THE IMPACT OF SOLID WASTE COLLECTION, PRICING AND RECYCLING POLICIES ON RESIDENTIAL SOLID WASTE

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Abstract

Most large cities have waste crises at some time or other. MSW (municipal solid waste) is a major component of the waste stream of cities, the bulk of which derives from residents (households) rather than businesses. Since MSW is an increasing function of per capita GDP, MSW typically grows with development, and many cities in the fastest-growing economies have had to find ways to regulate the solid waste generated by households. This thesis set up a household waste disposal model in order to evaluate the scope for MSW management using instruments that change household waste disposal decisions. The model is estimated by a panel of data on MSW disposal in 18 cities in Taiwan and Japan. The estimations are then used to test the effectiveness of a number of policy options.

The model shows that households elect to trade off storing/composting waste against the three main waste discarding options: legal dumping, illegal dumping and recycling. It is also shown that the household's decision to discard a unit of waste is based on each disposal option's marginal cost, including tariff, labour and disutility for storing/composting waste. The study confirms that the higher the frequency of non-recyclables collection, the less recycling and more waste dumping would be. This may be caused by a reduction in the marginal cost of dumping. For cities with garbage collection more than 5 times per week, decreasing the garbage collection frequency increases recycling and decreases garbage dumped.

It is also shown that the higher the price of non-recyclables collection (price of unit-pricing) the higher the recycling rate would be. The short run price elasticity of non-recyclable collection demand is estimated to be 0.069. In the long run, at higher unit-prices, the price elasticity is estimated to rise to 0.346. Applying a penalty on illegal dumping (fine) can prevent illegal dumping from increasing after unit-pricing is adopted. In Taiwan, the prosecuted penalty (fine) per 1000 residents has a significant positive effect on the dumping of non-recyclables. This is because the penalty decreases illegal dumping, which may increase non-recyclables.

Mandatory recycling policy is also shown to increase recycling and to decrease non-recyclables. The adoption of a transparent garbage bag policy also helps to increase recycling by lowering inspection costs. This has the effect of increasing paper recycling and decreasing non-recyclables. Because all Taiwanese cities now have both on-time collection and mandatory recycling, they should consider requiring residents to use transparent bags for garbage collection, which facilitate mandatory recycling.

Cities that have not adopted unit-pricing or mandatory recycling should consider adopting unit-pricing, with the price being no less than 0.086 USD/10litres which has higher social benefits than costs. Cities in Taiwan should consider a unit-price of no less than 0.144 USD/10litres which can fully cover the cost of treatment. It is argued that the unit-pricing policy provides waste management authorities with more options than mandatory recycling which has only one-off effects.

The models in the thesis show that some troublesome waste, such as kitchen waste, involved a high disutility of storage may become a household's first choice of illegal dumping if composting and recycling aren't available. Besides, the more kerbside recycling materials (recycling categories) increases recycling and the categories are increased by materials entered kerbside recycling later, such as kitchen waste recycling for public compost in Taiwan. Cities that haven't provided kerbside paper, plastics and kitchen waste should consider doing so.

Finally, it is shown that population density increases all kinds of recyclables. This is probably because the marginal cost of illegal dumping (expected fine) rises in high density areas. Greater population density also significantly decreases non-recyclables, which might be because households in high population density areas possess fewer commodities and generate less waste.

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Author's Declaration

I declare that this thesis represents my own work, except where due acknowledgement is made, and that it has not been previously included in a thesis dissertation or report submitted to this University or any other institution for a degree, diploma or qualification.

Kuo, Yen-Lien

Chapter 1 Introduction

Management of municipal solid waste (MSW)[1] is one of the most serious environmental issues in the world. Most large cities have waste crises, and the majority of MSW comes from residents (households) rather than businesses. For example, 74% MSW in England in 2002/03 derives from households[2]. Moreover, since MSW is an increasing function of per capita GDP the problem grows with development. The thesis focuses on this aspect of the MSW problem, analysing both the economic factors that determine the volume of residential waste, and policies for residential solid waste (RSW)[3] reduction and recycling.

1.1 Origin

Municipal solid waste is a serious environmental issue because, unlike most water and air pollutants, it does not decrease as per capita incomes rise. There is no turning point[4] in the relationship between per capita income and municipal solid waste, as there is with many other indicators of environmental stress (Cole *et al.*, 1997; Shafik, 1994). This means economic growth, or factors associated with economic growth, cannot stop the growth in solid waste production. Arrow *et al.* (1995) said:

> *Economic growth is not a panacea for environmental quality; indeed, it is not even the main issue. What matters is the content of growth...This content is determined by...the economic institutions... These institutions need to be designed so that they provide the right incentives for protecting the resilience of ecological systems.*

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[1] MSW excludes wastes from agriculture and forestry, industry, and construction *etc.*

[2] DEFRA (2004) pp. 11.

[3] RSW is solid waste from residents. In some cities, RSW is the same as MSW if solid waste collection system for residents and small business are the same.

[4] The hypothesis of environmental Kuzets curve (EKC) - the notion that environmental impact increases in the early stages of economic development followed by declines in the later stages and the turning point is the per capita income at which environmental impact, such as the concentration of SOx (sulphur dioxide), starts to decline as income increase.

Besides the growth of waste generation, in many decentralized countries, owing to the "not-in-my-backyard" (NIMBY) effect, a densely populated city cannot export its waste to other jurisdictions, and it is hard to find new landfill or incinerator sites in its territory. The problem, from an economic point of view, lies in the fact that the increasing waste burden has a number of external environmental costs (externalities) that are not taken into account by those who generate the waste[5]. These include that some older landfill sites are sources of pollution with uncontrolled leakages (leachate) which may pollute soil and groundwater, landfill gas can be hazardous since the largest component, methane, can reach explosive concentrations, and the emission of incinerator may have an adverse effect on health (Williams, 2005). Finding effective solid waste management policies (institutions) for these cities is very important. Existing waste policies will be evaluated and ways to improve them considered.

Amongst the waste policies considered will be the use of price-based incentives. These are frequently recommended as mechanisms to address the external environmental effects of a wide range of economic activities, including waste management. Taxes to correct market externalities have been popular with economists since they were advocated by Pigou (1920). A growing number of communities use unit-pricing policy[6] as a strategy for encouraging waste diversion and waste reduction. Nevertheless, the garbage price in most communities, including Taipei City, does not entirely reflect costs of waste disposal and treatment (price content on Appendix 8, pp. A91). Most communities use mixed residential solid waste policy, such as unit-pricing policy on garbage and free mandatory recycling[7], or free bulk

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[5] Baumol and Oates (1988) defined externality by two conditions. The condition 1 is that an externality is present whenever some individual's (say A's) utility or production relationships include real variables, whose values are chosen by others without particular attention to the effects A's welfare. The condition 2 is that the decision maker, whose activity affects others' utility levels or enters their production functions, does not receive (pay) in compensation for this activity an amount equal in value to the resulting benefits (or costs) to others. In Taipei City, the land cost of incinerator and landfill, and externality are not included in the price of unit-pricing.

[6] Garbage collection and treatment fee are based on, or partially based on, volume or weight of waste, rather than a fixed fee or based on other proxies which have no direct relation with waste amount.

[7] Garbage hauler or police fine residents whose garbage bag contains announced recyclable materials.

and yard-waste collection[8]. The thesis asks what kind of mixed RSW policy is most cost effective, and which minimises illegal dumping?

What makes a pricing policy effective? Most empirical studies of unit-pricing are from American communities. For example, Miranda and Aldy (1998) found nine American suburban communities reduced waste generation (non-recyclables) by about 20% after unit-pricing was adopted, but Fullerton and Kinnaman (1996) found that the price elasticity of garbage collection was only 0.076 in Charlottesville, Virginia. In Taipei City, which is the capital of Taiwan and has 2 million residents, the introduction of a unit-pricing policy[9] decreased RSW by 32.79% and increased the recyclable materials by 98.87% in the first two years (Figure 1.1 and 1.2). Besides unit-pricing, Taipei also has kerbside recycling and a "no garbage in the street" policy[10]. Do these kinds of collection polices make Taipei City's unit-pricing policy better than those of other cities?

Both planning and design of solid waste management systems require accurate quantity and quality prediction of solid waste generation. For example, while unit-pricing decreased RSW in Taipei City by more than 30%, it took more than two years to convince residents near incinerators to accept a waste disposal cooperation agreement with Keelung City[11]. In the agreement, the Taipei City government uses its excess incinerator capacity to burn some of Keelung's waste, while the burnt ash is returned to Keelung's landfill, which also accepts some of the ash from Taipei's incinerator, extending the lifespan of Taipei's landfills.

Conventional forecasting of amounts of solid waste generation uses demographic and socioeconomic factors to predict changes in waste production (Grossman *et al.*, 1974) or uses a time series model for historical

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[8] Based on the nature of waste, RSW can be classified as non-recyclable, recyclable, hazardous, and bulky waste. Non-recyclable waste is also called as un-sorted waste, mixed waste, or rubbish and garbage for colloquialism. Recyclable waste also called recycling are collected recyclable materials.

[9] Residents in Taipei have to buy an authorised garbage bag to throw garbage and the price of a bag includes its garbage collection and partial treatment cost.

[10] Residents in Taipei can only dispose garbage and recyclable materials via handing to a municipal waste hauler when they come at some specific time kerbside.

[11] "Taipei Mayor Ma said the waste disposal cooperation agreement is mutually beneficial to both Taipei and Keelung City," Central News Agency, June 21 2003.

waste data (Katsamaki *et al.*, 1998). These models do not include policy variables, and so are unable to predict waste generation under different policies. Because decisions about residential waste disposal are made by households, the aim of this thesis is to build and calibrate a model in order to predict household waste disposal behaviour under different policy options.

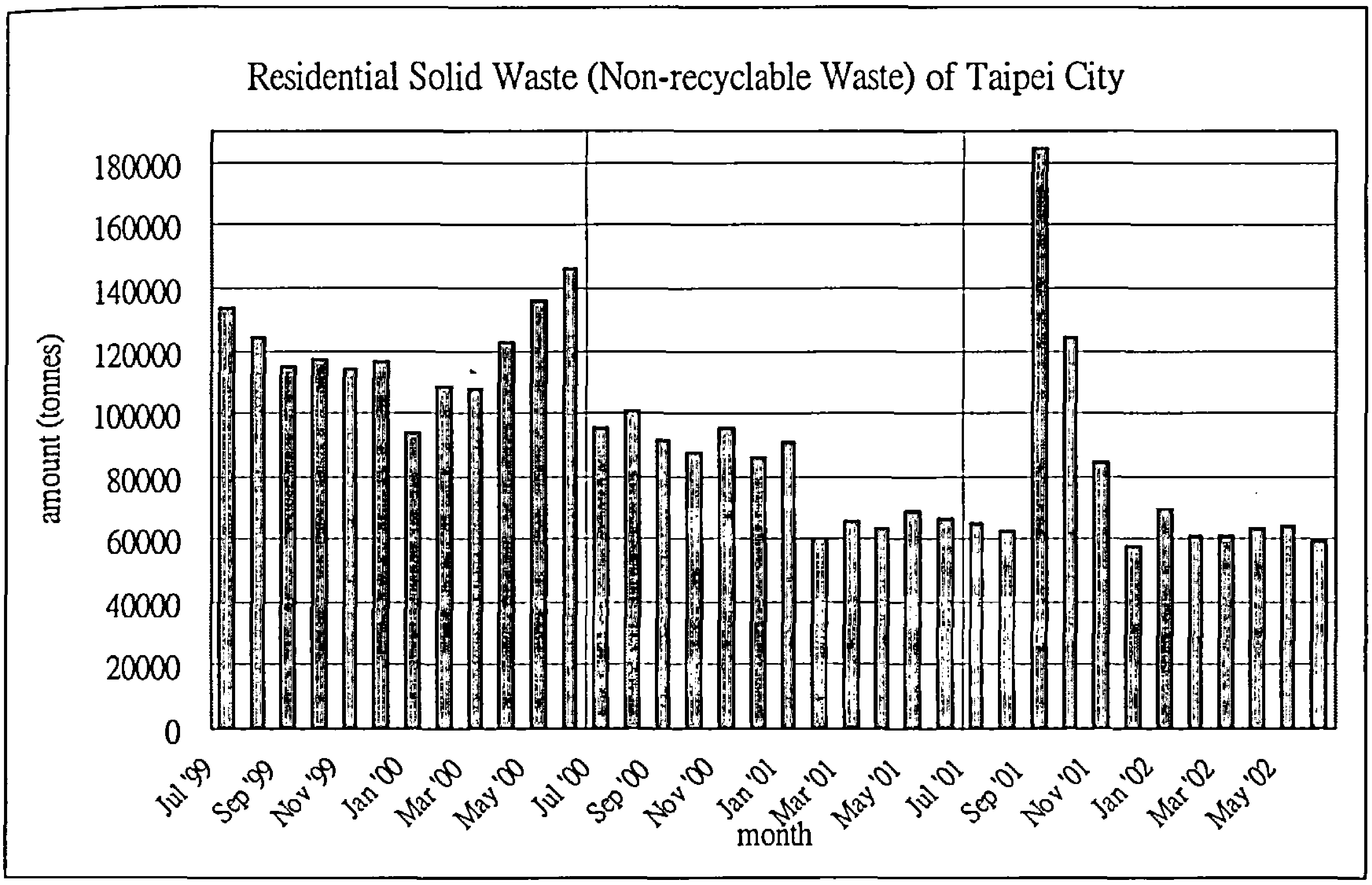

Fig 1.1 Monthly amount of residential solid waste in Taipei City from July 1999 to July 2002

Note: Due to a serious flood in Taipei in Sep. 2001, there was a sharp increase in garbage collection at that time. Source: Environmental Information System, EPA, Taiwan (ROC).

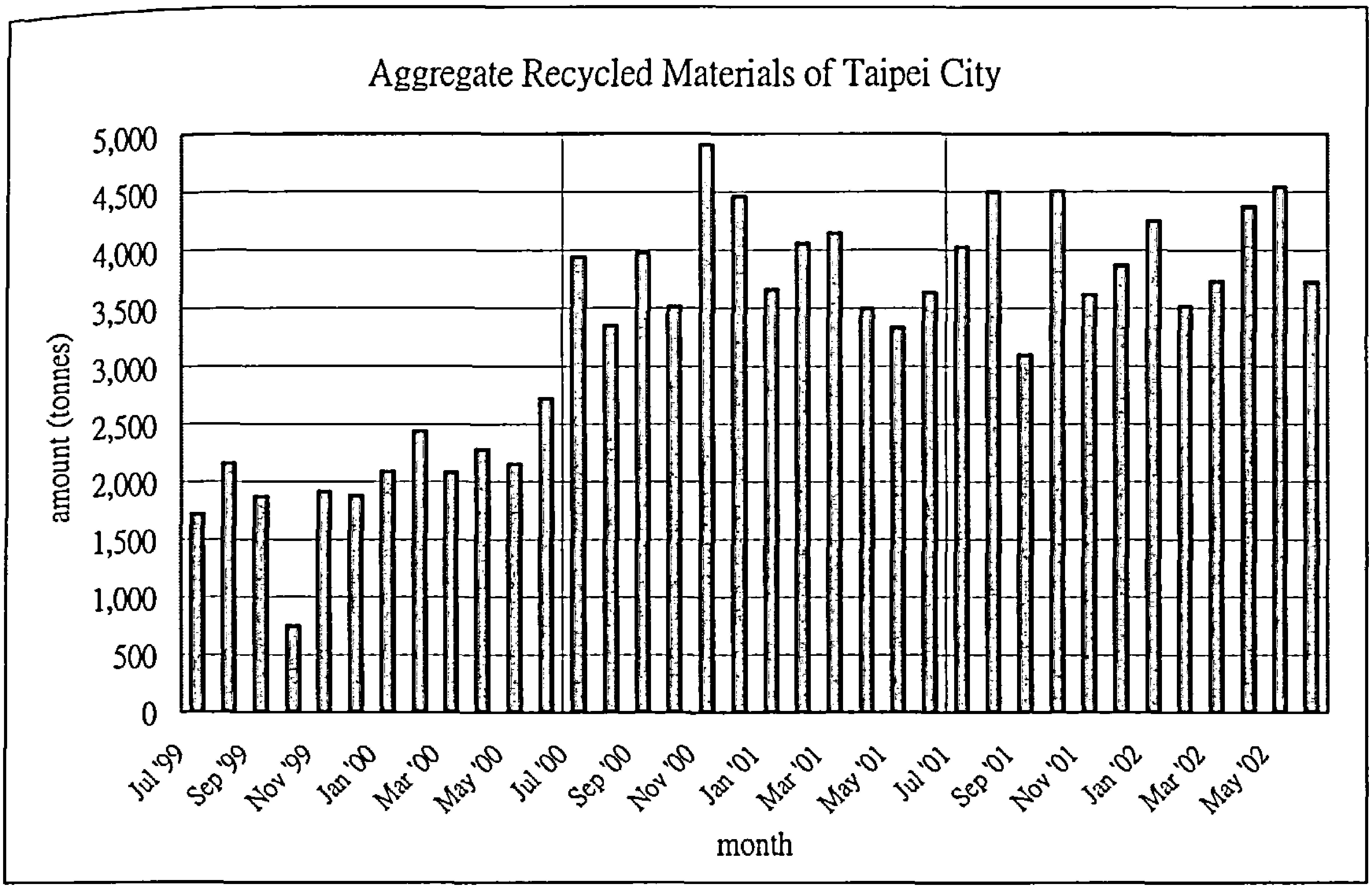

Fig 1.2 Monthly amounts of recyclable materials in Taipei City from 1999 to 2002

Note: The data only includes recyclable materials collected by city government (municipal waste haulers). Source: Environmental Information System, EPA, Taiwan (ROC).

1.2 Aims of the Thesis

The aims of this thesis are to answer the following questions.

a. How does a household decide on waste disposal?
b. How do waste management policies change household's behaviour on waste disposal and how are the quantity and quality of waste changed after various policies are adopted?

In order to answer these two questions, the following components are included in this thesis.

a. A theoretical model (based on microeconomic theory) of a household's solid waste disposal decision.
b. An empirical model (based on the theoretical model) using data to analyse the effects of waste pricing, collection, recycling and enforcement/inspection policies.
c. A policy simulation to estimate costs and benefits of applying various

policies some cities.

d. Recommendations to make solid waste pricing and recycling more effective based on the findings of the theoretical and empirical studies.

1.3 Thesis Outline

The thesis advances the following ideas that differ from those in previous studies of RSW policy. Firstly, the disposal option of waste storing or composting is considered in this thesis. Many cities had started to promote composting in house and many households do store useless or recyclable items in house. This option is introduced into the household waste disposal model in this thesis, which improves the knowledge of household waste disposal behaviour.

Secondly, waste management characteristics associated with dumping labour and illegal dumping prevention are considered in this thesis. The total cost of waste disposal includes tariff and labour cost, but previous studies only used price and/or dummies for garbage charging as variables in household waste disposal models. The cost of illegal dumping, such as enforcement and penalty (fine), haven't been included in previous empirical studies. This advance should improve the design of RSW management schemes and reduce illegal dumping.

Thirdly, the effect of recycling programs and unit-pricing on different recyclable materials is treated directly. Most previous empirical studies regard recyclable materials as uniform goods and use aggregate data on recycling. However, since each recyclable material has a unique nature, a household would make a different choice for each material for waste policies. Knowing the effects of waste policies on all kinds of recycling materials can contribute not only the design of comprehensive recycling policies, but also the design of a waste treatment system, such as the design of an incinerator, because the various effects change the quality of waste (composition of waste).

Finally, except for the case of Korean cities discussed by Hong (1999), unit-pricing policy in East Asian cities has not been evaluated. The results of the thesis may be compared with those from several previous studies in Western countries and show whether the pricing effect differs in different cultures.

The thesis comprises a literature review, the development of theoretical models, calibration of the models, policy analysis and conclusions. Chapter 1 will discuss the origin of the problem; chapter 2 will review existing literature, including theoretical and empirical research about solid waste disposal; chapter 3 will introduce a theoretical household model; chapter 4 will present the applied model and the data survey; chapter 5 will evaluate existing policies including estimation of waste disposal demand elasticity; chapter 6 reports some policy experiments; and chapter 7 offers conclusions which propose some effective solid waste policies including pricing and recycling schemes.

Chapter 2 Literature Review

Currently, most households in urban areas pay for waste removal through a flat monthly or quarterly fee, or through local property or income taxes. For example, since 1982, all communities in Taiwan have been charging households and small businesses for solid waste collection on the basis of each household's bi-monthly consumption of tap water. The scheme has a very low administrative cost. Tap water consumption is nearly universal in municipalities providing solid waste collection services in Taiwan, and is positively correlated with the volume of solid waste produced. However, the cost to the waste producer of one more bag of garbage is nearly zero. The cost to society is not. Because waste disposal needs capital and may cause foul odour, pollute groundwater, create an eyesore *etc.*, the social marginal cost of extra bags is greater than zero. In order to internalize the external costs of waste production, economists have suggested several tax and subsidy schemes.

2.1 The Optimal Policy for Residential Solid Waste Management

Since the pioneering study of Pigou (1920), there are many economic studies of mechanisms to encourage a decentralized economy to achieve an efficient allocation of resources for waste management. There are two categories of externalities[12] related to waste generation. The first one includes the external cost of waste disposal which may cause ground water pollution by landfill or air pollution by incinerator. It also includes the external costs of illegal dumping, which involve both soil and water pollution, but also a heightened risk of pests and pathogens. The second one is external benefit of recycling which can conserve virgin material and avoid at least some of the external costs of waste disposal. Kinnaman and Fullterton (2001) summarized previous studies of five kinds of waste policies including taxing on each unit of garbage disposed, subsidy for recycling effort, paying an

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[12] See footnote 5.

advanced disposal fee at the time of purchase, taxing on virgin material when goods produced, or subsidizing use of recycled materials for production. This section will review these theoretical waste management studies.

For the externality of waste disposal, Shinkuma (2003) indicated that the social optimum can be achieved in the decentralized first-best economy (ignoring transaction costs) through a combination of unit-pricing, advance disposal fees and recycling subsidies. Choe and Fraser (1999) and Fullerton and Kinnaman (1995) reported similar results. The latter showed that when illegal dumping can be taxed (fined), the tax or fine for legal dumping, illegal dumping and virgin material usage induced households to take externalities into account. If illegal dumping cannot be taxed directly, household consumption should be taxed to reflect the externality of illegal dumping, the tax being refunded when the waste is dumped legally or recycled (Fullerton and Kinnaman, 1995). This is effectively a deposit-refund system, which is also second-best policy for toxic waste in Sullivan (1987) (first best policy is direct taxation of the externality). Compared with advance disposal fees, taxing garbage directly requires information on the full social cost of each bag of garbage (Dinan, 1993).

Taxing virgin materials in combination with a user fee (unit-pricing) is not generally efficient, since the same material is effectively taxed twice (Dinan, 1993). For the same reason, taxing waste-intensive goods only would not be efficient when dumping could be taxed directly (Kinnaman and Fullterton, 2001).

Because different kinds of waste have different social costs, a uniform tax on all types of garbage may be inefficient (Dinan, 1993). In the real world, different waste policies apply for different type of waste. For example, many countries apply the deposit-refund system for refillable bottles and hazardous products: deposits are paid when products are sold and refunds given when they are recycled. However, for residential solid waste, few communities in the world adopt unit-pricing and free kerbside recycling. There are many empirical studies of unit-pricing trying to find the effect of such a policy.

2.2 The Household Model and Empirical Research

Most empirical studies of unit-pricing are based on a household behaviour model. This section reviews the household model and the results of associated empirical studies.

- Model for household's behaviour of waste disposal

The model of household behaviour of waste disposal originated in Smith (1972), who introduced a dynamic model of social waste accumulation which involved a household choice between waste disposal (legal dumping) and recycling. Papers discussing household waste disposal focused on these two options until Fullerton and Kinnaman (1995) added illegal dumping as the third option in their general equilibrium model. However, the household utility function in their theoretical model includes disutility from aggregate waste disposal and virgin material usage. There is no evidence that household's utility is directly affected by these.

Based on the paper of Fullerton and Kinnaman (1995), Shaw and Tsai (2002) built a household utility maximisation model with illegal dumping as an option. The household utility function is $u(x,B)$ which is in terms of consumption (x) and aggregate illegal dumping (B). Key factors are the price for consumption (p_x), price for garbage collection (p_g), compensation price for recycled material (p_r), wage rate for labour (w) and non-labour income (a). If the household dumps its garbage illegally, it has to face an expected fine based upon the amount of illegal dumping times the chance of been prosecuted (π) and the fine (p_b). Assume that the household time endowment is k and it spends kb, kr and kl on illegal dumping, recycling and leisure. The labour costs for illegal dumping and recycling are function of the amounts ($kb = g(b)$, $kr = h(r)$). The household's income includes labour, non-labour income and subsidy from recycling, which should be equal to expenditures on consumption, garbage dumping and expected fine for illegal dumping. Then, the household budget constraint becomes

$$a + w(k - g(b) - h(r) - kl) + p_r r = p_x x + p_d d + \pi p_b b$$

The household maximises its utility subject to the budget constraint by choosing d, b, r. From the first-order conditions for maximisation of this objective, household's decision for waste disposal depends on the price of unit-pricing and sum of cost/compensation and labour for illegal and recycling disposal.

Although the labour committed to illegal dumping and recycling is added into the household waste disposal model, the labour committed to legal dumping and disutility from dealing with garbage are disregarded. The labour committed to legal dumping is relatively small. Households in communities with different garbage collection policies may be expected to commit different amounts of labour to classification, storing waste or preparation for dumping. Using only one price for recycling is inappropriate because it's usually variable. In most cases, the expected fine for illegal dumping is not based on the amount dumped. There is no dynamic model for households' three waste disposal options, legal dumping, illegal dumping and recycling.

- Empirical studies from aggregate municipal data

Although a household's disposal decision depends on the price and labour committed to each disposal method, most empirical studies of unit-pricing and recycling policies do so through price or policy dummy variables only.

Due to insufficient quantity or variety of data, some studies of unit-pricing use descriptive statistics on aggregated communities' waste data, including those of Miranda *et al.*, (1994), Seguino *et al.*, (1995), and Miranda and Aldy (1998). These authors grouped communities according to different policy characteristics and compared communities' mean values of per capita garbage and found most communities with unit-pricing have about 20% less waste. However, because of the limitation of the methodology used, these studies cannot separate the reduction caused by unit-pricing from other characteristics of communities.

Miranda *et al.* (1994) found 7 out of 9 communities with unit-pricing decreased landfilled and incinerated waste by 20 to 50%, and all communities saw a 30 to 100% increase in recycling. Communities using average cost pricing had greater reduction in landfill and incinerated waste than two-tier pricing communities. Unit-pricing communities with mandatory or voluntary kerbside recycling programs experienced greater reduction than communities with voluntary drop-off recycling programs. Seguino's paper found per capita waste in unit-pricing (pay-by-the-bag) communities was 56% lower than that in communities without it. Both unit-pricing and mandatory recycling programs in non-unit-pricing communities can significantly decrease garbage. Moreover, net municipal solid waste management costs were lower in unit-pricing communities than in others. Miranda and Aldy (1998) showed most communities had at least 20% reduction in waste and 30% increase in recycling after unit-pricing being adopted, and communities with an average costs pricing system, smaller minimum sized container and higher unit fee reduce waste more. Moreover, these three studies found residents displayed source reduction after unit-pricing and illegal dumping was not significant in these communities.

