029	0.029	0.029	0.023
Debt-equity ratio (source: own calculation from Extel Limited data set)	0.190	0.224	0.251	0.363	0.500
Rate of economic depreciation (δ^R) (Source: King and Fullerton 1984 and own calculation)	0.070	0.050	0.045	0.057	0.016
Import substitution elasticity (source: Piggott and Whalley 1984 adjusted)	0.8	1.6	3.2	0.8	-
Export demand elasticity (source: Piggoot and Whalley 1984 adjusted)	0.6	1.2	2.4	1.8	-
Tax Parameters (source: own calculation)					
First year depreciation rate ($\delta^T{}_f$)	0.250	0.400	0.600	0.350	0.000
Initial depreciation rate ($\delta^T{}_a$)	0.010	0.015	0.060	0.010	0.000
Annual depreciation rate ($\delta^T{}_w$)	0.050	0.055	0.020	0.040	0.040
Investment grant rate (source: King and Fullerton)	0.000	0.000	0.066	0.003	0.000
Labour tax rate (source: tax code)	0.09	0.09	0.09	0.09	0.09

Scalars:	
Corporate tax rate (τ_c) (source: tax code)	0.52
Capital gains tax rate (τ_g) (King and Fullerton 1984)	0.075
Marginal income tax rate (τ_p) (source: Kay and King 1978)	0.35
Dividend credit rate (b) (source: tax code)	0.30
steady-state growth rate	0.0275
inflation rate	0.175
intertemporal elasticity subtitution (source: Piggott and Whalley 1985 and Lawrance (1991)	0.5
adjustment cost parameters	
α^d_0	0.035
α^d_1	15
(source: plausible values from works by Jenkinson 1981, Oulton 1981, Summers and Poterba 1983 and Bond and Devereux 1988)	
agency cost parameter	
α^g_1	0.5

APPENDIX D: PROGRAMME AND COMPUTATION

A programme in FORTRAN was written to stimulate the model described in chapter 4 and is called 'DAGETM', which stands for dynamic applied general equilibrium tax model. DAGETM structures overall computational procedure in three stages, namely DATDES, SOLVE and RESULT. DATDES modifies and transforms the basic data into a model admissible data set; SOLVE calculates alternative equilibria for the variables tax replacements considered; and RESULT analyses the final equilibrium data procedure for each run.

DATDES is short section in terms of code. SOLVE is a lengthy in terms of code and complex in terms of programme structure and interlinking subroutine calls. In DAGETM the most execution time is spent in SOLVE.

DATDES sets up the NAG subroutine codes and reads the basic data. It does a few calculation, such as shares of consumption goods in the consumer spending.

SOLVE involves two stages. The first is to solve a "benchmark equilibrium". In the second stage SOLVE finds a "counterfactual" or "policy replacement" equilibrium as the alternative equilibrium associated with any changed policy regime. Both stages greatly differ from those seen in the static models. Models like ours that include multi-periods, i.e., dynamic models, must satisfy two sets of equilibrium conditions. Intratemporal (within-period) equilibrium requires that, given expectations, current supplies and demand balance in each period. Intertemporal equilibrium requires that expectations conform to the values realized in later periods.

In the benchmark equilibrium, the commonly adopted assumption that the economy is in equilibrium in a particular year and grows at a constant rate, the balanced growth rate (i.e., the economy is on the balanced growth path) simplifies the benchmark equilibrium solution. It is simply to calculate the steady state values as concerning the intertemporal equilibrium condition. A commonly used units convention that is to choose units for both goods and factors so that they have a price of unity in the benchmark equilibrium further simplifies the solution.

In calibrating the model a difficulty arises. The relationship between stock variables and their flow variables are governed by the balanced growth requirement. This requirement condition are often not found in national account data or in others. One must then take one them from the national account data and solve the other from the condition. Usually stock variables are taken as given in the national account data and the program solves the level of flow variable implied by the condition.

DAGETM initiates calibration when IFIN=0. Calibration is divided into two parts. The first part involves the producer side of the model. The second part deal with the consumer side problem. The crucial task in the first part is to adjust the data so as to produce the Q ratio implied by the balanced growth requirement and the values of adjustment cost parameters (see eq. 18' of the model). From the equation of motion for capital, eq. 5, given the economic depreciation rates and the values of capital stocks, one can calculate the level of investment. The relationship between the rate of investment and Q, with exogenously chosen the values for adjustment cost parameters, then corresponds to a particular value for the Q ratio. The data supplied in official statistics do not generate this q ratio. For this reason, we adjust production level.

The subroutine PCALIB takes care of this adjustment procedure in production level. The algorithm used in PCALIB is a NAG subroutine called C05NCF. The algorithm is an improved hybrid POWELL method that is written to solve non-linear equations system. PCALIB works with the subroutine BPROD, in which the producer's demand functions are located.

Once the program adjusted production levels, we are able to calculate the consumer's income level and wealth (human and non-human wealth). To determine savings and consumption a pure rate of time preference rate is required. Once a value for time preference has been specified, we can identify initial consumption. Since the value of aggregate household savings must equal total external borrowing by firms, the subroutine DISRAT is written to calculate the rate of time preference[54]. From the intertemporal equilibrium condition for the consumer, it is required that the pure rate of time preference must be consistent with the nominal market rate of interest (see eq. 75). Since the calculation on the producer side is based on a specified rate of interest, on the consumer side we calculate a value for the pure rate of time preference. This is done in the subroutine BDMND. BDMND also calculates consumer spending on specific goods. The subroutine GVREV, accordingly, calculates various tax revenues, transfer payments and government spending on goods.

A consistency problem arises with balance in output supplies and demands. It is because we adjusted production levels whereas we used the data for demands from the Blue Book (National Income Account). The subroutine ADJUST then adjusts input demand levels to balance output supply and demands.

Once the model is calibrated, the parameter values thus generated can be used to solve for the alternative equilibrium associated with any changed policy regime. That is, we advanced to the second stage of SOLVE, that is 'counterfactual equilibrium solution. The calculation of the counterfactual equilibrium path of the economy proceeds in two stages: (1) solving for the long-run steady state to which the economy eventually converges after the policy takes effect, and (2) solving for the transition path that the economy takes between the old (initial) steady-state and the new steady state.

DAGETM places IFIN=2 to start the new steady state solution. In solving the new steady state equilibrium a complex simulation procedure is required. The simulation procedure involves the solution of the general equilibrium model under steady-state constraints. One of the constraints is to find the industry Q's equal to the steady state values. This requires adjustment in capital stocks. So in the constrained system we iterate over capital stocks as well as prices including interest rate and exchange rate to obtain a general equilibrium in which the derived industry Q's are equal to the steady-state values.

[54]Actually, there is no need such a subroutine. This is because from the intertemporal equilibrium condition for the consumer, eq. 75, one can calculate the pure rate of time preference.

Having the initial values for stock variables and the terminal values for the 'wealth' variables we can solve the transition path. Since households and firms are forward-looking with perfect foresight, solution of the model at this stage requires that expectations conform to actual future values. To derive perfect foresight expectations, one repeatedly solves the model forward, each time generating a path of equilibria under given set of expectations. At any period of time, t, expectations are assigned to SVE in period t+1, called 'lead' variables, corresponding to the certain wealth variables of the model; V, DN, WH, and N. In the case of endogenous international financial mobility we also assign expected values to the exchange rate. The reason why the expectations are not assigned to all wealth variables is that the other wealth variables can be expressed in terms of those used wealth variables. Q can be expressed in V, DN and DE and current price. DE can be written in terms of DN and current variables. Next we generate an initial path for the lead variables by expanding expectations assignment procedure to t=2,.......T=75. This is done in EXPFOR. We generally use the new steady state values to assign expectations. Once again IFIN is set to indicate a new state starting. This time it is assigned to 1.

We then solve the model for each within-period equilibrium given initial path of the lead variables. In solving each within-period equilibrium an initial guess I^* is necessary to move on defining the demand for products and assets. the guess of investment allows us to calculate net cash flows in the current period based on current bond stocks. Solving for industrial debt-equity ratios and in turn using them in obtaining cost of finance, given the lead values for V, we can calculate current values for V. The next stage now is to calculate current values for Q. Since it can be defined in terms of V, DN, and DE, we then need to obtain values for DN and DE. Given the lead value for DN_w, we calculate current values for DN. Given the nominal depreciable capital stock, K^T, for the current period, since the values of DE and DN for a given period can be related, it is possible to determine DE from this relation. Finally, using the derived values for V_t, DN_t and DE_t, we calculate the current value of Q. This value of Q implies a certain level of investment. If this values does not match the initial guess of investment which helped to generate it, the initial guess is updated and the entire sequence of derivations is performed again. This procedure is repeated until the initial investment guess matches the derived investment level.

From the optimal debt to equity ratio and the current Q we then derive investment adjustment costs, and agency costs. Once adjustment costs and agency costs are known, we can calculate each industry's output from the desired input level and the current capital stock. Given the lead value for WH, we calculate the current value for expected human and transfer wealth. We sum the values of firms' bonds and firms' equites and foreign bonds. The human and nonhuman wealth variables allow the calculation of total wealth, consumption and savings.

The within-period equilibrium solution provides a sequence of derived values: SV_1, SV_2,............,SV_T. We compare our lead variables with contemporaneous derived values updating the guesses in a Gauss-Seidel fashion.

$$SVE_t^{(k-1)} = \lambda SV_t^{(k)} + (1-\lambda)SVE_t^{(k)}$$

where k represents the iteration and λ is a parameter between zero and one. The procedure generally brings lead and realized values within 0.01 per cent on one another within fifty iterations.