The most popular method of data analysis in these studies is multivariate regression. This kind of empirical study uses panel or cross-sectional data to determine the unit-pricing policy effect using a multivariate regression model. All studies show unit-pricing policies decrease garbage and increase recycling. The demand elasticity for non-recyclables waste collection service is between -0.12 to -0.39 for American cases (see the upper half of Table 2.1). Note that the estimation from Strathman *et al.* (1995) should be excluded because it is for a tipping fee to landfill rather than unit-pricing on residential solid waste. The estimations from Wertz (1976) and Jenkins (1993) are lower than those by others, which may be explained by the pricing system used. The other three American cases found a higher elasticity (0.2- 0.39) from tag and bag pricing systems. A study in the Netherlands also found a high elasticity (0.71) for a bag system which is even higher than the value for a weight system (0.67) and volume system (0.12) (Dijkgraaf and Gradus, 2004). Callan and Thomas (1997) found towns using unit-pricing without kerbside recycling would increase recycling rate by 6.6 percentage points, towns using unit-pricing and kerbside recycling by 12.1 percentage points, and towns with only kerbside recycling by 4.15 percentage points. Unit-pricing with kerbside recycling has greater impact on recycling.

For garbage (un-sorted or non-recyclables) collection services, Table 2.2 shows most studies found that more people in the household (increase in household size) decreased per capita garbage generation. The coefficient of squared household size being positive means waste generation is an economy of household scale (Podolsky and Spiegel, 1998). Garbage generation showed a positive relation with both the percentage of 18-49 year-old residents and household income, suggesting that increasing income or economic activity raises consumption. The income elasticity is 0.272 and 0.279 in Wertz (1976), 0.57 in Podolsky and Spiegel (1998) and 0.262 in Kinnaman and Fullerton (2000). Dijkgraaf and Gradus (2004) inferred that the reason why the total and un-sorted waste increased with population density is the cost of occupied space increased with population density. In addition, higher temperature (summer), rain, and percentage of owned house in a community generate more garbage.

In Table 2.2, all studies found that unit-pricing (higher price) and kerbside recycling increased recycling. Carroll (1995) analysed the community's per household recycling cost of 57 Wisconsin towns with kerbside recycling. The result shows town's recycling costs decrease when population density is higher and if a town has private-contract collection. The kerbside recycling collection frequency and drop-off program had no significant impact on recycling cost. Besides policy variables, education level and household size had a positive effect on recycling. Small or rural village communities seem have higher recycling rates.

Miranda and Bynum (2002) is the only empirical study of illegal dumping (undesired diversion) which includes littering, burning, dumping in commercial dumpsters, charitable dumping, 'wrong' recycling, and carrying to other jurisdiction (totting). They found that the provision of kerbside yard waste collection, the rural population percentage, and the 18-24 year-old percentage significantly increased illegal dumping. This result shows illegal dumping may not be increased by unit-pricing.

Table 2.1 Empirical studies of unit-pricing with elasticity estimation

Study	Data	Pricing system	Price elasticity of non-recyclables waste	Cross-price elasticity of recycling (weight)
Wertz (1976)	per capita waste of San Francisco and all urban areas in the US	can [a]	$\epsilon_v{}^e$ =-0.15	
Jenkins (1993)	monthly panel of 9 communities in the US (5 with user fee) over 1980-88	tag, bag & can	ϵ_v = -0.12	
Strathman *et al.* (1995)	1984-1991 monthly data of landfilled waste in Portland, the US		$\epsilon_w{}^f$ = -0.45 (tipping fee)	
Podolsky and Spiegel (1998)	1992 cross-section of 159 municipalities in New Jersey, 12 with unit-pricing	tag [b] & bag [c]	ϵ_w = -0.39	
Houtven and Morris (1999)	panel of 39 months and 16 sanitation routes between 1991-4 in Marietta, Georgia	bag & can	ϵ_w = -0.2 (bag)	
Kinnaman and Fullerton (2000)	1991 cross-section of 959 towns in the US 114 with unit-pricing (50 bag system)	bag, tag & can	ϵ_w = -0.28 (bag & tag)	ϵ_w = 0.22 (bag & tag)
Dijkgraaf and Gradus (2004)	penal of 530 communities in the Netherlands over 1998-2000	various	ϵ_w = -0.71 (bag)	ϵ = 0.14 (bag)
Hong *et al.* (1993)	1990 survey of 4306 households in Portland metro. area	can	$\pm{}^g$	>0
Fullerton and Kinnaman (1996)	1992 two-period panel of 75 households in Charlottesville, Virginia	tag	ϵ_w = -0.058	ϵ = 0.073
Hong (1999)	1995 survey of 3017 households in 20 Korea cities	bag	ϵ_v = -0.154	ϵ = 0.457
Hong and Adams (1999)	1993 survey of 944 households in Portland metro. area	can	ϵ_w = -0.013	ϵ = 0.091
Houtven and Morris (1999)	panel of 398 households and 8 observations of each in 1993-4 Marietta, Georgia	bag & can	ϵ_w = -0.26 (bag)	$\pm{}^g$
Linderhof *et al.*(2001)	weekly panel of 3459 households from July 1993 to December 1996 in Oostzaan, the Netherlands	weight [d]	$\epsilon_{ws}{}^h$ = -0.34, $\epsilon_{cs}{}^i$ = -0.26 $\epsilon_{wl}{}^j$ = -1.39, $\epsilon_{cl}{}^k$ = -1.10	

Note: [a] can (or volume) subscription system in which households pay a pre-decided volume for a period; [b] tag (or sticker) system in which households buy a tag/sticker for discarding a specific volume of bag or can; [c] bag system in which households buy an authorized bag for discarding; [d] weight system in which cost is based on the weight of garbage collected; [e] price elasticity in volume change; [f] insignificant impact; [g] price elasticity in weight change; [h] short run non-recyclables; [i] short run compostable; [j] long run non-recyclables; [k] long run compostable.

Source: based on Kinnaman and Fullterton (2001), added to and modified by this research.

Table 2.2 Significant variables of empirical studies with aggregate data

Empirical Study	dependant variable	significant (over 95%) independent variables (except constant)
Jenkins (1993)	garbage per capita (pounds/day)	price per 30 to 32 gallon container (-), average household income (+), mean temperature (+), average precipitation (+), household size (-), % of 18-49 year-old (+), population density (+).
Strathman *et al.* (1995)	landfilled waste per 1000 residents	tipping fee (-), construction employment (+), manufacturing income (-).
Podolsky and Spiegel (1998)	garbage per capita (commercial waste included)	price (-), recycling per household (-), income (+), age (-), household size (-), density (-), rain (+), snow (-), no. of employees per household (+), no. of employees per household^2 (-).
Houtven and Morris (1999)	garbage per household (logged)	March to September (+), no. of customers in sanitation route (+), can system (-), bag system (-).
Kinnaman and Fullerton (2000)	garbage per capita	price (-), income (+), education (-).
Dijkgraaf and Gradus (2004)	total waste generated (logged)	all pricing systems (-), ln(retire) (+), ln(household size) (-), ln(foreigner) (-), city (-), ln(density) (+), own house (+), own flat (-), ln(income) (+).
Dijkgraaf and Gradus (2004)	unsorted waste (logged)	all pricing systems (-), ln(household size) (-), village (-), ln(density) (+), (ln(density))^2 (+), ln(income) (+).
Dijkgraaf and Gradus (2004)	compostable waste (logged)	weight, bag (unsorted & compostable), bag (unsorted), frequency pricing systems (-), ln(retire) (+), ln(household size) (+), ln(foreigner) (-), city (-), (ln(density))^2 (-), own house (+), own flat (-).
Callan and Thomas (1997)	recycling rate	unit-pricing (+), kerbside recycling (+), access state recycling facility (+), education (+), education^2 (-), population (-), population^2 (+), small rural communities (+)
Kinnaman and Fullerton (2000)	recycling per capita	kerbside recycling (+)
Dijkgraaf and Gradus (2004)	recycling (logged)	weight, bag (unsorted & compostable), bag (unsorted), frequency pricing systems (-), ln(retire) (+), city (-), village (+), own flat (-).
Miranda and Bynum (2002)	whether illegal dumping increase	whether provide kerbside yard waste (+), urban population % (-), 18-24 year-old population % (+)

- Empirical studies from household surveys data

Empirical studies from household survey data reveal a low elasticity of non-recyclables dumping, especially in the US case of can/volume system (see lower half of Table 2.1). It was insignificant in Hong *et al.* (1993), 0.058 in Fullerton and Kinnaman (1996), and 0.013 in Hong and Adams (1999). This is much lower than results from bag and weight systems (Hong, 1999; Houtven and Morris, 1999; Linderhof *et al.*, 2001). The cross-price elasticity for recycling is similar.

Although these estimates are for different pricing systems, the difference cannot be explained by estimation methods because two of Hong's papers (1993 and 1999) for the US cases corrected for the disposal price. The differences in elasticity values may be ascribed to the nature of the pricing system and to life styles. The can/volume, tag/sticker and bag system in the US are based on a large standard volume, about 32 gallons (121 litres), which is much larger than the bag system in Japan or Taiwan which uses 10, 20 or 30 litre bags. Households in the large block pricing system decide the disposal volume without direct price signals because the charge of disposal is the same no matter how full the garbage bag or can is. The pricing effect happens on the breakpoints in the collection service payment schedule (Hong *et al.*, 1993). Households use source reduction or recycling to meet the predefined volume. Fullerton and Kinnaman (1996) used direct measure and found a huge discrepancy between the arc-elasticity[13] for volume (0.226) and weight (0.058), which shows households in can/volume systems stomp their waste to decrease the collection payment. Nestor and Podolsky (1998) compared bag and can pricing systems and found the bag system increases kerbside recycling significantly more than the can system. The weight system in the Netherlands resulted in a much higher elasticity over both short and long terms (Linderhof *et al.*, 2001), probably because the pricing unit is kilogram which is smaller than dozens of litres in bag or can system. An important

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[13] When there is no price difference, only zero (flat fee) in advance and one price (unit-pricing) afterward, the elasticity (point-elasticity at unit-pricing price) cannot be obtained but arc-elasticity at mean price (half of unit-pricing price) can be calculated.

result in Hong (1999) is that the source reduction falls (total waste generation increases) when recycling is increased by free kerbside recycling and unit-pricing policies. This result is partially consistent with the household waste disposal model which shows household trade-offs between options.

For garbage (un-sorted or non-recyclables) collection services, most studies found more people in the household (increased household size) increased the household's dumping, and households with more children, infants, women, less elders, and less people staying at home would generate more garbage (Table 2.3). Shaw and Tsai (2002) found both unit-pricing and mandatory recycling can significantly increase household's time spending on recycling but only unit-pricing can decrease garbage dumped. Household income has variable effects on waste generation. It is negative in Fullerton and Kinnaman (1996) but positive in Richardson and Havlicek (1978), Hong *et al.*, (1993), and Hong (1999) (0.242, 0.049 and 0.055). The marginal effect of income is quite small which means garbage generation is income inelastic. Households in urban areas, those with smaller living area, and those having garages are found to generate less garbage. Hong and Adams (1999) found households generate more garbage in Spring. Linderhof *et al.* (2001) found more compostable disposals when temperature was high, which may be ascribed to more yard waste. In this research, he also found that less garbage is generated in the third quarter, which might be the effect of vacations or at least fewer people or less time spent in house.

For recycling activity, most studies found more people in the household (increased household size) would increase the household's recycling, and a household with more income, higher education, and less elderly people would do more recycling (Table 2.3). Households with less full-time working members - which means lower value of time - would do more recycling. In the community without unit-pricing, households don't have money incentives to reduce waste disposal and/or recycle. The time costs of recycling might be a dominant economic consideration. Bruvoll *et al.* (2002) surveyed in Norway and found that sorting at source involves significant extra use of time and energy (*e.g.* using warm water to clean the materials) in the households. Jakus *et al.* (1996) found households respond to the time cost of recycling paper but not glass. Since time cost is the main consideration for household recycling, Shaw and Tsai (2002) used time spent to represent household recycling efforts.

Besides policy (money) incentives and time costs, some households recycle without direct economic incentives. The meta-analysis of 67 empirical studies done by Hornik *et al.* (1995) found that the strongest predictors of recycling are internal facilitators: specifically, consumer knowledge and commitment to recycling best predicts propensity to recycle. Shaw and Tsai (2002) introduced many attitude variables and found that having more recycling knowledge can increase household recycling time, and environmentally friendly attitudes can decrease garbage and increase recycling time, which is consistent with results in Houtven and Morris (1999).

The only empirical study for illegal dumping behaviour with household survey data is Reschovsky and Stone (1994). That research asks whether respondents burned their trash, and showed that unit-pricing had no significant impact on illicit burning but single-family and family in rural area dwellings tended to do so.

Table 2.3 Significant variables of empirical studies with household survey data

Empirical Study	dependant variable	significant (over 95%) independent variables (except constant)
Hong *et al.* (1993)	reported recycling frequency	payment difference (+), value of time (-), household size (+), education (+), home renter (+).
Nestor and Podolsky (1998)	reported recycling volume	price (+), bag system (-), household size (+), income (+), non-minority (-).
Hong and Adams (1999)	recycling weight	payment difference (+), income (+), in Fall (+).
Hong (1999)	reported recycling volume	price (+), total waste (+), value of time (-), housewife's education (+).
Houtven and Morris (1999)	reported recycling participation	income (+), white (+), owner (+), no. of age 25-64 (+), % of full-time working (-), concerning waste (+), bag program (+), can program (+).
Shaw and Tsai (2002)	reported recycling time	mandatory recycling (+), unit-pricing (+), env. friendly attitudes (+), household size (+).
Hong *et al.* (1993)	reported garbage volume	income (+), household size (+), non-white (+), home renter (+)
Fullerton and Kinnaman (1996)	garbage weight	income (-)
Nestor and Podolsky (1998)	reported garbage volume	price (-), household size (+), % of over 65 (-), non-minority (-), owner (-), garbage disposal in household (+).
Hong and Adams (1999)	garbage weight	household size (+), has garage (-), children no. (+), in Spring (+), in Summer (+), in Fall (+).
Hong (1999)	reported total waste volume	recycling rate (+), income (+), household size (+).
Sterner and Bartelings (1999)	garbage weight	difficulties of recycling (+), composting of kitchen waste (-), age (-), staying at home no. (-), living area (+)
Houtven and Morris (1999)	garbage weight	income (+), in urban (-), no. of age 0-5 (+), no. of age 25-64 (+), bag program (-), can program (-).
Salkie *et al.* (2001)	self garbage disposal	travelling cost (-), household size (+).
Linderhof *et al.* (2001)	garbage weight	price (-), lagged dependant (+), household size (+), age (-), age^2 (+), share of female (+), no. of age 0-2 (+), no. of age 2-6 (-), temperature (+), second quarter (-), third quarter (-).
Shaw and Tsai (2002)	reported garbage volume	unit-pricing (-), household size (+), unwilling to reduce (+), env. friendly attitudes (-)
Sterner and Bartelings (1999)	reported compost in house	composting garden waste (+), time consuming (-)
Linderhof *et al.* (2001)	compostable disposal weight	price (-), lagged dependant (+), household size (+), share of female (+), child under 12 (+), temperature (+), third quarter (-), fourth quarter (-)
Reschovsky and Stone (1994)	reported burning trash	recycling program informed (-), graduated degree (-), income (-), single-family dwellings (+), urban (-).

- Empirical studies with recyclable material-specific data

There are fewer empirical studies focusing on recycling than those on garbage, and only Reschovsky and Stone (1994), Sterner and Bartelings (1999), Jenkins, Martinez *et al.* (2003) and Kipperberg (2006) used household material-specific recycling data to analyse the effect of recycling program features and unit-pricing. The summary of these studies is in Table 2.4. The first one surveyed 1422 households in Tompkins County, Ithaca, New York asking them whether they recycle (dichotomous variable). The combination of mandatory recycling and kerbside recycling increased the probability of recycling newspaper and glass by 22 and 37 percent respectively. Kerbside recycling with unit-pricing (tag system) significantly increased the probability of recycling glass, plastic and cardboard but unit-pricing alone had no significant impact on probability of recycling. Respondents who are married, have a higher education level, and include more females in the household recycle more waste. This is similar to studies on aggregate recycling. However, income has a negative effect on glass and plastic recycling, and household size also has a negative effect on newspaper recycling, which contradicts studies on aggregate recycling in Table 2.3. In addition to recycling, this study estimated that income elasticities of solid waste collection demand were 0.23 and 0.22 for volume and weight respectively.

Sterner and Bartelings (1999) surveyed 600 households in 3 Swedish communities, 200 in each, asking them what percentage they recycled for selected materials. The municipality dummies are only significant in glass recycling regression. Eda and Mark have higher recycling percentage than Amal, excluding household variables' effects. Respondents from municipality Eda have the highest average percentage of paper and glass recycling. This result probably because Eda adopted unit-pricing (weight system) and raised the price by 12% during the survey. The previous recycling experience and the ease of recycling have positive effect on most materials.

Jenkins *et al.* (2003) surveyed 1939 middle and upper-middle income households in 20 metropolitan areas with recycling programs in the US asking them what proportion of selected materials be recycled, within pre-selected ranges (0-10%, 11-95% and over 95%). They found both drop-off and kerbside recycling programs significantly increased recycling of all five materials, newspaper, glass bottles, aluminium, plastic bottles and yard waste, and increases for bottles and yard waste were larger, probably because recycling these materials has higher transportation and storage costs. Length of program life also increases the intensity of recycling effort for newspaper and yard waste. The number of materials collected at kerbside has positive effect on newspaper, plastic bottles, and yard waste recycling. Kipperberg (2006) used similar household material-specific recycling intensity survey to study the recycling behaviours in Norway and compare with Jenkins' paper. He found that disposal fee provides higher recycling incentive than it does in the US but recycling options, such as kerbside and drop-off recycling, have lower incentive than they do in the US. Jenkins' paper proposed two explanations for insignificant effect of disposal fee. The respondents of their survey are higher income and the disposal price is too low to affect behaviour, or the volume subscription pricing system provides discontinuous price signals which only make households reduce trash to the pre-decided volume rather than increase recycling.

These empirical studies disagree on whether unit-pricing significantly increases recycling, but got a consistent result that unit-pricing with kerbside recycling has the greater impact on recycling. Both Reschovsky and Jenkins' papers (cases in the US.) found that mandatory recycling did not have significant impact on the level of recycling but Kipperberg's paper (cases in Norway) found it can significantly increase metals and food waste recycling.

Household survey studies use self-reported recycling participation and only two or three recycling proportions are given, which are highly uncertain. The result may be biased if respondents were more likely to be recyclers, or if respondents tend to give high recycling proportions as 'social correct' responses (Reschovsky and Stone, 1994). For example, an English case (Burnley) shows 80% households claiming to recycle paper on survey but the community's recycling rate is only half the national average of 12% (Martin *et al.*, 2006). Reschovsky's paper also found information for recycling and adequate space for storing recyclable materials increase amount recycled for almost every recyclable. However, information and adequate space might be endogenous for respondent's behaviour because households that do not recycle may be more inclined to cite inadequate storage space or lack of information (Podolsky and Spiegel, 1998). The information and ease of recycling variables in Sterner's paper have the endogenous problem as well. Sterner's paper found that households with experience on recycling tend to recycle more for almost every kind of material, but this result cannot be inferred directly to accustoming to recycle because the experience variable also naturally picks up a large share of the relevant individual characteristics.

For socioeconomic variables, these studies found that higher education and elder have significant positive effect on most recyclable materials. Income was only significant for some materials. Finally, characteristics of garbage collection and illegal dumping prevention were not included in these studies.

Table 2.4 Significant variables of empirical studies with material-specific recycling data

Empirical Study	dependant variable	significant (over 95%) independent variables (except constant)
Reschovsky and Stone (1994)	whether recycle paper	informed (+), HS[1] (-), married (+), high school (+), postgraduate (+), hours of paid labour/ week (-), MR[2] * KR[3] (+), MR*KR*TA[4] (+).
	whether recycle glass	DO[5] within 5 miles (+), storage space (+), informed (+), married (+), female (+), high school (+), college (+), postgraduate (+), income (-), MR*KR (+), KR*TA (+), MR*KR*TA (+).
	whether recycle plastic	DO within 5 miles (+), storage space (+), informed (+), female (+), college (+), postgraduate (+), income (-), KR*TA (+).
	whether recycle cardboard	DO within 5 miles (+), storage space (+), informed (+), under age 30 (+), age 30-44 (+), college (+), postgrad. (+), KR (+), KR*TA (+).
	whether recycle metal	DO within 5 miles (+), not knowing where is DO (-), storage space (+), informed (+), married (+), college (+)
	whether composting	HS (+), married (+), under age 30 (-), age 30-44 (-), high school (+), college (+), post graduate (+), TA (+).
Sterner and Bartelings (1999)	glass recycling intensity	previous experience (+), ease of recycling (+), in town Eda (+), in town Mark (+).
	newspaper recycling int.	previous experience (+), information (+), change in buying behaviour (+), HS (+), ease of recycling (+), age (-).
	refundable recycling int.	previous experience (+), age (+).
	batteries recycling int.	previous experience (+), ease of recycling (+), attitude about importance of waste (+).
	hazardous waste rec. int.	previous experience (+).
	househ. machines rec. int.	previous experience (+).
	textiles recycling intensity	previous experience (+), HS (-), attitude about importance of waste (+).
Jenkins *et al.* (2003)	paper recycling intensity	DO (+), KR (+), no. of materials in KR (+), RP[6] is 1-2 years (+), RP is over 2 years (+), income (+), age (+), education level (+).
	glass bottles recycling int.	DO (+), KR (+), HS (+), owner (+), education level (+).
	aluminium recycling int.	DO (+), KR (+), income $10000-$14999 (+), age (+), owner (+), education level (+).
	plastic bottles recycling int.	DO (+), KR (+), no. of materials in KR (+), RP is 1-2 years (+) income (+), age (+), single family (+).
	yard waste recycling int.	DO (+), KR (+), no. of materials in KR (+), RP is over 2 years (+), population density (-), HS (+), single family (+), age (+), owner (+).

To be continued.

Table 2.4 (continued) Significant variables of empirical studies with material-specific recycling data

Empirical Study	dependant variable	significant (over 95%) independent variables (except constant)
Kipperberg (2006)	paper recycling intensity	disposal fee (voluntary) (+), age (+).
	glass recycling intensity	age (+).
	metals recycling intensity	disposal fee (mandatory) (+), no. of KR materials (+), age (+).
	plastic recycling intensity	disposal fee (voluntary) (+), no. of KR materials (+), population > 100000 (-).
	food waste recycling int.	disposal fee (voluntary) (+),disposal fee (mandatory) (+), KR (+), MR+KR (+).

Note: [1] household size; [2] mandatory recycling; [3] kerbside recycling; [4] unit-pricing (tag system) on garbage; [5] recycling drop-off centre; [6] recycling program.

2.3 Policy Simulation

The variables obtained from empirical studies can be used for policy simulations. Morris and Holthausen (1994) built a household solid waste generation model and calibrated it with per household data of expenditures and waste in Perkasie, Pennsylvania. From this model, they estimated the arc-elasticity of price changing from $0.05 to $0.075/lb to be 0.51 and from $0.75 to $0.10/lb to be 0.60. However, if the data contains variation in waste disposal prices, elasticities can be estimated directly. Using the estimated price elasticities, it is possible to simulate the household waste generation or recycling under various policy combinations.

2.4 Literature Review Summary

The price elasticity of garbage discards is between -0.2 to -0.28 in most multivariate regression studies for bag and tag system, which means this kind of unit-pricing decreases garbage but is quite inelastic. Almost every empirical study found kerbside recycling can promote recycling. However, most estimates based on household survey data were lower than those based on aggregate data. Besides the policy variables, empirical studies also found higher temperature, households with more income and household size would increase household's waste generation. Households with more income, education, time of staying in house, and environmental friendly attitudes favour greater recycling. These findings are consistent with expectations and with household waste disposal models.

According to the review of household waste disposal models, households have at least three disposal options, the decision depending on the cost of each option including price and the labour cost of disposal. However, previous studies still lack many important features and factors including:

a. Since the value of time significantly effected recycling, which means the labour for recycling is significant, the labour for dumping should be included as well.

b. Some papers, like that by Kinnaman and Fullerton (2000), used population density as a proxy for difficulty of illegal dumping and got insignificant result. However, the direct illegal dumping prevention policies, such as fine, enforcement and collection rules *etc.*, are all absent in previous studies.
c. For garbage generation, Dijkgraaf and Gradus (2004) referred to the significant positive coefficient of population density as increasing cost of storing. The coefficient of having garage is found significant negative (Hong and Adams, 1999). These results infer households may have another disposal option- storing or composting in house, which did not include in pervious household model.
d. Aside from a few material-specific recycling studies, the literature surveyed above regards garbage and recyclable materials as uniform goods and uses aggregate amounts of recyclable materials for empirical evaluation. Nevertheless, every material is found to have unique effects of drop-off and kerbside recycling policies (Jenkins *et al.*, 2003). In most countries, different recycling policies are applied to distinct materials, such as deposit-refund system on bottles, trade of scrap paper, mandatory recycling on hazardous waste and so on, which should be included in material-specific recycling studies to design adequate systems for each material.

All of these drawbacks will be treated in this thesis, and some will be corrected.

Chapter 3 Household Waste Disposal Models

In order to study the characteristics of different waste management policies, this chapter adapts models developed by Kinnaman and Fullterton (2001) and Smith (1972). However, issues not fully considered before, such as the fourth disposal option - storing or composting, recycling-specific models and the labour costs of legal dumping, illegal dumping and recycling, are all discussed in models of this chapter. Individual household models and social model, and the policy implications of them, are also discussed.

3.1 Background of Building Household Waste Disposal Models

According to the literature review, the labour for dumping has not been considered in previous literature. However, there are two main reasons why dumping labour is important for households in some highly populated cities and why, therefore, it should be considered in household waste disposal models. Firstly, most households in Taiwanese and Japanese cities live in flats/apartments or high-rise building and have to bring their garbage down to kerbside garbage collection points which may be around a block away from their building. Automatic waste collection systems are very rare because dumpsters which usually work with automatic collection systems are not allowed for residential waste collection in some cities. Secondly, households in flats/apartments have limited storage capacity even for temporary waste storing probably because of the smaller living space and/or high garbage collection frequency in some cities. When the amount of garbage is larger, a household would need more labour for temporary storing and preparing disposal.

Labour for garbage disposal is thus required by households, the same is true for recycling. In most households in Taiwanese and Japanese cities, the wife, children or elderly relatives in the household take care of waste disposal. That takes their time for household production.