PROGRAM DAGETM

```
c Set double precision
        implicit real*8 (a-h, o-z)
c Include common block 'dimensions'
        include 'com.lib'
c Include DATDES.LIB
        include 'datdes.lib'
c Program
        call expfor
        ifail=0
c If no print out required, then set iprint=0.
        iprint=0
c Call NAG subroutine CO5NCF to solve BCALIB, in which we adjust production level

c in consistent with q-ratios
        call c05ncf(calib,n5,x5,f5,xtol,maxfev,ml5,mu5,epsfcn,diag5
    +   ,mode,factor,nprint,nfev,fjac5,ldfjac5,r5,lr5,qtf5,w5,ifail)
        if(ifail .eq. 0) then
        fnorm=f06ejf(n5,f5,1)
        write(nout,*) 'Endogenous Financial Structure Results'
        write(nout,*)
        write(nout,99999) 'final 2-norm of the residuals=', fnorm
        write(nout,99998) 'Number of function evaluations=',nfev
        write(nout,*) 'final approximate solution'
        write(nout,*)
        write(nout,99997) (x5(J),j=1,n5)
        else
        write(nout,99996) 'ifail=',ifail
          if(ifail .ge. 2) then
            write(nout,*) 'approximate solution'
            write(nout,*)
            write(nout,99997) (x5(j),j=1,n5)
          end if
        end if
c Call DISRAT to calculate the pure rate of time preference
        CALL DISRAT
c Call ADJUST to perform required adjustments to balance output supplies and demands
        CALL ADJUST
c Assign IPRINT to 1 to print the calibrated values
        iprint=1
c Call SCALE to scale variables to be printed. First define a scale, which is set 3 digits.
        qmov=1.0/1d3
        call scale
        call prnt
C The following commands bring variables' values back to original levels
        qmov=1d3
```

```
          call scale
C DIGRESSION: We also calculate effective tax rates as suggested by King and
Fullerton (1984).
C Effective Tax Rate Analysis (ETRA). To this end call ETRA.
          CALL ETRA
C Iprint=5 is assigned to print effective tax rates
          iprint=5
          CALL PRNT
C NEW STEADY STATE SOLUTION
          ifin=2
C
C Before we advance on the counterfactual equilibrium solution, we check the program
C To check the program the following statements are used to operate it.
C
C We call subroutines EXPFOR to read expectations; PROD, DMND, GVREV and
OPTN  are
C called to calculate producer, consumer, government and the rest of the world supplies
and
C demands
          call expfor
          call prod
          call dmnd
          call gvrev
          call optn
          qmov=1.0/1d3
          call scale
C When print is required, write IPRINT=1.
          iprint=0
          call prnt
          qmov=1d3
          call scale
C Checking finishes
C INTERNATIONAL CAPITAL FLOWS: iflow=1 means that capital is internationally
mobile.
          iflow=1
C Assign terminal year. T+1=nyear=76
          ik=nyear
C
C Define replacement policy:
C IPOL1 = The cut in corporate income tax rate
C IPOL2 = The reduction in capital allowances
C IPOL3 = The cut in personal income tax rate
C IPOL4 = The rise in VAT rates
C IPOL5 = Reform proposals; IPOL5=1 : consumption tax.
C IPOLs = 1, the policy is unannounced. IPOLs = 2 indicates a surprise policy
          ipol1=1
          ipol2=1
          ipol3=1
```

```
        ipol4=1
        ipol5=0
        if(ipol1 .eq. 1) then
C Corporate income tax cut
        rct1=0.35
        do 300 i=1,nfirm
        rct(i)=rct1
        if(i .eq. 5) then
        rct(i)=sr(1)*rct1
        end if
        fct(i)=1.-rct(i)
300     continue
        end if
        ipol1=1
        if(ipol2 .eq. 1) then
C TAX DEPRECIATION RATES
C First Year Tax Depreciation Rate
      do 310 i=1,nfirm
        rtf1(i)=0.0
        rtf(i)=rtf1(i)
310     continue
C Initial Tax Depreciation Rate
      do 330 i=1,nfirm
        rti1(i)=0.0
        rti(i)=rti1(i)
330     continue
C Writind down allowances
        do 340 i=1,nfirm
        if(i .eq. 3) then
        rta1(i)=0.25
        else
        rta1(i)=0.5*0.25
        end if
        rta(i)=rta1(i)*fcap(i,2)+fcap(i,3)*0.04
340     continue
        end if
        ipol2=1
        if(ipol3 .eq. 1) then
C Personal income tax cut
        rmyt1=0.25
        rlab=rmyt1
        rmyt=rmyt1
        fmyt=1.0-rmyt
C Dividend tax credit
        rdtc1=0.20
        rdtc=rdtc1
        fdtc=1.0-rdtc
        end if
```

```
      ipol3=1
      if(ipol4 .eq. 1) then
      do 305 m=1,ncom
      rvt1(m)=2.0*rvt0(m)
      rvt(m)=rvt1(m)
      fvt(m)=1.+rvt(m)
305   continue
      end if
      ipol4=1
      if(ipol5 .eq. 1) then
      rmyt1=0.0
      rlab=rmyt1
      rmyt=rmyt1
      fmyt=1.0-rmyt
      rdtc1=0.0
      rdtc=rdtc1
      fdtc=1.0-rdtc
      fmyt=1.0-rmyt
      fdtc=1.0-rdtc
      rcon=0.30
      end if
C Write asterics for print out
      write(1, 13)
13    format(1x,63('*'))
      if(iflow .eq. 1) then
      write(1, *) ' International capital flows        '
      end if
      if(ipol4 .eq. 1) then
      write(1, *) ' Value Added Tax  Rise               '
      end if
      if(ipol3 .eq. 1) then
      write(1, *) ' Personal Income Tax Cut             '
      end if
      if(ipol2 .eq. 1) then
      write(1, *) ' Reducing Capital Allovances         '
      end if
      if(ipol1 .eq. 1 .and. ipol2 .eq. 1) then
      write(1, *) ' Corporate Income Tax Cut and Reducing Depr.'
      else
         if(ipol1 .eq. 1) then
      write(1, *) ' Corporate Income Tax Cut            '
         end if
      end if
      if(ipol1 .eq. 2) then
      write(1, *) ' Corporate Income Tax Cut-Announced Policy'
         end if
      if(ipol2 .eq. 2) then
      write(1, *) ' Reducing Capital Subsidy-Announced Policy'
```

```
            end if
      if(ipol3 .eq. 2) then
      write(1, *) ' Personal Income Tax Cut-Announced Policy'
            end if
      write(1, *) ' AFTER REPLACEMENT(SOLUTION GUESS):    '
      write(1, 14)
14    format(1x,63('*'))
C
C New steady-state solutions
C
C Set up prices to be iterated. We iterate 14 variables; 5 output prices, interest rate, wage level,
C exchange rate, income tax parameter (for equal-yield equilibrium) and industry capital stocks (for
C q-ratios)
      do 70 i=1,ngood
      p(i)=1.0
      p(5+i)=1.0
      p(10+i)=1.0
      x13(i)=p(i)
      pjd(ik,i)=p(i)*(1.+rinf)**(ik-1)
      x13(5+i)=p(5+i)
      scap(ik,i)=p(5+i)*scap0(1,i)*(1.+sgr)**(ik-1)
70    continue
      x13(11)=p(11)
      plab(ik)=p(11)**(1.+rinf)**(ik-1)
      x13(12)=p(12)
      rb(ik)=p(12)*rb(1)
      x13(13)=p(13)
      er(ik)=p(13)*er(1)
      if(igovd .ne. 2) then
      x13(14)=p(14)
      if(ipol5 .ne. 1) then
      ft(ik)=p(14)*ft0*((1.0+rinf)*(1.0+sgr))**(ik-1)
            else
            ft(ik)=0.0
            rcon=p(14)*0.3
            end if
      end if
      iprint=0
      call c05ncf(lrun,n13,x13,f13,xtol,maxfev,ml13,mu13,epsfcn,
     1 diag13,mode,factor,nprint,nfev,fjac13,ldfjac13,r13,lr13,
     2 qtf13,w13,ifail)
      if(ifail .eq. 0) then
      fnorm=f06ejf(n5,f5,1)
      write(nout,99999) 'final 2-norm of the residuals=', fnorm
      write(nout,*)
      write(nout,99998) 'Number of function evaluations=',nfev
```

```
          write(nout,*)
          write(nout,*) 'final approximate solution'
          write(nout,*)
          write(nout,99997) (x13(J),j=1,n13)
          else
          write(nout,99996) 'ifail=',ifail
            if(ifail .ge. 2) then
                write(nout,*) 'approximate solution'
                write(nout,*)
                write(nout,99997) (x13(j),j=1,n13)
            end if
          end if
C
C Set the value for the parameter that determines the effect of tax
C policy on government budget
          pf(ik)=p(14)
C Call the subroutine 'RESULT' to see the new steady state results
          call result
          qmov=1.0/1d3
          call scale
C Assign IPRINT=2 to print the new steady state results
          iprint=2
          call prnt
          qmov=1d3
          call scale
          ifin=1
          call expfor
          ifin=2
C Once mobility case is considered, we solve the steady state after each transition (75
years)
C This is because one must find the steady-state bondholdings.
179       iprint=0
          epsfcn=0.0d0
          call c05ncf(lrun,n13,x13,f13,xtol,maxfev,ml13,mu13,epsfcn,
    1     diag13,mode,factor,nprint,nfev,fjac13,ldfjac13,r13,lr13,
    2     qtf13,w13,ifail)
          if(ifail .eq. 0) then
          fnorm=f06ejf(n5,f5,1)
          write(nout,99999) 'final 2-norm of the residuals=', fnorm
          write(nout,*)
          write(nout,99998) 'Number of function evaluations=',nfev
          write(nout,*)
          write(nout,*) 'final approximate solution'
          write(nout,*)
          write(nout,99997) (x13(J),j=1,n13)
          else
          write(nout,99996) 'ifail=',ifail
            if(ifail .ge. 2) then
```

```
            write(nout,*) 'approximate solution'
            write(nout,*)
            write(nout,99997) (x13(j),j=1,n13)
         end if
      end if
      call result
      qmov=1.0/1d3
      call scale
      qmov=1d3
      call scale
C Effective Tax Rate Anaysis (ETRA). To this end call ETRA
      CALL ETRA
      iprint=5
      CALL PRNT
C
C TRANSITION CASE SOLUTION
C
C Set transition solution
      ifin=1
C Set accuracy
      epsfcn=1d-3
C Now We can solve the model
C Now iteration
      ntrys=75
      do 95 iter=1,ntrys
      niter=iter
      npass=0
      do 100 ik=1,nyear-1
      call polex
      do 110 i=1,9
      if(ik .eq. 1) then
      p(1)=1.0
      p(2)=1.0
      p(3)=1.0
      p(4)=1.0
      p(5)=1.0
      p(6)=1.0
      p(7)=1.0
      p(8)=1.0
      p(9)=1.0
      else
      p(i)=p(i)
      end if
      x8(i)=p(i)
110   continue
      do 120 i=1,ngood
      pjd(ik,i)=p(i)*(1.+rinf)**(ik-1)
120   continue
```

```
          plab(ik)=p(6)*(1.+rinf)**(ik-1)
          rb(ik)=p(7)*rb0
          er(ik)=p(9)
          if(igovd .ne. 2) then
                if(ipol5 .ne. 1) then
          ft(ik)=p(8)*ft0*((1.0+rinf)*(1.0+sgr))**(ik-1)
                else
                ft(ik)=0.0
                rcon=p(9)*0.3
                end if
          end if
          iprint=0
          call c05ncf(srun,n8,x8,f8,1d-6,maxfev,ml8,mu8,epsfcn,diag8,
     1    mode,factor,nprint,nfev,fjac8,ldfjac8,r8,lr8,qtf8,w8,ifail)
c
c Apply Gauss-Seidel method for intertemporal solution
c
                if(ik .gt. 1) then
          do 115 i=1,nsvar
          rms(ik,i)=(sv(ik,i)-sve(ik,i))/sve(ik,i)
          print '(" rms:",i3,1x,i2,1x,14f10.5)',  (ik,i,rms(ik,i))
                if(dabs(rms(ik,i)) .lt. 0.1d-3) then
                npass=1+npass
                end if
          sve(ik,i)=.75*sv(ik,i)+(1.-.75)*sve(ik,i)
          sv(ik,i)=sve(ik,i)
115       continue
                end if
          call result
          print '(" interest:",1x,i3,12x,f12.8)', (ik,rb(ik))
          if(dabs(p(15)) .gt. 1.0) then
c         print '(" saving:",3x,f15.6)', (p(15))
          end if
C
C Set the value for the parameter that determines the effect of tax
C policy on government budget
          pf(ik)=p(9)
100       continue
          print '(" iteration-Pass:",1x,2i6)', (niter,npass)
          if(npass .eq. (nsvar)*(nyear-2)) then
          go to 180
          else
                if(iflow .eq. 1) then
                ifin=2
                ik=nyear
                go to 179
                end if
          end if
```

```
95      continue
180     iprint=3
        qmov=1.0/1d3
        call scale
        call prnt
        qmov=1d3
        call scale
        iprint=4
        call util
        call prnt
        write(1,16) niter
16      format (' number of iteration:',1x,i6)
99999   format (1x,a,d12.4)
99998   format (1x,a,i10)
99997   format (1x,5f12.4)
99996   format (1x,a,i2)
        stop
        end


        SUBROUTINE PROD

        implicit real*8 (a-h, o-z)
        include 'com.lib'
C
C CALCULATION OF THE SUPPLY OF GOODS AND THE DEMANDS FOR
INTERMEDIATE C
C GOODS AND LABOUR
C
C Simplification:
c 1) Asset Tax Parameter
        fmyt=1.0-rmyt
        rh(ik)=fmyt*rb(ik)
c 2) Steady-state Growth Rate
        sgr0=1.+sgr
        sgrc=sgr0**(ik-1)
C Labour Endowment
        slab(ik)=sgrc*slab(1)
C
C PRICES
C
        pcap(ik)=0.0
        do 10 i=1,ngood-1
C Export Prices
        pjz(ik,i)=pjd(ik,i)/er(ik)
        if(itot .eq. 1) then
        pjz(ik,i)=(1.+rinf)**(ik-1)
        end if
```

```
C Capital prices
          pcap(ik)=pcap(ik)+ai(i)*pj(ik,i)
10        continue
          pcap(ik)=pcap(ik)+ai(5)*pj(ik,5)
          do 15 i=1,nfirm-1
C Leontief Prices
          pn(i)=0.0
          do 20 j=1,ngood-1
          pn(i)=pn(i)+aj(i,j)*pj(ik,j)
20        continue
15        continue
          pn(5)=0.0
C Capital Stock
          do 30 i=1,nfirm
          if(ik .gt. 1 .and. ifin .eq. 1) then
          scap(ik,i)=scap(ik-1,i)+dinv(ik-1,i)-redep(i)*scap(ik-1,i)
          end if
C
C Capital Stock Motions
C Steady-state Solution
C
          if(ifin .eq. 2) then
          dcap(ik,i)=sgr*scap(ik,i)
          dpcap=rinf
          else
C Intertemporal solution
          dcap(ik,i)=dinv(ik,i)-redep(i)*scap(ik,i)
          end if
C Steady-state depreciable capital stock
          if(ik .gt. 1) then
               if(ifin .eq. 2) then
C Depreciable capital stock
          sdep(ik,i)=(sgr+redep(i))*(1.-rtf(i))*(1.-ritc(i))
    +     *pcap(ik)*scap(ik,i)/((1.+rinf)*(1.+sgr)-(1.-rta(i)))
C Its intertemporal value
               else
          sdep(ik,i)=(1.-rta(i))*sdep(ik-1,i)+(1.-rtf(i))
    +              *(1.-ritc(i))*pcap(ik-1)*dinv(ik-1,i)
               end if
          end if
30        continue
C Demand for Labour Factor
          tlab(ik)=0.0
          do 40 i=1,nfirm
          dlab(ik,i)=scap(ik,i)*((flt*plab(ik)/(a0(i,1)*a1(i)
    +          *pjd(ik,i)))**(1.0/(a0(i,1)-1.0)))
          tlab(ik)=tlab(ik)+dlab(ik,i)
40        continue
```

```
C Total retained earnings
          tret(ik)=0.0
C SUPPLY
          do 50 i=1,nfirm
          vad(i)=a1(i)*(dlab(ik,i)**a0(i,1))*(scap(ik,i)**a0(i,2))
          supj(i)=vad(i)/ajv(i)
          if(ifin .eq. 2) then
          dinv(ik,i)=(aca+(1./acb)*sq(i))*scap(ik,i)
          end if
C Calculation of Adjustment Cost Function of Investment
          acf(i)=((acb/2.0)*((dinv(ik,i)/scap(ik,i))
     +       -aca)**2.0)/(dinv(ik,i)/scap(ik,i))
C Net Supply
          sup(ik,i)=supj(i)-acf(i)*dinv(ik,i)
C Earnings of Firms
          earn(ik,i)=((1.-rit(i))*pjd(ik,i)*sup(ik,i)-pn(i)*supj(i)
     1      -flt*plab(ik)*dlab(ik,i))*fct(i)+rct(i)*(rtf(i)+rti(i))
     2    *pcap(ik)*dinv(ik,i)+rct(i)*rta(i)*sdep(ik,i)-rwt(i)*
     3                   fcap(i,3)*(pcap(ik)*scap(ik,i))
C
C DEBT-EQUITY RATIOS
C
          c1=-agb*(1.0+aga(i)/2.0)*aga(i)
          if(ifin .eq. 2) then
          rpe(i)=sgr0*(1.+rinf)-1.
                if(i .eq. 5) then
                dpr(i)=fdtc*(((1.-0.35)*rb0+erp(i)-(1.-0.5*rgt)*
     +          rpe(i)))/(fdtc-sr(1)*(rmyt-rdtc))
                else
                dpr(i)=fdtc*((1.-0.35)*rb0+erp(i)-fgt*rpe(i))/fmyt
                end if
          end if
                if(ifin .eq. 1) then
          rpe(i)=(fmyt*rb(ik)+erp(i)-fmyt*dpr(i)/fdtc)/fgt
          if(i .eq. 5) then
          rpe(i)=(fmyt*rb(ik)+erp(i)-(fdtc-sr(1)
     +       *(rmyt-rdtc))*dpr(i)/fdtc)/(1.-0.5*rgt)
          end if
                end if
          c2=dpr(i)+rpe(i)
                if(ifin .eq. 2) then
          c3=fct(i)*(dpr(i)/fdtc+fgt*rpe(i)/fmyt-erp(i)/fmyt)-c2
          if(i .eq. 5) then
          c3=(fct(i)-sr(3)*rmyt)*((fdtc-sr(1)*(rmyt-rdtc))*dpr(i)
     +    /fdtc+(1.-0.5*rgt)*rpe(i)-erp(i))/fmyt-c2
          end if
                end if
                if(ifin .eq. 1) then
```

```
          c3=fct(i)*rb(ik)-c2
          if(i .eq. 5) then
          c3=(fct(i)-sr(3)*rmyt)*rb(ik)-c2
          end if
                end if
          der(ik,i)=(-agb+sqrt(agb*agb-4.0*agb*(c1+c3)/2.0))/agb
C Agency cost function
          agf(i)=(agb/2.)*((der(ik,i)-aga(i))**2.)/der(ik,i)
C Cost of Capital
                if(ifin .eq. 2) then
          rc(ik,i)=((fct(i)*(dpr(i)/fdtc+fgt*rpe(i)/fmyt-erp(i)/fmyt)
    +          +agf(i))*der(ik,i)+c2)/(1.+der(ik,i))
          if(i .eq. 5) then
          rc(ik,i)=(((fct(i)-sr(3)*rmyt)*((fdtc-sr(1)*(rmyt-rdtc))
    1    *dpr(i)/fdtc+(1.-0.5*rgt)*rpe(i)-erp(i))/fmyt+agf(i))
    2          *der(ik,i)+c2)/(1.+der(ik,i))
          end if
                end if
                if(ifin .eq. 1) then
          rc(ik,i)=((fct(i)*rb(ik)+agf(i))*der(ik,i)+c2)/(1.+der(ik,i))
          if(i .eq. 5) then
          rc(ik,i)=(((fct(i)-sr(3)*rmyt)*rb(ik)+agf(i))
    +          *der(ik,i)+c2)/(1.+der(ik,i))
          end if
                end if
C
C Total Investment Expenditures
          vexp(i)=fitc(i)*pcap(ik)*dinv(ik,i)
C
C CALCULATION OF MARKET VALUES OF THE FIRMS
C
C FIRST: Depreciation allowances on new capital
C Steady-state value
                if(ifin .eq. 2) then
          sv(ik,i)=rct(i)*rta(i)/(rta(i)+rc(ik,i))
C Intertemporal value
                else
          sv(ik,i)=((1.-rta(i))*sv(ik+1,i)+rct(i)*rta(i))/
    +            (1.+rc(ik,i))
                end if
C SECOND: Depreciation allowances on existing capital
          de(i)=(1.-rta(i))*sdep(ik,i)*
    +          (sv(ik,i)+rct(i)*rta(i)/(1.-rta(i)))
C Investment incentives
          dn(i)=(ritc(i)+rct(i)*(rtf(i)+rti(i))+sv(ik,i))
C THIRD: Market value of firms
C Steady-state value
                if(ifin .eq. 2) then
```

```
          sv(ik,5+i)=(earn(ik,i)-vexp(i))/
     +              ((1.+rc(ik,i))-(1.+rinf)*(1.+sgr))
C Intertemporal value
               else
          sv(ik,5+i)=(sv(ik+1,5+i)+earn(ik,i)-vexp(i))/(1.+rc(ik,i))
               end if
C Bond Stock of Firms
          if(ifin .eq. 2) then
          bond(ik,i)=der(ik,i)*sv(ik,5+i)/(1.+der(ik,i))
          else
          if(ik .gt. 1) then
          bond(ik,i)=bond(ik-1,i)+dbond(ik-1,i)
          end if
          end if
C Equity Stocks
          seqy(ik,i)=sv(ik,5+i)-bond(ik,i)
C Dividend Payments
          div(ik,i)=dpr(i)*seqy(ik,i)
          fv(ik,i)=sv(ik,5+i)
C Retained Earnnings
          if(i .eq. 5) then
          ret(ik,i)=earn(ik,i)-div(ik,i)-(agf(i)
     +          +(fct(i)-sr(3)*rmyt)*rb(ik))*bond(ik,i)
          else
          ret(ik,i)=earn(ik,i)-div(ik,i)-(agf(i)+fct(i)*rb(ik))
     +          *bond(ik,i)
          end if
C Total retained earnings
          tret(ik)=tret(ik)+ret(ik,i)
C New Bond Issues of Firms
          dbond(ik,i)=vexp(i)-ret(ik,i)
C Q Ratios
          q(ik,i)=((sv(ik,5+i)-de(i))/(pcap(ik)*scap(ik,i))
     1    -1.0+dn(i))*(pcap(ik)/(pjd(ik,i)*(1.0-rct(i))))
C
C Now We can Calculate Investment Demand
          dinv(ik,i)=(aca+(1./acb)*q(ik,i))*scap(ik,i)
          if(ifin .eq. 2) then
          dinv(ik,i)=(aca+(1./acb)*sq(i))*scap(ik,i)
          end if
          acf(i)=((acb/2.0)*(dabs(dinv(ik,i)/scap(ik,i))
     1       -aca)**2.0)/(dabs(dinv(ik,i)/scap(ik,i)))
          sup(ik,i)=supj(i)-acf(i)*dinv(ik,i)
50        continue
C Demand for intermediate goods
          do 60 i=1,nfirm-1
          do 70 j=1,ngood-1
          demji(i,j)=aj(i,j)*supj(i)
```

```
70      continue
60      continue

        return
        end
```

```
      SUBROUTINE DMND

      implicit real*8 (a-h, o-z)
      include 'com.lib'

C
C CALCULATION OF TOTAL WEALTH
C
C Nonhuman Wealth And Current Capital Income
      we(ik)=0.0
      wb(ik)=0.0
      tdb(ik)=0.0
      wv(ik)=0.0
      tv(ik)=0.0
      yk(ik)=0.0
      p(19)=0.0
      dcpi(ik)=0.0
      do 10 i=1,nfirm
      we(ik)=we(ik)+seqy(ik,i)
      wb(ik)=wb(ik)+bond(ik,i)
      p(19)=p(19)+agf(i)*bond(ik,i)
      tdb(ik)=tdb(ik)+dbond(ik,i)
      dv(ik,i)=rpe(i)*seqy(ik,i)
      tv(ik)=tv(ik)+fv(ik,i)
      if(i .eq. 5) then
      wv(ik)=wv(ik)+0.5*dv(ik,i)
      yk(ik)=yk(ik)+(fdtc-sr(1)*(rmyt-rdtc))*div(ik,i)/fdtc
     +         +(1.-0.5*rgt)*dv(ik,i)
      else
      wv(ik)=wv(ik)+dv(ik,i)
      yk(ik)=yk(ik)+fmyt*div(ik,i)/fdtc+fgt*dv(ik,i)
      end if
      dcpi(ik)=dcpi(ik)+ac1(i)*pjd(ik,i)/((1.+rinf)**(ik-1))
10    continue
C
C Closure Rule
C International Capital Flows
      if(iflow .eq. 1 .and. ik .gt. 1) then
      bondw(ik)=bondw(ik-1)+dbondw(ik-1)
      wbond(ik)=wbond(ik-1)+dwbond(ik-1)
      end if
      wb(ik)=wb(ik)+bondg(ik)+er(ik)*bondw(ik)-wbond(ik)
      tdb(ik)=tdb(ik)+dbondg(ik)
C Rate of Return on Equities
      re(ik)=yk(ik)/we(ik)
C Portfolio Share: Bond Share
      bps=we(ik)/(we(ik)+wb(ik))
```

```
C Average After-tax Return on the Household Portfolio
      rp(ik)=rh(ik)*(1.-bps)+bps*re(ik)
      if(ifin .eq. 1 .and. iflow .eq. 1) then
      rp(ik)=(1.-bps)*(rh(ik)*(wb(ik)-er(ik)*bondw(ik))/wb(ik)
     1 +((1.-0.35)*rw+(sv(ik+1,12)-er(ik))/er(ik))*er(ik)
     2   *bondw(ik)/wb(ik))+bps*re(ik)
      end if
C
C CALCULATION OF COMPOSITE CONSUMPTION
C
C First: Composite Good Price
C Conversion of producer prices into consumer prices
      pjj(ik,1)=pj(ik,1)
      do 12 i=2,5
      pjj(ik,i)=pj(ik,2)
12    continue
      do 13 i=6,21
      pjj(ik,i)=pj(ik,3)
13    continue
      do 14 i=22,ncom-1
      pjj(ik,i)=pj(ik,4)
14    continue
      pjj(ik,28)=pj(ik,5)
      pc(ik)=1.0
      pg(ik)=0.0
      do 15 m=1,ncom
      pc(ik)=pc(ik)*((pjj(ik,m)*fvt(m)*fst(m))
     +        /ac(m))**ac(m)
      pg(ik)=pg(ik)+ag(m)*pjj(ik,m)
15    continue
      yk(ik)=0.0
      tdiv(ik)=0.0
      do 20 i=1,ngood-1
      yk(ik)=yk(ik)+fmyt*(div(ik,i)/fdtc+rb(ik)*bond(ik,i))
     +    +fgt*dv(ik,i)
      tdiv(ik)=tdiv(ik)+div(ik,i)
20    continue
      if(ifin .eq. 2) then
      sv(ik+1,12)=er(ik)
      end if
      tdiv(ik)=tdiv(ik)+sr(1)*div(ik,5)
      yk(ik)=yk(ik)+(fdtc-sr(1)*(rmyt-rdtc))*div(ik,5)/fdtc
     1    +fmyt*rb(ik)*(bond(ik,5)-wbond(ik))+((1.-0.35)
     2    *er(ik)*rw+(sv(ik+1,12)-er(ik)))*bondw(ik)
     3    +(1.-0.5*rgt)*dv(ik,5)+fmyt*rb(ik)*bondg(ik)
C Secon:  Human Wealth: The present value of after tax labour
C income and transfers
      tran(ik)=(tran(1)*(sgr0*(1.+rinf))**(ik-1))
```

```
      if(ifin .eq. 2) then
      sv(ik,11)=(1.+rp(ik))*(tran(ik)-(1.+rcon)*pc(ik)*adem(ik)+p(19)
     +  +(1.-rlab)*plab(ik)*slab(ik))/((1.+rp(ik))-(1.+rinf)*sgr0)
      wh(ik)=sv(ik,11)-(1.+rp(ik))*(tran(ik)+p(19)-(1.+rcon)
     +  *pc(ik)*adem(ik))/((1.+rp(ik))-(1.+rinf)*sgr0)
      else
      sv(ik,11)=(1.-rlab)*plab(ik)*slab(ik)+tran(ik)-(1.+rcon)
     + *pc(ik)*adem(ik)+p(19)+sv(ik+1,11)/(1.+rp(ik))
      awh=(1.-rlab)*plab(ik)*slab(ik)/(tran(ik)+p(19)+(1.-rlab)
     +          *plab(ik)*slab(ik)-(1.+rcon)*pc(ik)*adem(ik))
      wh(ik)=(1.-rlab)*plab(ik)*slab(ik)+awh*sv(ik+1,11)/(1.+rp(ik))
      end if
      wk(ik)=we(ik)+wb(ik)
C
C Third: The ratio of consumption to wealth
C
      if(ifin .eq. 2) then
      sv(ik,13)=(((1.+rcon)*pc(ik))**(1.-esh))/(1.-(((1.+rinf)
     + **(1.-esh))*((1.+stp)**(-esh))*((1.+rp(ik))**(esh-1.))))
      else
      sv(ik,13)=(((1.+rcon)*pc(ik))**(1.-esh))+((1.+stp)**(-esh))*
     + ((1.+rp(ik))**(esh-1.))*sv(ik+1,13)
      end if
      rcw=(((1.+rcon)*pc(ik))**(esh-1.))*sv(ik,13)
C Forth: Present discounted value of income tax intercept
      if(ifin .eq. 2) then
      sv(ik,14)=(1.+rp(ik))*ft(ik)/((1.+rp(ik))-(1.+rinf)*sgr0)
      else
      sv(ik,14)=ft(ik)+sv(ik+1,14)/(1.+rp(ik))
      end if
C Fifth: Total Wealth
      tw(ik)=we(ik)+wb(ik)+sv(ik,11)+sv(ik,14)+yk(ik)
C
C Now we can calculate composite consumption
C
      cdem(ik)=tw(ik)/((1.+rcon)*pc(ik)*rcw)
     +        +((1.+rcon)*adem(ik))
      if(esh .eq. 1.0) then
      cdem(ik)=stp*tw(ik)/((1.+rcon)*pc(ik)*(1.+stp))
     +        +((1.+rcon)*adem(ik))
      end if
      if(model .eq. 1) then
      cdem(ik)=(a*tw(ik)/((1.+rcon)*pc(ik)*rcw))
     +        +((1.+rcon)*adem(ik))
      slab(ik)=elab(ik)-(cdem(ik)-adem(ik))*(1.+rcon)
     + *(1.-a)*pc(ik)/(a*(1.-rlab)*plab(ik))
      end if
C
```

```
C Calculation of instantaneous utility level at the revised case
C
          ul(ik)=(esh/(esh-1.))*((cdem(ik)-adem(ik))**((esh-1.)/esh))
C Consumption of Specific Consumer Goods
          do 35 m=1,ncom
          demcj(m)=ac(m)*pc(ik)*cdem(ik)
     +              /(pjj(ik,m)*fvt(m)*fst(m))
35        continue
C Converting consumer goods into producer goods
          demc(ik,1)=demcj(1)
          demc(ik,2)=0.0
          do 36 i=2,5
          demc(ik,2)=demc(ik,2)+demcj(i)
36        continue
          demc(ik,3)=0.0
          do 37 i=6,21
          demc(ik,3)=demc(ik,3)+demcj(i)
37        continue
          demc(ik,4)=0.0
          do 38 i=22,ncom-1
          demc(ik,4)=demc(ik,4)+demcj(i)
38        continue
          demc(ik,5)=demcj(28)
C Disposable Income
          yd(ik)=0.0
          do 40 i=1,ngood-1
          yd(ik)=yd(ik)+fmyt*div(ik,i)/fdtc+fmyt*rb(ik)*bond(ik,i)
40        continue
          yd(ik)=yd(ik)-rgt*wv(ik)+fmyt*(sr(1)*div(ik,5))/fdtc
     1    +fmyt*rb(ik)*(bond(ik,5)-wbond(ik))+((1.-0.35)
     2    *er(ik)*rw+(0.0))*bondw(ik)+(1.-sr(1))*div(ik,5)
     3    +(1.-rlab)*plab(ik)*slab(ik)+ft(ik)+p(19)+tran(ik)
     4    +fmyt*rb(ik)*bondg(ik)
C Savings
          sav(ik)=yd(ik)-(1.+rcon)*pc(ik)*cdem(ik)
C Government Expenditures on Indivudiual Commodities
          do 50 m=1,ncom
          demgj(ik,m)=sgrc*demgj(1,m)
50        continue
C Converting consumer goods demanded by government
C into producer goods
          demg(ik,1)=demgj(ik,1)
          demg(ik,2)=0.0
          do 51 i=2,5
          demg(ik,2)=demg(ik,2)+demgj(ik,i)
51        continue
          demg(ik,3)=0.0
          do 52 i=6,21
```

```
          demg(ik,3)=demg(ik,3)+demgj(ik,i)
52        continue
          demg(ik,4)=0.0
          do 53 i=22,ncom-1
          demg(ik,4)=demg(ik,4)+demgj(ik,i)
53        continue
C Total production and capital formation
          tsup(ik)=0.0
          gdpn(ik)=0.0
          tcap(ik)=0.0
          tacf=0.0
          p(18)=0.0
          p(17)=0.0
          p(16)=0.0
          p(15)=0.0
          tinv(ik)=0.0
          tret(ik)=0.0
          do 60 i=1,nfirm
          tsup(ik)=tsup(ik)+sup(ik,i)
          gdpn(ik)=gdpn(ik)+(1.-rit(i))*pjd(ik,i)*sup(ik,i)
     +        -pn(i)*supj(i)
          tcap(ik)=tcap(ik)+scap(ik,i)
          tacf=tacf+acf(i)
          p(18)=p(18)+div(ik,i)
          p(17)=p(17)+de(i)
          tinv(ik)=tinv(ik)+dinv(ik,i)
          tret(ik)=tret(ik)+ret(ik,i)
          p(16)=p(16)+sdep(ik,i)
          p(15)=p(15)+earn(ik,i)
60        continue
          return
          end

          SUBROUTINE GVREV

          implicit real*8 (a-h, o-z)
          include 'com.lib'

C Simplification: Steady-state Growth Rate
          sgr0=1.+sgr
          sgrc=sgr0**(ik-1)
C Import Duties
          tmt=0.0
          dcpi(ik)=0.0
          do 10 i=1,ngood
          tmt=tmt+rmt(i)*pjm(ik,i)*demm(ik,i)
          dcpi(ik)=dcpi(ik)+ac1(i)*pjd(ik,i)/((1.+rinf)**(ik-1))
10        continue
```

```
C Intermediate Taxes
        tit=0.0
        do 20 i=1,nfirm
        tit=tit+rit(i)*pjd(ik,i)*sup(ik,i)
20      continue
C Value Added Taxes
        tvt=0.0
        do 30 m=1,ncom
        tvt=tvt+rvt(m)*pjj(ik,m)*fst(m)*demcj(m)
30      continue
C Value Added Taxes
        tst=0.0
        do 35 m=1,ncom
        tst=tst+rst(m)*pjj(ik,m)*demcj(m)
35      continue
C Corporate taxes
        tct=0.0
        do 40 i=1,nfirm
        if(i .eq. 2) then
        tct=tct+rct(i)*((1.-rpt)*((1.-rit(i))*pjd(ik,i)*sup(ik,i)
     1  -pn(i)*supj(i)-plab(ik)*flt*dlab(ik,i))-rb(ik)*bond(ik,i))
     2  -rct(i)*((rtf(i)+rti(i))*pcap(ik)*dinv(ik,i)+rta(i)
     3  *sdep(ik,i))-ritc(i)*pcap(ik)*dinv(ik,i)
        else
        tct=tct+rct(i)*((1.-rit(i))*pjd(ik,i)*sup(ik,i)-pn(i)
     1  *supj(i)-plab(ik)*flt*dlab(ik,i)-rb(ik)*bond(ik,i))
     2  -rct(i)*((rtf(i)+rti(i))*pcap(ik)*dinv(ik,i)+rta(i)
     3  *sdep(ik,i))-ritc(i)*pcap(ik)*dinv(ik,i)
        end if
40      continue
C Capital Gains Taxes
        tgt=0.0
        do 50 i=1,nfirm
        if(i .eq. 5) then
        tgt=tgt+0.5*rgt*dv(ik,i)
        else
        tgt=tgt+rgt*dv(ik,i)
        end if
50      continue
C Labour Taxes
        tlt=0.0
        do 60 i=1,nfirm
        tlt=tlt+rlt*plab(ik)*dlab(ik,i)
60      continue
C Personel Income Taxes
        tyt=-(ft(ik)/fmyt)+rmyt*(yd(ik)+rgt*wv(ik)-tran(ik)
     1  -(1.-sr(1))*div(ik,5)-p(19)-((1.-0.35)*er(ik)*rw+(0.0
     2  ))*bondw(ik))/fmyt-rdtc*tdiv(ik)/fdtc-rmyt*sr(3)
```

```
    3     *rb(ik)*bond(ik,5)
          if(ipol5 .eq. 1) then
          tyt=rcon*(yd(ik)-sav(ik))/(1.+rcon)
          end if
C Wealth Taxes
          twt=0.0
          do 70 i=1,nfirm
          twt=twt+rwt(i)*fcap(i,3)*pcap(ik)*scap(ik,i)
70        continue
C Petroleum Revenue Tax
          tpt=rpt*((1.-rit(2))*pjd(ik,2)*sup(ik,2)
    +     -pn(2)*supj(2)-flt*plab(ik)*dlab(ik,2))
C Total Taxes
          tax(ik)=tmt+tit+tvt+tst+tct+tlt+tgt+tyt+twt+tpt
C Base case Transfer Payments to Household
                if(ifin .eq. 0) then
          gexp(1)=tax(1)-tran(1)
C Government Expenditures
          do 75 m=1,ncom
          demgj(ik,m)=ag(m)*(tax(ik)-tran(ik))/pjj(ik,m)
75        continue
                else
C Government Expenditures
          gexp(ik)=0.0
          do 80 m=1,ncom
          demgj(ik,m)=demgj(1,m)*(sgr0*(1.+rinf))**(ik-1)
          gexp(ik)=gexp(ik)+pjj(ik,m)*demgj(ik,m)/((1.+rinf)**(ik-1))
80        continue
C Converting consumer goods demanded by the government
C into producer goods
          demg(ik,1)=demgj(ik,1)
          demg(ik,2)=0.0
          do 120 i=2,5
          demg(ik,2)=demg(ik,2)+demgj(ik,i)
120       continue
          demg(ik,3)=0.0
          do 130 i=6,21
          demg(ik,3)=demg(ik,3)+demgj(ik,i)
130       continue
          demg(ik,4)=0.0
          do 140 i=22,ncom-1
          demg(ik,4)=demg(ik,4)+demgj(ik,i)
140       continue
          demg(ik,5)=demgj(ik,28)
          sv(ik,12)=er(ik)
          return
          end
```

```
      SUBROUTINE OPEN

      include 'com.lib'

C Capital flows
          if(iflow .eq. 1) then
      if(ifin .eq. 1) then
      dbondf=(((1.+sgr)*(1.+rinf))**(ik-1))*bond0
   +  *((1.-0.35)*rw+(sv(ik+1,12)-er(ik))/er(ik)-fmyt*rb(ik))
          if(dbondf .gt. 0.0) then
          dbondw(ik)=dbondf
          dwbond(ik)=0.0
          tdb(ik)=tdb(ik)+dbondw(ik)/er(ik)
          else
          dwbond(ik)=(-1.)*dbondf
          dbondw(ik)=0.0
          tdb(ik)=tdb(ik)-dwbond(ik)
          end if
      else
      dbondw(ik)=0.0
      end if
          end if
      return
      end
```

```
      SUBROUTINE BPROD

      implicit real*8 (a-h, o-z)
      include 'com.lib'
C
C Simplification
      sgr0=1.0+sgr
C Interest Rate
      rh(ik)=fmyt*rb(ik)
      dpcap=rinf
C Initial Investment Level
      tinv(ik)=0.0
      do 20 i=1,nfirm
      dinv(ik,i)=(sgr+redep(i))*scap(ik,i)
      tinv(ik)=tinv(ik)+dinv(ik,i)
C Tobin Tax AdJusted Q-Ratio
      sq(i)=((dinv(ik,i)/scap(ik,i))-aca)*acb
C Depreciable capital stock
      sdep(ik,i)=(sgr+redep(i))*(1.-rti(i))*(1.-ritc(i))
     1    *scap(ik,i)/((1.+rinf)*(1.+sgr)-(1.-rta(i)))
C Equation of Motion for Capital
      dcap(ik,i)=dinv(ik,i)-redep(i)*scap(ik,i)
C Adjustment Cost Function
      acf(i)=((acb/2.)*(dinv(ik,i)/scap(ik,i)-aca)**2)
     1      /(dinv(ik,i)/scap(ik,i))
C Net Supply
      supj(i)=vad(i)/ajv(i)
      sup(ik,i)=supj(i)-acf(i)*dinv(ik,i)
20    continue
C PRICES
C Import Prices
      do 30 j=1,ngood-1
      pjm(ik,j)=pw(j)*er(ik)
C Export Prices
      pjz(ik,j)=pjd(ik,j)/er(ik)
C Export
      ddem(ik,j)=sup(ik,j)-demz0(ik,j)
C Import Share Parameters
      a10=((demm0(ik,j)/ddem(ik,j))**(1.0/esm(j)))*pjm(ik,j)
     +      /pjd(ik,j)
      am(j,1)=a10/(1.0+a10)
      am(j,2)=1.0-am(j,1)
C Composite Prices (of Import and Domestic Goods)
      a20=(am(j,1)**esm(j))*(pjm(ik,j))**(1.0-esm(j))
      a30=(am(j,2)**esm(j))*(pjd(ik,j))**(1.0-esm(j))
      am1(j)=((a20+a30)**(1./(1.0-esm(j))))/pj(ik,j)
30    continue
```

```
      am1(5)=1.0
      do 35 i=1,nfirm-1
      pn(i)=0.0
      do 40 j=1,ngood-1
C Leontief Prices
      pn(i)=pn(i)+aj(i,j)*pj(ik,j)
C Input Demand
      demji(i,j)=aj(i,j)*supj(i)
40    continue
35    continue
C Total retained earnings
      tret(ik)=0.0
      pn(5)=0.0
      gdpn0(ik)=0.0
      tsup0(ik)=0.0
      tcap(ik)=0.0
      do 45 i=1,nfirm
C Production Share Parameter
      a0(i,1)=flt*dlab(ik,i)/(vad(i))
      a0(i,2)=1.-a0(i,1)
C Efficiency Parameter
      a1(i)=vad(i)/((dlab(ik,i)**a0(i,1))*(scap(ik,i)**a0(i,2)))
C Earnings
      earn(ik,i)=((1.-rit(i))*pjd(ik,i)*sup(ik,i)-pn(i)*supj(i)
     1 -flt*plab(ik)*dlab(ik,i))*fct(i)+rct(i)*(rtf(i)+rti(i))
     2 *dinv(ik,i)+rct(i)*rta(i)*sdep(ik,i)-
     3    rwt(i)*(fcap(i,3)*scap(ik,i))
C Total Investment Expenditures
      vexp(i)=fitc(i)*dinv(ik,i)
C Dividend payout ratio
      rpe(i)=sgr0*(1.+rinf)-1.
      if(i .eq. 5) then
      dpr(i)=fdtc*((fmyt*rb(ik)+erp(i)-(1.-0.5*rgt)*
     +    rpe(i)))/(fdtc-sr(1)*(rmyt-rdtc))
      else
      dpr(i)=fdtc*(fmyt*rb(ik)+erp(i)-fgt*rpe(i))/fmyt
      end if
C Agency Cost Parameter
      c1=dpr(i)+rpe(i)
      c2=agb*der(ik,i)+(agb*der(ik,i)*der(ik,i)/2.)
      if(i .eq. 5) then
      c3=c1-(fct(i)-sr(3)*rmyt)*((fdtc-sr(1)*(rmyt-rdtc))*dpr(i)
     + /fdtc+(1.-0.5*rgt)*rpe(i)-erp(i))/fmyt
      else
      c3=c1-fct(i)*(dpr(i)/fdtc+fgt*rpe(i)/fmyt-erp(i)/fmyt)
      end if
      aga(i)=(-agb+sqrt(agb*agb-4.*agb*(c3-c2)/2.))/agb
C Agency Cost Function
```

```
      agf(i)=(agb/2.)*((der(ik,i)-aga(i))**2.)/der(ik,i)
C Cost of Capital
      rc(ik,i)=((fct(i)*rb(ik)+agf(i))*der(ik,i)+rpe(i)+dpr(i))
     +          /(1.+der(ik,i))
      if(i .eq. 5) then
      rc(ik,i)=(((fct(i)-sr(3)*rmyt)*rb(ik)+agf(i))
     +      *der(1,i)+rpe(i)+dpr(i))/(1.+der(1,i))
      end if
C CALCULATION OF MARKET VALUE OF FIRMS
C Depreciation allowances on new capital
      sv(ik,i)=rct(i)*rta(i)/(rta(i)+rc(ik,i))
C Investment incentives
      dn(i)=(ritc(i)+rct(i)*(rtf(i)+rti(i))+sv(ik,i))
C Depreciation allowances on existing capital
      de(i)=(1.-rta(i))*sdep(1,i)*
     +       (sv(1,i)+rct(i)*rta(i)/(1.-rta(i)))
C Market value of firms
      sv(1,5+i)=(earn(ik,i)-vexp(i))/
     +          ((1.+rc(ik,i))-(1.+rinf)*(1.+sgr))
      fv(1,i)=sv(1,5+i)
C Bond Stock of Firms
      bond(ik,i)=der(1,i)*sv(1,5+i)/(1.+der(1,i))
C Calculate bond/capital ratio (Gearing ratio)
      dcr(i)=bond(ik,i)/scap(ik,i)
C Equity Stocks
      seqy(ik,i)=sv(1,5+i)/(1.+der(1,i))
C Dividend Payments
      div(ik,i)=dpr(i)*seqy(ik,i)
C Retained Earnnings
      if(i .eq. 5) then
      ret(ik,i)=earn(ik,i)-div(ik,i)-(agf(i)+(fct(i)
     +    -sr(3)*rmyt)*rb(ik))*bond(ik,i)
      else
      ret(ik,i)=earn(ik,i)-div(ik,i)-(agf(i)+fct(i)*rb(ik))
     +       *bond(ik,i)
      end if
      tret(ik)=tret(ik)+ret(ik,i)
C New Bond Issues of Firms
      dbond(ik,i)=(sgr0*(1.+rinf)-1.)*bond(ik,i)
      dbond(ik,i)=vexp(i)-ret(ik,i)
C Equation of Motion for Market Value of Firms
      dv(1,i)=rpe(i)*seqy(1,i)
C Q Ratios
      q(ik,i)=((sv(ik,5+i)-de(i))/(pcap(ik)*scap(ik,i))
     1  -1.0+dn(i))*(pcap(ik)/(pjd(ik,i)*(1.0-rct(i))))
C Assign Base Year Values to certain variables
      earn0(1,i)=earn(1,i)
      v0(1,i)=fv(1,i)
```

```
      s0(1,i)=seqy(1,i)
      der0(1,i)=der(1,i)
      rc0(1,i)=rc(1,i)
      dinv0(1,i)=dinv(1,i)
      sup0(1,i)=sup(1,i)
      gdpn0(1)=gdpn0(ik)+(1.-rit(i))*pjd(ik,i)*sup(ik,i)
     +     -pn(i)*supj(i)
      tsup0(1)=tsup0(1)+sup(1,i)
      scap0(1,i)=scap(1,i)
      tcap(1)=tcap(1)+scap(1,i)
      dlab0(1,i)=dlab(1,i)
45    continue
      rb0=rb(1)
      return
      end

      SUBROUTINE BDMND

      implicit real*8 (a-h, o-z)
      include 'com.lib'
C
C Simplification
      sgr0=1.0+sgr
C
C Composite Good Price
C
C Conversion of producer prices into consumer prices
      pjj(ik,1)=pj(1,1)
      do 101 i=2,5
      pjj(ik,i)=pj(1,2)
101   continue
      do 102 i=6,21
      pjj(ik,i)=pj(1,3)
102   continue
      do 103 i=22,ncom-1
      pjj(ik,i)=pj(1,4)
103   continue
      pjj(ik,28)=pj(1,5)
      pc(ik)=1.0
      do 105 m=1,ncom
      pc(ik)=pc(ik)*(pjj(ik,m)*fvt(m)*fst(m)
     +        /ac(m))**ac(m)
105   continue
      slab(1)=0.0
      do 10 i=1,ngood
      slab(1)=slab(1)+dlab(1,i)
10    continue
      elab(1)=1.5*slab(1)
```

```
C
C TOTAL WEALTH OF THE CONSUMER
C
C Nonhuman Wealth And Current Capital Income
      we(1)=0.
      wb(1)=0.
      tdb(1)=0.
      yk(1)=0.
      wv(1)=0.
      tv(1)=0.
      p(19)=0.0
      tdemm0(ik)=0.0
      do 20 i=1,nfirm
      we(1)=we(1)+seqy(1,i)
      wb(1)=wb(1)+bond(1,i)
      tdb(1)=tdb(1)+dbond(1,i)
      if(i .eq. 5) then
      yk(1)=yk(1)+(fdtc-sr(1)*(rmyt-rdtc))*div(1,i)/fdtc
     +   +(1.-0.5*rgt)*dv(1,i)
      wv(1)=wv(1)+0.5*dv(1,i)
      else
      yk(1)=yk(1)+fmyt*div(1,i)/fdtc+fgt*dv(1,i)
      wv(1)=wv(1)+dv(1,i)
      end if
      tv(1)=tv(1)+fv(1,i)
      p(19)=p(19)+agf(i)*bond(ik,i)
      tdemm0(ik)=tdemm0(ik)+demm0(ik,i)
20    continue
      wb(1)=wb(1)+bondg(1)
      tdb(1)=tdb(1)+dbondg(1)
C Rate of Return on Equities
      re(1)=yk(1)/we(1)
C Portfolio Share: Bond Share
      bps=wb(1)/(we(1)+wb(1))
C Average After-tax Return on the Household Portfolio
      rp(ik)=bps*rh(ik)+(1.-bps)*re(ik)
C Pure time preference
      stp=(((1.+rh(ik))/(sgr0*(1.+rinf))**esh)-1.0
C Human Wealth
      sv(ik,11)=(1.+rh(ik))*(tran(ik)+p(19)+fmyt*slab(1))/
     +         ((1.+rh(ik))-(1.0+rinf)*sgr0)
      wk(ik)=wb(ik)+we(ik)
C The ratio of consumtion to wealth
      sv(ik,13)=((pc(ik))**(1.-esh))/(1.-((((1.+rinf))**(1.-esh))
     +       *((1.+stp)**(-esh))*((1.+rp(ik))**(esh-1.))))
      rcw=(pc(ik)**(esh-1.))*sv(ik,13)
C National Income
      yd(1)=0.
```

```
          yk(1)=0.0
          tdiv(ik)=0.0
          do 30 i=1,ngood-1
          yd(1)=yd(1)+div(1,i)/fdtc+(rb(1))*bond(1,i)
          yk(1)=yk(1)+fmyt*(div(1,i)/fdtc+rb(1)*bond(1,i))
     +      +fgt*dv(1,i)
          tdiv(ik)=tdiv(ik)+div(1,i)
30        continue
          tdiv(ik)=tdiv(ik)+sr(1)*div(1,5)
          yd(1)=yd(1)+sr(1)*div(1,5)/fdtc+rb(1)*bond(1,5)
     +      +slab(1)+rb(ik)*bondg(ik)
          yk(1)=yk(1)+(fdtc-sr(1)*(rmyt-rdtc))*div(1,5)/fdtc
     1    +fmyt*rb(1)*(bond(1,5))+(1.-0.5*rgt)
     2    *dv(1,5)
C Income Tax Intercept
          ryt=(tyt+rmyt*sr(3)*rb(ik)*bond(ik,5))/yd(1)
          ft0=rmyt*yd(1)-ryt*yd(1)-rdtc*tdiv(ik)/fdtc
          ft(ik)=ft0
C The present value of income tax intercept
          sv(ik,14)=(1.+rh(ik))*ft0/((1.+rh(ik))+0.0-(1.+rinf)*sgr0)
C Disposable Income
          yd(1)=ft(ik)+fmyt*yd(1)+tran(ik)+p(19)
     +    +(1.-sr(1))*div(ik,5)-rgt*wv(1)
C Now Total Wealth
          tw(ik)=we(ik)+wb(ik)+sv(ik,11)+sv(ik,14)+yk(ik)
          cdem(ik)=tw(ik)/(pc(ik)*rcw)
          if(esh .eq. 1.0) then
          cdem(ik)=stp*tw(ik)/(pc(ik)*(1.+stp))
          end if
          adem(ik)=0.75*cdem(ik)
          wh(ik)=sv(ik,11)-(1.+rp(ik))*(tran(ik)+p(19))
     +                   /((1.+rp(ik))-(1.+rinf)*sgr0)
          rfdis0=wk(ik)/wh(ik)
          radis0=wb(ik)/we(ik)
C
C Assign total wealth to tw0, which will be used to welfare assessment
C
          tw0=tw(ik)-(1.+rh(ik))*pc(ik)*adem(ik)/
     +             ((1.+rh(ik))-(1.0+rinf)*sgr0)
          demcj(28)=sup(ik,5)-demz0(ik,5)
          ac(28)=(1.+rvt(28))*(1.+rst(28))*pjj(ik,28)*demcj(28)
     +          /(pc(ik)*cdem(ik))
          acsum=0.0
          do 15 i=1,ncom-1
          acsum=acsum+ac(i)
15        continue
          do 25 m=1,ncom-1
          ac(m)=ac(m)*(1.0-ac(28))/acsum
```

```
25      continue
        acsum=0.0
        do 35 m=1,ncom
        acsum=acsum+ac(m)
35      continue
C Savings
        sav(ik)=yd(ik)-pc(ik)*cdem(ik)
C Consumption of Specific Consumer Goods
        do 45 m=1,ncom
        demcj(m)=ac(m)*(yd(ik)-sav(ik))
   +           /(pjj(ik,m)*fvt(m)*fst(m))
45      continue
C Converting consumer goods into producer goods
        demc(ik,1)=demcj(1)
        demc(ik,2)=0.0
        do 46 i=2,5
        demc(ik,2)=demc(ik,2)+demcj(i)
46      continue
        demc(ik,3)=0.0
        do 47 i=6,21
        demc(ik,3)=demc(ik,3)+demcj(i)
47      continue
        demc(ik,4)=0.0
        do 48 i=22,ncom-1
        demc(ik,4)=demc(ik,4)+demcj(i)
48      continue
        demc(ik,5)=demcj(28)
C Assign Base Year Values
        sav0(ik)=sav(1)
        cdem0(1)=cdem(1)
        pc0=pc(1)
        tdemz(ik)=0.0
        do 50 i=1,ngood-1
        tdemz(ik)=tdemz(ik)+demz0(ik,i)
50      continue
        do 60 i=1,ngood-1
        az(i)=demz0(ik,i)/tdemz(ik)
60      continue
        u0=0.0
        do 70 k=1,nyear
C
C Calculation of instantaneous utility level at the base case
C
        ul(k)=(esh/(esh-1.))*(((sgr0**(k-1))*(cdem(1)-adem(1)))
   +          **((esh-1.)/esh))
C
C Calculation of intertemporal utility level at the base case
C
```

```
         u0=u0+ul(k)/((1.+stp)**(k-1))
70       continue
         return
         end

         SUBROUTINE BGEXP

         implicit real*8 (a-h, o-z)
         include 'com.lib'

         gexp(ik)=0.0
         do 10 m=1,ncom
         gexp(ik)=gexp(ik)+demgj(ik,m)
10       continue
         do 20 m=1,ncom
         ag(m)=demgj(ik,m)/gexp(ik)
20       continue
         return
         end


         SUBROUTINE RESULT

         implicit real*8 (a-h, o-z)
         include 'com.lib'

C Assign Base Year Values to certain variables
         gdpr(ik)=0.0
         dcpi(ik)=0.0
         do 10 i=1,nfirm
         earn0(ik,i)=earn0(1,i)*(sgr0*(1.+rinf))**(ik-1)
         v0(ik,i)=v0(1,i)*(sgr0*(1.+rinf))**(ik-1)
         s0(ik,i)=s0(1,i)*(sgr0*(1.+rinf))**(ik-1)
         dinv0(ik,i)=sgrc*dinv0(1,i)
         sup0(ik,i)=sgrc*sup0(1,i)
         scap0(ik,i)=sgrc*scap0(1,i)
         dlab0(ik,i)=sgrc*dlab0(1,i)
         demm0(ik,i)=sgrc*demm0(1,i)
         demz0(ik,i)=sgrc*demz0(1,i)
         qdem0(ik,i)=sgrc*qdem0(1,i)
         gdpr(ik)=gdpr(ik)+demc(ik,i)+demg(ik,i)+demi(ik,i)
    +        +demz(ik,i)-demm(ik,i)
         dcpi(ik)=dcpi(ik)+ac1(i)*pjd(ik,i)/((1.+rinf)**(ik-1))
10       continue
         do 15 i=1,ngood-1
         demj0(ik,i)=sgrc*demj0(1,i)
15       continue
         qdem(ik,5)=sup(ik,5)
```

```
      sav0(ik)=sav0(1)*(sgr0*(1.+rinf))**(ik-1)
      cdem0(ik)=sgrc*cdem0(1)
      tax0(ik)=sgrc*tax0(1)*(1.+rinf)**(ik-1)
      gdpr0(ik)=sgrc*gdpr0(1)
      tsup0(ik)=sgrc*tsup0(1)
      pdef(ik)=gexp(ik)+tran(ik)-tax(ik)
      fdef(ik)=gexp(ik)+tran(ik)+rb(ik)*bondg(ik)-tax(ik)
C Calculation of aggregate variables
      tearn(ik)=0.0
      tearn0(ik)=0.0
      tcap0(ik)=0.0
      tv0(ik)=0.0
      ts0(ik)=0.0
      tinv0(ik)=0.0
      tv(ik)=0.0
      ts(ik)=0.0
      tlab0(ik)=0.0
      tdemm0(ik)=0.0
      tdemz0(ik)=0.0
      tdemm(ik)=0.0
      tdemz(ik)=0.0
      do 20 i=1,nfirm
      tearn(ik)=tearn(ik)+earn(ik,i)
      tearn0(ik)=tearn0(ik)+earn0(ik,i)
      tlab0(ik)=tlab0(ik)+dlab0(ik,i)
      tcap0(ik)=tcap0(ik)+scap0(ik,i)
      tdemm0(ik)=tdemm0(ik)+demm0(ik,i)
      tdemz0(ik)=tdemz0(ik)+demz0(ik,i)
      tdemm(ik)=tdemm(ik)+er(ik)*pw(i)*demm(ik,i)
      tdemz(ik)=tdemz(ik)+er(ik)*pjz(ik,i)*demz(ik,i)
      tv0(ik)=tv0(ik)+v0(ik,i)
      ts0(ik)=ts0(ik)+s0(ik,i)
      tinv0(ik)=tinv0(ik)+dinv0(ik,i)
      tv(ik)=tv(ik)+fv(ik,i)
      ts(ik)=ts(ik)+seqy(ik,i)
20    continue
      bot(ik)=tdemz(ik)-tdemm(ik)
      bos(ik)=(1.-0.35)*rw*bondw(ik)-fmyt*rb(ik)*wbond(ik)
      boc(ik)=er(ik)*dbondw(ik)-dwbond(ik)
      bop(ik)=bot(ik)+bos(ik)+boc(ik)
      cpi(ik)=0.0
      do 25 m=1,ncom
      cpi(ik)=cpi(ik)+ac(m)*pjj(ik,m)*fvt(m)*fst(m)
25    continue
      err(ik)=er(ik)/dcpi(ik)
      tdemm(ik)=0.0
      tdemz(ik)=0.0
      do 30 i=1,nfirm
```

```
      tdemm(ik)=tdemm(ik)+demm(ik,i)
      tdemz(ik)=tdemz(ik)+demz(ik,i)
      rearn(ik,i)=100.0*(earn(ik,i)/earn0(ik,i)-1.0)
      rs(ik,i)=100.0*(seqy(ik,i)/s0(ik,i)-1.0)
      rv(ik,i)=100.0*(fv(ik,i)/v0(ik,i)-1.0)
      rder(ik,i)=100.0*(der(ik,i)/der0(1,i)-1.0)
      rrc(ik,i)=100.0*(rc(ik,i)/rc0(1,i)-1.0)
      rdinv(ik,i)=100.0*(dinv(ik,i)/dinv0(ik,i)-1.0)
      anum=dinv(ik,i)/scap(ik,i)
      aden=dinv0(1,i)/scap0(1,i)
      rik(ik,i)=100.0*((anum/aden)-1.0)
      rdlab(ik,i)=100.0*(dlab(ik,i)/dlab0(ik,i)-1.0)
      rscap(ik,i)=100.0*(scap(ik,i)/scap0(ik,i)-1.0)
      rsup(ik,i)=100.0*(sup(ik,i)/sup0(ik,i)-1.0)
30    continue
      pen(ik)=0.0
      rwel(ik)=0.0
      rwel1=0.0
      tot(ik)=0.0
      dtot(ik)=0.0
      do 35 i=1,ngood-1
      rwel1=rwel1+pj(ik,i)*qdem(ik,i)
      rwel0=rwel0+qdem0(ik,i)*((1.+rinf)**(ik-1))
      tot(ik)=tot(ik)+100.*er(ik)*((pjz(ik,i)/(1.+rinf)**(ik-1))-1.0)
      dtot(ik)=dtot(ik)+er(ik)*((pjz(ik,i)/(1.+rinf)**(ik-1))-1.0)
     +   *demz0(ik,i)/gdpr(ik)
      rdemm(ik,i)=100.0*(demm(ik,i)/demm0(ik,i)-1.0)
      rdemz(ik,i)=100.0*(demz(ik,i)/demz0(ik,i)-1.0)
      pen(ik)=pen(ik)+((pjd(ik,i)/(1.+rinf)**(ik-1))*(sup(ik,i)
     1   -sup0(ik,i))-(pjd(ik,i)/(1.+rinf)**(ik-1))
     2   *(demj(ik,i)-demj0(ik,i))-(demm(ik,i)-demm0(ik,i))
     3   *er(ik))/gdpr(ik)
35    continue
      rwel(ik)=rwel1/rwel0
      pen(ik)=pen(ik)+(pjd(ik,5)/(1.+rinf)**(ik-1))*(sup(ik,5)
     +   -sup0(ik,5))/gdpr(ik)
      fre(ik)=dbondw(ik)*er(ik)/gdpr(ik)
      cri(ik)=fre(ik)+dtot(ik)+pen(ik)
      wkwh=wk(ik)/wh(ik)
      wbwe=wb(ik)/we(ik)
      rfdis(ik)=100.0*(wkwh/rfdis0-1.0)
      radis(ik)=100.0*(wbwe/radis0-1.0)
      atw0=(sgr0*(1.+rinf))**(ik-1)
      rtw(ik)=100.0*(tw(ik)/(atw0*tw0)-1.0)
      rtearn(ik)=100.0*(tearn(ik)/tearn0(ik)-1.0)
      rtv(ik)=100.0*(tv(ik)/tv0(ik)-1.0)
      rts(ik)=100.0*(ts(ik)/ts0(ik)-1.0)
      rtinv(ik)=100.0*(tinv(ik)/tinv0(ik)-1.0)
```

```
      rtcap(ik)=100.0*(tcap(ik)/tcap0(ik)-1.0)
      rtlab(ik)=100.0*(tlab(ik)/tlab0(ik)-1.0)
      rtsup(ik)=100.0*(tsup(ik)/tsup0(ik)-1.0)
      rgdpr(ik)=100.0*(gdpr(ik)/gdpr0(ik)-1.0)
      cf1=er(ik)*dbondw(ik)
      if(cf1 .gt. 0.0) then
      rsav(ik)=100.0*(sav(ik)/sav0(ik)-1.0)
      else
      rsav(ik)=100.0*((sav(ik)-cf1)/sav0(ik)-1.0)
      end if
      rtax(ik)=100.0*(ft(ik)-(ft0*((1.0+rinf)*(1.0+sgr))
     +          **(ik-1)))/tax0(ik)
      rcdem(ik)=100.0*(cdem(ik)/cdem0(ik)-1.0)
      rtdemm(ik)=100.0*(tdemm(ik)/tdemm0(ik)-1.0)
      rtdemz(ik)=100.0*(tdemz(ik)/tdemz0(ik)-1.0)
      rrb(ik)=100.0*(rb(ik)/rb0-1.0)
      rplab(ik)=100.0*(plab(ik)/(1.+rinf)**(ik-1)-1.)
      rer(ik)=100.0*(er(ik)-1.0)
      rerr(ik)=100.0*(err(ik)-1.0)
      rcpi(ik)=100.0*(pc(ik)/(pc0*(1.+rinf)**(ik-1))-1.0)
      gdpd(ik)=100.0*(gdpn(ik)/(gdpr(ik)*(1.+rinf)**(ik-1))-1.0)
      rdcpi(ik)=100.0*(dcpi(ik)-1.0)
      rpdef(ik)=pdef(ik)/gdpn(ik)
      rfdef(ik)=fdef(ik)/gdpn(ik)
      rbot(ik)=1d-3*bot(ik)/((1.+sgr)*(1.+rinf))**(ik-1)
      rboc(ik)=1d-3*boc(ik)/((1.+sgr)*(1.+rinf))**(ik-1)
      return
      end


      SUBROUTINE UTIL

      implicit real*8 (a-h, o-z)
      include 'com.lib'

C
C Calculation of intertemporal utility level at the revised case
C
      u=0.0
      do 10 k=1,nyear
      u=u+ul(k)/((1.+stp)**(k-1))
10    continue
      do 20 i=1,nfirm
C
C Calculation of total transition
C Investment transition
      tsit(i)=0.0
C Market value of firm transition
```

```
      tsvt(i)=0.0
      do 30 k=1,nyear
      tsit(i)=tsit(i)+rdinv(k,i)
      tsvt(i)=tsvt(i)+rv(k,i)
30    continue
20    continue
      do 40 i=1,nfirm
      tsi5(i)=0.0
      tsv5(i)=0.0
      do 50 k=1,5
      tsi5(i)=tsi5(i)+rdinv(k,i)
      tsv5(i)=tsv5(i)+rv(k,i)
50    continue
40    continue
      do 60 i=1,nfirm
      tsi10(i)=0.0
      tsv10(i)=0.0
      do 70 k=1,10
      tsi10(i)=tsi10(i)+rdinv(k,i)
      tsv10(i)=tsv10(i)+rv(k,i)
70    continue
60    continue
      do 80 i=1,nfirm
      tsi20(i)=0.0
      tsv20(i)=0.0
      do 90 k=1,20
      tsi20(i)=tsi20(i)+rdinv(k,i)
      tsv20(i)=tsv20(i)+rv(k,i)
90    continue
80    continue
      do 110 i=1,nfirm
      tsi50(i)=0.0
      tsv50(i)=0.0
      do 120 k=1,50
      tsi50(i)=tsi50(i)+rdinv(k,i)
      tsv50(i)=tsv50(i)+rv(k,i)
120   continue
110   continue
      do 130 i=1,nfirm
      rtsi5(i)=100.0*tsi5(i)/tsit(i)
      rtsi10(i)=100.0*tsi10(i)/tsit(i)
      rtsi20(i)=100.0*tsi20(i)/tsit(i)
      rtsi50(i)=100.0*tsi50(i)/tsit(i)
      rtsv5(i)=100.0*tsv5(i)/tsvt(i)
      rtsv10(i)=100.0*tsv10(i)/tsvt(i)
      rtsv20(i)=100.0*tsv20(i)/tsvt(i)
      rtsv50(i)=100.0*tsv50(i)/tsvt(i)
130   continue
```

```
C Calculation of equivalent variation
        ev=tw0*(u-u0)/u0
        return
        end

        SUBROUTINE SCALE

        implicit real*8 (a-h, o-z)
        include 'com.lib'

        do 10 i=1,nfirm
        sup(ik,i)=qmov*sup(ik,i)
        scap(ik,i)=qmov*scap(ik,i)
        dlab(ik,i)=qmov*dlab(ik,i)
        dinv(ik,i)=qmov*dinv(ik,i)
        if(ifin .eq. 0) then
        acf(i)=acf(i)*dinv(ik,i)
        end if
        sdep(ik,i)=qmov*sdep(ik,i)
        seqy(ik,i)=qmov*seqy(ik,i)
        fv(ik,i)=qmov*fv(ik,i)
        bond(ik,i)=qmov*bond(ik,i)
        de(i)=qmov*de(i)
        div(ik,i)=qmov*div(ik,i)
        dpr(i)=div(ik,i)/seqy(ik,i)
        earn(ik,i)=qmov*earn(ik,i)
        ret(ik,i)=qmov*ret(ik,i)
        dbond(ik,i)=qmov*dbond(ik,i)
        dv(ik,i)=qmov*dv(ik,i)
        demc(ik,i)=qmov*demc(ik,i)
        demz(ik,i)=qmov*demz(ik,i)
        demm(ik,i)=qmov*demm(ik,i)
        demg(ik,i)=qmov*demg(ik,i)
        demi(ik,i)=qmov*demi(ik,i)
        ddem(ik,i)=qmov*ddem(ik,i)
10      continue
        do 20 i=1,ngood-1
        demj(ik,i)=qmov*demj(ik,i)
20      continue
        slab(ik)=qmov*slab(ik)
        wb(ik)=qmov*wb(ik)
        wv(ik)=qmov*wv(ik)
        we(ik)=qmov*we(ik)
        ts(ik)=qmov*ts(ik)
        tv(ik)=qmov*tv(ik)
        tdb(ik)=qmov*tdb(ik)
        sav(ik)=qmov*sav(ik)
        dbondw(ik)=qmov*dbondw(ik)
```

```
      bondg(ik)=qmov*bondg(ik)
      dbondg(ik)=qmov*dbondg(ik)
      tw(ik)=qmov*tw(ik)
      yd(ik)=qmov*yd(ik)
      yk(ik)=qmov*yk(ik)
      wh(ik)=qmov*wh(ik)
      p(19)=qmov*p(19)
      cdem(ik)=qmov*cdem(ik)
      gexp(ik)=qmov*gexp(ik)
      tax(ik)=qmov*tax(ik)
      tran(ik)=qmov*tran(ik)
      tct=qmov*tct
      tlt=qmov*tlt
      tyt=qmov*tyt
      tgt=qmov*tgt
      tvt=qmov*tvt
      tst=qmov*tst
      twt=qmov*twt
      tpt=qmov*tpt
C Total production and capital formation
      tsup(ik)=0.0
      tcap(ik)=0.0
      tacf=0.0
      p(18)=0.0
      p(17)=0.0
      p(16)=0.0
      p(15)=0.0
      tinv1(ik)=0.0
      tret(ik)=0.0
      do 30 i=1,nfirm
      tsup(ik)=tsup(ik)+sup(ik,i)
      tcap(ik)=tcap(ik)+scap(ik,i)
      tacf=tacf+acf(i)
      p(18)=p(18)+div(ik,i)
      p(17)=p(17)+de(i)
      tinv1(ik)=tinv1(ik)+dinv(ik,i)
      tret(ik)=tret(ik)+ret(ik,i)
      p(16)=p(16)+sdep(ik,i)
      p(15)=p(15)+earn(ik,i)
30    continue


      return
      end

      SUBROUTINE EXPFOR

      implicit real*8 (a-h, o-z)
```

```
          include 'com.lib'

          if(ifin .eq. 0) then
C Adjust the nominal interest rate according to the rate of inflation
          rh0=(1.-rmyt0)*rb(1)-rinf0
          rb(1)=(rh0+rinf)/(1.-rmyt0)
C Initial Guess for Supply of Goods
      vad(1)=05000.0
      vad(2)=45000.0
      vad(3)=25000.0
      vad(4)=60000.0
      vad(5)=20000.0
          do 5 i=1,ngood
          qdem(1,i)=supj(i)
5         continue
          bondw(ik)=0.0
          wbond(ik)=0.0
          bond0=1.0*bond0
          if(igovd .eq. 0) then
          bondg(ik)=0.0
          end if
          dbondg(ik)=((1.+sgr)*(1.+rinf)-1.)*bondg(ik)
c
c *******************************************************
c policy parameters
c taxes
          rmyt=rmyt0
          rlab=rmyt
          rlab1=rlab0
          rcon=0.0
          fmyt=1.-rmyt
          rw=rb(1)
          flt=1.+rlt
C Calculation of the rate of capital gains tax
          rgt=0.1*rgt/(0.1+rh0+rinf)
          fgt=1.-rgt
          rdtc=rdtc0
          fdtc=1.-rdtc
          do 10 m=1,ncom
          rvt(m)=rvt0(m)
          fvt(m)=1.+rvt(m)
          rst(m)=rst0(m)
          fst(m)=1.+rst(m)
10        continue
          do 15 i=1,nfirm
          rct(i)=rct0
          if(i .eq. 5) then
          rct(i)=sr(1)*rct0
```

```
            end if
            fct(i)=1.-rct(i)
            fitc(i)=1.-ritc(i)
15          continue
C Benchmark prices
            er(0)=1.0
            er(1)=1.0
            pf(ik)=1.0
            pr(1)=1.0
            do 20 i=1,ngood
            rc(1,i)=rb(1)
            pj(1,i)=1.0
            pjd(1,i)=1.0
20          continue
            plab(1)=1.0
            pcap(1)=1.0
            sv(1,12)=er(ik)
                  end if
c
c Replacement Case
c
                  if(ifin .eq. 2) then
            plab(ik)=(1.0+rinf)**(ik-1)
            rb(ik)=rb(1)
            er(ik)=er(1)
            er(ik-1)=er(1)
            pf(ik)=1.0
            pr(ik)=1.0
            ft(ik)=ft0*((1.0+sgr)*(1.+rinf))**(ik-1)
            do 30 i=1,nfirm
            p(i)=1.0
            p(5+i)=1.0
            p(9+i)=1.0
            q(ik,i)=q(1,i)
            dinv(ik,i)=dinv(1,i)*(1.+sgr)**(ik-1)
            scap(ik,i)=scap(1,i)*(1.+sgr)**(ik-1)
            seqy(ik,i)=seqy(1,i)*(1.+sgr)**(ik-1)
            pjd(ik,i)=pjd(1,i)*(1.0+rinf)**(ik-1)
            pj(ik,i)=pjd(ik,i)
            bond(ik,i)=bond(1,i)
30          continue
            sv(ik,12)=er(ik)
                  end if

                  if(ifin .eq. 1) then
C First Define Expected Lead Variables
            do 40 i=1,nsvar
c           rsv(i)=(sv(nyear,i)-sve(nyear,i))/sve(nyear,i)
```

```
40        continue
          pf(1)=1.0
          do 75 l=2,nyear-1
          ft(l)=ft0*((1.0+sgr)*(1.+rinf))**(l-1)
          er(l)=1.0
          pcap(l)=1.0
          pf(l)=1.0
          pr(l)=1.0
          rb(l)=1.0
          plab(l)=(1.0+rinf)**(l-1)
          do 80 i=1,nfirm
          pjd(l,i)=(1.0+rinf)**(l-1)
          pj(l,i)=pjd(l,i)
          dinv(l,i)=dinv0(1,i)*((1.0+sgr)**(l-1))
          seqy(l,i)=(1.+rinf)*s0(1,i)*(1.+sgr)**(l-1)
C Firms
          sve(l,i)=sv(nyear,i)
          sv(l,i)=sve(l,i)
          sve(l,5+i)=(1.+rsv(5+i))*sv(nyear,5+i)
    +           *((1.0+rinf)*(1.0+sgr))**(l-nyear)
          sv(l,5+i)=sve(l,5+i)
80        continue
C Household Wealth
          sve(l,11)=(1.+rsv(11))*sv(nyear,11)*((1.0+rinf)
    +             *(1.0+sgr))**(l-nyear)
          sve(l,12)=er(nyear)
          sve(l,13)=sv(nyear,13)*(((1.+rinf)**(l-nyear))**(1.0-esh))
                if(model .eq. 1) then
          sve(l,13)=sv(nyear,13)*(((1.+rinf)**(l-nyear))**(1.0-esh))
    +     *((1.+rcon)**((esh-1.)*(1.-a)))
                end if
          sve(l,14)=(1.+rsv(14))*sv(nyear,14)*((1.0+rinf)
    +           *(1.0+sgr))**(l-nyear)
          sve(l,15)=(1.+rsv(15))*sv(nyear,15)*((1.0+rinf)
    +           *(1.0+sgr))**(l-nyear)
          sve(l,16)=(1.+rsv(16))*sv(nyear,16)*((1.0+rinf)
    +           *(1.0+sgr))**(l-nyear)
          sve(l,16)=sv(nyear,16)*(((1.+rinf)**(l-nyear))**(1.0-esz(1)))
          sv(l,11)=sve(l,11)
          sv(l,12)=sve(l,12)
          sv(l,13)=sve(l,13)
          sv(l,14)=sve(l,14)
          sv(l,15)=sve(l,15)
          sv(l,16)=sve(l,16)
75        continue
                end if
          return
          end
```

SUBROUTINE POLEX

```
          implicit real*8 (a-h, o-z)
          include 'com.lib'

          if(ipol1 .eq. 2) then
          if(ik .lt. 5) then
                 do 105 i=1,nfirm
                 rct(i)=rct0
                        if(i .eq. 5) then
                        rct(i)=sr(1)*rct0
                        end if
                 fct(i)=1.-rct(i)
105              continue
          else
                 do 106 i=1,nfirm
                 rct(i)=rct1
                        if(i .eq. 5) then
                        rct(i)=sr(1)*rct1
                        end if
                 fct(i)=1.-rct(i)
106              continue
          end if
          end if
          if(ipol2 .eq. 2) then
                 do 107 i=1,nfirm
                 if(ik .lt. 5) then
                 rtf(i)=rtf0(i)
                 rti(i)=rti0(i)
                 else
                 rtf(i)=rtf1(i)
                 rti(i)=rti1(i)
                 end if
107              continue
          end if

          if(ipol3 .eq. 2) then
                 if(ik .lt. 5) then
                 rmyt=rmyt0
                 rdtc=rdtc0
                 else
                 rmyt=rmyt1
                 rdtc=rdtc1
                 fmyt=1.-rmyt
                 fdtc=1.-rdtc
                 end if
          end if
```

```
      if(ipol4 .eq. 2) then
            do 108 m=1,ncom
            if(ik .lt. 5) then
            rvt(m)=rvt0(m)
            fvt(m)=1.-rvt(m)
            else
            rvt(m)=rvt1(m)
            fvt(m)=1.-rvt(m)
            end if
108         continue
      end if
      return
      end

      SUBROUTINE CALIB(n5,x5,f5,IFLAG)

      implicit real*8 (a-h, o-z)
      include 'com.lib'

      integer iflag, n5
      real*8 f5(n5), x5(n5)
      do 10 i=1,nfirm
      vad(i)=x5(i)
10    continue
      call bprod
      do 20 i=1,nfirm
      f5(i)=q(1,i)-sq(i)
20    continue
      if(iprint .eq. 1) then
      write (1,11) f5(1),f5(2),f5(3),f5(4),f5(5)
11    format(1x,'excess dem',2x,5f13.4)
      end if
      return
      end


      SUBROUTINE DISRAT

C This subroutine uses a Newton method to solve the time preference rate
C Excess demand functions are defined as follows.

      implicit real*8 (a-h, o-z)
      include 'com.lib'
c
c calculation of jacobian matrix of excess demands
c
      stp=0.015
      call bprod
```

```
      call bgexp
500   call bdmnd
      call gvrev
      call bdmnd
      fexs=sav(1)-tdb(1)
      fexs1=fexs
      stp=stp+0.1d-4
      call bdmnd
      call gvrev
      call bdmnd
      call gvrev
      fexs=sav(1)-tdb(1)
      delta=fexs1-fexs
      stp=stp-0.1d-4
      fexs=fexs1
      qmov=fexs1/delta
      stp=stp+qmov*0.1d-4
c
c equilibrium solution criterion
c
      if(dabs(fexs) .gt. 1d-9) go to 500
      call bdmnd
      call gvrev
      return
      end


      SUBROUTINE ADJUST

      implicit real*8 (a-h, o-z)
      include 'com.lib'
C
C CONSISTENCY ADJUSTMENT
C
      iprint=1
      call optn
C Excess demand
      fexs=0.0
      do 10 i=1,nfirm-1
      exs(i)=ddem(ik,i)+demz0(ik,i)-sup(ik,i)
   +     -demm0(ik,i)+demm(ik,i)
      fexs=fexs+exs(i)
10    continue
      do 20 i=1,ngood-1
      demj(ik,i)=0.0
      do 30 j=1,nfirm-1
      demj(ik,i)=demj(ik,i)+demji(i,j)
30    continue
```

```
20      continue
        tbdem=0.0
        do 40 i=1,ngood-1
        tbdem=tbdem+demj(ik,i)
40      continue
        tinv(ik)=0.0
        do 50 i=1,nfirm-1
        tinv(ik)=tinv(ik)+demi(ik,i)
        do 60 j=1,ngood-1
        demji(i,j)=demji(i,j)-exs(j)*demj(ik,i)/tbdem
        aj(i,j)=demji(i,j)/supj(i)
60      continue
50      continue
        do 70 i=1,ngood-1
        ai(i)=demi(ik,i)/tinv(ik)
70      continue
        call bprod
        call bdmnd
        call gvrev
        call bdmnd
        call optn
        do 80 i=1,nfirm-1
C Import
        a20=(am(i,1)/am(i,2))**esm(i)
        a30=(pjd(ik,i)/pjm(ik,i))**esm(i)
        demm(ik,i)=a20*a30*ddem(ik,i)
        qdem0(1,i)=qdem(ik,i)
80      continue
        qdem0(1,5)=sup(ik,5)
        tax0(1)=tax(1)
        gdpr0(ik)=0.0
        do 90 i=1,ngood
        gdpr0(ik)=gdpr0(ik)+demc(ik,i)+demg(ik,i)+demi(ik,i)
   +          +demz(ik,i)-demm(ik,i)
90      continue
        return
        end


        SUBROUTINE ETRA

        implicit real*8 (a-h, o-z)
        include 'com.lib'
        include 'opt.lib'

C Calculation of the rate of return to savings
        rrh=rh(ik)-rinf
        do 10 i=1,nfirm
```

```
C Calculation of the rate of return to capital
        qk(i)=((1.-dn(i))/(1.-rct(i)))*(rc(ik,i)+
     +        redep(i)-rinf)-redep(i)
C Calculation of the tax wedge (qk-rrh)
        qr(i)=qk(i)-rrh
10      continue
        soetr=0.0
        do 15 i=1,nfirm
C Calculation of the effective tax rates
        etr(i)=qr(i)/qk(i)
C Calculation of the overall marginal effective tax rate
        soetr=soetr+(etr(i)*dinv(ik,i))/tinv(ik)
15      continue
        aetr=soetr/5.0
        sumv=0.0
        do 20 i=1,nfirm
C Calculation of the variance of the effective tax rates
        sumv=sumv+((etr(i)-aetr)**2.0)*dinv(ik,i)/tinv(ik)
20      continue
        vetr=sumv
        setr=sqrt(vetr)

        return
        end

        SUBROUTINE OPTN

        implicit real*8 (a-h, o-z)
        include 'com.lib'
        include 'opt.lib'
        return
        end

        SUBROUTINE LRUN(N13,X13,F13,IFLAG)

        implicit real*8 (a-h, o-z)
        include 'com.lib'

C
c set up prices
        integer iflag, n13
        real*8 f13(n13), x13(n13)
c 2) Steady-state Growth Rate
        sgr0=1.+sgr
        sgrc=sgr0**(ik-1)
        do 10 i=1,ngood
        p(i)=x13(i)
        pjd(ik,i)=p(i)*(1.0+rinf)**(ik-1)
```

```
          p(5+i)=x13(5+i)
          scap(ik,i)=p(5+i)*scap0(1,i)*sgrc
10        continue
          p(11)=x13(11)
          plab(ik)=p(11)*(1.0+rinf)**(ik-1)
          p(12)=x13(12)
          rb(ik)=p(12)*rb(1)
          p(13)=x13(13)
          er(ik)=p(13)*er(1)
          if(igovd .ne. 2) then
          p(14)=x13(14)
          ft(ik)=p(14)*ft0*((1.0+sgr)*(1.0+rinf))**(ik-1)
                if(ipol5 .eq. 1) then
                ft(ik)=0.0
                rcon=p(14)*0.3
                end if
          end if
          include 'opt.lib'
C Define the excess demand functions
C 1-) Product markets
          do 80 i=1,ngood-1
          f13(i)=(ddem(ik,i)+demz(ik,i)-sup(ik,i))
80        continue
          f13(5)=(demc(ik,5)-sup(ik,5))
C 2-)  Q-ratios
          do 90 i=1,nfirm
          f13(5+i)=(q(ik,i)-sq(i))
90        continue
C 3-) Labour market
          f13(11)=(tlab(ik)-slab(ik))
C 4-) Funds market
          f13(12)=(sav(ik)-tdb(ik))
C 5-) Balance of Payments Condition
          tdemm(ik)=0.0
          tdemz(ik)=0.0
          do 100 i=1,ngood
          tdemm(ik)=tdemm(ik)+pw(i)*demm(ik,i)
          tdemz(ik)=tdemz(ik)+pjz(ik,i)*demz(ik,i)
          f13(13)=tdemm(ik)-tdemz(ik)
     +    +fmyt*rb(ik)*wbond(ik)/er(ik)-(1.-0.35)*rw*bondw(ik)
100       continue
C 6-) Equal yield equilibrium
          f13(14)=tax(ik)-gexp(ik)-tran(ik)
          return
          end

          SUBROUTINE SRUN(N8,X8,F8,IFLAG)
```

```
          implicit real*8 (a-h, o-z)
          include 'com.lib'
c
c set up prices
          integer iflag, n8
          real*8 f8(n8), x8(n8)
          do 10 i=1,ngood
          p(i)=x8(i)
          pjd(ik,i)=p(i)*(1.+rinf)**(ik-1)
10        continue
          p(6)=x8(6)
          plab(ik)=p(6)*(1.0+rinf)**(ik-1)
          p(7)=x8(7)
          rb(ik)=p(7)*rb0
          p(8)=x8(8)
          er(ik)=p(8)
          if(igovd .ne. 2) then
          p(9)=x8(9)
          ft(ik)=p(9)*ft0*((1.0+sgr)*(1.0+rinf))**(ik-1)
                if(ipol5 .eq. 1) then
                ft(ik)=0.0
                rcon=p(9)*0.3
                end if
          end if
C Adjustment of investment levels
          do 15 i=1,nfirm
          dine(i)=dinv(ik,i)
15        continue
          call prod
199       acc=0.0
          do 25 i=1,nfirm
          acc=acc+(dinv(ik,i)-dine(i))
25        continue
          if(dabs(acc) .gt. 1d-2) then
          do 35 i=1,nfirm
          dine(i)=dinv(ik,i)
35        continue
          call prod
          go to 199
          end if
          include 'opt.lib'
C EXCESS DEMAND FUNCTIONS
C Product markets
          do 80 i=1,ngood-1
          f8(i)=(ddem(ik,i)+demz(ik,i)-sup(ik,i))
80        continue
          f8(5)=(demc(ik,5)-sup(ik,5))
C Labour market
```

```
          f8(6)=(tlab(ik)-slab(ik))
C Funds market
          f8(7)=sav(ik)-tdb(ik)
C Balance of Payments Condition
          tdemm(ik)=0.0
          tdemz(ik)=0.0
          do 100 i=1,ngood
          tdemm(ik)=tdemm(ik)+pw(i)*demm(ik,i)
          tdemz(ik)=tdemz(ik)+pjz(ik,i)*demz(ik,i)
          f8(8)=dwbond(ik)/er(ik)+tdemz(ik)/er(ik)-tdemm(ik)-dbondw(ik)
100       continue
C Equal yield equilibrium
          f8(9)=tax(ik)+dbondg(ik)-gexp(ik)-tran(ik)
          return
          end

          OPT.LIB
                if(ifin .eq. 0) then
          ac1(1)=ac(1)
          rvtj(1)=rvt(1)
          ac1(2)=0.0
          rvtj(2)=0.0
          do 41 m=2,5
          ac1(2)=ac1(2)+ac(m)
          rvtj(2)=rvtj(2)+rvt(m)
41        continue
          ac1(3)=0.0
          rvtj(3)=0.0
          do 42 m=6,21
          ac1(3)=ac1(3)+ac(m)
          rvtj(3)=rvtj(3)+rvt(m)
42        continue
          ac1(4)=0.0
          rvtj(4)=0.0
          do 43 m=22,27
          ac1(4)=ac1(4)+ac(m)
          rvtj(4)=rvtj(4)+rvt(m)
43        continue
          ac1(5)=ac(28)
          rvtj(5)=rvt(28)
                end if
                if(ifin .eq. 1 .or. ifin .eq. 2) then
          do 40 i=1,nfirm-1
C Import Prices
          pw(i)=(1.+rinf)**(ik-1)
          pjm(ik,i)=pw(i)*er(ik)
C Composite Prices (of Import and Domestic Goods)
          a20=(am(i,1)**esm(i))*(pjm(ik,i)**(1.0-esm(i)))
```

```
          a30=(am(i,2)**esm(i))*(pjd(ik,i)**(1.0-esm(i)))
          pj(ik,i)=((a20+a30)**(1.0/(1.0-esm(i))))/am1(i)
40        continue
          pj(ik,5)=pjd(ik,5)
          psum=0.0
          do 45 i=1,ngood-1
          psum=psum+pj(ik,i)
45        continue
          do 50 i=1,nfirm-1
          pj(ik,i)=4.0*pj(ik,i)*((1.+rinf)**(ik-1))/psum
50        continue
                end if
          if(ifin .eq. 1 .or. ifin .eq. 2) then
                call prod
                call dmnd
                call gvrev
                call dmnd
          else
                call bprod
                call bdmnd
                call bgexp
                call gvrev
          end if
          tlab(ik)=0.
          tinv=0.
          do 55 i=1,nfirm
          tlab(ik)=tlab(ik)+dlab(ik,i)
          tinv=tinv+dinv(ik,i)
55        continue
          do 60 i=1,ngood-1
          demj(ik,i)=0.0
          do 65 j=1,nfirm-1
          demj(ik,i)=demj(ik,i)+demji(j,i)
65        continue
          demi(ik,i)=ai(i)*tinv
60        continue
C Domestic Demand
          pz(ik)=1.0
          tdemm(ik)=0.0
          tdemz(ik)=0.0
          do 70 i=1,ngood-1
          qdem(ik,i)=demc(ik,i)+demg(ik,i)+demi(ik,i)+demj(ik,i)
C Domestic Use Ratio
          dm1=(am(i,1)/am(i,2))**esm(i)
          dm2=(pjd(ik,i)/pjm(ik,i))**esm(i)
          dm3=dm1*dm2
          dm4=am(i,1)*(dm3**((esm(i)-1.0)/esm(i)))
          d1=am1(i)*((dm4+am(i,2))**(esm(i)/(esm(i)-1.0)))
```

```
        ddem(ik,i)=qdem(ik,i)/d1
C Import
        a20=((am(i,1)/am(i,2))**esm(i))
        a30=(pjd(ik,i)/pjm(ik,i))**esm(i)
        demm(ik,i)=a20*a30*ddem(ik,i)
        if(itot .eq. 1) then
        demm(ik,i)=sgrc*demm0(1,i)
        ddem(ik,i)=qdem(ik,i)-demm(ik,i)
        end if
        tdemm(ik)=tdemm(ik)+pw(i)*demm(ik,i)
        pz(ik)=pz(ik)*(pjz(ik,i)/az(i))**az(i)
C Export
        demz(ik,i)=sgrc*demz0(1,i)*((pw(i)/pjz(ik,i))**esz(i))
        if(itot .eq. 1) then
        demz(ik,i)=sgrc*demz0(1,i)
        end if
        tdemz(ik)=tdemz(ik)+pjz(ik,i)*demz(ik,i)
70      continue
        if(iflow .eq. 1) then
        if(ifin .eq. 0) then
        stz=(1.+(1.-0.35)*rw)/((1.+rinf)*((1.+sgr)**(1./esz(1))))-1.0
        end if
C Export
        do 85 i=1,ngood-1
        demz(ik,i)=az(i)*pz(ik)*tdemz(ik)/pjz(ik,i)
85      continue
        end if
```