3.2 Models for a Household

A household's solid waste management decision can be modelled in many ways. In a city with n households, at time t, the representative household (i) consumes goods (x_t), a portion of which (ax_t) becomes useless goods (potential waste). If the city has a solid waste and recycling collection service, a household's waste must either be discarded as garbage for collection (d_t), recycling (r_t) or dumped illegally (b_t)[14]. Waste not discarded in these three ways must be stored or composted (s_t) in house. If waste is composted, it has decomposition rate (ϕ). The waste in house can still be discarded in the future. These together imply that the change of s, or mass constraint, is

$$\partial s / \partial t = ax_t - d_t - b_t - r_t - \phi s_t \qquad (3\text{-}1)$$

If the waste is durable or stored without composting, the decomposition rate (ϕ) is zero, which implies that the mass constraint becomes

$$ax_t - d_t - b_t - r_t - s_t = 0 \qquad (3\text{-}2)$$

Although storing/compost option is added into the model, the storage capacity in most dwellings in city area where empirical study will be taken is very limited. Assuming that the waste accumulation doesn't transfer to successive time periods, household waste disposal behaviour will be modelled as time-static choice.

The household obtains utility from consumption, and disutility from storing waste in the house because, for example, it has foul odour or takes space. The aggregate level of illegal dumping ($B_t = \sum_{i=1}^{n} b_t^i$) imposes a cost on all households, in terms of the disutility of odour, sight, the increased risk of pests and diseases and so on. Assume that the marginal utility of consumption, the disutility of storing garbage and the disutility of illegal dumping are diminishing, which means $u_x > 0$, $u_{xx} < 0$, $u_s < 0$, $u_{ss} < 0$, $u_B < 0$ and $u_{BB} < 0$. Illegal dumping is a public non-depletable externality. If the household's

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[14] Define as any waste disposal outside a resident's house but not via municipal garbage and recycling collection services.

discount rate is δ, the i household's utility is

$$\int_{t=0}^{T} u_t^i(x_t, s_t, B_t)e^{-\delta t}dt \tag{3-3}$$

Assume that the household labour time endowment is L and that the household spends Ld, Lb, Lr and Ls on legal dumping, illegal dumping, recycling and composting (classifying, preparing, bringing materials to discarding points and composting). Assume that the labour committed to waste disposal is a function of the amounts, $Ld(d)$, $Lb(b)$, $Lr(r)$ and $Ls(s)$. The marginal effect of dumping amount is positive and diminishing, implying that $Ld_d > 0$ and $Ld_{dd} < 0$. However, because the household's budget constraint is different under different waste management policies, so is the model of household waste disposal.

3.2.1 The household model with flat fee garbage collection services

Marginal costs for garbage and recycling dumping are zero when prices are not based on the amount of waste disposed of (disposal is either free or subject to a flat fee). The first model considers a household in a high population density area in which composting is not available. Waste can only be disposed or stored in house. Storing waste is assumed to require no labour and the decomposition rate is zero. Therefore, given the price for consumption (p_x) and wage for labour (w), the household budget constraint becomes

$$w(L - Ld(d_t) - Lb(b_t) - Lr(r_t)) = p_x x_t \tag{3-4}$$

The household maximizes its utility (3-3) subject to the budget constraint (3-4) and mass constraint (3-2) by choosing x_t, d_t, b_t, r_t and s_t. The Lagrangian function for this system is

$$L_h = u^i(x_t, s_t, B_t) +$$
$$\lambda_1[w(L - Ld(d_t) - Lb(b_t) - Lr(r_t)) - p_x x_t] + \lambda_2(ax_t - d_t - b_t - r_t - s_t)$$

while the first-order conditions for optimization of the Lagrangian function include

$$u_x^i - p_x\lambda_1 + a\lambda_2 = 0 \tag{3-5}$$
$$w(Ld_{dt})\lambda_1 + \lambda_2 = 0 \tag{3-6}$$
$$-u_B^i + w(Lb_{bt})\lambda_1 + \lambda_2 = 0 \tag{3-7}$$

$$w(Lr_{rt})\lambda_1 + \lambda_2 = 0 \tag{3-8}$$

$$u_s^i - \lambda_2 = 0 \tag{3-9}$$

$$ax_t - d_t - b_t - r_t - s_t = 0 \tag{3-2}$$

$$w(L - Ld(d_t) - Lb(b_t) - Lr(r_t)) - p_x x_t = 0 \tag{3-4}$$

The second derivative of L_h on x_t, d_t, r_t and s_t are u_{xx}^i, $w(Ld_{dd})\lambda_1$, $w(Lr_{rr})\lambda_1$ and u_{ss}^i. λ_1 is the multiplier of budget constraint which is the marginal utility of income (the shadow price of income) and is positive. Replacing the λ_2 with u_s^i (Eq. 3-9), λ_1 is equal to $(au_s^i + u_x^i)/p_x$. Because the wage (w) must be positive, and u_{xx}^i, Ld_{dd}, Lr_{rr} and u_{ss}^i are negative, these second derivatives ensure that Eq. 3-5, 3-6, 3-8 and 3-9 can maximise L_h. The second derivative of L_h on b is $-u_{BB}^i + w(Lb_{bb})\lambda_1$, which is negative only when $u_{BB}^i > w(Lb_{bb})\lambda_1$. With this constraint, a household's utility can be maximised, and the first-order conditions have following interpretations.

a. Equation 3-5 shows that when a household pays the price (p_x) to consume a marginal unit of goods, it gets marginal utility (u_x^i) plus a unit of waste.
b. Equations 3-6 and 3-8 show that a household has to spend labour cost, $w(Ld_{dt})\lambda_1$, to discard a unit of waste by legal dumping or $w(Lr_{rt})\lambda_1$ for recycling a unit of waste.
c. Because illegal dumping is a public non-depletable externality, u_B^i is the disutility from a household increasing a unit of aggregate illegal dumping. Equation 3-7 shows that when a household spends labour, $w(Lb_{bt})\lambda_1$, to discard a unit of waste by illegal dumping, that also generates disutility from increasing aggregate illegal dumping (u_B^i) to itself.
d. From Equation 3-9, the marginal change of useless goods amounts (λ_2) should be equal to u_s^i which is the marginal cost of storing a unit of waste in house.
e. The equilibrium condition for a household's waste disposals can be found by Equation 3-6, 3-7, 3-8 and 3-9, which is

$$w(Ld_{dt}) = w(Lb_{bt}) - \frac{u_B^i}{\lambda_1} = w(Lr_{rt}) = -\frac{u_s^i}{\lambda_1} \tag{3-11}$$

This equilibrium condition shows that the equilibrium is achieved when a household's marginal total cost on each disposal option is equal.

When composting is available, the household budget constraint becomes

$$w(L - Ld(d_t) - Lb(b_t) - Lr(r_t) - Ls(s_t)) = p_x x_t \tag{3-4a}$$

The problem now takes the form:

$$L_h = u^i(x_t, s_t, B_t) +$$
$$\lambda_1[w(L - Ld(d_t) - Lb(b_t) - Lr(r_t) - Ls(s_t)) - p_x x_t] + \lambda_2(ax_t - d_t - b_t - r_t - \phi s_t)$$

The first-order conditions for x_t, d_t, b_t and r_t are exactly the same as Equations 3-5, 3-6, 3-7 and 3-8, but for s_t becomes

$$-u^i_s + w(Ls_{st})\lambda_1 + \phi\lambda_2 = 0 \tag{3-9a}$$

$$\dot{\lambda}_2 = \lambda_2\delta - (-\phi) \tag{3-10a}$$

Equation 3-9a shows that when a household uses labour, $w(Ls_{st})\lambda_1$, to compost a unit of waste, that also generates disutility (u^i_s) to itself. The second derivative of L_h on s is $-u^i_{ss} + w(Ls_{ss})\lambda_1$, which is negative only when $u^i_{ss} > w(Ls_{ss})\lambda_1$. With this constraint, a household's utility can be maximised, and the equilibrium condition between disposals becomes

$$w(Ld_{dt}) = w(Lb_{bt}) - \frac{u^i_B}{\lambda_1} = w(Lr_{rt}) = \left(w(Ls_{st}) - \frac{u^i_s}{\lambda_1}\right) / \phi \tag{3-11a}$$

This equilibrium condition (Eq. 3-11a) is similar to the previous one (Eq. 3-11) except for the marginal cost of composting or storing. Compared with storing, composting demands household labour of $w(Ls_{st})$ but benefits by reducing a part (ϕ) of stored waste.

These two models, models with and without composting option, support the following propositions.

I. In a town with only flat fee kerbside garbage collection service, a household would have only a small incentive to illegal dumping, recycling, composting and storing because these options have higher marginal cost than legal dumping which only contains labour for bring garbage to kerbside.

II. In a city with flat fee kerbside garbage and recycling collection services, a household recycles more waste than those without kerbside recycling does because kerbside recycling lowers the labour for carrying recyclables.

III. In the city where composting is not available, a household with higher wages (w) stores more waste than those with lower wages because dumping and recycling demand more labour than storage (from Eq. 3-11).

3.1.4 The household model with unit-pricing policy on waste collection

Some waste management authorities want to internalise the externalities of garbage collection. Given prices for garbage and recycling collection are p_d and p_r. When composting is unavailable for the household, the budget constraint becomes

$$w(L - Ld(d_t) - Lb(b_t) - Lr(r_t)) = p_x x_t + p_d d_t + p_r r_t \qquad \text{(3-4b)}$$

The Lagrangian function is

$$L_h = u^i(x_t, s_t, B_t) +$$
$$\lambda_1 [w(L - Ld(d_t) - Lb(b_t) - Lr(r_t)) - p_x x_t - p_d d_t - p_r r_t] + \lambda_2 (a x_t - d_t - b_t - r_t - s_t)$$

and the first-order conditions for x_t, b_t and s_t are exactly the same as for Equations 3-5, 3-7 and 3-9, but Equation 3-6 and 3-8 become

$$(w(Ld_{dt}) + p_d)\lambda_1 + \lambda_2 = 0 \qquad \text{(3-6b)}$$

$$(w(Lr_{rt}) + p_r)\lambda_1 + \lambda_2 = 0 \qquad \text{(3-8b)}$$

The second derivative of L_h on d_t and r_t are $w(Ld_{dd})\lambda_1 < 0$ and $w(Lr_{rr})\lambda_1 < 0$ which ensure Eq. 3-6b and 3-8b can maximise L_h. Equation 3-6b and 3-8b show that the marginal cost of household dumping includes both labour and the price of collection. When composting is available, the first-order condition for s_t is the same as in with Equation 3-9a. The equilibrium conditions under flat fee and unit-pricing policies are listed in Table 3.1A.

Equilibrium conditions in Table 3.1A have some policy implications. Assume that a household's legal dumping level is $d*$ whilst its illegal dumping is $b*$. The equilibrium condition between legal and illegal dumping is $w(Ld_{d*}) = w(Lb_{b*}) - (u^i_{B*} / \lambda_1)$. From proposition I, $w(Ld_{d*})$ is small and $b*$ is close to zero. When the unit-price, p_d, is applied, the household's dumping is d' and illegal dumping is b', $w(Lb_{b'}) - (u^i_{B'} / \lambda_1) > w(Lb_{b*}) - (u^i_{B*} / \lambda_1)$ because $p_d + w(Ld_{d'}) > w(Ld_{d*})$. Since $\partial Ld / \partial d > 0$, the household engages in more illegal dumping than before ($b' > b*$). Using this method, two propositions can be found in Table 3.1A.

IV. A household under unit-pricing policy (garbage and/or recycling collection) does more illegal dumping than under a flat fee because the marginal cost of dumping and/or recycling are increased by unit-pricing.

V. A household under a unit-pricing policy composts or stores more waste than under a flat fee because the marginal cost of dumping and/or recycling are increased in unit prices.

Table 3.1A Equilibrium conditions under various solid waste policies

waste management policy	equilibrium conditions
between legal dumping (d_t) and illegal dumping (b_t)	
flat fee	$w(Ld_{dt}) = w(Lb_{bt}) - (u_B^i / \lambda_1)$
unit-pricing on d_t and r_t	$p_d + w(Ld_{dt}) = w(Lb_{bt}) - (u_B^i / \lambda_1)$
between illegal dumping (b_t) and recycling (r_t)	
flat fee	$w(Lb_{bt}) - (u_B^i / \lambda_1) = w(Lr_{rt})$
unit-pricing on d_t and r_t	$w(Lb_{bt}) - (u_B^i / \lambda_1) = w(Lr_{rt}) + p_r$
between legal dumping (d_t) and recycling (r_t)	
flat fee	$w(Ld_{dt}) = w(Lr_{rt})$
unit-pricing on d_t and r_t	$p_b + w(Ld_{dt}) = w(Lr_{rt}) + p_r$
between storing (s_t) and legal dumping (d_t)	
flat fee	$w(Ld_t) = -u_s^i / \lambda_1$
unit-pricing on d_t and r_t	$p_b + w(Ld_t) = -u_s^i / \lambda_1$
between composting (s_t) and legal dumping (d_t)	
flat fee	$w(Ld_t) = (w(Ls_t) - (u_s^i / \lambda_1)) / \phi$
unit-pricing on d_t and r_t	$p_b + w(Ld_t) = (w(Ls_t) - (u_s^i / \lambda_1)) / \phi$

In proposition **IV**, households under unit-pricing on garbage collection do more illegal dumping. Therefore, some authorities apply penalties for illegal dumping and maybe provide free recycling collection ($p_r = 0$). Assume the nominal fine for illegal dumping is p_b and the chance of being prosecuted is π which is function of enforcement (*Eb*) and dumping amount (*b*). The marginal effect of illegal dumping and enforcement on π are positive and diminishing, such as $\pi_b > 0$ and $\pi_{bb} < 0$. When composting is unavailable for the household, the budget constraint becomes

$$w(L - Ld(d_t) - Lb(b_t) - Lr(r_t)) = p_x x_t + p_d d_t + \pi(Eb, b_t) p_b + p_r r_t \qquad \text{(3-4c)}$$

The Lagrangian function is

$$L_h = u^i(x_t, s_t, B_t) +$$
$$\lambda_1 [w(L - Ld(d_t) - Lb(b_t) - Lr(r_t)) - p_x x_t - p_d d_t - \pi(Eb, b_t) p_b - p_r r_t] +$$
$$\lambda_2 (a x_t - d_t - b_t - r_t - s_t)$$

The first-order conditions for x_t, d_t, r_t and s_t are exactly the same as in

Equations 3-5, 3-6b, 3-8b and 3-9, but Equation 3-7 becomes

$$-u_B^i + \left(w(Lb_{bt}) + \pi_{bt}p_b\right)\lambda_1 + \lambda_2 = 0 \qquad (3\text{-}7c)$$

The second derivative of L_h on b_t is $-u_{BB}^i + \left(w(Lb_{bb}) + \pi_{bb}p_b\right)\lambda_1$, which is negative only when $\left(w(Lb_{bb}) + \pi_{bb}p_b\right)\lambda_1 < u_B^i$. With this constraint, a household's utility can be maximised.

When composting is available, the first-order condition for s_t is the same as in Equation 3-9a. The equilibrium conditions between composting, storing and legal dumping are the same as Table 3.1A. The equilibrium conditions for unit-pricing with penalties for illegal dumping and free recycling are listed in Table 3.1B. Comparing the equilibrium conditions in Table 3.1A and 3.1B, yields the following proposition.

VI. If the marginal expected fine ($\pi_b p_b$) is the same as the price of unit-pricing (p_d), the equilibrium condition between legal and illegal dumping is the same as under flat fee. With this condition, a household would not increase illegal dumping after unit-pricing is adopted.

Assume that a household's dumping is d^* and recycling is r^* when household's utility is maximised under flat fee policy. The equilibrium condition between dumping and recycling is $w(Ld_{d^*}) = w(Lr_{r^*})$. From proposition **I**, r^* is small. When the unit-pricing price, p_d, is applied and the household's dumping is d' and recycling is r', $w(Lr_{r'}) > w(Lr_{r^*})$ because $p_d + w(Ld_{d'}) > w(Ld_{d^*})$. This results in the following proposition.

VII. When policies of unit-pricing on garbage collection, fining illegal dumping and free recycling collection are adopted, a household recycles more waste than it does in the flat fee policy.

Table 3.1B Equilibrium conditions under various solid waste policies

solid waste policy	equilibrium conditions
between legal dumping (d_t) and illegal dumping (b_t)	
flat fee	$w(Ld_{dt}) = w(Lb_{bt}) - (u_B^i / \lambda_1)$
unit-pricing [1, 2]	$p_d + w(Ld_{dt}) = w(Lb_{bt}) - (u_B^i / \lambda_1) + \pi_{bt} p_b$
between illegal dumping (b_t) and recycling (r_t)	
flat fee	$w(Lb_{bt}) - (u_B^i / \lambda_1) = w(Lr_{rt})$
unit-pricing [1]	$\pi_{bt} p_b + w(Lb_{bt}) - (u_B^i / \lambda_1) = w(Lr_{rt}) + p_r$
unit-pricing [2]	$\pi_{bt} p_b + w(Lb_{bt}) - (u_B^i / \lambda_1) = w(Lr_{rt})$
between legal dumping (d_t) and recycling (r_t)	
flat fee	$w(Ld_{dt}) = w(Lr_{rt})$
unit-pricing [1]	$p_b + w(Ld_{dt}) = w(Lr_{rt}) + p_r$
unit-pricing [2]	$p_b + w(Ld_{dt}) = w(Lr_{rt})$

Note: [1] unit-pricing is applied on d_t and r_t, and fine on b_t; [2] unit-pricing is applied on d_t, fine on b_t, and free kerbside recycling is provided ($p_r = 0$).

The equilibrium conditions in Table 3.1A and Table 3.1B show how policies influence the household's waste disposal choices, but the function of each disposal and policy variables must be found by solving the optimisation system. Because the effort for legal, illegal and recycling dumping are functions of the amount of waste disposal, the function forms can be assumed to be $Ld = 0.5\alpha d^2$, $Lb = 0.5\beta b^2$ and $Lr = 0.5\gamma r^2$. α, β and γ are legal dumping, illegal dumping and recycling labour factors. Many papers including Kinnaman and Fullterton (2001) and Shaw and Tsai (2002) have a similar quadratic assumption for function form of labour cost. The first-order conditions for x_t, d_t, r_t and s_t, Eq. 3-5, 3-6b, 3-7c, 3-8b, and 3-9, become:

$$u_x^i - p_x \lambda_1 + a\lambda_2 = 0 \tag{3-5}$$

$$(w\alpha d_t + p_d)\lambda_1 + \lambda_2 = 0 \tag{3-6b'}$$

$$-u_B^i + (w\beta b_t + \pi_{bt} p_b)\lambda_1 + \lambda_2 = 0 \tag{3-7c'}$$

$$(w\gamma r_t + p_r)\lambda_1 + \lambda_2 = 0 \tag{3-8b'}$$

$$u_s^i - \lambda_2 = 0 \tag{3-9}$$

Solving the first order conditions yields the household waste disposal choices which are summarised by:

$$d_t = \frac{\psi - p_d}{w\alpha}, \quad b_t = \frac{\psi - \pi_{bt} p_b + u_B^i}{w\beta}, \quad r_t = \frac{\psi - p_r}{w\gamma} \qquad \text{(3-12)}$$

The ψ in Eq. 3-12 is $\left(-u_s^i p_x\right)/\left(u_x + a u_s\right)$ which is the marginal disutility of storing useless items measured in the income's shadow price. Each waste disposal decreases as its tariff ($p_d, \pi_{bt} p_b, p_r$), wage (w) and/or labour factor (α, β, γ) increased.

3.2.3 The household model with mandatory recycling policy

In order to promote recycling, some cities adopt mandatory recycling policy with fines for households dumping recyclable materials as non-recyclable garbage. Assume that the chance of being prosecuted (μ) increases with enforcement (*Er*), and decreases with recycling (1/*r*), and the fine for insufficient recycling p_m. To prevent illegal dumping, fining of illegal dumping may be applied. When composting is unavailable for the household, the budget constraint becomes

$$w\left(L - Ld(d_t) - Lb(b_t) - Lr(r_t)\right) = p_x x_t + \mu\left(Er, \frac{1}{r_t}\right) p_m + \pi\left(Eb, b_t\right) p_b = 0 \qquad \text{(3-4e)}$$

The Lagrangian function is

$$L_h = u^i\left(x_t, s_t, B_t\right) +$$
$$\lambda_1\left[w\left(L - Ld(d_t) - Lb(b_t) - Lr(r_t)\right) - p_x x_t - \mu\left(Er, \frac{1}{r_t}\right) p_m - \pi\left(Eb, b_t\right) p_{b_t}\right] +$$
$$\lambda_2\left(a x_t - d_t - b_t - r_t - s_t\right)$$

The first-order conditions for x_t, d_t, b_t and s_t are exactly the same as in Equations 3-5, 3-6, 3-7c and 3-9, but Equation 3-8 and the equilibrium condition becomes

$$\left(w\left(Lr_{rt}\right) - \frac{\mu_{rt}}{r_t^2} p_m\right)\lambda_1 + \lambda_2 = 0 \qquad \text{(3-8e)}$$

The second derivative of L_h on r_t is $\left(w\left(Lr_{rr}\right) - 2\mu_{rr}/r^3\right)\lambda_1$, which is negative only when $w\left(Lr_{rr}\right) < \left(2\mu_{rr}/r^3\right)$. With this constraint, a household's utility can be maximised. The expected fine decreases as more recycling and the marginal cost of recycling is decreased. When the composting is available, the first-order condition for s_t is the same as Equation 3-9a. The equilibrium conditions under various solid waste policies are listed in Table 3.1C.

Table 3.1C Equilibrium conditions under various solid waste policies

solid waste policy	equilibrium conditions
between legal (d_t) and illegal dumping (b_t)	
flat fee	$w(Ld_{dt}) = w(Lb_{bt}) - (u_B^i / \lambda_1)$
unit-pricing (fine on b and $p_r = 0$)	$p_d + w(Ld_{dt}) = w(Lb_{bt}) - (u_B^i / \lambda_1) + \pi_{bt} p_b$
mandatory recycling	$w(Ld_{dt}) = w(Lb_{bt}) - (u_B^i / \lambda_1) + \pi_{bt} p_b$
between illegal dumping (b_t) and recycling (r_t)	
flat fee	$w(Lb_{bt}) - (u_B^i / \lambda_1) = w(Lr_{rt})$
unit-pricing (fine on b and $p_r = 0$)	$\pi_{bt} p_b + w(Lb_{bt}) - (u_B^i / \lambda_1) = w(Lr_{rt})$
mandatory recycling	$\pi_{bt} p_b + w(Lb_{bt}) - (u_B^i / \lambda_1) = w(Lr_{rt}) - \mu_{rt} p_m / r_t^2$
between legal dumping (d_t) and recycling (r_t)	
flat fee	$w(Ld_{dt}) = w(Lr_{rt})$
unit-pricing (fine on b and $p_r = 0$)	$p_b + w(Ld_{dt}) = w(Lr_{rt})$
mandatory recycling	$w(Ld_{dt}) = w(Lr_{rt}) - \mu_{rt} p_m / r_t^2$
between storing (s_t) and recycling (r_t)	
flat fee	$-u_s^i / \lambda_1 = w(Lr_{rt})$
unit-pricing (fine on b and $p_r = 0$)	$-u_s^i / \lambda_1 = w(Lr_{rt})$
mandatory recycling	$-u_s^i / \lambda_1 = w(Lr_{rt}) - \mu_{rt} p_m / r_t^2$
between composting (s_t) and recycling (r_t)	
flat fee	$(w(Ls_t) - (u_s^i / \lambda_1)) / \phi = w(Lr_t)$
unit-pricing (fine on b and $p_r = 0$)	$(w(Ls_t) - (u_s^i / \lambda_1)) / \phi = w(Lr_t)$
mandatory recycling	$(w(Ls_t) - (u_s^i / \lambda_1)) / \phi = w(Lr_{rt}) - \mu_{rt} p_m / r_t^2$

The equilibrium conditions in Table 3.1C support following proposition.

VIII. A household under mandatory recycling (including fines for illegal dumping) recycles more waste, has less illegal dumping, and stores/composts less waste than under a flat fee policy, because the marginal cost of recycling is decreased by the expected value of the fine ($\mu_{rt} p_m / r_t^2$) and the marginal cost of illegal dumping is increased by expected fine ($\pi_{bt} p_b$).

Assume the function form of labour cost is also quadratic. Then, Eq.

3-8e becomes

$$\left(w\gamma r_t - \frac{\mu_r}{r_t^2} p_m\right)\lambda_1 + \lambda_2 = 0 \qquad \text{(3-8e')}$$

The function of each disposal and policy option can be found by solving the first-order condition set, Eq. 3-5, 3-6b', 3-7c', 3-8e', and 3-9. Eq. 3-8e' can be further sorted out as

$$r_t^2 (w\gamma r_t - \psi) = \mu_r p_m \qquad \text{(3-8e")}$$

The household's recycling (r_t) is function of the marginal fine ($\mu_r p_m$), the wage rate (w), recycling labour factor (γ) and the disutility of storing waste measured by the shadow value of income (ψ) ($r_t = f(w, \gamma, \mu_r p_m, \psi)$).

3.2.4 The model with more disposal options

In many cases, households have more than four disposal options, including recycling, such as kerbside recycling, recycling (reuse) in house and selling to private collectors. Assume waste can be recycled into K recycling streams (r_{kt}) and the price for each is (p_{rk}). The mass constraint becomes

$$ax_t - d_t - b_t - \sum_{k=1}^{K} r_{kt} - s_t = 0 \qquad \text{(3-2f)}$$

The labour for recycling is assumed to be function of the total amount, $Lr\left(\sum r_k\right)$. Then the budget constraint becomes

$$w\left(L - Ld(d_t) - Lb(b_t) - Lr\left(\sum r_{kt}\right)\right) = p_x x_t + \sum p_{rk} r_{kt} + p_d d_t + \pi(Eb, b_t) p_b \qquad \text{(3-4f)}$$

The first-order conditions for x_t, d_t, b_t and s_t are exactly the same as Equation 3-5, 3-6, 3-7c and 3-9, but Equation 3-8 becomes

$$\left(w(Lr_{rkt}) + p_{rk}\right)\lambda_1 + \lambda_2 = 0 \qquad \text{(3-8f)}$$

This condition is the same as Eq. 3-8b except for the subscript of specific recyclable material. A household's recycling behaviour depends on each material's marginal recycling labour cost and tariff.

This model shows the various recycling ways make equilibrium change. For example, a household chooses between kerbside recycling and recycling in house (on-site recycling). The price for kerbside recycling is p_{KR}. The equilibrium condition becomes $w(Lr_{HO}) = w(Lr_{KR}) + p_{KR}$. If the labours for both are similar, a household does more recycling in house. Labours of recycling, such as garbage classification and reuse, depend on the nature of material and knowledge/technology of doing.