COMMON.LIB

```
      common/prmt/ifin,iprint,ik,ngood,nfirm,ncap,nyear,iflow
     1 ,igovd,model,ider,ipol1,ipol2,ipol3,ipol4,ipol5,ipol6,itot
     2 ,ncom,nsvar,sgr,rinf,stp,stz,crp,aca(5),acb,agb,aga(5),esh
     3 ,esm(5),esz(5),esc,a1(5),a0(5,2),ajv(5),aj(4,4),ac(28)
     4 ,ac1(5),ai(5),am(5,2),am1(5),az(5),ag(28),fcap(5,3),pw(5)
     5 ,rw,dpr(5),atp(5),bps,psp0,psp,redep(5),rpe(5),rpe1(5),rta(5)
     6 ,rtf0(5),rtf1(5),rtf(5),rti0(5),rti1(5),rti(5),rtdf(5,3)
     7 ,rtdi(5,3),rtda(5,3),rlt,flt,rct0,rct1,rct(5),sr(4),fct(5)
     8 ,rpt,rgt,fgt,rmyt0,rmyt1,rmyt,ryt,fmyt,rlab,rdiv,rint,ft(76)
     9 ,ft0,rit(5),rwt(5),fwt(5),rvt0(28),rvt1(28),rvt(28),fvt(28)
      common/prmt_ctnd/rvtj(5),rst0(28),rst1(28),rst(28),fst(28)
     1 ,rmt(5),fmt(5),rcon,ritc(5),fitc(5),rdtc0,rdtc1,rdtc,fdtc
     2 ,cdiv(5),afgt(5),bond0
      common/vrbl/rb(76),re(76),rh(76),rp(76),erp(5),rc(76,5)
     1 ,pg(76),pc(76),pcap(76),dpcap,pz(76),plab(76),pjd(76,5)
     2 ,pjm(76,5),pjz(76,5),pj(76,5),pjj(76,28),pn(5),er(0:76)
     3 ,vad(5),supj(5),sup(76,5),qdem(76,5),ddem(76,5),demj(76,4)
     4 ,demji(4,4),rcw,cdem(76),demc(76,5),demcj(28)
     5 ,demg(76,5),demgj(76,28),demm(76,5),demz(76,5),demi(76,5)
     6 ,slab(76),dles(76),dlab(76,5),scap(76,5)
     7 ,sdep(76,5),dcap(76,5),earn(76,5),ebit(76,5),div(76,5)
     8 ,tdiv(76),acf(5),tacf,vexp(5),de(5),dn(5),q(76,5)
     9 ,dinv(76,5),tinv,agf(5),der(76,5),dcr(5),bond(76,5)
   common/vrbl_ctnd/dbond(76,5),wbond(76),bondf,dwbond(76)
     1 ,dbondw(76),bondg(76),dbondg(76),bondw(76),dbondf
     2 ,seqy(76,5),tdb(76),sav(76),tw(76),wb(76),we(76),dv(76,5)
     3 ,wv(76),wv1(76),yk(76),yd(76),tct,tlt,tit,tmt,tst,tgt,tyt
     4 ,tvt,twt,tpt,tax(76),tran(76),gexp(76)
      common/sltn/sq(5),dine(5),sv(76,14),sve(76,14),rms(76,14)
     1 ,niter,ntrys,iter,sgr0,sgrc,acc,demm0(76,5),demz0(76,5)
     2 ,exs(4),d1,psum,p(20),pf(76),pr(76),bsup(5),bdemji(4,4)
     3 ,bdemj(4),tdemm(76),tdemz(76),delta,fexs,fexs1,qmov
     4 ,gdpn(76),gdpr(76),tlab(76),tcap(76),ret(76,5),tret(76)
     5 ,rsv(16),acsum,atol
      common/bncmk/earn0(76,5),rearn(76,5),tearn(76),tearn0(76)
     1 ,rtearn(76),der0(76,5),rder(76,5),v0(76,5),rv(76,5),tv(76)
     2 ,tv0(76),rtv(76),fv(76,5),s0(76,5),rs(76,5),ts(76),ts0(76)
     3 ,rts(76),dinv0(76,5),rdinv(76,5),tinv1(76),tinv0(76)
     4 ,rtinv(76),scap0(76,5),rscap(76,5),tcap0(76),tlab0(76)
     5 ,rtlab(76),rtcap(76),dlab0(76,5),rdlab(76,5),sup0(76,5)
     6 ,rsup(76,5),tsup(76),tsup0(76),rtsup(76),gdpr0(76),rgdpr(76)
     7 ,gdpn0(76),sav0(76),rsav(76),tax0(76),rtax(76),rdemm(76,5)
     8 ,rdemz(76,5),rtdemm(76),rtdemz(76),tdemm0(76),tdemz0(76)
     9 ,pdef(76),fdef(76),rpdef(76),rfdef(76),bot(76),bos(76)
      common/bctnd/boc(76),bop(76),rbot(76),rboc(76),rwel(76)
```

```
     1 ,tot(76),dtot(76),fre(76),pen(76),cri(76),rc0(76,5)
     2 ,rrc(76,5),rb0,rrb(76),rplab(76),rer(76),err(76),rerr(76)
     3 ,cdem0(76),pc0,cpi(76),dcpi(76),rcpi(76),rdcpi(76),gdpd(76)
     4 ,rcdem(76),wh(76),wk(76),rfdis0,rfdis(76),radis0,radis(76)
     5 ,qdem0(76,5),demj0(76,4),rik(76,5),dtemm(76),dtemz(76)
     6 ,rtw(76),ul(76),u,u0,ev,tw1,tw0,tsit(5),tsi5(5),tsi10(5)
     7 ,tsi20(5),tsi50(5),rtsi5(5),rtsi10(5),rtsi20(5),rtsi50(5)
     8 ,tsitt,tsitt5,tsitt10,tsitt20,tsitt50,rtsitt5
     9 ,rtsitt10,rtsitt20,rtsitt50
       common/eftax/qk(5),qr(5),etr(5),aetr,vetr,setr,rinf0,rh0
     1 ,rrh,soetr,sumv
```

DATDES.LIB

```
C Set up the NAG routine C05NCF
C BENCHMARK CASE
      integer n5, ldfjac5, lr5
      parameter (n5=5,ldfjac5=n5,lr5=(n5*(n5+1))/2)
C TRANSITION (WITHIN PERIOD)
      integer n8, ldfjac8, lr8
      parameter (n8=8+1,ldfjac8=n8,lr8=(n8*(n8+1))/2)
C NEW STEADY STATE
      integer n13, ldfjac13, lr13
      parameter (n13=13+1,ldfjac13=n13,lr13=(n13*(n13+1))/2)
C Common part
      integer nout
      parameter (nout=6)
      real*8 fnorm
      integer ifail
      real*8 epsfcn, factor, xtol
      integer maxfev,ml,mode,mu,nfev,nprint
C Benchmark case variables defined
      real*8 diag5(n5),fjac5(ldfjac5,n5),f5(n5),qtf5(n5),r5(lr5),
   +     w5(n5,4),x5(n5)
C New steady state variables defined
      real*8 diag13(n13),fjac13(ldfjac13,n13),f13(n13),qtf13(n13),
   +     r13(lr13),w13(n13,4),x13(n13)
C Transition variables defined
      real*8 diag8(n8),fjac8(ldfjac8,n8),f8(n8),qtf8(n8),r8(lr8),
   +     w8(n8,4),x8(n8)
C Common subroutines called in NAG
      real*8 f06ejf, x02ajf
      external f06ejf, x02ajf
C Subroutines defined in the program which call C05NCF, the NAG solution
c algrithm: CALIB subroutine is used to solve the producer side of
c calibration; LRUN subroutine is designated to solve the new steady state
c equilibrium; and SRUN subroutine solves within period equilibrium.
      external c05ncf, calib, lrun, srun
C Define the values for NAG subroutine variables
      intrinsic sqrt, dabs
      xtol=sqrt(x02ajf())
      do 10 j=1,n5
      diag5(j)=1.0d0
10    continue
      do 15 j=1,n8
      diag8(j)=1.0d0
15    continue
      do 20 j=1,n13
      diag13(j)=1.0d0
```

```
20        continue
          maxfev=2000*(n13+1)
          ml5=n5-1
          mu5=n5-1
          ml8=n8-1
          mu8=n8-1
          ml13=n13-1
          mu13=n13-1
          epsfcn=0.0d0
          mode=2
          factor=100.0d0
          nprint=0
C Open an output file
          open(unit=1, file='tk.out', status='new')
C Data are supplied through a librariry file, 'DAT.LIB'
          include 'dat.lib'
c
c setup code
c
C To initiate cases, whether benchmark or others, IFIN label is used.
c IFIN=0,1,2 stand for the benchmark, the transition, and
c the new steady state cases, respectively.
          ifin=0
C To initiate the structure of the model, the `MODEL' line
c is used.
          model=0
          itot=0
c         IFLOW distinguishes the economy's stituation in regard to
c foreign financial capital flows; if IFLOW=0, no capital flows is
c allowed but if IFLOW=1, then capital flows take place between the
c UK economy and the rest of the world
          iflow=0
c
c Benchmark sequencing
c
          write(1, 11)
11        format(1x,63('*'))
          write(1, *)  'BENCHMARK '
          write(1, 12)
12        format(1x,63('*'))
          ik=1
c
c Composite Consumption Level
c
        cdem(1)=0.0
          do 25 m=1,ncom
          cdem(1)=cdem(1)+demcj(m)*(1.+rvt0(m))*(1.+rst0(m))
25        continue
```

```
          do 26 i=1,ngood
          do 27 j=1,ncap
          if(fcap(i,j) .ne. 0.0) then
C Initial Investment Level
          dinv(ik,i)=(sgr+redep(i))*scap(ik,i)
C Depreciation Rates for Tax Purposes
          rtdf(i,j)=rtdf(i,j)/(fcap(i,j)*dinv(ik,i))
          rtdi(i,j)=rtdi(i,j)/(fcap(i,j)*dinv(ik,i))
          end if
27        continue
26        continue
c Production parameter
c Leontief coefficients
          do 30 i=1,nfirm-1
          ajv(i)=vad(i)/bsup(i)
          do 35 j=1,ngood-1
          aj(i,j)=bdemji(i,j)/bsup(i)
35        continue
30        continue
          ajv(5)=1.0
Consumption Share Parameter
          do 31 m=1,ncom
          ac(m)=(1.+rvt0(m))*(1.+rst0(m))*demcj(m)/cdem(1)
31        continue
          do 50 i=1,nfirm
          x5(i)=vad(i)
50        continue
```