3.2.5 The model for specific waste materials

Most previous models treat waste and recycling as a uniform material. However, in most cities, there are many different recycling policies applied on materials, such as deposit-refund systems on glass bottles, trade in scrap paper, mandatory recycling on hazardous waste and so on. Assume that there are J kinds of consumption goods (x_j) and each of them can be disposed by legal (d_j), illegal (b_j), recycling (r_j) and storing (s_j) after be used. The mass constraint becomes

$$a_j x_{jt} - d_{jt} - b_{jt} - r_{jt} - s_{jt} = 0 \tag{3-1g}$$

Assume that a household spends a certain part of its income on a kind of consumption good (I_j) which is independent of waste treatment labour. The total cost, including tariff and labour, of dumping a particular kind of waste via legal (Cdj), illegal (Cbj) and recycling (Crj) options are function of the quantity of waste involved. Then the budget constraint then becomes

$$I_j = p_{jx} x_{jt} + Crj(r_{jt}) + Cdj(d_{jt}) + Cbj(b_{jt}) \tag{3-4g}$$

The Lagrangian function for this system is

$$L_h = u_j^i(x_{jt}, s_{jt}, B_{jt}) +$$
$$\lambda_1 [I_j - Crj(r_{jt}) - Cdj(d_{jt}) - Cbj(b_{jt}) - p_{jx} x_{jt}] + \lambda_2 (a_j x_{jt} - d_{jt} - b_{jt} - r_{jt} - s_{jt})$$

The first-order conditions are similar to those obtained before and the equilibrium condition becomes

$$Cdj_{dj} = Cbj_{bj} - \frac{u_{Bj}^i}{\lambda_1} = Crj_{rj} = -\frac{u_{sj}^i}{\lambda_1} \tag{3-11g}$$

A household's waste disposal choice is based on marginal cost of each option, even for one material. This result has a number of implications for household responses to various policies applied on recycling materials. For example:

a. When unit-pricing garbage collection and free kerbside recycling are provided, a household prefers to recycle materials which have low labour cost of recycling and lower than the disposal price.
b. The deposit-refund system on plastic and glass bottle makes the price for

recycling bottles negative, but the labour to bring bottles to recycling points is generally higher than where there is kerbside recycling. Usually the subsidy or the deposit on the material is small. Thus, the labour required for recycling, including bringing waste to the recycling point, is the most important factor. This is reduced when the density of recycling points is high.

c. For bulky waste, the disutility of storage is high. The price for bulky waste collection is positive in most cities, and there is no recycling choice. If the labour cost of illegal dumping in rural areas and the expected fines are not high enough, illegal bulky waste dumping may be favoured by households.

d. For kitchen waste (or food consumption), if there is no composting space and recycling is not an option, household's disposal choices are legal dumping, illegal dumping and storage. If the frequency of garbage collection is low, which means the labour of preparing legal dumping is high, illegal dumping may be the household's first choice, especially when the garbage collection is charged (unit-pricing) and/or the expected fine for illegal dumping is not significant. If free kitchen waste collection for public composting is provided and the frequency of collection is high enough, which can be regarded as a way of recycling kitchen waste, household's disposal options would be similar with other consumption goods.

3.3 The Social Model for Local Government

In most countries, solid waste management is the responsibility of local governments. In a local area, the decision made by solid waste management authority usually cannot affect prices of either commodities or labour. This section therefore introduces a partial equilibrium model which describes how the local government waste disposal decisions are made.

Assume the social welfare function is the aggregate household's utility:

$$\sum_{i=1}^{n} \int_{t=0}^{T} u_t^i(x_t, s_t, B_t) e^{-\delta t} dt \qquad (3\text{-}13)$$

Assume that household i is representative. Aggregate illegal dumping is $B_t = nb_t$. The authority can tax or subsidise legal dumping with the price of t_d, subsidise recycling with the price of t_r, and/or fine illegal dumping ($\pi(Eb, b_t)p_b$). When composting is unavailable, the household budget constraint becomes

$$w(L - Ld(d_t) - Lb(b_t) - Lr(r_t)) = p_x x_t + t_r r_t + (p_d + t_d)d_t + \pi(Eb, b_t)p_b \qquad (3\text{-}14)$$

The authority gets the fees, fines, tax revenues and benefits from treating waste, and spends on garbage and recycling collection, and treating waste. The labour costs of garbage and recycling collections are functions of the quantities involved ($G = G(nd_t) = nG(d_t)$ and $H = H(nr_t) = nH(r_t)$). If the city has garbage treatment facilities, like incinerators and landfills, they should take account of both the social costs and benefits from treating garbage. For example, incinerators can both generate electricity and produce air pollution. Assume that the net social benefits and costs from treating garbage are a function of aggregate legal dumping ($E_t = E(nd_t) = nE(d_t)$ and $P_t = P(nd_t) = nP(d_t)$). The authority also can get the benefit from selling, using or exporting a part of recyclable materials, which is also function of aggregate recyclable materials ($R_t = R(nr_t) = nR(r_t)$). The marginal cost and benefit of dumping is assumed to be positive and diminishing, such that $E_d > 0$ and $E_{dd} < 0$. The authority's budget constraint is

$$n[t_r r_t + (p_d + t_d)d_t + \pi(E_b, b_t)p_b] = w(G_t + H_t) + E_t + P_t + R_t \qquad (3\text{-}15)$$

The social decision problem is to maximise the aggregate utility of households (3-13) subject to the constraints, Equation (3-14), (3-2) and (3-15). The Lagrangian function for this system is

$$\begin{aligned} L_{sc} &= nu^i(x_t, s_t, B_t) \\ &+ \lambda_3\{n[w(L - Ld(d_t) - Lb(b_t) - Lr(r_t)) - p_x x_t - t_r r_t - (p_d + t_d)d_t - \pi(Eb, b_t)p_b]\} \\ &+ \lambda_4\{n[ax_t - d_t - b_t - r_t - s_t]\} \\ &+ \lambda_5\{n[t_r r_t + (p_d + t_d)d_t + \pi(Eb, b_t)p_b] - w(G_t + H_t) - E_t - P_t - R_t\} \end{aligned}$$

The first-order conditions for x_t, d_t, b_t, r_t, s_t are

$$u^i_x - p_x\lambda_3 + a\lambda_4 = 0 \qquad (3\text{-}5h)$$

$$-(w(Ld_{dt}) + p_d + t_d)\lambda_3 - \lambda_4 + (p_d - wG_{dt} + t_d + E_{dt} + P_{dt})\lambda_5 = 0 \qquad (3\text{-}6h)$$

$$nu^i_B - (w(Lb_{bt}) + \pi_{bt}p_b)\lambda_3 - \lambda_4 + (\pi_{bt}p_b)\lambda_5 = 0 \qquad (3\text{-}7h)$$

$$-(w(Lr_{rt}) + t_r)\lambda_3 - \lambda_4 + (t_r + wH_{rt} + R_{rt})\lambda_5 = 0 \qquad (3\text{-}8h)$$

$$u^i_s - \lambda_4 = 0 \qquad (3\text{-}9h)$$

Comparing first order conditions of household models and the social model, Equation 3-5, 3-5h, 3-9 and 3-9h, λ_4 should be equal to λ_2 and λ_3

should be equal to λ_1. λ_5 is Lagrange multiplier of the authority's budget. λ_5 is the shadow price of the authority's budget. Two policy implications are found.

IX. By adding Eq. 3-7c and 3-7h, the expected fine for illegal dumping ($\pi_b p_b$) should be equal to $(n-1)u_B^i/(\lambda_3 - \lambda_5)$ which is the social cost of illegal dumping to other households (aside from the dumping household) in shadow price difference between the authority and a household's budgets.

X. In the case of a city with unit-pricing policy and free kerbside recycling, the total of garbage collection charges reflects its labour cost, which means $p_d - wG_d - wH_r$ would be zero when Equation 3-6h is added to 3-8h. The optimal tax for legal dumping (t_d) should be $(E_d + P_d)\lambda_5/(\lambda_3 - \lambda_5)$ which is the net social cost of aggregate waste (Eq. 3-6b and 3-6h). The optimal subsidy for recycling (t_r) should be $R_r\lambda_5/(\lambda_3 - \lambda_5)$ which is the net social benefit of aggregate recycling (Eq. 3-8b and 3-8h).

3.4 Summary of Theoretical Models

According to the equilibrium conditions in Table 3.1C, the household's decision to discard a unit of waste is based on the marginal total cost of each disposal. Therefore, a household's waste disposal depends on solid waste management policies. Some of the household's preferences between disposal options under various solid waste management policies are the following:

a. In a city where composting is not available, high income households will store more waste than low income households because legal dumping, illegal dumping and recycling demand more labour than storage, and the opportunity cost of their time is higher.

b. In a city providing flat fee kerbside garbage collection, since the marginal cost of garbage disposal is close to zero, households have no incentive to recycle or to dump illegally.

c. In a city with unit-pricing on garbage and recycling collection, a household does more illegal dumping and composting than it does under flat fee policy. Applying a penalty on illegal dumping (fine) can prevent illegal dumping from increasing after unit-pricing is adopted but the effect depends on the enforcement and the level of the fine.

d. Both unit-pricing with free kerbside recycling and mandatory recycling policies can increase recycling but the effect of mandatory recycling depends on the enforcement and nominal fine.
e. When unit-pricing garbage collection and free kerbside recycling are provided, a household prefers to recycle materials involving low labour costs.
f. Recycling materials which deposit-refund or compensation system are applied would be favoured when transportation costs are not higher than the unit-pricing price.
g. Some troublesome wastes, such as kitchen waste, yield high disutility of storage. When a household doesn't have space for composting and kitchen waste recycling is unavailable, illegal dumping of kitchen waste may be its first choice.

In the case of a city with unit-pricing policy and kerbside recycling, when the garbage collection charge only includes labour costs, the optimal tax for legal dumping and the optimal subsidy for recycling are their net social cost and benefit. The expected fine for illegal dumping equals to its externality.

Chapter 4 Applied Waste Disposal Models and the Data

The theoretical model discussion in chapter 3 provides implications of household waste disposal behaviour under various waste management policies. In order to estimate the effects of a particular policy, it is necessary to transform the result of theoretical model to the appropriate empirical model. In this chapter, the reduced form applied models and the hypotheses of variables would be found, and the data survey is introduced.

4.1 Empirical Models

Eq. 3-12 in Chapter 3 shows the determinants of each disposal option when composting is unavailable (only storage). The amount of recycling (r_t) is function of wage (w), recycling labour factor (γ), price of recycling collection (p_r), consumption goods price (p_x), utility of consumption (u_x), disutility of storing waste (u_s), and percentage of waste generation (a). Therefore, the reduced form model for a household's recycling decision is $r_t = f(w, \gamma, p_r, p_x, u_x, u_s, a)$. The legal dumping function is $d_t = f(w, \alpha, p_d, p_x, u_x, u_s, a)$ in which α is the dumping labour factor and p_d is the price of garbage collection. The illegal dumping function is $b_t = f(w, \beta, \pi_b p_b, p_x, u_x, u_s, u_B, a)$ in which $\pi_b p_b$ is the marginal expected fine for illegal dumping and u_B is the marginal disutility from aggregate illegal dumping. For households under mandatory recycling policy, the recycling function is $r_t = f(w, \gamma, \mu_r p_m, p_x, u_x, u_s, a)$ in which $\mu_r p_m$ is the marginal expected fine for insufficient recycling.

Assume that consumption goods price (p_x) and percentage of waste generation (a) are fixed for a particular household, *i.e.* exogenous. The wage (w), marginal utility of consumption (u_x) and disutility of illegal dumping (u_B) would not be changed by waste management policy but those can be affected directly by household's socioeconomic factors (SE), such as income. Therefore, the reduce form of household recycling is $r_t = f(\gamma, p_r, \mu_r p_m, u_s, SE)$. The equilibrium condition for the material-specific model (Eq. 3-11g) confirmed that each recycling material is treated in the same way as aggregate recycling. The household recycling of each material (r_{jt}) is $r_{jt} = f(\gamma_j, p_{rj}, \mu_r p_m, u_{sj}, SE)$. The legal dumping is $d_t = f(\alpha, p_d, u_s, SE)$, and illegal dumping is $b_t = f(\beta, \pi_b p_b, u_s, SE)$. These functions are consistent with microeconomic demand theory - the quantity of demand is a function of prices and income.

The equilibrium conditions, Eq. 3-11 and 3-11a, and Table 3.1C in Chapter 3 shows that households trade-off between four disposal options until the marginal cost of each disposal option is the same. This implies that the amount of recycling also depends on other alternatives. For example, every previous empirical study found that adopting unit-pricing or higher dumping price (p_d) can increase recycling (see Table 2.2, 2.3 and 2.4). Households usually adopt some recycling behaviour when waste is generated. Instead of throwing waste into non-recyclables bins, they usually predetermine what is to be recycled. Hence, recycling should be estimated first. The variables affecting legal dumping, illegal dumping and storing have to be added into the function of recycling

$$r_{jt} = f(\gamma_j, p_{rj}, \mu_r p_m; \alpha, p_d; \beta, \pi_b p_b; u_s; SE) \tag{4-1}$$

Because the marginal labour cost of dumping (α, β, γ) cannot be observed directly, some proxies are introduced in this empirical study. One of the non-market valuation techniques, Travel Cost Method (TCM), indicates travel cost of a site "*j*" (C_{ij}) is function of distance costs for each individual "*i*" (DC_{ij}), time cost (TC_{ij}) and fee (F_i) (Fletcher *et al.*, 1990), $C_{ij} = C(DC_{ij}, TC_{ij}, F_i)$. Salkie *et al.* (2001) also found that travelling cost had significant negative effect on waste generation when households lose public waste removal services. Therefore, the concept of TCM is suitable in describing waste dumping or recycling behaviours.

Waste dumping costs also can be separated into distance costs, time costs and tariffs. For Eq. 4-1, the price of garbage (non-recyclables) collection (PNR) can be used as p_d ($p_d = PNR$), and the dumping labour factor (α) can be separated into distance cost (DC_d) and time cost (TC_d). Because most cities provide kerbside garbage collection, the distance cost of dumping (TC_d) is assumed to be similar for each household in a city. The lower the frequency of garbage collection causes the greater the quantity of waste discarded at each collection, and the higher the labour cost of storing, packing and taking garbage out. Assume that the time cost of legal dumping (TC_d) is function of preparation labour and that the garbage collection frequency (FNR) can be used as its proxy. Therefore, the labour cost factor of dumping is a decreasing function of the garbage collection frequency (FNR).

$\alpha = f(TC_d) = f(FNR)$ and $\alpha_{FNR} \leq 0$ (4-2)

When unit-pricing is applied to a recyclable material, the price of recycling collection (PKR_j) can be used as p_{rj} ($p_{rj} = PKR_j$) in Eq. 4-1. If the kerbside recycling is provided without charge, the tariff of recycling collection is zero. When mandatory recycling policy is applied, the tariff of recycling becomes the marginal expected fine which is the nominal fine (p_m) multiplied by the chance of being prosecuted (μ_r). Define the nominal fine as FIM. The marginal chance of being prosecuted (μ_r) can be assumed to be related to enforcement policies, including recycling enforcement (REN). For example, the policy of using transparent bags for garbage dumping can lower the inspection cost when cities adopt mandatory recycling. When the nominal fine is higher and more recycling enforcements are adopted, the marginal expected fine is higher. The marginal expected fine for non-compliance with mandatory recycling can be written as

$p_m = FIM$ and $(\mu_r p_m)_{FIM} \geq 0$

$\mu_r = f(REN)$ and $(\mu_r)_{REN} \geq 0$ (4-3)

The recycling labour factor (γ_j) can also be separated into DC_{rj} and TC_{rj}. The time cost of recycling (TC_{rj}) is assumed to be the same for a particular recyclable material. The distance cost of recycling (DC_{rj}) decreases when kerbside recycling (KR_j)[15] is provided. DC_{rj} is assumed to be function of KR_j. Therefore, the recycling labour factor is function of whether kerbside recycling is provided (KR).

$\gamma = f(DC_{rj}) = f(KR_j)$ and $\gamma_{KR} \leq 0$ (4-4)

The tariff on illegal dumping is the marginal expected fine, which is the nominal fine (p_b) multiplied by the chance of being prosecuted (π_b). Define

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[15] Currently, there are two kinds of recycling collection policies, drop-off centre and kerbside collection. The latter one means residents can just bring recyclables to specific kerbside near their house for collection rather than go to recycling centre.

the nominal fine as *FIB*. Assume that both the chance of being prosecuted (π_b) and the factor of illegal dumping labour (β) are related to population density (*DEN*) and inspection (enforcement) effort (*EN*). The chance of being prosecuted and the marginal distance cost of illegal dumping are lower when a household is in a lower population density area. The chance of being prosecuted is increasing in inspection effort.

$p_b = FIB$ and $(\pi_b p_b)_{FIB} \geq 0$

$\pi_b = f(DEN, EN)$, $(\pi_b)_{DEN} \geq 0$ and $(\pi_b)_{EN} \geq 0$

$\beta = f(DEN)$ and $\beta_{DEN} \geq 0$ (4-5)

The marginal disutility of storing waste (u_s) is assumed to be related to the population density (*DEN*) because the opportunity cost of space increases as density increases.

$u_s = f(DEN)$ and $\partial u_s / \partial DEN \geq 0$ (4-6)

With the assumptions of Eq. 4-2, 4-4, 4-5 and 4-6, the reduced-form model of each recyclable material depends on dumping policy variables (*PNR* and *FNR*), recycling policy variables (PKR_j, KR_j, *FIM* and REN_j), illegal dumping and storing variables (*FIB*, *EN* and *DEN*) and household's socioeconomic factors (*SE*).

$$r_{jt} = f(PKR_j, KR_j, FIM, REN_j; PNR, FNR; FIB, EN, DEN; SE) \qquad (4\text{-}7)$$

The aggregate recycling (or total recyclables (*TOR*)) is summation of all kinds of recyclable materials

$$TOR = \sum_{j=1}^{J} r_{jt} \text{ and } TOR_J > 0 \qquad (4\text{-}8)$$

When recycling policies applied on each recyclable material are the same, variables effecting household's aggregate recycling remain the same as Eq. 4-7. However, recycling categories (*CR*) should be added in because more recycling categories mean more materials can be recycled. The reduced-form of the aggregate recycling model is

$$TOR = f(PKR, KR, FIM, REN, CR; PNR, FNR; FIB, EN, DEN; SE) \qquad (4\text{-}9)$$

The recycling ratio is the ratio of the aggregate recycling and the total waste which is aggregate recycling (*TOR*) plus non-recyclables (*NRW*).

$$RR = \frac{TOR}{TOR + NRW} = f(PKR, KR, FIM, REN, CR; PNR, FNR, FIB, EN, DEN; SE)$$

(4-10)

Like each recyclable material, the household's dumping (d_t, or NRW) depends on the total marginal cost of each disposal option.

$$d_t = f(\gamma, p_r, \mu_r p_m; \alpha, p_d; \beta, \pi_b p_b; u_s; SE) \qquad (4\text{-}11)$$

The assumptions for α, β, γ, and $\mu_r p_m$ (Eq. 4-2, 4-5, 4-4 and 4-3) still can be applied on Eq. 4-11. Besides the variables in Equation 4-7, dumping demand is related to unit-pricing enforcement (UEN). For example, on-time collection policy is a kind of UEN which demands residents to hand garbage bags to haulers rather than just leave them at collection points. This lets haulers check paid bag usage. In this case, the reduced-form of the non-recyclables dumping and total waste generation ($TOW = TOR + NRW$) models become

$$d_t = NRW = f(PKR, KR, FIM, REN; PNR, FNR, UEN; FIB, EN, DEN; SE) \qquad (4\text{-}12)$$

$$TOW = f(PKR, KR, FIM, REN; PNR, FNR, UEN; FIB, EN, DEN; SE) \qquad (4\text{-}13)$$

4.2 Comparative Static Analysis and Hypotheses

The theoretical model in Chapter 3 and the empirical model in the previous section show how waste disposal is affected by policy variables, which is the hypothesis of this thesis. Assume that the utility-maximised solutions for household's waste disposals are d^*, b^*, r^* and s^*. The comparative static results reported below are obtained by first substituting the solutions into Eq. 3-12 and the first-order conditions (Eq. 3-5, 3-6b', 3-7c', 3-8b', and 3-9), then differentiating with respect to the exogenous variable of interest, and finally solving the system of differential equations of the comparative static terms. The set of hypothesis is listed in Table 4.1.

4.2.1 The tariff for each disposal

Firstly, differentiating the tariff for each disposal function in Eq. 3-12, shows that higher tariffs may be expected to decrease disposal.

$$\frac{\partial d_t^*}{\partial p_d} = \frac{\partial r_t^*}{\partial p_r} = -1 < 0$$

The price of garbage collection (p_d) and recycling collection (p_r) are negatively related to garbage and recycling, respectively. According to the assumptions in section 4.1, higher *PNR* and *PKR* have negative effect on non-recyclables collection and recycling, respectively. Almost every previous empirical study (see Table 2.2, 2.3 and 2.4) has found that higher collection prices (*PNR*) or adopting unit-pricing decreases garbage and increases recycling. If unit-pricing enforcement (*UEN*) can ensure the garbage collection price, then, *UEN* can decrease dumping as well.

When a household is subject to a mandatory recycling policy, the impact of higher marginal expected fines ($\mu_r p_m$) on recycling can be find out by differentiating Eq. 3-8e".

$$\frac{\partial r_t^*}{\partial \mu_r p_m} = 1 > 0$$

From Eq. 4-3, the higher the fine for non-compliance with mandatory recycling (*FIM*), and the more recycling enforcements (*REN*) adopted, the higher will be the quantity of recycling. The mandatory recycling policy has been shown to increase the time spent on recycling in Taiwanese households (Shaw and Tsai, 2002), and to increase the quantity of paper, glass, plastic and cardboard recycling from households of Ithaca, New York, the US. (Reschovsky and Stone, 1994).

Secondly, substituting the solutions into the first-order conditions (Eq. 3-5, 3-6b', 3-7c', 3-8b', and 3-9) and differentiating the tariff of each disposal can show the effect of tariffs on other disposal. For example, when household's utility is maximised, Eq. 3-6b' and 3-8b' become $w\alpha d_t^* + p_d = w\gamma r_t^* + p_r$. Sorting out d_t^* and differentiating it with the price of recycling (p_r) can show that the change in dumping attributable to a change in the price of recycling is

$$\frac{\partial d_t^*}{\partial p_r} = 1 > 0$$

Using the same method, it can be shown that

$$\frac{\partial d_t^*}{\partial \pi_b p_b} = \frac{\partial r_t^*}{\partial p_d} = \frac{\partial r_t^*}{\partial \pi_b p_b} = 1 > 0$$

The price of recycling (p_r) and the price of dumping (p_d) have positive effects on dumping and recycling, respectively. The marginal expected fine ($\pi_b p_b$) has positive effects on dumping and recycling. According to the assumptions in section 4.1, higher *PNR* and *PKR* have positive effects on kerbside recycling and on non-recyclables collection demands, respectively. Higher *FIB*, *EN* and

DEN have positive effects on non-recyclables and recycling collection. When a household is subject to mandatory recycling policy, the impact of higher marginal expected fine ($\mu_r p_m$) on dumping can be find out by differentiating Eq. 3-8e' and 3-6b'.

$$\frac{\partial d_t^*}{\partial \mu_r p_m} = -1 < 0$$

According to the assumption of Eq. 4-3, higher *FIM* and more recycling enforcements (*REN*) adopted can decrease dumping.

4.2.2 The labour factor in each disposal option

Firstly, differentiating the labour factor in each disposal function in Eq. 3-12, shows that higher labour factors can decreases disposal.

$$\frac{\partial d_t^*}{\partial \alpha} = \frac{-1}{\alpha^2} < 0 \text{ and } \frac{\partial r_t^*}{\partial \gamma} = \frac{-1}{\gamma^2} < 0$$

The higher labour factors, α, β and γ, can decrease garbage, recycling and illegal dumping, respectively. According to the assumptions described in section 4.1, the higher frequency of non-recyclables collection (*FNR*) and providing kerbside recycling (*KR*) can increase garbage and recycling, respectively. Two previous empirical studies found that providing kerbside recycling (*KR*) significantly increases aggregate recycling (Callan and Thomas, 1997; Kinnaman and Fullerton, 2000). Kerbside recycling can increase most recyclable materials except metal and composting (Jenkins *et al.*, 2003; Reschovsky and Stone, 1994).

Secondly, substituting the solutions into the first-order conditions (Eq. 3-5, 3-6b', 3-7c', 3-8b', and 3-9) and differentiating the labour factor shows its effects on other disposal options:

$$\frac{\partial d_t^*}{\partial \gamma} = wr_t^* > 0,\ \frac{\partial d_t^*}{\partial \beta} = wb_t^* > 0,\ \frac{\partial r_t^*}{\partial \alpha} = wd_t^* > 0 \text{ and } \frac{\partial r_t^*}{\partial \beta} = wb_t^* > 0$$

The labour factor in recycling has a positive effect on dumping. According to Eq. 4-4, providing kerbside recycling (*KR*) can decrease dumping. The labour factor in dumping has a positive effect on recycling. According to Eq. 4-2, the higher garbage collection frequency (*FNR*) can decrease recycling. The labour factor of illegal dumping has positive effect on dumping and recycling. According to Eq. 4-5, higher population density (*DEN*) can increase both dumping and recycling.

4.2.3 Income

In this thesis, income (*INC*) is used as a proxy for household's socioeconomic variables (*SE*). When a household's utility is maximised, according to the mass constraint, Eq. 3-2, the household's consumption is x^*.

$$x_t^* = \left(d_t^* + b_t^* + r_t^* + s_t^*\right)/a \qquad (3\text{-}2')$$

The left hand side of a household's budget constraint, Eq. 3-4c, is the household's income (*INC*).

$$INC = w\left(L - Ld(d_t) - Lb(b_t) - Lr(r_t)\right) = p_x x_t^* + p_d d_t^* + \pi\left(Eb, b_t^*\right)p_b + p_r r_t^* \qquad (3\text{-}4c')$$

Differentiating x^* with income can get a positive result

$$\frac{\partial x_t^*}{\partial INC} = 1 > 0$$

which means income can increase a household's consumption and increase dumping and recycling based on Eq. 3-2'. Almost every previous study (see Table 2.2, 2.3 and 2.4) found higher income increased garbage and recycling except Fullerton and Kinnaman (1996).

4.2.4 The disutility of waste storage

In Eq. 3-12, u_s is negative which means that higher u_s decreases each disposal. Differentiating the dumping and recycling in Eq. 3-12 shows that

$$\frac{\partial d_t}{\partial u_s} = \frac{\partial r_t}{\partial u_s} = -1 < 0$$

According to Eq. 4-6, higher population density (*DEN*) can increase the marginal disutility of storage and decrease dumping and recycling. The reason is that a household consumes fewer commodities and generates fewer waste items when the marginal disutility of storing is high. Because the higher *DEN* can also increase the marginal cost of illegal dumping and increase dumping and recycling, the net effect of *DEN* is not unambiguous. Some previous empirical studies confirm these two hypotheses. They found that population density (*DEN*) significantly affects garbage generation, but in quite different ways (see Table 2.2, 2.3 and 2.4).