DATA SET

```
c Number of Firms, producer goods, consumer goods, capital assets, lead variables and
Years
          Data NFIRM, NGOOD, NCOM, NCAP, NSVAR, NYEAR
   +      /5, 5, 28, 3, 14, 76/
c PARAMETERS
c structural parameters
c Adjustment Cost Parameters
          Data (ACA(I),i=1,5), ACB/5*0.035, 15.0/
c Agency Cost parameter
          Data AGB/0.5/
C Elasticity Parameters
c Intertemporal elasticity of subtitution
          Data ESH/0.8/
c Import demand elasticity
          Data (ESM(J),j=1,5)/0.325, 0.65, 1.30, 0.325, 0.0/
c Export supply elasticity
          Data (ESZ(J),j=1,5)/0.240, 0.48, 0.96, 0.75, 0.0/
c International Capital Mobility Parameter
          Data bond0/1d7/
c policy parameters
c Interest Rate, Inflation Rate and Steady-state Growth Rate
          Data RB(1), RINF0, SGR/0.175, 0.075, 0.0275/
c TAX RATES
c Corporate tax rates
          Data RCT0/0.52/
c Housing sector shares
          Data (SR(I),i=1,4)/0.1, 0.3, 0.6, 0.5/
c Income Tax Rates (Marginal and average) and Dividend Tax Credit
      Data RMYT0, TYT, RDTC0/0.35, 25000.0, 0.3/
c Wealth Tax Rates
      Data (RWT(I),i=1,5)/0.02, 0.02, 0.02, 0.02, 0.02/
c Capital Gains Tax Rate
      Data RGT/0.075/
c Consumer Tax Rates
      Data (RVT0(J),j=1,28)/0.08,
   1   0.08,  0.08, 0.08, 0.08,
   2   0.08,  0.08, 0.08, 0.08, 0.08, 0.08, 0.08,
   3   0.08,  0.00, 0.08, 0.08, 0.08, 0.08, 0.08,
   4   0.08,  0.08,
   5   0.08,  0.08, 0.08, 0.08, 0.08, 0.08,
   6   0.00/
c Specific Excise Duties
      Data (RST0(J),j=1,28)/0.0,
   1   0.0,  0.0, 2.4, 0.0,
   2   0.0,  0.0, 0.0, 0.0, 0.0, 0.0, 0.2,
```

```
      3    0.0,  0.0, 2.0, 0.0, 0.0, 0.0, 0.0,
      4    0.0,  0.0,
      5    0.0,  0.0, 0.0, 0.0, 0.0, 0.10,
      6    -0.30/
c           Import Taxes Rates
         Data (RMT(J),j=1,5)/0.021, 0.000, 0.050,  0.000, 0.0/
C           Labour Taxes Rates
         Data RLT/0.09/
C Demand for Labour by Firms
            Data (DLAB(1,I),I=1,5)/
      +          1302.0,  6568.0,  43202.0,  93549.0, 995.0/
C Capital Stock By Firms
            Data (SCAP(1,J),j=1,5)/
      +       15800.0, 90600.0, 136700.0, 263100.0, 246000.0/
C Capital Stock Proportion to Assets
            Data ((FCAP(I,J),j=1,3),i=1,5)/
      1          0.092, 0.400, 0.508,
      2          0.013, 0.495, 0.492,
      3          0.076, 0.692, 0.232,
      4          0.154, 0.307, 0.539,
      5          0.000, 0.000, 1.000/
C Capital Economic Depreciation Rates
            Data (REDEP(J),j=1,5)/0.070,  0.050, 0.045,  0.057,  0.016/
C Tax depreciation allowances
C    First Year Tax Depreciation
            Data (RTDF(I,),i=1,5)/0.250, 0.400, 0.600, 0.350, 0.0/
C    Initial Tax Deprecition
            Data ((RTDI(I,J),j=1,3),i=1,5)/0.01, 0.015, 0.06, 0.01, 0.0/
C Annual Tax Depreciation Rate
            Data ((RTDA(I,J),j=1,3),i=1,5)/0.05, 0.055, 0.02, 0.04, 0.04/
C Rate of investment grants
            Data (RITC(J),j=1,5)/0.0, 0.0, 0.066, 0.003, 0.0/
C Supply of Goods by Firms
            Data (BSUP(I),I=1,5)/
      +       15119.0, 59682.0, 180466.0, 235418.0, 12147.0/
C Value Added by Firms
            Data (VAD(I),I=1,5)/
      +          4019.0,  19356.0, 52872.0, 125000.0,  12147.0/
C Demand for Intermediate goods
            Data ((BDEMJI(I,J),j=1,4),i=1,4)/
      1           2725.0,   687.0,  4646.0,  2139.0,
      2          0.0, 24576.0,  3443.0,  5553.0,
      3          10454.0,  7902.0, 72254.0, 28325.0,
      4            605.0,  7977.0, 30035.0, 61350.0/
C Demand for Imported Goods
            Data (DEMM0(1,J),j=1,5)/
      +          2226.0,  7014.0,  41040.0,  9720.0,    0.0/
C Demand for Exported Goods
```

```
         Data (DEMZ0(1,J),j=1,5)/
   +         930.0,  11424.0,  32994.0, 14652.0,     0.0/
C Share Parameter of Consumer Demand for Goods
         Data (DEMCJ(J),j=1,28)/3307.0,
   1      606.0,      5.0, 2688.0, 9150.0,
   2        7.0,   550.0, 2409.0,  677.0,  212.0, 3605.0, 3653.0,
   3      612.0, 18221.0, 5613.0, 2457.0, 6029.0, 1400.0, 2881.0,
   4      726.0,  1354.0,
   5     1836.0, 53009.0, 7347.0, 3532.0,11205.0,
   6    13954.0,
   7    24203.0/
C Government Demand for Goods
         Data (DEMGJ(1,J),j=1,28)/132.0,
   1      103.0,      5.0, 1080.0, 1293.0,
   2       51.0,   190.0, 2307.0,  290.0, 1225.0, 2986.0,  394.0,
   3     3987.0,   834.0,   32.0,   81.0,  276.0,  163.0,  473.0,
   4      120.0,   189.0,
   5     2740.0,  3495.0,  850.0,  695.0, 1717.0,
   6    49503.0,
   7        0.0/
C Share Parameter of Investment Good
         Data (AI(J),j=1,5)/
   +         0.0000,  0.0004,  0.4818, 0.5178, 0.0000/
C Taxes on Intermediate Goods
         Data (RIT(J),J=1,5)/-0.042, -0.0163, 0.0155, 0.07, 0.0/
C Debt-equity Ratios
         Data (DER(1,J),j=1,5)/0.190, 0.224, 0.251, 0.363, 0.500/
C Dividend-payout Ratios
         Data (DPR(J),j=1,5)/0.0, 0.0, 0.0, 0.0, 0.0/
C Imported Goods World Prices
         Data (PW(J),j=1,5)/5*1.0/
C Expoted Goods World Prices
         Data (PW(J),j=1,5)/5*1.0/
C Transfers at Base Case
         Data TRAN(1)/12500.0/
C Government Expenditure
         Data GEXP(1)/70000.0/
```

```
      SUBROUTINE PRNT

      implicit real*8 (a-h, o-z)
      include 'com.lib'

            if(iprint .eq. 1) then
      write (1, 1)
1     format(1x, ' Production  Prameters ')
      write (1, 2)
2     format(12x,'agricul  energy  manufac  service  housing')
      write (1, 3) a1(1),a1(2),a1(3),a1(4),a1(5)
3     format(1x,'scale fac',5f9.3)
      write (1, 4) a0(1,1),a0(2,1),a0(3,1),a0(4,1),a0(5,1)
4     format(1x,'share fac',5f9.3)
      write (1, 5) a0(1,2),a0(2,2),a0(3,2),a0(4,2),a0(5,2)
5     format(1x,'share fac',5f9.3)
      write (1, 6) redep(1),redep(2),redep(3),redep(4),redep(5)
6     format(1x,'dep  rate',5f9.3)
      write (1, 7) rta(1),rta(2),rta(3),rta(4),rta(5)
7     format(1x,'wd d rate',5f9.3)
      write (1, 8) rti(1),rti(2),rti(3),rti(4),rti(5)
8     format(1x,'iy d rate',5f9.3)
      write (1, 9) rtf(1),rtf(2),rtf(3),rtf(4),rtf(5)
9     format(1x,'fy d rate',5f9.3)
      write (1, 10) ritc(1),ritc(2),ritc(3),ritc(4),ritc(5)
10    format(1x,'inv grant',5f9.3)
      write (1, 11) rct(1),rct(2),rct(3),rct(4),rct(5)
11    format(1x,'cor tax r',5f9.3)
      write (1, 12) dpr(1),dpr(2),dpr(3),dpr(4),dpr(5)
12    format(1x,'Div/V    ',5f9.3)
      write (1, 13) der(1,1),der(1,2),der(1,3),der(1,4),der(1,5)
13    format(1x,'B/E      ',5f9.3)
      write (1, 14) esz(1),esz(2),esz(3),esz(4),esz(5)
14    format(1x,'ESZ      ',5f9.3)
      write (1, 15) esm(1),esm(2),esm(3),esm(4),esm(5)
15    format(1x,'ESM      ',5f9.3)
      write (1, 34)
34    format(1x, ' Consumption Prameters' )
      write (1, 35) ac(1),ac(2),ac(3),ac(4),ac(5)
35    format(1x,'share con',5f9.3)
      write (1,36) esh
36    format(1x,'con sigma',f9.1)
      write (1,37) stp
37    format(1x,'time  dis',f12.8)
      write (1,38) psp0
38    format(1x,'Bd/Bw    ',f9.4)
      write (1,39) rmyt
39    format(1x,'mit rate ',f9.3)
```

```
      write (1,40) rgt
40    format(1x,'cgt rate ',f9.3)
      write (1,41) sgr
41    format(1x,'ssg rate ',f9.3)
      write (1,42) rb(1)
42    format(1x,'interest ',f9.4)
      write (1,44) aca(1),aca(2),aca(3),aca(4),aca(5)
44    format(1x,'cost par ',5f9.3)
      write (1,45) acb
45    format(1x,'acost par',f9.3)
      write (1,46) agb
46    format(1x,'gcost par',f9.3)
      write (1,47) bond0
47    format(1x,'Bond0    ',f16.5)
        end if
      if(iprint .eq. 2 .or. iprint .eq. 1) then
      write (1, 49)
49    format(1x,63('*'))
      write (1, 50)
50    format(12x,'agricul  energy  manufac  service  housing   total')
      write (1, 51) sup(ik,1),sup(ik,2),sup(ik,3),sup(ik,4),sup(ik,5)
     +         ,tsup(ik)
51    format(1x,'X        ',6f9.1)
      write (1, 53) scap(ik,1),scap(ik,2),scap(ik,3),scap(ik,4)
     +         ,scap(ik,5),tcap(ik)
53    format(1x,'K        ',6f9.1)
      write (1, 55) dlab(ik,1),dlab(ik,2),dlab(ik,3),dlab(ik,4)
     +         ,dlab(ik,5),slab(ik)
55    format(1x,'L        ',6f9.1)
      write (1, 57) acf(1),acf(2),acf(3),acf(4),acf(5),tacf
57    format(1x,'adj  cost',6f9.1)
      write (1, 59) sdep(ik,1),sdep(ik,2),sdep(ik,3),sdep(ik,4)
     +         ,sdep(ik,5),p(16)
59    format(1x,'KDEP     ',6f9.1)
      write (1, 61) fv(ik,1),fv(ik,2),fv(ik,3),fv(ik,4),fv(ik,5)
     +       ,tv(ik)
61    format(1x,'V        ',6f9.1)
      write (1, 62) seqy(ik,1),seqy(ik,2),seqy(ik,3),seqy(ik,4)
     +        ,seqy(ik,5),we(ik)
62    format(1x,'E        ',6f9.1)
      write (1, 63) bond(ik,1),bond(ik,2),bond(ik,3),bond(ik,4)
     +        ,bond(ik,5),wb(ik)
63    format(1x,'B        ',6f9.1)
      write (1, 65) dn(1),dn(2),dn(3),dn(4),dn(5)
65    format(1x,'DN       ',5f9.1)
      write (1, 67) de(1),de(2),de(3),de(4),de(5),p(17)
67    format(1x,'DE       ',6f9.1)
      write (1, 69) q(ik,1),q(ik,2),q(ik,3),q(ik,4),q(ik,5)
```

```
69      format(1x,'Q        ',5f9.3)
        write (1, 71) dinv(ik,1),dinv(ik,2),dinv(ik,3),dinv(ik,4)
   +            ,dinv(ik,5),tinv1(ik)
71      format(1x,'I        ',6f9.1)
        write (1, 73) earn(ik,1),earn(ik,2),earn(ik,3),earn(ik,4)
   +            ,earn(ik,5),p(15)
73      format(1x,'EARN     ',6f9.1)
        write (1, 75) div(ik,1),div(ik,2),div(ik,3),div(ik,4)
   +            ,div(ik,5),p(18)
75      format(1x,'Div      ',6f9.3)
        write (1, 79) ret(ik,1),ret(ik,2),ret(ik,3),ret(ik,4)
   +            ,ret(ik,5),tret(ik)
79      format(1x,'retained ',6f9.1)
        write (1, 81) dbond(ik,1),dbond(ik,2),dbond(ik,3),dbond(ik,4)
   +    ,dbond(ik,5),tdb(ik)
81      format(1x,'borrowing',6f9.1)
        write (1, 83) dv(ik,1),dv(ik,2),dv(ik,3),dv(ik,4),dv(ik,5),wv(ik)
83      format(1x,'cap gains',6f9.1)
        write (1, 85) der(ik,1),der(ik,2),der(ik,3),der(ik,4),der(ik,5)
85      format(1x,'B/E      ',5f9.3)
        write (1, 87) agf(1),agf(2),agf(3),agf(4),agf(5),p(19)
87      format(1x,'agencycos',6f9.3)
        write (1, 89) rc(ik,1),rc(ik,2),rc(ik,3),rc(ik,4),rc(ik,5)
89      format(1x,'costofcap',5f9.3)
        write (1, 100)
100     format(1x,63('*'))
        write (1, 80) pc(ik)
80      format(1x,'com price',f15.6)
        write (1, 82) re(ik)
82      format(1x,'equity rt',f15.6)
        write (1, 84) rp(ik)
84      format(1x,'porfo  rt',f15.6)
        write (1, 88) yk(ik)
88      format(1x,'YK       ',f15.1)
        write (1, 90) yd(ik)
90      format(1x,'YD       ',f15.1)
        write (1, 96) wh(ik)
96      format(1x,'WH       'f15.1)
        write (1, 98) tw(ik)
98      format(1x,'TW       ',f15.1)
        write (1, 102) cdem(ik)
102     format(1x,'PC       ',f15.1)
        write (1, 104) sav(ik)
104     format(1x,'Saving   ',f15.1)
        write (1, 110) boc(ik)
110     format(1x,'cap  flow',f15.1)
        write (1, 112)
112     format(1x,63('*'))
```

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      write (1, 114) tct
114   format(1x,'Tc       ',f15.3)
      write (1, 116) tgt
116   format(1x,'TCG      ',f15.3)
      write (1, 118) tyt
118   format(1x,'Ty       ',f15.3)
      write (1, 119) tlt
119   format(1x,'TL       ',f15.3)
      write (1, 120) tvt
120   format(1x,'VAT      ',f15.3)
      write (1, 121) tst
121   format(1x,'Excise   ',f15.3)
      write (1, 122) twt
122   format(1x,'Tw       ',f15.3)
      write (1, 123) tpt
123   format(1x,'Tp       ',f15.3)
      write (1, 124) tax(ik)
124   format(1x,'TAX      ',f15.3)
      write (1, 126) tran(ik)
126   format(1x,'Tr       ',f15.3)
      write (1, 128) gexp(ik)
128   format(1x,'G        ',f15.3)
      write (1, 130) bondg(ik)
130   format(1x,'Bg       ',f15.3)
      write (1, 132) rpdef(ik)
132   format(1x,'PSBR     ',f15.3)
      write (1, 134)
134   format(1x,63('*'))
      write (1, 135)
135   format(1x,'final dem    C      G      y      I
     +    Z      M')
      write (1, 136) demc(ik,1),demg(ik,1),demj(ik,1),demi(ik,1)
     +    ,demz(ik,1),demm(ik,1)
136   format(1x,'Agricul  ',6f9.1)
      write (1, 138) demc(ik,2),demg(ik,2),demj(ik,2),demi(ik,2)
     +    ,demz(ik,2),demm(ik,2)
138   format(1x,'Energy   ',6f9.1)
      write (1, 140) demc(ik,3),demg(ik,3),demj(ik,3),demi(ik,3)
     +    ,demz(ik,3),demm(ik,3)
140   format(1x,'Manufac  ',6f9.1)
      write (1, 142) demc(ik,4),demg(ik,4),demj(ik,4),demi(ik,4)
     +    ,demz(ik,4),demm(ik,4)
142   format(1x,'Services ',6f9.1)
      write (1, 144) demc(ik,5),demg(ik,5),demi(ik,5),demi(ik,5)
     +    ,demz(ik,5),demm(ik,5)
144   format(1x,'Housing  ',6f9.1)
      write (1, 146)
146   format(1x,63('*'))
```

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      write (1, 148)
148   format(12x,'agricul  energy  manufac  service  housing')
      write (1, 150) pjd(ik,1),pjd(ik,2),pjd(ik,3),pjd(ik,4),pjd(ik,5)
150   format(1x,'PD        ',5f9.3)
      write (1, 152) pj(ik,1),pj(ik,2),pj(ik,3),pj(ik,4),pj(ik,5)
152   format(1x,'P         ',5f9.3)
      write (1, 154) pn(1),pn(2),pn(3),pn(4),pn(5)
154   format(1x,'PN        ',5f9.3)
      write (1, 156) rb(ik)
156   format(1x,'rb        ',f9.8)
      write (1, 158) rplab(ik)
158   format(1x,'w         ',f9.3)
      write (1, 160) er(ik)
160   format(1x,'ER        ',f9.3)
      write(1,*) '    RESULT    '
      write (1, 162)
162   format(/12x,'agricul  energy  manufac  service  housing    total')
      write(1,164) rearn(ik,1),rearn(ik,2),rearn(ik,3),rearn(ik,4)
     +        ,rearn(ik,5),rtearn(ik)
164   format(1x,'EARN      ',6f9.4)
      write (1, 165) rder(ik,1),rder(ik,2),rder(ik,3),rder(ik,4),rder(ik,5)
165   format(1x,'B/E       ',5f9.4)
      write (1, 166) rrc(ik,1),rrc(ik,2),rrc(ik,3),rrc(ik,4),rrc(ik,5)
166   format(1x,'WACC      ',5f9.4)
      write(1,167) rs(ik,1),rs(ik,2),rs(ik,3),rs(ik,4),rs(ik,5),rts(ik)
167   format(1x,'E         ',6f9.4)
      write(1,168) rv(ik,1),rv(ik,2),rv(ik,3),rv(ik,4),rv(ik,5),rtv(ik)
168   format(1x,'V         ',6f9.4)
      write(1,170) rdinv(ik,1),rdinv(ik,2),rdinv(ik,3),rdinv(ik,4)
     +        ,rdinv(ik,5),rtinv(ik)
170   format(1x,'I         ',6f9.4/)
      write(1,172) rdlab(ik,1),rdlab(ik,2),rdlab(ik,3),rdlab(ik,4)
     +        ,rdlab(ik,5),rtlab(ik)
172   format(1x,'L         ',6f9.4)
      write(1,173) rscap(ik,1),rscap(ik,2),rscap(ik,3),rscap(ik,4)
     +        ,rscap(ik,5),rtcap(ik)
173   format(1x,'K         ',6f9.4)
      write(1,174) rsup(ik,1),rsup(ik,2),rsup(ik,3),rsup(ik,4)
     +        ,rsup(ik,5),rtsup(ik)
174   format(1x,'X         ',6f9.4)
      write(1,175) rdemz(ik,1),rdemz(ik,2),rdemz(ik,3),rdemz(ik,4)
     +        ,rdemz(ik,5),rtdemz(ik)
175   format(1x,'Z         ',6f9.4)
      write(1,176) rdemm(ik,1),rdemm(ik,2),rdemm(ik,3),rdemm(ik,4)
     +        ,rdemm(ik,5),rtdemm(ik)
176   format(1x,'M         ',6f9.4/)
      write(1,177) rgdpr(ik)
177   format(1x,'GDP       ',f9.4)
```