Table 4.1 Hypothesises of empirical models

effects on	r_j	RR	TOR	NRW
price of garbage collection (*PNR*)	+	+	+	-
price of kerbside recycling (*PKR*)	-	-	-	+
garbage collection freq. (*FNR*)	-	-	-	+
kerbside recycling (*KR*)	+	+	+	-
population density (*DEN*)	+/-	+/-	+/-	+/-
household's income (*INC*)	+	+	+	+
nominal fine for illegal dump (*FIB*)	+	+	+	+
inspection effort for illegal dumping (*EN*)	+	+	+	+
nominal fine for insufficient recycling (*FIM*)	+	+	+	-
unit-pricing enforcement (*UEN*)	na.	na.	na.	-
recycling enforcement (*REN*)	+	+	+	-
categories of kerbside recycling (*CR*)	na.	+	+	na.

4.3 Data

There are two kinds of data used in the empirical study of Equation 4-7, 4-9, 4-10, 4-11, 4-12 and 4-13. The first is statistics of household dumping and recycling. The second is the solid waste management system variables, including KR_j, PKR_j, CR, PNR, DEN, UEN, REN, FIM, FIB, INC and FNR. These two kinds of data can either be obtained from aggregate cities' statistics or the individual household survey. Waste management system variables are the same in aggregate or household survey data.

Aggregate data (city level data) are used for the empirical study. The main reasons are listed below.

a. From the social model in Chapter 3, using aggregate representative households and maximising aggregated utility yield the same result as the individual household model when the illegal dumping externality is internalised.

b. Most cities take full responsibility for treating garbage and recycling except for some non-regional externalities. This responsibility allows us to aggregate households.

c. It is hard to get real household garbage and recycling data from household surveys. Self reported data may have some biases (Reschovsky and Stone, 1994). By contrast, aggregate data yields real response predictions for policies.

In order to study effects of waste management policies and to compare these with previous cases in Western countries and Korean cities (see Table 2.2, 2.3 and 2.4), this thesis will focus on specific dense urban areas in East Asia. Because many cities change policies over time, panel date from these cities is used for the empirical study. Table 4.2 lists the cities chosen in this thesis and their population density. The reasons for choosing these cities are the following.

a. Choosing only dense urban area can eliminate some obvious differences in life-styles. Many empirical studies have found that household behaviour has significant differences in urban and suburban areas, such as Dijkgraaf and Gradus (2004), and Houtven and Morris (1999).

b. The chosen city has unified waste management policy within the city. Some cities have various frequencies or methods of garbage and recycling collection within city, such as Tokyo City.

c. Cities in Japan and Taiwan use several solid waste policies, such as unit-pricing in Taipei City and Fukuoka City *etc.*, and mandatory recycling in Taichung City.

d. Analyzing the effect of policies has to compare with control cities which are in the same country. Although categories of waste statistics are the same in Japan and Taiwan, two countries may have other systematic country difference.

Table 4.2 Chosen cities and their population density in 2002

Country	Japan				Taiwan	
City name and density (people/ km^2)	Sapporo	1646.60	Osaka	11225.09	Taipei	9720.39
	Sendai	1270.28	Kobe	2697.95	Hsinchu	3640.86
	Chiba	3257.53	Kitakyushu	2060.86	Tainan	4241.50
	Yokohama	7995.17	Fukuoka	3864.42	Kaohsiung	9831.20
	Nagoya	6696.51	Nagasaki	1244.27	Keelung	2945.19
	Kyoto	2406.30	Naha	7831.70	Taichung	6100.64

All data required for the empirical study were obtained from city and national statistics, and from a questionnaire to the waste management authorities in each city. The statistics on household dumping and recycling are obtained from online databases of Environmental Protection Administration, Taiwan and Ministry of Environment, Japan[16]. The data is available from 1998 to 2003. Appendix 1 (pp. A1) lists per capita per day weights (g) of non-recyclables (*NRW*), total waste generation (non-recyclables plus recyclables, *TOW*), recyclable waste of each material (r_{jt}): recyclable paper (*PAW*), recyclable metal (*MEW*), recyclable glass (*GLW*), recyclable PET bottles[17] (*PTW*), recyclable plastics (*PLW*), other recyclable waste (*OTH*) and total recyclables (*TOR*) of all selected cities. Table 4.3 is descriptive statistics of these variables. Japanese cases have fewer per capita non-recyclables and more recyclables than Taiwanese cases except recyclable plastics.

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[16] 1. Environmental Database, Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) (http://edb.epa.gov.tw/); 2. Survey of Municipal Solid Waste Management of Ministry of Environment, Japan (http://www.env.go.jp/recycle/waste_tech/ippan/).

[17] PET bottle is made from Polyethylene Terephthalate.

Table 4.3 Descriptive statistics of waste and recycling amount (g / person.day)

Variable	Mean	Std.Dev.	Minimum	Maximum	Cases
NRW	839.35	179.94	472.00	1491.00	108
Japan cases	794.85	133.83	571.47	1180.62	72
Taiwan cases	928.36	224.58	472.00	1491.00	36
TOW	978.90	162.71	634.28	1639.89	108
Japan cases	954.48	142.44	634.28	1295.18	72
Taiwan cases	1027.74	189.99	635.92	1639.89	36
PAW	81.86	68.74	0	325.92	108
Japan cases	98.45	75.14	0	325.92	72
Taiwan cases	48.68	35.98	0.82	148.83	36
MEW	22.14	13.64	0.29	57.95	108
Japan cases	24.01	11.64	2.52	52.86	72
Taiwan cases	18.42	16.51	0.29	57.95	36
GLW	11.34	11.03	0.02	49.32	108
Japan cases	15.85	10.92	0.23	49.32	72
Taiwan cases	2.32	2.00	0.02	6.92	36
PTW	4.03	3.07	0	11.95	108
Japan cases	3.41	2.44	0	9.84	72
Taiwan cases	5.25	3.79	0.12	11.95	36
PLW	5.77	8.95	0	36.35	108
Japan cases	3.94	9.22	0	36.35	72
Taiwan cases	9.44	7.18	0	28.99	36
OTH	14.41	16.79	0	87.42	108
Japan cases	13.98	15.56	0	56.23	72
Taiwan cases	15.27	19.21	0	87.42	36
TOR	139.55	94.43	2.09	419.45	108
Japan cases	159.64	99.01	29.64	419.45	72
Taiwan cases	99.38	69.89	2.09	241.17	36

This thesis uses per capita Regional Gross Domestic Product (R-GDP) as proxy for real per capita income in each city and each year. Japanese cities' per capita GDP is unavailable but prefectural per capita GDP[18] is a reasonable proxy because the Prefecture is a higher level of local government than the City and most selected cities are capitals of prefectures. However, the prefectural income statistics are only available to 2002. In order to use 2003 dumping statistics, this thesis extrapolates from national GDP growth rate, 1.2%, to get 2003 prefectural per capita income. The function is:

2003 per capita income = 2002 per capita income * 1.012

Although Taiwanese cities' GDP per capita is also unavailable from government statistics, using the ratio of national and cities' per capita income

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[18] Prefectural per capita GDP is from Prefectural Account, Economic and Social Research Institute, Cabinet Office, Japan (http://www.esri.cao.go.jp/jp/sna/toukei.html#kenmin).

(PCI)[19] to convert national per capita GDP[20] to city's can be a suitable proxy. The function is:

City's per capita GDP = (city's PCI / national PCI) * (national per capita GDP)

To ensure that income data for each city and year in two countries are consistent, the nominal per capita R-GDP has to be converted into the same unit. It is firstly converted to real R-GDP based on the same year (1995 prices) by Price Index[21]. Then, it is converted to the same currency. One conversion method uses actual exchange rates at 1995 to convert both Japanese Yen and Taiwanese Dollars to the US Dollars. The other uses purchasing-power-parity (PPP)[22]. Because commodity prices are different in different countries, the per capita income discounted by PPP can reflect commodity purchasing power. Therefore, the income, dumping and recycling data of Taiwanese and Japanese cities from 1998 to 2003 can be analysed together. The data on per capita income (*INC*, converted to US dollar by actual exchange rate at 1995, and *PPPINC*, converted to international dollars by purchasing-power-parity) are listed in Appendix 2 (pp. A4) and the descriptive statistics are given in Table 4.4. It shows that the average of *INC* in Japanese cities is double that in Taiwanese cities, but the average of *PPPINC* in Taiwan and Japan are very close.

According to the empirical household waste disposal model, the dumping choice is also affected by population density (*DEN*). The data for *DEN*[23] are also listed in Appendix 2 (pp. A4) and the descriptive statistics given in Table 4.4. The population density of Japanese and Taiwanese cities is from 1239 to 11690 people per squared kilometre and the average is 4873.

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[19] National and cities' PCI is from Household Income and Expenditure Survey, Directorate General of Budget, Accounting and Statistics, Executive Yuan, R.O.C. (Taiwan) which is available to 2003.

[20] National per capita GDP is from R.O.C. (Taiwan) Statistical Yearbook 2005 (http://eng.dgbas.gov.tw/).

[21] The General (price) Index of city area is from Japanese Statistical Yearbook 2005 (http://www.stat.go.jp/data/nenkan/index.htm), and the price index is from Consumer Price Index, R.O.C. (Taiwan) Statistical Yearbook 2005 (http://eng.dgbas.gov.tw/).

[22] Would Economic Outlook Database, International Monetary Fund (http://www.imf.org/external/pubs/ft/weo/2005/02/data/index.htm)

[23] The data source of population is the same as footnote 16. City territory data for Taiwanese cities is from Environmental Database, Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan), and for Japanese cities is from Japanese Local Governments (http://uub.jp/).

Table 4.4 Descriptive statistics of per capita income and population density

Variable	Mean	Std. Dev.	Minimum	Maximum	Cases
INC[1]	31095.66	11161.82	13539.23	52054.74	108
Japan cases	37995.87	6254.46	27564.47	52054.74	72
Taiwan cases	17295.23	2772.00	13539.23	23656.80	36
PPPINC[2]	20946.24	3549.61	14676.60	30608.02	108
Japan cases	20230.76	3330.16	14676.60	27716.36	72
Taiwan cases	22377.20	3586.51	17517.54	30608.02	36
DEN[3]	4872.92	3130.94	1239.09	11690.07	108
Japan cases	4313.62	3150.25	1239.09	11690.07	72
Taiwan cases	5991.53	2811.83	2862.33	9831.20	36

Note: 1. 1995USD/person.year; 2. international dallors/person.year; 3. pepele/km^2.

Figure 4.1 and 4.2 are the waste and income (*INC*) of Taiwanese and Japanese cities. In contrast to the more general findings of the EKC studies (Cole *et al.*, 1997; Shafik, 1994), non-recyclables do not increase as income grows, which indicates the effectiveness of existing policies to reduce the volume of RSW.

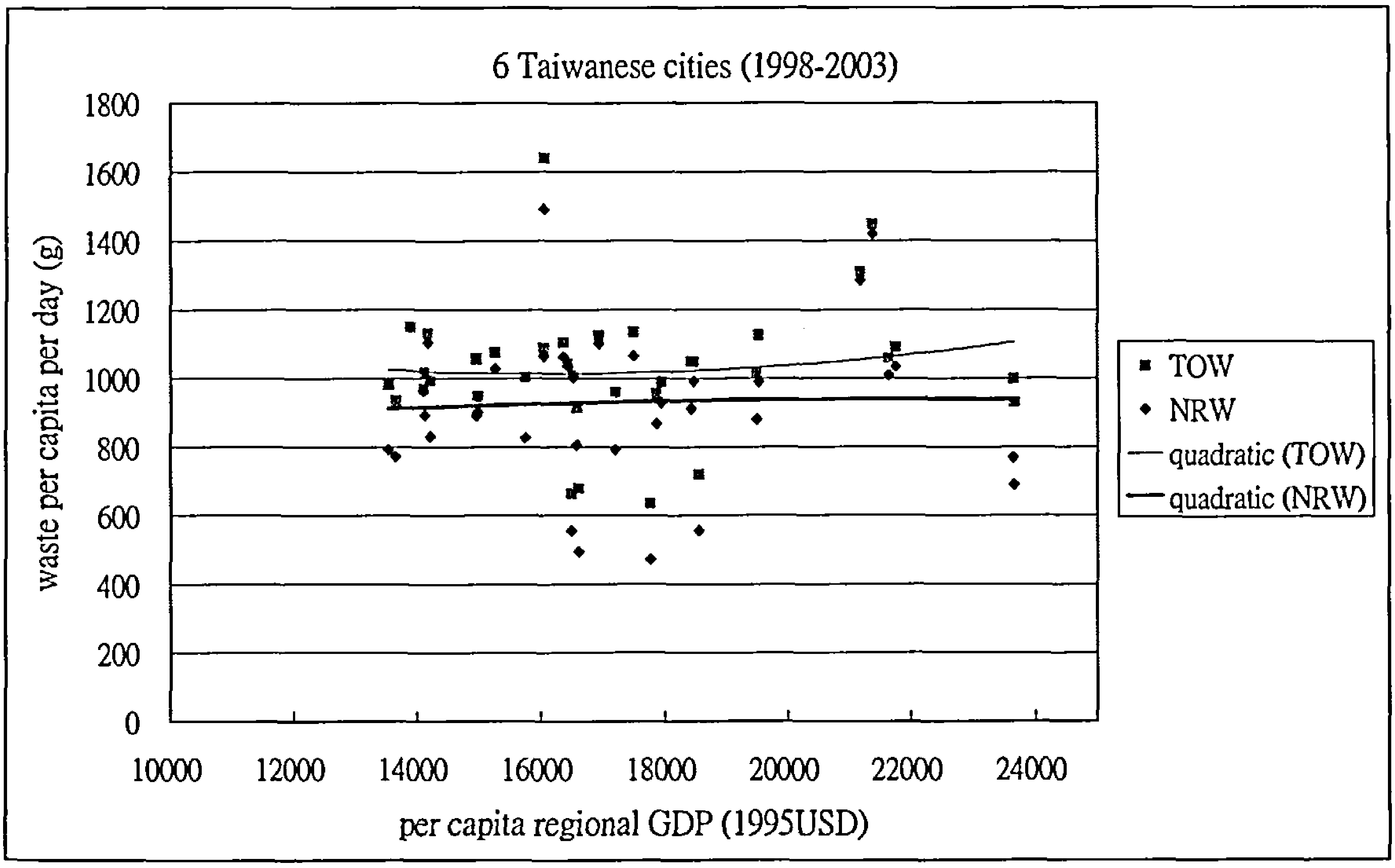

Fig 4.1 per capita NRW, TOW and income of 6 Taiwanese cities

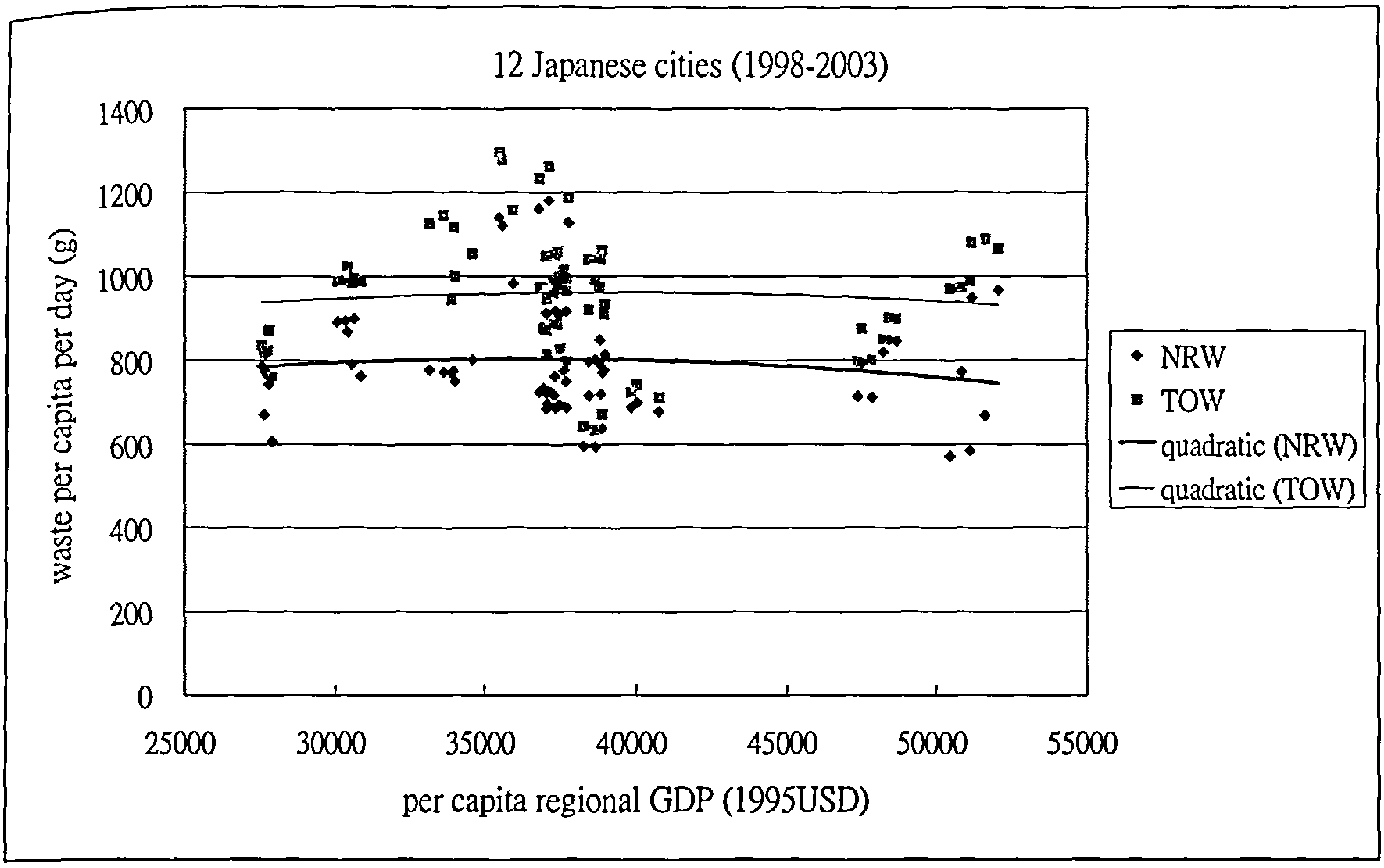

Fig 4.2 per capita NRW, TOW and income of 12 Japanese cities

The data on waste management variables were obtained from the survey of cities' solid waste management authorities. The survey method and the questionnaire are in Appendix 3 (pp. A7). The questionnaire includes four parts: non-recyclables collection, recyclable material collection, bulky waste collection and penalty for illegal dumping. It elicits information of the development of policies in respect of each part from 1998 to 2005. Besides the price of each kind of waste, the survey yielded information on collection, classification methods and the frequency of collections. Since the data on dumping, recycling and income is from 1998 to 2003, only information on policy variables applied in this period was used.

Questions about recyclables collection included frequencies and pricing of each recyclable material. Because some cities did not change policies from the beginning of the fiscal year (dumping statistics are based on the fiscal year), the value of a dichotomous policy dummy variable is 1 when the policy is adopted sometime in the fiscal year. Appendix 4 (pp. A12) lists all policy variables involving recyclables. The descriptive statistics of these variables are in Table 4.5. Most cities started to provide kerbside recycling (*KR*) for some materials before 2002. Kerbside recycling for paper is *PAK*, metal is *MEK*, glass is *GLK*, PET bottle is *PEK*, and plastics is *PLK*. Kerbside recycling is free in most cases except Sendai City, Nagoya City, Kyoto City, Fukuoka City and Nagasaki City which charge for cans, jars, or PET bottles for kerbside recycling by demanding that residents use only authorised bags for collection. The 10 litre volume price for the jth material is PKR_j. Because different charges are applied to different materials, the *PKR* in Table 4.5 and Appendix 4 (pp. A12), is the maximum price applied in each city. There are fewer than three categories of recyclable waste (*CR*) in most cases, which are scrap paper (all kinds), cans (all kinds of tins, cans and bottles) and plastics. Most Taiwanese cities provided kerbside plastics recycling before 2003, which might be the reason that Taiwanese cities recycle more plastics than Japanese cities. In Japan, only Naha City provides municipal regular kerbside paper recycling and other cities let private companies or voluntary groups recycle paper. In Taiwan, all cities provide kerbside paper recycling but private paper recycling organisations are also operating. Besides these recyclable materials, some Taiwanese cities also provide kerbside kitchen waste collection (*KWC*), which is for public composting. Taichung City, Tainan City and Keelung City started from July 2002, January 2003 and July 2003 respectively.

There are two kinds of recycling enforcement policies (*REN*) adopted in chosen cities. Many Japanese cities require their residents to use transparent bags for non-recyclables collection (*TBG*), but only Taipei City in Taiwan has done so since the adoption of unit-pricing in 2000. The policy of using transparent bag for non-recyclables lowers inspection cost of recycling. Another recycling enforcement policy, mandatory recycling policy (*MR*), has been adopted only in Taiwanese cities. Taichung City, Kaohsiung City, Keelung City and Tainan City started mandatory recycling from July 1998, January 2001, July 2001 and July 2003 respectively.

Table 4.5 Descriptive statistics of recyclable waste management variables

Variable	Mean	Std. Dev.	Minimum	Maximum	Cases
MR^1	0.12	0.33	0	1	108
Japan cases	0	0	0	0	72
Taiwan cases	0.36	0.49	0	1	36
PAK^1	0.35	0.48	0	1	108
Japan cases	0.14	0.35	0	1	72
Taiwan cases	0.78	0.42	0	1	36
MEK^1	0.93	0.26	0	1	108
Japan cases	1.00	0	1	1	72
Taiwan cases	0.78	0.42	0	1	36
GLK^1	0.93	0.26	0	1	108
Japan cases	1.00	0	1	1	72
Taiwan cases	0.78	0.42	0	1	36
PTK^1	0.86	0.35	0	1	108
Japan cases	0.90	0.30	0	1	72
Taiwan cases	0.78	0.42	0	1	36
PLK^1	0.40	0.49	0	1	108
Japan cases	0.21	0.41	0	1	72
Taiwan cases	0.78	0.42	0	1	36
KWC^1	0.05	0.21	0	1	108
Japan cases	0	0	0	0	72
Taiwan cases	0.14	0.35	0	1	36
CR^2	2.69	1.74	0	7	108
Japan cases	3.17	1.70	2	7	72
Taiwan cases	1.75	1.42	0	5	36
TBG^1	0.57	0.50	0	1	108
Japan cases	0.81	0.40	0	1	72
Taiwan cases	0.11	0.32	0	1	36
PKR^3	0.016	0.057	0	0.294	108
Japan cases	0.024	0.068	0	0.294	72
Taiwan cases	0	0	0	0	36

Note: 1. policy adopted=1, policy not adopted=0; 2. categories of recyclable waste; 3. USD/10litres.

Questions about non-recyclables waste management included the pricing system, categories and frequency of collection. The data on non-recyclables policies applied in cities is listed in Appendix 5 (pp. A15). The survey confirmed that all cities provide kerbside non-recyclables collection in which the distance from each collection point (called Station in Japan) is no more than a few blocks. The categories of non-recyclables waste are only one (mixed) or two (burnable and non-burnable). Therefore, transportation and classification costs of non-recyclables waste dumping are similar in all cities.

Between 1998 and 2003, six cities adopted unit-pricing through a requirement that residents use authorised garbage bag for dumping. In Taiwan, only Taipei City uses unit-pricing through it's "Per Bag Garbage Collection Fee Policy" from July 2000. In Japan, five cities have started to use unit-pricing: Sendai City from April 1991, Chiba City from January 1995, Fukuoka City from December 1997, Kitakyushu City July 1998, and Nagoya City from August 2000. The price of garbage bag (*PNR*) is about 0.047US$ per 10 litres waste in Japanese cities, and 0.145US$ per 10 litres in Taipei City, reflecting the fact that the price in Taipei City includes full collection and treatment costs. The price content is on Appendix 8 (pp. A91). Because residents in cities without unit-pricing policy still have to use garbage bags for disposal, according to market survey, *PNR* in cases without unit-pricing are 0.005 US$ in Japanese cases and 0.01 in Taiwanese cases. The non-recyclables waste collection frequency (*FNR*) in Taiwanese cases (5 to 7 times per week) is much higher than Japanese cases (2 to 3 times per week). Table 4.6 provides descriptive statistics for *PNR* and *FNR*.

Table 4.6 Descriptive statistics of garbage bag price and collection frequency

Variable	Mean	Std. Dev.	Minimum	Maximum	Cases
PNR[1]	0.024	0.030	0.005	0.152	108
Japan cases	0.024	0.023	0.005	0.086	72
Taiwan cases	0.023	0.040	0.010	0.152	36
FNR[2]	3.57	1.93	2	7	108
Japan cases	2.25	0.44	2	3	72
Taiwan cases	6.22	0.48	5	7	36

Note: 1. USD/10litres; 2. times/week.

Based on the empirical household waste disposal model, the dumping choice is also affected by the nominal fine for non-compliance with mandatory recycling (*FIM*) and illegal dumping (*FIB*), inspection effort for illegal dumping (*EN*), and unit-pricing enforcement (*UEN*). One of unit-pricing enforcements is on-time collection (*OTC*) which demands residents to hand garbage bags to haulers rather than just leave them at collection points like Japanese cases. Taiwanese cities gradually started to adopt on-time collection and all adopted it after 2003. Although both Japan and Taiwan have nominal penalties for illegal dumping and insufficient recycling in national waste management laws or local government laws/rules, the penalty is a range and the actual penalty depends on cities and cases. Therefore, the data of each city's nominal fine

(*FIM* and *FIB*) cannot be retrieved by questionnaire or national statistics. The data on inspection effort (*EN*) for Japanese cases is also unavailable. Therefore, the questionnaire directly asks waste management authority "if the city fines for illegal dumping (*FI*)?". This tells us whether the authority at least tries to enforce the penalty or just warns and corrects illegal dumping behaviour when it is found. Almost all Taiwanese cities and approximately half of Japanese cities fine or try to fine for illegal dumping. The data of *OTC* and *FI* is listed in Appendix 5 (pp. A15) and the descriptive statistics of it is on Table 4.7.

Table 4.7 Descriptive statistics of fining illegal dumping and on-time collection

Variable	Mean	Std. Dev.	Minimum	Maximum	Cases
FI[1]	0.65	0.47	0	1	108
Japan cases	0.50	0.50	0	1	72
Taiwan cases	0.94	0.23	0	1	36
OTC[2]	0.27	0.45	0	1	108
Japan cases	0	0	0	0	72
Taiwan cases	0.81	0.40	0	1	36

Note: 1. the authority tries to enforce (fine) =1, not try to enforce=0; 2. OTC adopted=1, not adopted=0.

Three kinds of inspection effort (*EN*) data can be found for Taiwanese cases. The data on actual illegal dumping prosecution and inspection can be found in Taiwan Environmental Database (see footnote 16) including the prosecuted fines on illegal dumping of residential solid waste per 1000 residents (USD, *ENAF*), the rate of local authority inspection times per 1000 residents (*ENAT*), and the annual labour cost of inspection per 100000 residents (people, *ENAP*). These data are listed in Appendix 6 (pp. A18) and the descriptive statistics are given in Table 4.8. The data covers inspections (enforcements) of overall city's waste management, including littering[24] and violation of unit-pricing and mandatory recycling rules[25] *etc.* They do not disaggregate by policy. Therefore, *ENAF*, *ENAT* and *ENAP* cannot fully represent the *EN* variable in Eq. 4-5.

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[24] Discard waste not via municipal waste and recycling collection and/or at unauthorised places.

[25] Discard waste without using authorised garbage bag and/or discard recyclable materials as non-recyclables.

Table 4.8 Descriptive statistics of prosecution and inspection in Taiwanese cities

Variable	Mean	Std. Dev.	Minimum	Maximum	Cases
$ENAF^1$	6.36	3.96	1.00	16.15	36
$ENAT^2$	28.00	89.00	0.97	543.64	36
$ENAP^3$	4.06	2.59	0.51	14.32	36

Note: 1. prosecuted fines per 1000 residents (USD/year); 2. authority inspection times per 1000 residents (times/year); 3.labour for inspection per 100000 residents (people/year).

4.4 Summary

Based on the theoretical models in Chapter 3 and some assumptions, this chapter has developed a set of reduced form empirical models. These are used in the next chapter to test the behavioural hypotheses coming out of the comparative static analysis of the theoretical models. Many variables in the empirical models have not been studied before, including the frequency of garbage collection (*FNR*), the price of kerbside recycling (*PKR*), on-time collection policy (*OTC*), transparent garbage bag policy (*TBG*), penalties for illegal dumping (*FI*), and inspection effort for illegal dumping (*EN*). The models will be estimated using city level data. The quality of dumping and recycling data is fair because it is obtained from city and national statistics and because the categories of dumping and recycling statistics are the same in Japan and Taiwan. The data on policy variables derive directly from questionnaires of city's waste management authorities, and most policy information can be verified through the literature.

Chapter 5 Estimations of Waste Disposal Models

This Chapter provides estimations of waste disposal models set up in Chapter 4. The first part of the Chapter describes the methodology of the panel data estimation techniques used. The second part reports the results of the estimations including recyclables and non-recyclables.

5.1 Methods of Model Estimation

The data used in this thesis comprises a panel collected from 18 cities in Taiwan and Japan between 1998 and 2003. Two models are usually used to estimate panel data: Fixed Effects Model (FEM) and Random Effects Model (REM). The estimation methods and diagnostic tests applied derive from Maddala (2001).

- Fixed Effects Model

For simplicity, FEM for only one explanatory variable is

$$y_{it} = \alpha_i + \beta x_{it} + u_{it} \quad i = 1,2,\ldots,N \quad t = 1,2,\ldots,T \tag{5-1}$$

y_{it} is the per capita waste generation or recycling, and x_{it} is an explanatory variable, such as the waste collection price, in city i and year t. We assume $u_{it} \sim IN(o,\sigma^2)$. Define group means $\overline{x_i} = \frac{1}{T}\sum_t x_{it}$ and $\overline{y_i} = \frac{1}{T}\sum_t y_{it}$.

Within-group sums of squares and sums of products are

$W_{xxi} = \sum_t (x_{it} - \overline{x_i})^2$, $W_{xyi} = \sum_t (x_{it} - \overline{x_i})(y_{it} - \overline{y_i})$ and $W_{yyi} = \sum_t (y_{it} - \overline{y_i})^2$.

Also let $W_{xx} = \sum_i W_{xxi}$, $W_{xy} = \sum_i W_{xyi}$ and $W_{yy} = \sum_i W_{yyi}$. The estimations of the parameters α_i and β are obtained by minimising

$Q = \sum_{i,t}\left(y_{it} - \hat{\alpha}_i - \hat{\beta} x_{it}\right)^2$ with respect to $\hat{\alpha}_i$ and $\hat{\beta}$.

$$\frac{\partial Q}{\partial \hat{\alpha}_i} = 0 \Rightarrow \sum_{i,t} 2\left(y_{it} - \hat{\alpha}_i - \hat{\beta} x_{it}\right)(-1) = 0 \Rightarrow \hat{\alpha}_i = \overline{y_i} - \hat{\beta}\,\overline{x_i}$$

$$\frac{\partial Q}{\partial \hat{\beta}} = 0 \Rightarrow \sum_{i,t} 2\left(y_{it} - \hat{\alpha}_i - \hat{\beta} x_{it}\right)\left(-x_{it}\right) = 0 \Rightarrow \sum_{i,t} y_{it}x_{it} = \hat{\alpha}\sum_{i,t} x_{it} + \hat{\beta}\sum_{i,t} x_{it}^2$$

Substituting the expression for $\hat{\alpha}_i$ in the second equation, $\hat{\beta}$ can be simplified as $\hat{\beta} = W_{xy} / W_{xx}$. This method is also referred to as the "least squares with dummy variables" (LSDV) model. Therefore, the estimation often denoted $\hat{\beta}_{LSDV}$ or within-group estimation $\hat{\beta}_w$. The residual sum of squares is $W_{yy} - W_{xy}^2 / W_{xx}$.

In the case of several explanatory variables, W_{xx} is a matrix and $\hat{\beta}$ and W_{xy} are vectors. We get $\hat{\alpha}_i = \overline{y_i} - \hat{\beta}'\overline{x_i}$ and $\hat{\beta} = W_{xx}^{-1}W_{xy}$. The residual sum of squares is then $W_{yy} - W_{yx}\left(W_{xx}\right)^{-1}W_{xy}$.

- Ordinary Least Square Model

If we define $\bar{x}$ and $\bar{y}$ as deviation from the overall mean (rather than group means), overall sums of squares and sums of products are

$T_{xx} = \sum_{i,t}\left(x_{it} - \overline{x_i}\right)^2$, $T_{xy} = \sum_{i,t}\left(x_{it} - \overline{x_i}\right)\left(y_{it} - \overline{y_i}\right)$ and $T_{yy} = \sum_{i,t}\left(y_{it} - \overline{y_i}\right)^2$.

If we consider the hypothesis $\alpha_1 = \alpha_2 = \ldots = \alpha_N = \alpha$ then the model is $y_{it} = \alpha + \beta x_{it} + u_{it}$, in this case, $\hat{\alpha} = \bar{y} - \hat{\beta}\bar{x}$ and $\hat{\beta} = T_{xy} / T_{xx}$ which means no panel data specifics and known as ordinary least square estimations ($\hat{\beta}_{OLS}$).

- Random Effects Model

In the random effects model, the α_i in equation 5-1 are treated as random variables rather than fixed constants. The α_i are assumed to be independent of the errors u_{it} and also mutually independent. This model became popular in econometrics following the paper by Balestra and Nerlove

(1966) on the demand for natural gas. We shall assume that $\alpha_i \sim IID(0, \sigma_\alpha^2)$ and $u_{it} \sim IID(0, \sigma_u^2)$. *IID* stands for independent and identically distributed.

For simplicity, REM for only one explanatory variable is the same as equation 5-1 except that α_i are random variables. Since α_i are random, the errors now are $v_{it} = \alpha_i + u_{it}$ and the presence of α_i produces a correlation among the errors of the same cross-section unit though the errors from the different cross-section units are independent. Thus we have

$$\mathrm{cov}(u_{it}, v_{is}) = \sigma_u^2 + \sigma_\alpha^2 \ \textit{for} \ t = s \qquad \mathrm{cov}(u_{it}, v_{is}) = \sigma_\alpha^2 \ \textit{for} \ t \neq s$$

$$\mathrm{cov}(u_{it}, v_{js}) = 0 \ \textit{for all } t, s \textit{ if } i \neq j$$

Since the errors are correlated, we have to use generalised least squares (GLS) to get efficient estimates. The GLS estimator can be written in the simple form

$$\hat{\beta}_{GLS} = \frac{W_{xy} + \theta B_{xy}}{W_{xx} + \theta B_{xx}}, \quad \theta = \frac{\sigma_u^2}{\sigma_u^2 + T\sigma_\alpha^2}$$

where W refers to within-group sums of squares and sums of products defined earlier. Thus B refers to between-group sums of squares and sums of products $B_{xx} = T_{xx} - W_{xx}$, $B_{xy} = T_{xy} - W_{xy}$ and $B_{yy} = T_{yy} - W_{yy}$.

In the case of several explanatory variables, W_{xx} and B_{xx} will be matrices, W_{xy} and B_{xy} will be vectors, and $\hat{\beta}_{GLS}$ will be $(W_{xy} + \theta B_{xy})(W_{xx} + \theta B_{xx})^{-1}$.

Because there are three models used to estimate panel data, two tests are usually used to choose a better model.

- Lagrange Multiplier Test (Breusch and Pagan Test)

This test, proposed by Breusch and Pagan (1980), tests whether $\sigma_\alpha^2 = 0$. This is the case where the individual components do not exit and we can use the OLS method. If we denote the residuals from the least squares regression by $\hat{u}_{it}$ and define

$S_1 = \sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{u}_{it}\right)^2$, $S_2 = \sum_{i=1}^{N}\sum_{t=1}^{T}\hat{u}_{it}^2$ and $\lambda = \frac{NT}{2(T-1)}\left(\frac{S_1}{S_2} - 1\right)^2$ then λ has a x^2-distribution with d.f. 1.

- Hausman Test

The Hausman Test is usually applied to test for fixed versus random effects models. Mundlak (1978) said that we can test the hypothesis:
H_0: α_1 are not correlated with x_{it}.
H_1: α_1 are correlated with x_{it}.
Under H_0, GLS estimator (REM) is consistent and efficient. On the other hand, the within-group estimator $\hat{\beta}_w$ (FEM) is consistent whether the null hypothesis is valid or not since all time-invariant effects are subtracted out. Thus we can construct $q = \hat{\beta}_w - \hat{\beta}_{GLS}$. Also $V(q) = V\left(\hat{\beta}_w\right) - V\left(\hat{\beta}_{GLS}\right)$. Hence we use $m = \hat{q}'\left[\hat{V}\left(\hat{q}\right)\right]^{-1}\hat{q}$ as a x^2-statstic with d.f. k where k is the dimensionality of β.

5.2 Functional Form Test and Estimations of Recyclables Models

Suitable functional forms for dumping and recycling models may be obtained from previous studies. However, only two studies (Houtven and Morris, 1999; Sterner and Bartelings, 1999) showed various functional form results, Dijkgraaf and Gradus (2004) used exponential functional form, and all other studies use linear models. Houtven and Sterner's papers showed that the choice of functional form was not unambiguous although exponential models did have a higher adjusted R square. One reason why linear models are most popular in waste empirical studies is that policy variables, such as kerbside recycling (*KR*), involve dichotomous or discrete variables which may have value of zero and cannot be logged. Only income (*INC*), density (*DEN*), prices (*PNR* and *PKR*) can be logged in exponential models.

The household's choice is based on the marginal cost of every disposal method. Because the recycling ratio reflects the choice between dumping and recycling, this thesis uses a reduced-form of recycling ratio (Eq. 4-10) to identify suitable functional forms. Two recycling enforcement policies, the policy of using transparent garbage bag (*TBG*) and mandatory recycling (*MR*), replace the *REN* in Eq. 4-10.

Three kinds of functional form are tested, including Linear-linear, Log-linear and Log-log with Eq. 4-10. Table 5.1 reports estimates of the Fixed Effects Model (FEM, dummy of cities' fixed effects) of recycling rate. The Limdep result reports are in Appendix 7 (pp. A19). Four models are tested. This thesis uses Limdep 8 and NLOGIT 3[26] to run all estimations. All variables in Model 1 are linear, *DEN* is logged in Model 2, and only variables-*PNR*, *FNR*, *INC* and *DEN* are logged in Model 3 (Lin-log) and Model 4 (Log-log) because other variables have some zero value. All four models can reject that coefficients are jointly zero at 99% confidence level. Model 2 and Model 3 have better adjusted R^2 than Model 1.

Since dependant variable is logged in Model 4, adjusted R^2 cannot be compared with other models directly. According to the method suggested in Wooldridge (2003), regressing the actual recycling ratios (*RR*) on the exponential fitted values in Model 4 ($\exp\left(\log \hat{RR}\right)$), and the squared of the correlation between actual recycling ratio (*RR*) and the fitted value of above regression ($\hat{RR}$) can be compared with adjusted R^2 obtained from model without logged dependant. The Limdep report of this supplement regression is shown in Appendix 7 (pp. A30). The squared correlation is 0.46 which is much lower than other models. Model 2 and 3 are better than Model 4.

The coefficients of Model 2 and Model 3 have signs that are consistent with expectations (Table 4.1). The Lagrange multiplier test shows that these two models dominate the non-panel data model (only independent variables and a constant) is better at 1% significance. The Hausman Test result shows that these two FEM is better than REM at 1% significance. Both Model 2 and Model 3 may be suitable for household's dumping and recycling estimations

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[26] Copyright of 1996-2003 Econometrics Software written by William H. Greene

and both will be tested for total recyclables (Eq. 4-9), disaggregated recyclables (Eq. 4-7), non-recyclables (Eq. 4-12) and total waste generation (Eq. 4-13).

Besides functional forms, some alternative variables and estimation method are tested. When *PPPINC* in Model 2 and Model 3 is replaced by *INC* (per capita income counted in 1995 USD), the FEM estimations have similar results with original models but lower R^2. When White's robust covariance matrix[27] is used to estimate Model 2 and Model 3, the estimations are the same as in the original models. Therefore, correction for heteroscedasticity is unnecessary.

Table 5.1 FEM estimates of recycling rate

	Dependent: recycling rate (*RR*) of per capita per day waste			
Independent	Lin-lin, Model 1	Lin-lin, Model 2	Lin-log, Model 3	Log-log, Model 4
PNR (price of NR)	.66792 (2.231)**	.62512 (2.277)**	.28445E-01 ^ (2.837)***	.27281 ^ (2.240)**
FNR (frequency of NR)	-.11607 (-3.792)***	-.96950E-01 (-3.475)***	-.63346 ^ (-3.772)***	-4.82901 ^ (-2.367)**
KR (kerbside rec.)	-.80310E-02 (-.235)	-.13569E-01 (-.432)	-.46958E-02 (-.149)	.75991 (1.989)**
PPPINC (PPP based inc.)	.71918E-05 (.909)	.96866E-05 (1.334)	.15966 ^ (1.035)	4.22509 ^ (2.253)**
TBG (transparent bag)	.18272E-01 (.685)	.38412E-01 (1.584)	.28361E-01 (1.149)	.15083 (.503)
DEN (density)	.29895E-03 (6.123)***	2.00720 ^ (7.732)***	2.01764 ^ (7.896)***	17.85602 ^ (5.752)***
FI (dummy of fine)	-.35634E-02 (-.073)	-.49940E-01 (-1.096)	-.45647E-01 (-1.032)	.20220 (.376)
MR (mandatory rec.)	.63319E-01 (2.444)**	.62751E-01 (2.648)***	.62516E-01 (2.661)***	.75881 (2.659)***
PKR (price of KR)	.53929E-02 (.044)	-.10069 (-.874)	-.10601 (-.934)	-1.07470 (-.780)
CR (recycling cat.)	.27885E-01 (3.534)***	.22891E-01 (3.133)***	.18986E-01 (2.573)**	.77522E-01 (.865)
adjusted R^2	.79162	.82486	.83027	.75226
F(27, 80)	16.06	19.66	20.39	13.03

Note: (a.) *, ** and *** indicate significance at 0.1, 0.05 and 0.01 level, respectively.

(b.) ^ is coefficient of logged variable. (c.) Limdep reports are on pp. A19.

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[27] the classic correction for heteroscedasticity proposed by White (1980). In the OLS (including FEM) regression, if cases don't have equal error variance, it's called heteroscedasticity and correction is required.

To make sure the functional form is correct, no omitted variable, a popular test of functional form misspecification, suggested by Ramsey (1969), is Regression Specification Error Test (RESET), which is based on the idea that nonlinear independent terms, if added to the proposed model, should not be able to explain the dependent. The original function, Model 2 and 3, is restricted regression and their residuals sums of squares are 0.12170 and 0.11794. Models that squared and cubic estimated recycling ratios are added are unrestricted regression and their residuals sum of squares are 0.11636 and 0.11696 (Limdep result reports are in Appendix 7 (pp. A32)). The null hypothesis (H_0) is that restricted regression has no omitted variables. The calculation of test statistic is following.

$$F = \frac{(RSS_R - RSS_{UR})/J}{RSS_{UR}/(T-K)}$$

In this equation, J is one restricted number, T is 108 total observations, and K is 30 parameters to be estimated. The P-value of this statistic is 0.42 for Model 3 which shows the unrestricted model cannot reject the null hypothesis of correct functional form. The results of the RESET show Model 3 (Lin-log model) to be better than Model 2. Model 3 is particularly suitable for recycling ratio estimation.

The FEM estimation of total recyclables is reported in Table 5.2. It can reject the hypothesis that coefficients are jointly zero at the 99% confidence level. The LM Test and Hausman Test show that this model can reject non-penal model and REM are better at 1% significance, respectively. The Limdep result report is in Appendix 7 (pp. A39). The implications of variables in the recycling ratio and total recyclables models will be discussed later.

Table 5.2 FEM estimates of total recyclables

Independent	*TOR*
PNR (price of NR)	20.48963 ^ (1.883)*
FNR (frequency of NR)	-574.56364 ^ (-3.152)***
KR (kerbside rec.)	11.43873 (.335)
PPPINC (PPP based inc.)	193.56270 ^ (1.155)
TBG (transparent bag)	41.21266 (1.538)
DEN (density)	1791.06553 ^ (6.456)***
FI (dummy of fine)	-47.71348 (-.993)
MR (mandatory rec.)	44.40290 (1.741)*
PKR (price of KR)	-91.01401 (-.739)
CR (recycling cat.)	18.43853 (2.302)**
adjusted R^2	.80517
$F(27, 80)$	17.38

Note: (a.) *, ** and *** indicate significance at 0.1, 0.05 and 0.01 level, respectively.

(b.) ^ is coefficient of logged variable. (c.) Limdep report is on pp. A39.

The estimation of each kind of recyclable (Eq. 4-7) is based on the functional form of Model 2 or Model 3. The coefficient of *PKR* is unavailable in recyclable paper model because no city charges for paper recycling. According to the data, three Japanese cities including Sendai City at 2002, Nagoya City at 2000 and Nagasaki City at 2002 started to provide kerbside plastics container recycling with charge, and the amount of plastics recycling is zero before kerbside recycling is provided. Since the correlation between $PKR_{plastics}$ and $KR_{plastics}$ is high, *PKR* in recyclable plastic has also been abandoned. The estimations for each kind of recyclable are reported in Table 5.3 and the Limdep reports of these models appear in Appendix 7 (pp. A42). All models can reject that coefficients are jointly zero at 99% confidence level. The LM Test of shows that these panel data models are better than non-panel data models at the 1% significance level. The Hausman Test shows that these FEMs are better than REMs at 1% significance except for the plastics

(5% significance) and glass models (15% significance).

Table 5.3 FEM estimates of recyclable materials

Independent	Dependent: per capita per day recyclable				
	PAW (paper)	*MEW* (metal)	*GLW* (glass)	*PTW* (PET bottles)	*PLW* (plastics)
PNR (price of NR)	10.58976 ^ (1.162)	171.68137 (3.385)***	60.63698 (2.803)***	40.80697 (3.679)***	.70125 ^ (.584)
FNR (freq. of NR)	-246.19722 ^ (-1.677)*	-16.55294 (-3.359)***	-.82485 (-.392)	.44375 (.411)	-11.18275 ^ (-.580)
KR (kerbside rec.)	44.80343 (2.096)**	6.21815 (1.175)	2.01219 (.891)	1.84535 (2.219)**	13.37900 (7.691)***
PPPINC (PPP income)	-12.39166 ^ (-.093)	.46546E-02 (3.541)***	-.29281E-03 (-.522)	.52628E-03 (1.946)*	-10.42644 ^ (-.615)
TBG (trans. bag)	62.53126 (2.917)***	-5.05549 (-1.325)	-1.32321 (-.813)	1.34199 (1.586)	1.35214 (.471)
DEN (density)	1095.59704 ^ (4.736)***	114.53416 ^ (2.438)**	47.20572 ^ (2.356)**	58.04681 ^ (5.559)***	111.42355 ^ (3.711)***
FI (dummy of fine)	-54.10606 (-1.348)	-.16201 (-.019)	.39397 (.110)	.57189 (.320)	-4.70648 (-.918)
MR (mand. rec.)	3.54324 (.172)	12.46093 (2.852)***	.86346 (.463)	3.36733 (3.772)***	1.59576 (.616)
PKR (price of KR)	na.	-25.54755 (-1.198)	-11.28778 (-1.241)	.43922 (.094)	na.
adjusted R^2	.72951	.72110	.92229	.73546	.72289
F-statistics	12.54	11.64	49.85	12.44	12.17

Note: (a.) *, ** and *** indicate significance at 0.1, 0.05 and 0.01 level, respectively.

(b.) ^ is coefficient of logged variable. (c.) Limdep reports are on pp. A42.

All significant coefficients in paper, metal, glass, PET bottles and plastics models in Table 5.3 have signs that are consistent with expectations (Table 4.1). The recycling ratio (Model 3), total recyclables and each recyclable material model show similar results. The implications of the coefficients are discussed below.

1. price of non-recyclables collection (*PNR*)

The coefficient of *PNR* is positive in all regressions, which is consistent with expectations (Table 4.1). The higher *PNR* raises marginal cost of dumping and increases recycling. *PNR* can significantly increase recycling ratio, total recyclables, recyclable metal, glass and PET bottles. The coefficient of *PNR* is highest in recyclable metal including all kinds of cans, tins, cutlery, cooking staff and metal container *etc.* which might be largest part of waste composition of recyclables and one of most traditional and popular recyclable material.

The coefficient of *PNR* is higher significant in recycling ratio model than in total recyclables model. The possible reason is that the higher *PNR* causes source reduction, in which the total waste generation is reduced, the recycling ratio is increased, but total recyclables is only increased slightly.

2. frequency of non-recyclables collection (*FNR*)

The coefficient of *FNR* is negative in models, which is consistent with expectations (Table 4.1). It's significant in the recycling ratio, total recyclables, recyclable paper and metal models. The higher *FNR* decreases marginal cost of dumping (less dumping preparation), which increases dumping and decreases recycling. The *FNR* is highly significant in recyclable metal model. One possible reason is that dumping recyclable metal is more troublesome than other materials because metal is the largest part of waste composition of recyclables.

3. providing kerbside recycling (*KR*)

KR is significant in recyclable paper, PET bottles and plastics models and the coefficient is positive which is consistent with expectations (Table 4.1). *KR* can decrease the marginal cost of recycling, which can increase the recycling amount. *KR* is insignificant in recyclable metal and glass. One possible reason is that 93% of all cases provide kerbside metal and glass recycling, and paper and plastics are the latest materials to be added into Japanese kerbside recycling systems.

4. per capita income based on PPP (*PPPINC*)

Purchasing power parity adjusted income slightly increases metal and PET bottles recycling, which is consistent with expectations (Table 4.1). Households with higher incomes may consume more goods and generate more recyclables.

5. logged population density (*LDEN*)

LDEN increase all kinds of recyclables, which is also consistent with expectations (Table 4.1). One explanation is that higher population density increases the marginal cost of illegal dumping, which increases recycling. Another explanation might be that garbage treatment cost is higher in densely populated cities leading those cities to do more recycling promotions.

6. mandatory recycling adopted (*MR*)

MR, a recycling enforcement (*REN*), increases the recycling ratio, total recyclables, metal and PET bottles, all of which matches expectations (Table 4.1). The reason for the insignificance of paper and glass recycling may be that paper and glass recycling have a very long history in Taiwan and many private organizations provide paper recycling. Households may not recycle more paper and glass after mandatory recycling adopted.

7. fine for illegal dumping (*FI*)

FI has no significant effect in any recyclable models. The reason is that while all cities have nominal fines for illegal dumping, only half of them are enforced in any measure, which may be ascribed to difficulty of detection.

8. the policy of using transparent garbage bag (*TBG*)

TBG, a recycling enforcement (*REN*), increases paper recycling, which is consistent with expectations (Table 4.1). The reason may be that paper takes more space in garbage bags and can be seen easily. Because *TBG* policy is mainly adopted in Japanese cases and all cases adopting *MR* are in Taiwan, this significant effect in recycling increasing is attributable to social pressure rather than mandatory recycling.

9. the price of kerbside recycling (*PKR*)

PKR has no significant effect on recycling. All cities that charge for kerbside recycling have the same price on non-recyclables collection. The relative price of kerbside recycling is zero, which decreases the negative effect of *PKR*.

10. recycling categories (*CR*)

CR has significant effect on recycling ratio and total recyclables models, which matches expectation (Table 4.1). *CR* increases materials that can be recycled. According to the data, recycling categories are increased by materials entered kerbside recycling later, such as kerbside paper and plastics recycling in Japan, and kitchen waste recycling in Taiwan.

5.3 Estimations of Non-recyclables and Total Waste Generation Models

The FEM estimations of Equation 4-12 and 4-13 (non-recyclables and total waste generation) are shown in Table 5.4. Two models are estimated for each equation. One includes only original variables and the other one includes an interaction term for enforcements. An assumption in Chapter 4 is that on-time collection (*OTC*) is a kind of unit-pricing enforcement (*UEN*) which can enforce unit-pricing by increasing the chance of being prosecuted. The interaction term *INT*, on-time collection and unit-pricing (or transparent bag), is added into the regressions. The Limdep result reports of these models are in Appendix 7 (pp. A56).

These four models are suitable for describing household dumping behaviour. They all reject the hypothesis that coefficients are jointly zero at 99% confidence level. The LM Test shows that these four panel data models are better than the non-panel models at the 99% confidence level. The Hausman Test shows that two FEM models of non-recyclables are better than REM models at the 99% confidence level and that two FEM models of total waste are better than REM models at the 80% confidence level. These four models show similar results and all significant coefficients have expected signs. The lower price of garbage collection and higher garbage collection frequency can significantly increase non-recyclables. Mandatory recycling can significantly decrease both non-recyclables and total waste. Two enforcements, the policy of using transparent garbage bag and on-time collection, have a barely significant effect on both non-recyclables and total waste. The interaction term *INT* is significant in two FEM estimations.