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          write(1,178) rcdem(ik)
178       format(1x,'C         ',f9.4)
          write(1,179) rsav(ik)
179       format(1x,'S         ',f9.4)
          write(1,180) bondw(ik)
180       format(1x,'bondw     ',f13.4)
          write(1,181) wbond(ik)
181       format(1x,'wbond     ',f13.4)
          write(1,182) rtax(ik)
182       format(1x,'dTAX      ',f9.4)
          write(1,183) rpdef(ik)
183       format(1x,'(G-T)/GDP',f9.4)
          write(1,184) rfdef(ik)
184       format(1x,'PSBR      ',f9.4)
          write(1,186) rbot(ik)
186       format(1x,'BOT       ',f9.4)
          write(1,188) rplab(ik)
188       format(1x,'w         ',f9.4)
          write(1,190) rb(ik)
190       format(1x,'rb        ',f9.4)
          write(1,192) rcpi(ik)
192       format(1x,'CPI index',f9.4)
          write(1,194) gdpd(ik)
194       format(1x,'GDP index',f9.4)
          write(1,195) rerr(ik)
195       format(1x,'ER^R      ',f9.4)
          write(1,196) er(ik)
196       format(1x,'ER        ',f9.4)
          write(1,197) tot(ik)
197       format(1x,'TOT       ',f9.4)
          write(1,201) fre(ik)
201       format(1x,'dBOC*ER  ',f9.4)
          write(1,202) dtot(ik)
202       format(1x,'dTOT      ',f9.4)
          write(1,203) pen(ik)
203       format(1x,'output ef',f9.4)
          write(1,205) cri(ik)
205       format(1x,'d REAL YD',f9.4)
          write(1,198) rwel(ik)
198       format(1x,'Welfare  ',f9.4)
          write (1, 199) ik
199       format(1x,'year :',1x,i2)
                end if
                if(iprint .eq. 3) then
          write (1, 501)
501       format(12x,'agricul  energy  manufac  service  housing   total')
          do 502 ik=1,nyear
          write (1, 503) rearn(ik,1),rearn(ik,2),rearn(ik,3),rearn(ik,4)
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```
     +           ,rearn(ik,5),rtearn(ik)
503        format(1x,'EARN      ',6f9.4)
502        continue
           write (1, 505)
505        format(12x,'agricul  energy  manufac  service  housing')
           do 506 ik=1,nyear
           write (1, 507) rder(ik,1),rder(ik,2),rder(ik,3),rder(ik,4),rder(ik,5)
507        format(1x,'B/E       ',5f9.4)
506        continue
           write (1, 510)
510        format(12x,'agricul  energy  manufac  service  housing')
           do 511 ik=1,nyear
           write (1, 512) rrc(ik,1),rrc(ik,2),rrc(ik,3),rrc(ik,4),rrc(ik,5)
512        format(1x,'WACC      ',5f9.4)
511        continue
           write (1, 520)
520        format(12x,'agricul  energy  manufac  service  housing   total')
           do 521 ik=1,nyear
           write (1, 522) rv(ik,1),rv(ik,2),rv(ik,3),rv(ik,4)
     +           ,rv(ik,5),rtv(ik)
522        format(1x,'V         ',6f9.4)
521        continue
           write (1, 530)
530        format(12x,'agricul  energy  manufac  service  housing   total')
           do 531 ik=1,nyear
           write (1, 532) rik(ik,1),rik(ik,2),rik(ik,3),rik(ik,4)
     +           ,rik(ik,5)
532        format(1x,'I/K       ',5f9.4)
531        continue
           write (1, 535)
535        format(12x,'agricul  energy  manufac  service  housing   total')
           do 536 ik=1,nyear
           write (1, 537) rdinv(ik,1),rdinv(ik,2),rdinv(ik,3),rdinv(ik,4)
     +           ,rdinv(ik,5)
537        format(1x,'I         ',5f9.4)
536        continue
           write (1, 540)
540        format(12x,'agricul  energy  manufac  service  housing   total')
           do 541 ik=1,nyear
           write (1, 542) rscap(ik,1),rscap(ik,2),rscap(ik,3),rscap(ik,4)
     +           ,rscap(ik,5),rtcap(ik)
542        format(1x,'K         ',6f9.4)
541        continue
           write (1, 550)
550        format(12x,'agricul  energy  manufac  service  housing   total')
           do 551 ik=1,nyear
           write (1, 552) rdlab(ik,1),rdlab(ik,2),rdlab(ik,3),rdlab(ik,4)
     +         ,rdlab(ik,5)
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552     format(1x,'L        ',5f9.4)
551     continue
        write (1, 560)
560     format(12x,'agricul  energy  manufac  service  housing   total')
        do 561 ik=1,nyear
        write (1, 562) rsup(ik,1),rsup(ik,2),rsup(ik,3),rsup(ik,4)
     +         ,rsup(ik,5),rtsup(ik)
562     format(1x,'X        ',6f9.4)
561     continue
        write (1, 570)
570     format(12x,'agricul  energy  manufac  service  housing   total')
        do 571 ik=1,nyear
        write (1, 572) rdemz(ik,1),rdemz(ik,2),rdemz(ik,3),rdemz(ik,4)
     +         ,rdemz(ik,5)
572     format(1x,'Z        ',5f9.4)
571     continue
        write(1,600)
600     format(12x,'interest investment saving  consmptn  GDP ')
        do 601 ik=1,nyear
        write (1, 602) rb(ik),rtinv(ik),rsav(ik),rcdem(ik),rgdpr(ik)
602     format(1x,'Macro var',5f9.4)
601     continue
        write(1,610)
610     format(12x,'exchange  export  trade ac  capflow   dTAX  ')
        do 611 ik=1,nyear
        write (1, 612) er(ik),rtdemz(ik),rbot(ik),rboc(ik),rtax(ik)
612     format(1x,'Foreign v',5f9.4)
611     continue
        write (1, 615)
615     format(12x,'tot effect  wages  TW   WK/WH   WB/WE')
        do 616 ik=1,nyear
        write (1, 617) tot(ik),rplab(ik),rtw(ik),rfdis(ik),radis(ik)
617     format(1x,'Returns  ',5f9.4)
616     continue
              end if
              if(iprint .eq. 4) then
        write(1,701) bondw(ik)
701     format(1x,'bondw    ',f13.4)
        write(1,702) wbond(ik)
702     format(1x,'wbond    ',f13.4)
        write(1,703) ev
703     format(1x,'eq-va    ',f13.4)
        write (1, 705)
705     format(12x,'agricul  energy  manufac  service  housing')
        write(1,706) rtsi5(1),rtsi5(2),rtsi5(3),rtsi5(4),rtsi5(5)
706     format(1x,'trns-5  I',5f9.4)
        write(1,707) rtsi10(1),rtsi10(2),rtsi10(3),rtsi10(4),rtsi10(5)
707     format(1x,'trns-10 I',5f9.4)
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         write(1,708) rtsi20(1),rtsi20(2),rtsi20(3),rtsi20(4),rtsi20(5)
708      format(1x,'trns-20 I',5f9.4)
            end if
            if(iprint .eq. 5) then
         write (1, 805)
805      format(12x,'agricul  energy  manufac  service  housing')
         write(1,810) qk(1),qk(2),qk(3),qk(4),qk(5)
810      format(1x,'ret to  K',5f9.4)
         write(1,812) rrh
812      format(1x,'ret toSAV',f9.4)
         write(1,815) qr(1),qr(2),qr(3),qr(4),qr(5)
815      format(1x,'tax wedge',5f9.4)
         write(1,820) etr(1),etr(2),etr(3),etr(4),etr(5)
820      format(1x,'ef taxrat',5f9.4)
         write(1,825) aetr
825      format(1x,'overall r',f9.4)
         write(1,830) vetr
830      format(1x,'variance ',f9.4)
         write(1,835) setr
835      format(1x,'stand dev',f9.4)
            end if
            if(iprint .eq. 6) then
         write (1, 1501)
1501     format(12x,'earning   B/PeE   Cost    Asset  I/K    I    K')
         write(1, 1503) rearn(1,1),rder(1,1),rrc(1,1),rv(1,1),rik(1,1)
   +              ,rdinv(1,1),rscap(1,1)
1503     format(1x,'Year    1',7f9.3)
         write(1, 1505) rearn(5,1),rder(5,1),rrc(5,1),rv(5,1),rik(5,1)
   +              ,rdinv(5,1),rscap(5,1)
1505     format(1x,'        5',7f9.3)
         write(1, 1507) rearn(76,1),rder(76,1),rrc(76,1),rv(76,1),rik(76,1)
   +              ,rdinv(76,1),rscap(76,1)
1507     format(1x,'      INF',7f9.3)
         write(1, 1509) rearn(1,2),rder(1,2),rrc(1,2),rv(1,2),rik(1,2)
   +              ,rdinv(1,2),rscap(1,2)
1509     format(1x,'Year    1',7f9.3)
         write(1, 1511) rearn(5,2),rder(5,2),rrc(5,2),rv(5,2),rik(5,2)
   +              ,rdinv(5,2),rscap(5,2)
1511     format(1x,'        5',7f9.3)
         write(1, 1513) rearn(76,2),rder(76,2),rrc(76,2),rv(76,2),rik(76,2)
   +              ,rdinv(1,2),rscap(1,2)
1513     format(1x,'      INF',7f9.3)
         write(1, 1515) rearn(1,3),rder(1,3),rrc(1,3),rv(1,3),rik(1,3)
   +              ,rdinv(1,3),rscap(1,3)
1515     format(1x,'Year    1',7f9.3)
         write(1, 1517) rearn(5,3),rder(5,3),rrc(5,3),rv(5,3),rik(5,3)
   +              ,rdinv(5,3),rscap(5,3)
1517     format(1x,'        5',7f9.3)
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      write(1, 1519) rearn(76,3),rder(76,3),rrc(76,3),rv(76,3),rik(76,3)
     +              ,rdinv(76,3),rscap(76,3)
1519  format(1x,'      INF',7f9.3)
      write(1, 1521) rearn(1,4),rder(1,4),rrc(1,4),rv(1,4),rik(1,4)
     +              ,rdinv(1,4),rscap(1,4)
1521  format(1x,'Year    1',7f9.3)
      write(1, 1523) rearn(5,4),rder(5,4),rrc(5,4),rv(5,4),rik(5,4)
     +              ,rdinv(5,4),rscap(5,4)
1523  format(1x,'        5',7f9.3)
      write(1, 1525) rearn(76,4),rder(76,4),rrc(76,4),rv(76,4),rik(76,4)
     +              ,rdinv(76,4),rscap(76,4)
1525  format(1x,'      INF',7f9.3)
      write(1, 1527) rearn(1,5),rder(1,5),rrc(1,5),rv(1,5),rik(1,5)
     +              ,rdinv(1,5),rscap(1,5)
1527  format(1x,'Year    1',7f9.3)
      write(1, 1529) rearn(5,5),rder(5,5),rrc(5,5),rv(5,5),rik(5,5)
     +              ,rdinv(5,5),rscap(5,5)
1529  format(1x,'        5',7f9.3)
      write(1, 1531) rearn(76,5),rder(76,5),rrc(76,5),rv(76,5),rik(76,5)
     +              ,rdinv(76,5),rscap(76,5)
1531  format(1x,'      INF',7f9.3)
      write(1, 1545) rdlab(1,1),rdlab(1,2),rdlab(1,3),rdlab(1,4)
     +         ,rdlab(1,5)
1545  format(1x,'L        ',5f9.3)
      write(1, 1547) rdlab(5,1),rdlab(5,2),rdlab(5,3),rdlab(5,4)
     +         ,rdlab(5,5)
1547  format(1x,'L        ',5f9.4)
      write (1, 1549) rdlab(76,1),rdlab(76,2),rdlab(76,3),rdlab(76,4)
     +         ,rdlab(76,5)
1549  format(1x,'L        ',5f9.4)
      write (1, 1551) rsup(1,1),rsup(1,2),rsup(1,3),rsup(1,4)
     +         ,rsup(1,5),rtsup(1)
1551  format(1x,'X        ',6f9.4)
      write (1, 1553) rsup(5,1),rsup(5,2),rsup(5,3),rsup(5,4)
     +         ,rsup(5,5),rtsup(5)
1553  format(1x,'X        ',6f9.4)
      write (1, 1555) rsup(76,1),rsup(76,2),rsup(76,3),rsup(76,4)
     +         ,rsup(76,5),rtsup(76)
1555  format(1x,'X        ',6f9.4)
      write (1, 1557) rdemz(1,1),rdemz(1,2),rdemz(1,3),rdemz(1,4)
     +         ,rdemz(1,5)
1557  format(1x,'Z        ',5f9.4)
      write (1, 1559) rdemz(5,1),rdemz(5,2),rdemz(5,3),rdemz(5,4)
     +         ,rdemz(5,5)
1559  format(1x,'Z        ',5f9.4)
      write (1, 1561) rdemz(76,1),rdemz(76,2),rdemz(76,3),rdemz(76,4)
     +         ,rdemz(76,5)
1561  format(1x,'Z        ',5f9.4)
```

```
      write(1,1600)
1600  format(12x,'interest investment saving  consmptn  GDP ')
      write (1, 1602) rb(1),rtinv(1),rsav(1),rcdem(1),rgdpr(1)
1602  format(1x,'Macro var',5f9.4)
      write (1, 1604) rb(5),rtinv(5),rsav(5),rcdem(5),rgdpr(5)
1604  format(1x,'Macro var',5f9.4)
      write (1, 1606) rb(76),rtinv(76),rsav(76),rcdem(76),rgdpr(76)
1606  format(1x,'Macro var',5f9.4)
      write(1,1610)
1610  format(12x,'exchange  export  trade ac  capflow dTAX  CPI index')
      write (1, 1612) er(1),rtdemz(1),rbot(1),rboc(1),rtax(1),rcpi(1)
1612  format(1x,'Foreign v',6f9.4)
      write (1, 1614) er(5),rtdemz(5),rbot(5),rboc(5),rtax(5),rcpi(5)
1614  format(1x,'Foreign v',6f9.4)
      write (1, 1616) er(76),rtdemz(76),rbot(76),rboc(76),rtax(76)
     +          ,rcpi(76)
1616  format(1x,'Foreign v',6f9.4)
      write (1, 1620)
1620  format(12x,'tot effect  wages  TW   WH/WK  WB/WE  GDP index')
      write (1, 1622) tot(1),rplab(1),rtw(1),rfdis(1),radis(1),gdpd(1)
1622  format(1x,'Returns  ',6f9.4)
      write (1, 1624) tot(5),rplab(5),rtw(5),rfdis(5),radis(5),gdpd(5)
1624  format(1x,'Returns  ',6f9.4)
      write (1, 1626) tot(76),rplab(76),rtw(76),rfdis(76),radis(76)
     +          ,gdpd(76)
1626  format(1x,'Returns  ',6f9.4)
      end if

      return
      end
```

APPENDIX E: EFFECTIVE TAX RATE CALCULATION

To summarize the impact of pre-reform and post-reform UK tax law on capital allocation, we employ the notion of an effective tax rate for each type of Maximization of private wealth results in an effecient allocation of capital only if the effective rate is the same for all assets. Discrepancies in the tax treatment of different types of assets result in sizable obstacles to efficient capital allocation.

In order to represent the effect of the UK tax structure on capital allocation we distinguish among assets held in the agriculture, energy, manufacturing, services, and housing serives sectors. Since assets held in different sectors differ enormously in tax treatment under the individual and corporate income taxes, we would expect to find that UK tax law presents formidiable barriers to the efficient allocation of capital. In addition, the tax rules for capital recovery within a sector, including the investment tax credit and capital consumption allowances, differ drastically among different types of assets, giving rise to further obstacles to efficient allocation. Summing up the effective tax rates may vary, they depend upon the asset and industry in which the funds are invested, and the nature of of the financial calims on the profits (equity versus debt).

King and Fullerton (1984) defines the effective tax rate, t_e, as to be the tax "wedge" between the rate of return on investment and the rate of return on savings for industries' marginal investment divided by the rateof return on savings, r_s;

$$t_{ej} = \frac{t_{wj}}{r_s} \qquad \textit{with} \quad j=1,....,J=5$$

Since with distortionary taxes the rate of return on investment and the rate of return on savings can differ, the effective tax rate then is expected to move from zero. A negative value for the effective tax rate of any sector means that the tax system favours investment in that sector while a positive value means that investment in that sector is discouraged. This implies that as the effective tax rate measures the degree of misallocation of capital the tax wedge provides a qualitative information in defining the sign of the effective tax rate.

To define the tax wedge we should first derive formulas for the post-tax real rate of return to saving and the rate of return net of depreciation to capital. The post-tax real rate of return to the saver, r_s, is, in terms of instantaneous rates, given by

$$r_s = (1-\tau_p) r_B - \pi$$

where τ_p, is the margianl personal income tasx rate, r_B, denotes the nominal interst rate, and π stands for the inflation rate. As for the latter, the rate of return net of depreciaton

to capital, it is derived by King and Fullerton (1984) as

$$r_{Ij} = \frac{(1-DN_j-z_j)}{(1-\tau)}(\Gamma_j + \delta_j^R - \pi) - \delta_j^R$$

where DN_j is the tax savings from depreciation allownces, and z represents the investment grants.

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