Table 5.4 FEM estimates of non-recyclables and total waste generation

ndependent	*NRW* (non-recyclables)	*NRW* (non-recyclables)	*TOW* (total waste)	*TOW* (total waste)
PNR (price of NR)	-2424.14809 (-4.225)***	-1675.41059 (-1.377)**	-1980.18947 (-3.275)***	-692.14558 (-.943)
FNR (freq. of NR)	118.28808 (2.105)**	112.41849 (1.532)**	54.07069 (.913)	43.97330 (.773)
KR (kerbside rec.)	106.24069 (1.117)	103.38135 (.808)	150.31215 (1.499)	145.39327 (1.512)
PPPINC (PPP income)	.48117E-02 (.322)	.91928E-02 (1.761)	.12481E-01 (.792)	.20018E-01 (1.305)
TBG (trans. bag)	-82.61071 (-1.914)*	-69.98588 (.812)	2.74703 (.060)	24.46538 (.553)
DEN (density)	-3078.22610 ^ (-5.889)***	-3162.47787 ^ (-5.775)***	-1182.99816 ^ (-2.147)**	-1327.93546 ^ (-2.503)**
FI (dummy of fine)	11.40524 (.116)	6.70256 (.259)	-45.35186 (-.436)	-53.44183 (-.536)
MR (mand. rec.)	-264.95845 (-5.365)***	-260.36985 (-3.093)***	-223.57938 (-4.295)***	-215.68567 (-4.316)***
OTC (on-time coll.)	-48.34895 (-.453)	-50.52695 (-.453)	-51.89429 (-.461)	-55.64108 (-.516)
INT (*OTC* * *TBG*)	na.	-186.84161 (-2.016)*	na.	-321.42131 (-2.858)***
adjusted R^2	.79486	.79952	.72126	.74393
F-statistics	16.95	16.80	11.65	12.51

Note: (a.) *, ** and *** indicate significance at 0.1, 0.05 and 0.01 level, respectively.
(b.) ^ is coefficient of logged variable. (c.) Limdep reports are on pp. A56.

The implications of of the findings in Table 5.4 are discussed below.

1. price of non-recyclables collection (*PNR*)

The coefficients of *PNR* are significant in models of non-recyclables and the model of total waste without interaction terms (Table 5.4). The garbage collection price elasticity of non-recyclables can be derived from the definition of elasticity by this equation.

$$\varepsilon = \frac{NRW'-NRW}{NRW} / \frac{PNR'-PNR}{PNR} = \frac{\Delta NRW}{\Delta PNR} \times \frac{PNR}{NRW} \cong \beta_{PNR} \times \frac{\overline{PNR}}{\overline{NRW}} \qquad (5\text{-}2)$$

The marginal effect of *PNR* on non-recyclables (β_{PNR}) is -2424.15 in model without any interaction term. According to Table 4.3 and 4.6, $\overline{PNR}$ is 0.024 and $\overline{NRW}$ is 839.35, so the price elasticity of non-recyclables at the average price is 0.069. *PNR* also significantly decreases total waste generation (model without interaction term) but the price elasticity of total waste generation at the average price is only 0.049. The price of non-recyclables collection in the data is per 10 litres but the price elasticity is the same as per litre. Compared with other empirical studies on bag or tag waste pricing system (Table 2.1), the estimated price elasticity in this thesis is similar to that obtained by Fullerton and Kinnaman (1996) but is lower than other studies including Hong (1999) in Korean survey. There may be two reasons for the low price elasticity calculated by whole data regression:

a. The average *PNR* is very low;
b. Some unit-pricing effects may be captured by cities' dummy variables in the FEM estimations, since there is no change in the price charged by those cities from 1998 to 2003.

The data only includes the four cities that started to adopt unit-pricing during 1998 to 2003, which are Taipei, Nagoya, Nagasaki and Naha City. The price elasticity for each of these cities should be calculated by arc-elasticity which uses average price ($\overline{PNR}$) and quantity ($\overline{NRW}$) rather than original price (PNR) and quantity (NRW) because the original price is close to zero which will make the elasticity unreasonable low (Eq. 5-3).

$$\varepsilon_{arc} = \frac{\Delta NRW}{\Delta PNR} \times \frac{\overline{PNR}}{\overline{NRW}} = \frac{NRW'-NRW}{PNR'-PNR} \times \frac{(PNR'+PNR)/2}{(NRW'+NRW)/2} \tag{5-3}$$

The average price ($\overline{PNR}$) is approximate half of unit-price. The price elasticities of non-recyclables are listed in Table 5.5. The price elasticity increases as the unit-price increases but may also increase over time. The price elasticity of demand is lower in the short run than in the long run[28] (Begg *et al.*, 2000). Households can change their consumption patterns which decrease waste generation in the long run. Linderhof *et al.* (2001) found higher elasticity for waste collection in long run as well. In Table 5.5, the elasticity in Nagoya City calculated over five years is higher than that in Naha City calculated over three years, despite the that fact that unit-prices are higher in Naha than in Nagoya. In the cases where unit-prices are relatively high, and where the scheme has been in force for a long time, the price elasticity ranges from 0.220, Nagoya, to 0.346, Taipei.

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[28] The short run refers to the period immediately after prices change and before long-term adjustment can occur. The long run is the period necessary for complete adjustments to a price change. Its length depends on the type of adjustments consumers wish to make.

Table 5.5 Price elasticity for non-recyclables

data	whole data	Nagasaki from 2001 to 2003	Nagoya from 1999 to 2003	Naha from 2001 to 2003	Taipei from 1999 to 2003
price	at average *PNR*: 0.024	unit-price: 0.028	unit-price: 0.041	unit-price: 0.086	unit-price: 0.144
NRW	0.069	0.092	0.220	0.114	0.346

The significant negative coefficient of *PNR* in *TOW* estimation (without interaction term) is consistent with the results that *PNR* significantly increase recycling ratio (Table 5.1) but only slightly increase total recyclables (Table 5.2) because the higher *PNR* generates source reduction. This is illustrated in Figure 5.1.

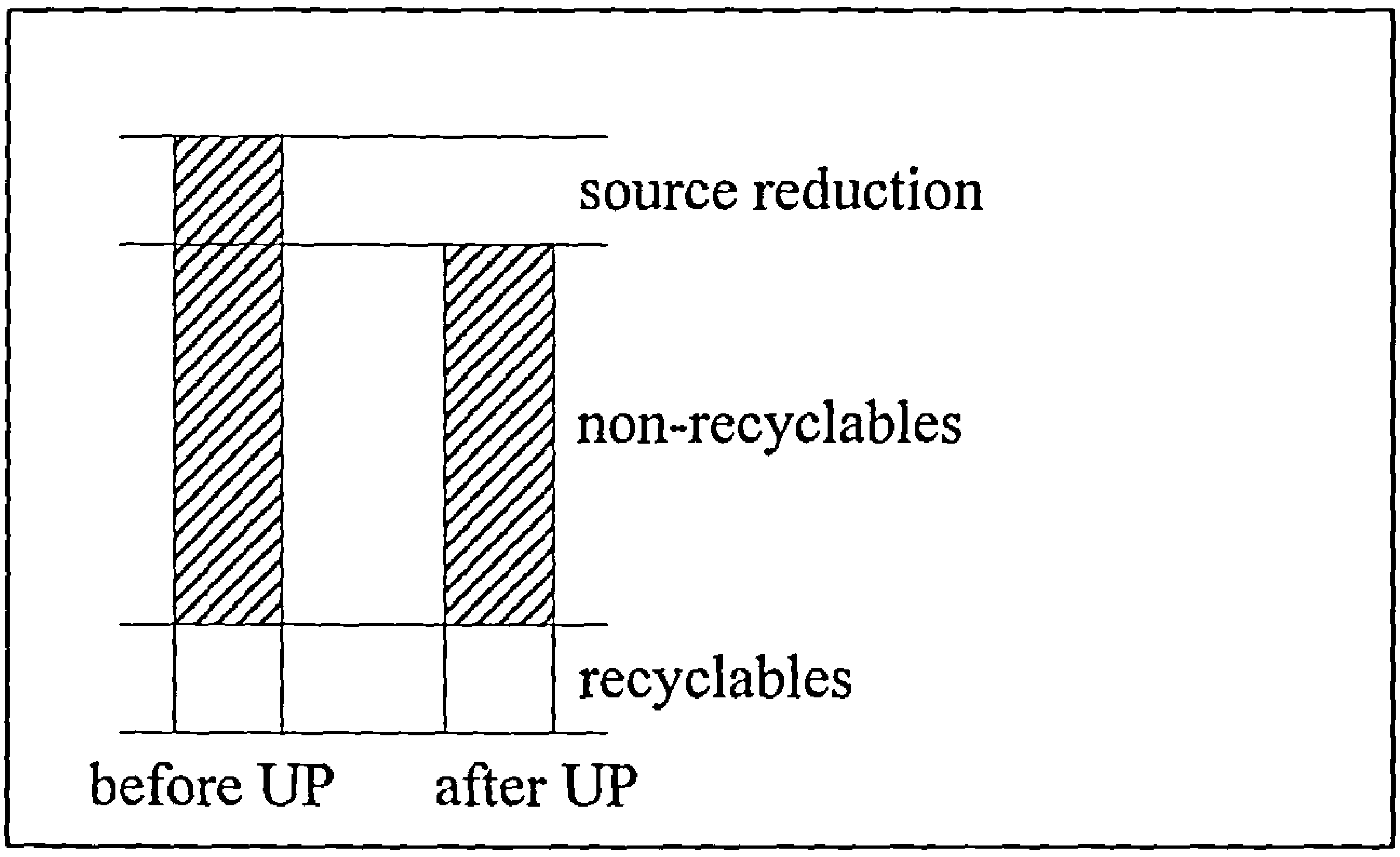

Fig 5.1 Composition of waste before and after unit-pricing

2. per capita income based on PPP (*PPPINC*)

PPPINC has insignificant effect on non-recyclables and total waste generation. These results show that among income groups in the range 10000 to 30000 PPP based per capita income, waste management policies can be effective in preventing solid waste from increasing.

3. policy of using transparent bag (*TBG*) and on-time collection (*OTC*)

Only *TBG* can slightly decrease non-recyclables and *OTC* are insignificant in non-recyclables and total waste generation models. It shows that each of these two enforcements alone cannot decrease garbage disposal.

4. logged population density (*LDEN*)

LDEN significantly decreases non-recyclables and total waste, which is consistent with expectations (Table 4.1). Households in high population density areas possess fewer physical commodities and generate less waste. This result is the same as that reported in Podolsky and Spiegel (1998).

5. fine for illegal dumping (*FI*)

FI has no significant effect on non-recyclables and total waste. The reason may be the same as that reported for the recyclables models. All cities have nominal fines for illegal dumping but only half of them enforce it or try to do it. Whether cities try to fine illegal dumping or not, it does not have effect on waste. The lack of enforcement may be ascribed to the difficulty of detection.

6. mandatory recycling adopted (*MR*)

MR, a recycling enforcement (*REN*), decreases non-recyclables and total waste in every models (Table 5.5), which is consistent with expectation (Table 4.1). These results show that mandatory recycling can not only increase recycling but also decrease waste generation.

7. interaction term (*INT*)

INT has significant negative effect on the amount of non-recyclables and total waste generation and *PNR* is also significant in *NRW* models, which means on-time collection does enforce unit-pricing, especially to non-recyclables. However, *PNR* is insignificant in the *TOW* model with interaction term, which means only where there is *INT*, Taipei's unit-pricing case, can the policy significantly decreases total waste generation, and unit-pricing in other cities has limited source reduction. Because Taipei is the only city with *INT* and their *PNR* are higher than other cities, this result cannot be taken to mean that enforcement is definitely the cause of source reduction in Taipei.

5.4 Empirical Study of Inspection Effort with Taiwanese Cases

Whether or not the municipal authority fines illegal dumping (*FI*) is insignificant in all recyclables and non-recyclables models in the data including Japanese and Taiwanese cases. In this section, three illegal dumping[29] prosecution and inspection variables from Taiwan Environmental Database (see footnote 16) will replace *FI* one by one and be tested with Taiwanese data. These three variables includes the annual prosecuted fines per 1000 residents (USD, *ENAF*), the annual inspection times per 1000 residents (*ENAT*), and the inspection labours per 100000 residents (people, *ENAP*). Because no Taiwanese city charges residents for kerbside recycling, and because a high percentage of Taiwanese cities (81%) have adopted on-time collection which also has a high correlation (0.92) with providing kerbside recycling (*KR*), *PKR* and *OTC* are omitted from models for Taiwanese data.

The following discussion focuses on *ENAF* because *ENAT* and *ENAP* aren't significant in all models. Table 5.6 lists FEM estimations for recycling ratio model. The Limdep estimation report is on Appendix 7 (pp. A68). This model rejects that coefficients are jointly zero at 99% confidence level and LM test shows that this panel data model (FEM) is better than OLS model at 90% confidence level. All significant variables have signs that are consistent with expectations (Table 4.1).

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[29] As mentioned in section 4.3, the illegal dumping in the database includes waste disposal not via municipal waste and recycling collections and violation of unit-pricing and mandatory recycling rules.

Table 5.6 FEM estimations for recycling ratio model with *ENAF*

	RR
PNR	1.1284 #
FNR	-.4682E-01
KR	.1999E-01
PPPINC	.2980E-05
LDEN	2.8422 #
ENAF	.3969E-02
MR	.6367E-01 #
CR	-.1604E-01
adj- R^2	.8126

Note: (a.) # indicates the coefficient is significant at higher than 90% confidence level.

(b.) Limdep report is on pp. A68.

OLS estimations for recyclables and waste models are listed in Table 5.7 because LM test shows that their panel data models aren't better than OLS models at 90% confidence level. The Limdep estimation reports are on Appendix 7 (pp. A71). *ENAF* has significant positive effect on *NRW* and *TOW*, which is consistent with expectations (Table 4.1). The inspection effort (prosecuted fine) can decrease illegal dumping, which may increase non-recyclables and total waste generation. However, *ENAF* has a negative effect in some recyclable models, which is unexpected. The possible reason is that *ENAF* data includes all kinds of violations of waste management laws/rules. The prosecuted fine is likely increased by fining incorrect recycling classifications and discarding recyclable materials at unauthorised time and places rather than littering, after unit-pricing or mandatory recycling policies adopted. When the cost of recycling is increased by this enforcement, the effect of *ENAF* is similar with *PKR* which is expected to have negative effect on recycling (Table 4.1).

Table 5.7 OLS estimations for recyclables and waste models with *ENAF*

	TOR ^	*PAW ^*	*MEW*	*GLW ^*
PNR	51.6791 #	26.1430 #	201.5085 #	.1503E-01
FNR	-67.5755	-71.9202	1.1905	-3.4366
KR	113.2071 #	39.8640 #	16.5419 #	2.5409 #
PPPINC	3.7692	-13.9170	.4966E-03	-.6721
LDEN	-12.9194	-22.9757 #	-13.0592 #	-.8271
ENAF	-35.1717 #	-11.1098	-.5413	-1.5159 #
MR	48.9965 #	21.4647 #	5.2914	.3582
CR	-20.6280	na.	na.	na.
constant	507.0944	608.8932	96.0285	22.8473
adj- R^2	.5036	.4834	.3316	.4355
	PTW	*PLW ^*	*NRW*	*TOW*
PNR	24.3153	.1530	-2003.7212 #	-1148.6580
FNR	.2413	30.8088 #	141.8978 #	121.3151 #
KR	2.2739	7.8300 #	7.0694	90.8030
PPPINC	.3162E-03	3.7658	.3159E-02	.1207E-02
LDEN	2.1894 #	.9399	27.0971	-7.7916
ENAF	-.5205 #	-4.5054 #	17.9309 #	12.9980 #
MR	2.1229 #	3.5202	-326.0787 #	-284.0842 #
CR	na.	na.	na.	na.
constant	-21.9233	-91.8919	-213.0118	288.9006
adj- R^2	.5542	.5076	.5059	.4307

Note: (a.) # indicates the coefficient is significant at higher than 90% confidence level.

(b.) ^ indicates Lin-log model in which *PNR*, *FNR*, *PPPINC* and *ENAF* are logged, and other models are Lin-lin model in which only *DEN* is logged, *LDEN*.

(c.) Limdep reports are on pp. A71.

5.5 Summary of Empirical Study

For the data including Japanese and Taiwanese cases, the FEM estimates of recycling ratio, total recyclables, recyclable materials and total waste generation are found adequate to explain household recycling and waste generation behaviours. All significant coefficients have expected signs. A summary of the estimated models is listed in Table 5.8. The higher price of non-recyclables collection (price of unit-pricing) can significantly increase recycling ratio, total recyclables, recyclable metal, glass and PET bottles. Unit-pricing combined with on-time collection enforcement can significantly decrease non-recyclables and total waste generation. The price elasticity of non-recyclables and total waste at the average price are 0.069 and 0.049, respectively. When the unit-pricing price goes high and in the long run, the price elasticity may be as high as 0.220, like Nagoya's case, or 0.346, like Taipei's case. The higher frequency of non-recyclables collection decreases the recycling ratio, total recyclables, recyclable paper and metal, which may be caused by lowering marginal dumping cost.

Mandatory recycling policy increases the recycling ratio, total recyclables, recyclable metal and PET bottles. The recycling categories significantly increase recycling ratio and total recyclables due to increasing materials that can be recycled. According to the data, recycling categories are increased by materials entered kerbside recycling later, such as kerbside paper and plastics recycling in Japan, and kitchen waste recycling in Taiwan. Mandatory recycling decreases non-recyclables and total waste generation as well. The policy of using transparent garbage bag only increases paper recycling. The reason probably is that paper takes more space in garbage bag and can be seen easily.

Table 5.8 Summary of estimated models

	RR ^	*TOR* ^	*PAW* ^	*PLW* ^	
PNR	.28445E-01 #	20.48963 #	10.58976	.70125	
FNR	-.63346 #	-574.56364 #	-246.19722 #	-11.18275	
KR	-.46958E-02	11.43873	44.80343 #	13.37900 #	
PPPINC	.15966	193.56270	-12.39166	-10.42644	
TBG	.28361E-01	41.21266	62.53126 #	1.35214	
LDEN	2.01764 #	1791.06553 #	1095.59704 #	111.42355 #	
FI	-.45647E-01	-47.71348	-54.10606	-4.70648	
MR	.62516E-01 #	44.40290 #	3.54324	1.59576	
PKR	-.10601	-91.01401	na.	na.	
CR	.18986E-01 #	18.43853 #	na.	na.	
	NRW	*TOW*	*MEW*	*GLW*	*PTW*
PNR	-2424.1481 #	-1980.1895 #	171.68137 #	60.63698 #	40.80697 #
FNR	118.28808 #	54.07069	-16.55294 #	-.82485	.44375
KR	106.24069	150.31215	6.21815	2.01219	1.84535 #
PPPINC	.48117E-02	.12481E-01	.46546E-02 #	-.29281E-03	.52628E-03 #
TBG	-82.61071 #	2.74703	-5.05549	-1.32321	1.34199
LDEN	-3078.2261 #	-1182.9982 #	114.53416 #	47.20572 #	58.04681 #
FI	11.40524	-45.35186	-.16201	.39397	.57189
MR	-264.95845 #	-223.57938 #	12.46093 #	.86346	3.36733 #
PKR	na.	na.	-25.54755	-11.28778	.43922
OTC	-48.34895	-51.89429	na.	na.	na.

Note: (a.) # indicates the coefficient is significant at higher than 90% confidence level.

(b.) ^ is Lin-log model and others are Lin-lin model (only *DEN* is logged).

Concerning illegal dumping inspection efforts, whether or not the authority tries to fine illegal dumping is insignificant in all models. In Taiwanese data, the prosecuted penalty (fine) per 1000 residents has significant positive effect on non-recyclables and total waste generation because the average penalty can decrease illegal dumping, which may increase non-recyclables and total waste generation.

Purchasing power based per capita income can slightly increase metal and PET bottles recycling. Population density increases all kinds of recyclables probably because the marginal cost of illegal dumping is increased in high density area. Population density also significantly decreases non-recyclables and total waste generation, which might be because households in high population density areas possess fewer commodities and generate less waste. Another possible reason is that cities with higher population density put more effort into promoting recycling and waste reduction.

Chapter 6 Policy Simulations

In Chapter 5, waste and recycling models are estimated. Using these models we can simulate residents' waste generation and recycling behaviours when waste management policies are applied. This chapter simulates the effects of unit-pricing, garbage collection and mandatory recycling policies, and estimates the social cost of each policy. These estimates are then used to make policy recommendations.

6.1 Simulation of Unit-pricing Policy

In Table 5.8, the price of non-recyclables collection (*PNR*) is shown to increase recycling significantly, and to decrease non-recyclables and total waste generation. This section will simulate the application of unit-pricing policy on Hsinchu City because it didn't adopt unit-pricing or mandatory recycling policy during 1998 to 2003 and its non-recyclables per capita is relatively high. The data shows that the price of normal garbage bag in Taiwanese cities is 0.01 USD/10litres. Four scenarios are considered. The first applies unit-price to 0.144 USD/10litres which is the price in Taipei City, the second sets to 0.086 which is the highest unit-price in Japan, and the third sets to 0.041 which is the lowest unit-price in Japan. Because *PNR* has no significant effect on paper and plastics recycling, this simulation focuses on garbage and other recyclables. The models estimated in Chapter 5 (Table 5.8) are used to calculate the short run effects. The impacts on garbage and recycling are listed in Table 6.1.

Table 6.1 Short run simulation results (impacts) of unit-pricing (UP)

unit-price (USD/10litres)	*NRW* (g/p.d.)	*MEW* (g/p.d.)	*GLW* (g/p.d.)	*PTW* (g/p.d.)	*RR*
0.144	-324.836	23.005	8.125	5.468	0.076
0.086	-184.235	13.048	4.608	3.101	0.061
0.041	-75.149	5.322	1.880	1.265	0.040

Table 6.1 shows short run decreases of non-recyclables and increases of

recycling subject to various unit-pricing schemes. For example, when unit-pricing policy is applied and the price is 0.041 USD/10litres, per capita per day non-recyclables decrease by 75.149g, recyclable metal increases by 5.322g, glass increases by 1.880g, PET bottles increase by 1.265g and the recycling ratio increases by 0.040 in short run (less then three years after adopted). The decrease of non-recyclables and the increase of recycling both diminish as unit-price falls.

It is expected that residents will dump less waste when the price of waste disposal is raised. Assume that the demand for garbage collection is linear in the simulation prices. According to Table 5.5, elasticity for long run and higher price would be higher than that for short run and lower price. Based on elasticities in Taipei and Nagoya, three elasticities for higher unit-prices in the long run are set in Table 6.2. The elasticity for unit-price 0.086 is the average of elasticities for 0.041 and 0.144. Assume that the original *NRW* is 991g which is the non-recyclables per capita of Hsinchu City in 2000. The non-recyclables after unit-pricing adopted (*NRW'*) can be found by Eq. 5-3.

$$\varepsilon_{arc} = \frac{\Delta NRW}{\Delta PNR} \times \frac{\overline{PNR}}{\overline{NRW}} = \frac{NRW'-NRW}{PNR'-PNR} \times \frac{(PNR'+PNR)/2}{(NRW'+NRW)/2} \qquad (5\text{-}3)$$

Assume that the waste collection and treatment operation cost (*WTC*) is the same as in Taipei City which is 0.144 USD/10litres and 6.667E-05 USD/g. The price content is on Appendix 8 (pp. A91). Because unit-pricing decreases waste, the saving of *WTC* (a part of social benefit, *SWTC*) can be calculated by following equation.

$$SWTC = \Delta NRW(g) \times WTC(\$/g) \qquad (6\text{-}1)$$

The long run unit-pricing simulation results and benefits of unit-pricing are listed in Table 6.2.

Table 6.2 Long run unit-pricing simulation results and benefits

unit-price (USD/10litres)	elasticity	*NRW* (g/p.d.)	*NRW'* (g/p.d.)	*SWTC* (USD/p.d.)
0.144	0.346	991.000	532.367	0.031
0.086	0.283	991.000	628.226	0.024
0.041	0.220	991.000	757.219	0.016

When the price of commodity or service is raised, consumer surplus decreases which is the cost of unit-pricing. The *CSD* can be illustrated by

Figure 6.1 and the calculation for *CSD* is Eq. 6-2.

$$CSD = (NRW' + NRW) \times (PNR' - PNR)/2 \qquad (6\text{-}2)$$

PNR is assumed to be the original price in Taiwanese cities, 0.01 USD/10litres and 4.603E-06 USD/g (according to Taipei's case, Appendix 8, 0.216 kg/litre). The unit-prices have to be counted in USD/g as well. *NRW* is 991g and *NRW'* are in Table 6.2. The costs of all pricing scenarios are listed in Table 6.3.

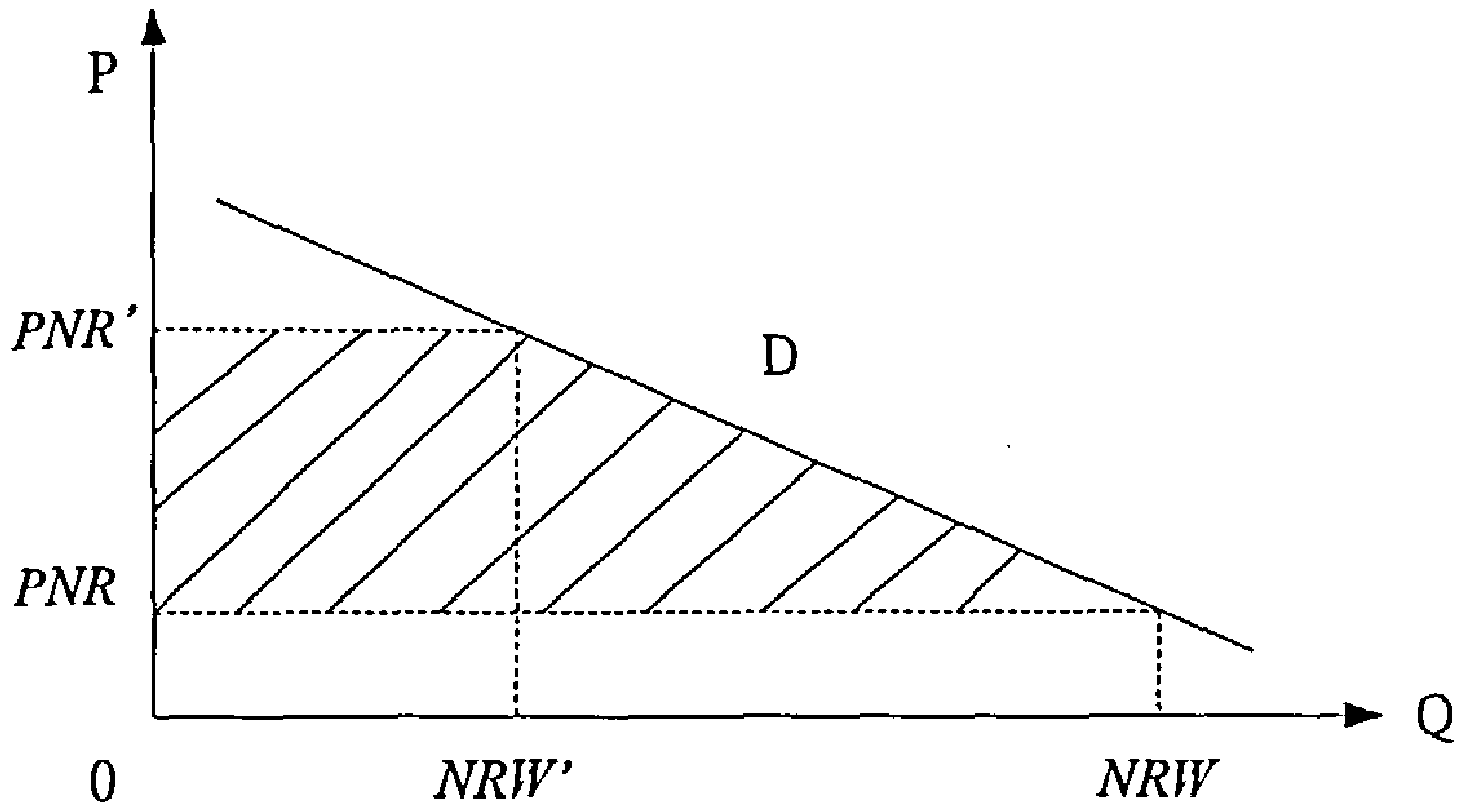

Fig 6.1 Consumer surplus decrease when price raises

Table 6.3 Cost-benefit analysis for long run unit-pricing simulations

unit-price (USD/10litres)	*PNR* (USD/g)	*PNR'* (USD/g)	*CSD* (social cost)	*SWTC* (partial social benefits)
0.144	4.630E-06	6.667E-05	0.047	0.031
0.086	4.630E-06	3.981E-05	0.028	0.024
0.041	4.630E-06	1.898E-05	0.013	0.016

According to simulation results in Table 6.3, *SWTC* is slightly larger than *CSD* when unit-price is 0.041 USD/10litres, it is slightly smaller when unit-price is 0.086 USD/10litres, and it is smaller than *CSD* when unit-price is 0.144 USD/10litres. The *WTC* used for this simulation is from Taipei City and excludes land use and external costs (Appendix 8, pp. A91). The *WTC* for real social cost should be higher and the social benefit from waste decrease would be higher as well. If unit-pricing were adopted in cities in Taiwan, the original garbage collection fee collected from water consumption would be terminated which costs 144 NTD per household per month and 0.051 USD per person per day (Appendix 8, pp. A91). This can be regarded as a benefit for households, and that makes unit-pricing beneficial even when unit-price is

0.144 USD/10litres. Despite the reduction in the former garbage collection fee, the social benefits of unit-pricing, including externalities from waste reduction, are higher than the loss of consumer surplus providing that the unit-price is lower than 0.086 USD/10litres.

Besides the loss of consumer surplus, other costs of unit-pricing, such as administration cost and transaction cost, cannot be fully estimated, but some clues can be obtained about inspection efforts for policies. Two policy variables, whether adopting mandatory recycling (*MR*) and unit-pricing (*NRU*), are tested to explain each three inspection variables, *ENAF*, *ENAP* and *ENAT* (the data shown in Appendix 6, pp. A18). Limdep estimation reports for all three models are in Appendix 9 (pp. A92). Based on the LM test and Hausman test results, FEM estimations are chosen for *ENAF* model, and OLS estimations are chosen for *ENAT* and *ENAP* models. Both *MR* and *NRU* are insignificant in *ENAT* and *ENAF* models. Only *ENAP* is significantly affected by a policy variable - *NRU* and the model can reject that coefficients are jointly zero at 99% confidence level. That estimation is shown on Table 6.4. *ENAP* (inspection labours per 100,000 people) is significantly increased when unit-pricing is adopted. Therefore, when unit-pricing is adopted in a 368,000 population city, waste management authority may need to increase approximate 16 inspection labours. That costs about 683 USD/day (40000 NTD/month.person) which is relatively small comparing with *CSD* for unit-price 0.086 (10482 USD/day). Since the average inspection times (*ENAT*) and average prosecuted fines (*ENAF*) don't increase after unit-pricing, the increase of inspection labours may not be necessary. The cost of specific garbage bag may be regardless because any waste is either pack in normal bag or specific bag which doesn't have much difference on cost. Therefore, social benefits for unit-pricing are likely higher than costs when unit-price is lower than 0.086 USD/10litres.

Table 6.4 OLS estimates of policy variables on inspection labours

Independent	*ENAP*
MR (mandatory rec.)	.63090 (.767)
NRU (unit-pricing)	4.35293 (3.465)***
constant	3.34410 (6.382)***
adjusted R^2	.22272
F(2, 33)	6.01

Note: (a.) *, ** and *** indicate significance at 0.1, 0.05 and 0.01 level, respectively.

(b.) Limdep report is on pp. A92.

6.2 Simulation of Mandatory Recycling and Transparent bag Policy

In Table 5.8, it was shown that a mandatory recycling policy (*MR*) can also significantly increase recycling and decrease waste generation. This simulation uses the models estimated in Chapter 5 (Table 5.8) to calculate the effects. Because *MR* has no significant effect on glass, paper and plastics recycling, this simulation focuses on waste generation and other recyclables. Furthermore, using transparent garbage bag (*TBG*) is an enforcement of mandatory recycling which can further decrease non-recyclables. These effects are listed in Table 6.5.

Table 6.5 Simulation results (impacts) of mandatory recycling policy (MR)

	NRW (g/p.d.)	*TOW* (g/p.d.)	*MEW* (g/p.d.)	*PTW* (g/p.d.)	*RR*
MR	-264.958	-223.579	12.461	3.367	0.063
MR+TBG	-347.569	-	-	-	-

If mandatory recycling is applied on Hsinchu City in 2000, the non-recyclables per capita after adoption can be found by Table 6.5. Assume that the waste collection and treatment operation cost (*WTC*) is the same as in Taipei City which is 0.144 USD/10litres and 6.667E-05 USD/g. The calculations for the saving of waste collection and treatment cost (*SWTC*) is the same as Eq. 6-1. The benefits for mandatory recycling simulations are in Table 6.6. The benefits of mandatory recycling (MR) and it plus transparent bag (MR+TBG) are similar as unit-price 0.041 and 0.086 USD/10litres. The social cost of mandatory recycling is consumer surplus decrease (*CSD*) and the price is household's expected fine for insufficient recycling. However, the social cost cannot be estimated because there is no data for household's expected fine for insufficient recycling before and after adoption. The elasticities found in unit-pricing cases (Table 5.5) may be used to estimate *CSD* of mandatory recycling. If elasticities 0.220 and 0.283 which have similar effects as MR and MR+TBG, respectively, are chosen, the *CSDs* will be similar as unit-pricing as well. Then, MR and MR+TBG have similar cost-benefit results as unit-price 0.041 and 0.086 USD/10litres.

Table 6.6 Benefits of mandatory recycling

	NRW (g/p.d.)	*NRW'* (g/p.d.)	*SWTC* (partial social benefits)
MR	991.000	726.040	0.018
MR+TBG	991.000	643.431	0.023

Besides the consumer surplus decreases, mandatory recycling doesn't have significant enforcement costs according to the estimated model of inspection labour (Table 6.4). Comparing Table 6.3 and Table 6.6, adopting mandatory recycling can generate similar benefits as unit-price 0.041 and 0.086 USD/10litres. However, mandatory recycling is one-off effect policy which is hard to further decrease waste, like rising unit-price. Considering cities adopted mandatory recycling, using transparent garbage bag can further enforce it. The cost of using transparent garbage bag is expected to be low because the prices of normal garbage bag and transparent one is very close.

6.3 Simulation of Decreasing Garbage Collection Frequency

In Table 5.8, the garbage collection frequency (*FNR*) can also significantly affect metal recycling and non-recyclables because the higher frequency can decrease garbage dumping labours. Taiwanese cities have much higher garbage collection frequency than Japanese cities. Hsinchu, Tainan, Kaohsiung and Taichung City provide 6 times collection per week, and Keelung City even provides 7 times. This section will simulate decreasing garbage collection frequency from 7 and 6 times per week to 5 in these

Taiwanese cities. Using the models estimated in Chapter 5 (Table 5.8) to estimate the effects. These effects are listed in Table 6.7.

Table 6.7 Simulation result of decreasing garbage collection frequency (FNR)

	NRW (g/p.d.)	*MEW* (g/p.d.)	*PAW* (g/p.d.)	*RR*
6 to 5 times	-118.288	16.553	44.887	0.115
7 to 5 times	-236.576	33.106	82.839	0.213

The cost of decreasing garbage collection frequency is expected to be low because the disutility of keeping waste is expected to be low if the two non-collection days are not alongside. For example, Taipei City doesn't provide garbage collection on Wednesday and Sunday. This policy may have some other benefits, such as decreasing garbage collection labour costs.

6.4 Summary of Simulations

Three kinds of waste management policies are simulated in this chapter-unit-pricing, mandatory recycling and decreasing garbage collection frequency. Some conclusions can be found as following

1. Ironically, decreasing the frequency of garbage collection from 7 or 6 times per week to 5 yields a positive net benefit, simply because it tends to increase recycling and to decrease waste dumping by 118 to 236g per capita per day, and has few costs.
2. The introduction of unit-pricing policy is beneficial once the benefit of offsetting the garbage fee based on water consumption is considered.
3. Despite the offset of garbage fee, unit-prices of 0.041 USD/10litres yield net benefits, and unit-prices of 0.086 USD/10litres yield net benefits if externalities are considered. According to the data, inspection costs will increase when unit-pricing is adopted but the cost is lower than consumer surplus forgone.
4. Mandatory recycling is beneficial, and is expected to have similar costs and benefits as a unit-price of 0.041 USD/10litres.
5. Cities adopting mandatory recycling should use transparent garbage bags, since these can increase the effectiveness of mandatory recycling at very low cost.

Chapter 7 Conclusions

This thesis develops and estimates a model of household waste disposal decisions using panel data on 18 cities in Taiwan and Japan. The model is then used to test a number of policy instruments, the results of which are reported in Chapter 6. This chapter summarises the main findings of the thesis and discusses the policy recommendations that fall out of these findings. A final section discusses ideas for further research.

7.1 Conclusions

Households trade off storing/composting waste against the three main waste discarding options: legal dumping, illegal dumping and recycling. Household's waste disposal decisions are based on the marginal private cost of each disposal option, which includes tariff, labour and disutility for storing/composting waste. Social disposal decisions are based on the marginal social cost of each disposal option, taking external environmental effects into account. Given the external effects of the different private options, especially illegal dumping, the social decision-maker – in this case the municipal authority – may be interested in identifying policy instruments that will change private waste disposal decisions. The household model developed in the thesis enables us to evaluate the potential effectiveness of alternative instruments in different socio-economic conditions. The main findings on the effectiveness of alternative instruments are as follows:

1. The estimated models confirm that the higher frequency of non-recyclables collection, the less recycling and more waste dumping would be. This may be because the marginal private cost of dumping falls as the frequency of waste collection rises.

2. In a city with unit-pricing on waste, a household does more recycling, illegal dumping and composting than it does under flat fee policy. Increasing the price of non-recyclables collection (price of unit-pricing) can significantly increase the recycling rate. The short run price elasticity of

non-recyclables and total waste are 0.069 and 0.049, respectively. As one would expect, the long run price elasticities are higher, the price elasticity for non-recyclables rising to 0.346.

3. Applying a penalty on illegal dumping (fines) can prevent illegal dumping from increasing after unit-pricing is adopted, and the effect depends on both enforcement and the nominal fine. In Taiwan, increasing the penalty (fine) per 1000 residents has a significant positive effect on legal dumping (non-recyclables) and total waste generation because the higher penalty can decrease illegal dumping, which may increase non-recyclables.
4. Mandatory recycling increases recycling and decreases non-recyclables disposals.
5. Some troublesome wastes, such as kitchen waste, have a high disutility of storage and typically become a household's first choice for illegal dumping if composting and recycling are not available. The empirical study found that the more kerbside recycling materials (recycling categories) increases recycling and the categories are increased by materials entered kerbside recycling later, such as kitchen waste recycling for public compost in Taiwan.
6. Using transparent garbage bags is a cost effective way of supporting mandatory recycling by lowering the inspection cost. It increases paper recycling and decreases waste disposal (non-recyclables).
7. There is a minor positive correlation between per capita income (at PPP) and both metal and PET bottles recycling.
8. There is much stronger positive correlation between population density and all kinds of recyclables. This is thought to be due to the fact that the marginal private and social cost of illegal dumping is increased in high density areas. Population density is significantly negatively correlated with both non-recyclables and total waste generation. This is thought to be because households in high population density areas typically consume less and generate less waste.

7.2 Policy Recommendations

Based on these findings, a number of policy recommendations follow. Many of these recommendations are generally intuitive, and would apply to MSW policy in any city. However, they do reflect the results of specific analyses of data from cities in Taiwan and Japan, and the details – of, for example, estimates of the short and long run price elasticity of household waste disposals – are especially relevant to those cities. Similarly, the effectiveness of particular mechanisms, such as the use of transparent bags for mandatory recyclables, may be greater in some settings than others. This needs to be taken into account in reading the findings.

1. There are several very low cost mechanisms for supporting recycling efforts. All Taiwanese cities have already adopted on-time collection and mandatory recycling. In this case requiring residents to use transparent bags for garbage collection can improve recycling and decrease dumping, at negligible additional cost.

2. Given the negative correlation between the frequency of garbage collection and recycling rates, there is scope in some cases to reduce collection costs and at the same time to increase recycling and decrease waste disposal. In particular, where cities have garbage collection more than 5 times per week, decreasing the garbage collection frequency can increase recycling and decrease waste disposal.

3. Unit pricing of garbage disposal is a potentially effective mechanism for increasing recycling rates. However, the effectiveness depends upon the level of the charge. Cities that haven't adopt unit-pricing should consider adopting unit-pricing. In this study, a charge of 0.086 USD/10litres was shown to yield positive net social benefits.

4. There is more flexibility in unit pricing options where householders would benefit from a reduction in existing water consumption-based fees. For cities in Taiwan a unit-price of 0.144 USD/10litres would fully cover the cost of treatment, and still yield positive net social benefits due to the

offset of water consumption-based garbage fees. The unit-pricing policy provides waste management authority more variability than mandatory recycling which has only one-off effects.

5. Kerbside collections of recyclables significantly increase the rate of recycling. Cities that do not provide kerbside paper, plastics and kitchen waste collections should consider doing so. This both increases recycling and may prohibit the illegal dumping of waste with high disutility of storing and potentially high social costs, such as kitchen waste.

7.3 Further Research

While the thesis has addressed some of the gaps in our understanding of MSW policies identified in the literature review, there are still a number of issues that have yet to be addressed, both in the specific case of Taiwan and Japan, and elsewhere. Concerning unit-pricing of MSW, the following research questions remain unanswered.

1. The price elasticity of household waste disposals found in this thesis is very low, and this limits the effectiveness of price mechanisms for changing household waste disposal decisions. It may be that this is due to the fact that cities applying unit-pricing (except Taipei) have adopted very low unit-prices. If the study were extended to include household responses to a wider range of unit-prices, the elasticity estimates could be improved and clearer guidance could be given to municipal decision-makers about the changes in waste disposal patterns that could be brought about through this mechanism.

2. We would expect to find a difference between the short and long run elasticity estimates. However, this was difficult to identify in the present study. Some unit-pricing effects may be captured by city dummy variables in the Fixed Effect Model, but there was no change in the price charged by many cities within the time range of data. Hence, extending the longitudinal data might be expected to improve the quality of the elasticity estimates.

On enforcement, which is one of main topics in this thesis, the research may be extended in the following ways:

1. The incentive effects of penalties for non-compliance with regulations depends both on the nominal value of the penalty for non-compliance and the probability that infringement will be detected and successfully prosecuted. It has already been noted that detection of illegal dumping in the case of unit-pricing is facilitated by on-time collection. Other factors in enforcement have yet to be fully analysed. This requires interaction terms between existing variables in the models. It also requires the extension of both private and social decision models to include more policies on enforcement options.
2. The penalty data used in this thesis refer to all kinds of waste management violations, which make the results ambiguous. If the penalty and/or inspection effort can be classified by regulation and waste stream, and if household surveys can be used to uncover the real incentive effects of penalties, as well as the penalties actually paid by households, the results should be more helpful to policy-makers.

In fact the development of household surveys to generate data with which to estimate the household decision models is the most important and logical extension of the research. This would generate a database of household dumping and recycling behaviour. It would also make it possible to relate the results of the research more readily to survey-based research on MSW disposal decisions elsewhere.

The natural extension of the research on social decisions is to identify the optimal policy, given data on the external environmental costs of different household decisions. While the research is motivated by the fact that household waste disposal does impose costs on society, estimation of these costs has been beyond the scope of the thesis. To identify the optimal level of unit prices (or other charging mechanisms) requires understanding of the social costs associated with legal versus illegal disposals, and of recycling. With data on external costs, and with the appropriate elasticity estimates, it would be possible to identify the level of charges that would yield the optimal distribution of effort between household disposal options. This does, however, require research into the health and other consequences of different options, along with a valuation of these consequences.

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Appendix 1 Data on Non-recyclables and Recyclables

City	Year	*NRW*	*TOW*	*PAW*	*MEW*	*GLW*	*PTW*	*PLW*	*OTH*	*TOR*
Japanese Cities										
Sapporo	1998	733	875	69.86	10.75	7.70	2.29	0.00	51.24	141.84
	1999	723	878	66.34	18.21	10.07	5.75	0.00	55.12	155.49
	2000	717	885	68.88	17.23	9.66	6.45	11.22	54.47	167.91
	2001	717	960	141.73	15.34	11.06	6.57	16.87	51.71	243.28
	2002	725	974	148.73	15.22	10.72	6.76	19.19	49.26	249.87
	2003	725	991	155.89	15.04	9.73	7.04	21.65	56.23	265.57
Sendai	1998	803	991	83.08	43.01	36.65	3.84	0.00	21.42	188.00
	1999	793	977	83.13	41.99	33.95	4.50	0.00	19.75	183.32
	2000	849	1043	87.18	50.45	32.48	4.63	0.53	18.73	194.01
	2001	772	1062	183.17	30.57	32.35	5.90	1.77	36.48	290.24
	2002	716	1040	184.22	30.16	30.99	6.85	34.23	37.64	324.09
	2003	720	1040	186.51	27.30	29.57	7.21	36.35	33.28	320.22
Chiba	1998	770	944	63.85	52.86	37.88	0.85	0.00	18.83	174.28
	1999	750	1000	146.95	46.95	35.03	1.24	0.00	20.12	250.29
	2000	801	1054	156.05	46.77	33.11	1.74	0.00	14.94	252.61
	2001	777	1125	243.51	47.69	34.19	5.84	0.00	16.48	347.72
	2002	772	1145	232.20	51.66	49.32	6.54	0.00	32.98	372.71
	2003	774	1115	225.96	38.56	31.74	6.90	0.00	37.75	340.93
Yokohama	1998	814	934	80.56	16.17	17.42	0.03	0.00	5.64	119.82
	1999	798	919	80.42	17.11	17.49	0.62	0.00	6.11	121.74
	2000	778	911	88.23	19.33	17.73	1.81	0.00	6.48	133.59
	2001	777	1015	183.08	18.20	17.30	3.00	0.99	15.16	237.74
	2002	763	981	164.13	16.17	15.95	5.33	1.04	15.94	218.55
	2003	749	965	165.23	16.10	15.24	6.07	1.05	11.61	215.32
Nagoya	1998	967	1067	62.25	19.92	14.99	0.79	0.00	2.12	100.06
	1999	947	1080	83.73	21.18	22.91	1.94	0.00	2.69	132.45
	2000	771	973	127.15	22.08	27.74	4.87	15.51	4.49	201.83
	2001	571	970	305.80	20.86	28.41	7.35	27.44	8.81	398.66
	2002	585	988	313.68	18.41	26.69	6.63	29.37	9.04	403.82
	2003	668	1087	325.92	16.25	26.96	7.05	33.39	9.87	419.45
Kyoto	1998	699	742	1.55	19.44	11.71	1.90	0.00	8.20	42.80
	1999	688	723	0.77	14.84	9.78	2.53	0.00	7.40	35.32
	2000	678	711	0.23	15.12	8.18	2.80	0.00	7.21	33.54
	2001	638	672	0.21	11.69	8.14	3.23	0.00	10.90	34.17
	2002	595	641	0.20	8.81	7.38	2.99	0.09	26.46	45.94
	2003	594	634	0.19	8.85	7.96	3.31	0.20	20.07	40.58
Osaka	1998	820	850	0.20	18.47	9.70	1.27	0.00	0.00	29.64
	1999	849	901	23.05	16.98	9.47	1.78	0.00	0.46	51.74
	2000	846	900	24.10	17.47	9.35	2.19	0.00	0.49	53.59
	2001	794	876	50.83	17.50	8.70	2.57	0.98	1.02	81.60
	2002	714	797	51.07	16.10	9.11	3.01	2.21	0.98	82.48
	2003	711	801	54.46	15.13	10.59	3.39	4.81	1.07	89.46
Kobe	1998	1127	1186	54.33	2.52	0.24	0.37	0.00	1.53	58.99
	1999	1160	1233	58.97	11.61	0.24	0.47	0.00	1.50	72.78
	2000	1181	1261	63.86	13.76	0.23	0.63	0.00	1.62	80.11
	2001	1140	1295	134.07	16.88	0.43	0.77	0.00	3.42	155.57
	2002	1121	1278	133.42	17.86	1.01	1.08	0.00	3.65	157.01
	2003	982	1157	143.86	18.54	2.27	1.69	0.00	8.09	174.45

City	Year	*NRW*	*TOW*	*PAW*	*MEW*	*GLW*	*PTW*	*PLW*	*OTH*	*TOR*
Kitakyushu	1998	916	993	44.48	22.22	8.89	1.77	0.00	0.34	77.69
	1999	911	945	0.00	22.74	7.78	2.72	0.00	0.27	33.53
	2000	911	1000	49.83	26.38	8.04	3.12	0.00	0.98	88.36
	2001	918	1052	101.70	19.03	10.19	2.67	0.00	0.37	133.96
	2002	912	1049	100.55	18.03	13.96	3.14	0.00	0.52	136.21
	2003	912	1058	104.27	16.44	20.93	3.58	0.00	0.56	145.78
Fukuoka	1998	686	797	59.11	33.48	4.36	0.03	0.00	14.12	111.09
	1999	697	815	62.79	35.62	3.76	0.05	0.00	15.96	118.19
	2000	694	827	66.61	37.16	8.16	3.99	0.00	17.01	132.93
	2001	686	886	130.02	33.85	10.99	4.73	0.00	19.78	199.37
	2002	685	873	127.56	31.56	10.67	4.82	0.00	13.92	188.54
	2003	692	886	130.15	30.51	10.04	5.14	0.00	18.04	193.88
Nagasaki	1998	893	989	35.14	36.06	20.95	2.72	0.00	0.43	95.29
	1999	891	987	34.63	37.24	20.25	3.17	0.00	0.83	96.11
	2000	899	995	37.73	33.43	19.55	4.05	0.00	0.91	95.68
	2001	868	1021	94.92	33.68	17.88	4.76	0.90	1.58	153.73
	2002	789	984	133.48	31.09	19.16	5.44	4.05	1.12	194.35
	2003	763	987	147.79	29.73	17.79	7.60	19.63	1.51	224.05
Naha	1998	772	821	32.14	10.79	5.02	0.00	0.00	0.51	48.47
	1999	786	836	33.45	10.80	4.76	0.00	0.00	0.48	49.50
	2000	764	824	38.89	10.80	4.46	0.00	0.00	6.00	60.14
	2001	743	873	68.23	27.52	16.28	0.00	0.00	17.66	129.69
	2002	670	816	77.91	30.03	17.39	0.00	0.00	21.10	146.43
	2003	606	762	73.99	27.07	20.77	9.84	0.00	24.01	155.68
Taiwanese Cities										
Taipei	1998	1420	1448	17.82	3.11	0.53	2.23	3.21	0.68	27.57
	1999	1285	1309	15.26	3.05	0.30	1.93	2.62	0.66	23.82
	2000	1009	1060	31.58	8.52	0.43	2.51	2.52	5.17	50.73
	2001	1034	1091	28.94	8.99	0.62	9.02	5.39	4.34	57.29
	2002	769	999	140.53	57.95	1.70	10.27	8.58	10.56	229.58
	2003	690	931	148.83	57.49	2.61	11.28	8.30	12.67	241.17
Hsinchu	1998	1003	1011	6.41	0.73	0.07	0.18	0.02	0.12	7.52
	1999	1036	1044	6.63	1.01	0.12	0.25	0.05	0.34	8.41
	2000	991	1048	33.44	7.79	1.83	2.60	4.86	6.86	57.39
	2001	989	1126	66.83	39.58	3.99	7.29	11.36	7.74	136.80
	2002	911	1049	56.69	29.26	3.40	11.23	18.36	18.80	137.75
	2003	880	1012	55.01	35.29	6.92	8.40	17.78	8.77	132.17
Tainan	1998	1147	1149	0.82	0.29	0.02	0.16	0.80	0.00	2.09
	1999	964	970	3.46	0.89	0.31	0.40	0.88	0.45	6.40
	2000	901	948	19.22	6.61	2.45	3.24	3.87	11.20	46.58
	2001	893	1017	50.97	11.82	4.04	6.13	6.78	44.48	124.22
	2002	891	1058	82.47	17.89	6.31	6.19	8.36	45.38	166.60
	2003	826	1005	94.25	17.99	6.28	9.89	11.25	39.27	178.93
Kaohsiung	1998	1064	1087	7.51	4.12	1.35	2.16	6.55	1.77	23.46
	1999	1063	1105	17.46	7.39	0.48	3.91	9.77	3.18	42.18
	2000	1065	1136	29.85	11.99	0.89	7.39	14.04	6.35	70.52
	2001	867	955	37.33	11.30	1.22	11.95	17.86	8.42	88.08
	2002	806	915	45.27	21.83	3.48	11.01	16.98	10.68	109.25
	2003	792	958	59.26	36.63	4.72	9.73	16.17	39.19	165.70

City	Year	*NRW*	*TOW*	*PAW*	*MEW*	*GLW*	*PTW*	*PLW*	*OTH*	*TOR*
Keelung	1998	1105	1130	23.34	1.31	0.05	0.12	0.00	0.64	25.47
	1999	1028	1076	29.53	10.64	1.23	0.35	3.71	2.58	48.03
	2000	1491	1640	65.55	44.73	3.43	1.40	16.82	16.97	148.89
	2001	830	994	80.78	43.22	4.38	3.48	12.20	19.68	163.73
	2002	792	981	81.80	42.39	4.04	4.65	28.99	27.40	189.27
	2003	772	934	83.16	24.97	3.83	5.26	20.58	23.73	161.53
Taichung	1998	1101	1124	15.04	4.18	0.31	2.03	1.35	0.45	23.36
	1999	927	989	39.73	9.47	0.75	4.27	6.01	1.28	61.52
	2000	556	665	59.83	15.23	1.62	7.41	14.09	10.40	108.59
	2001	556	719	68.56	17.82	3.03	7.48	12.85	53.71	163.46
	2002	495	681	58.98	25.41	1.77	4.67	7.35	87.42	185.59
	2003	472	636	90.25	22.26	4.89	8.56	19.65	18.32	163.92

Note:

1. Definition: *NRW*: weight of non-recyclable waste; *TOW*: weight of total waste; *PAW*: weight of recyclable paper; *MEW*: weight of recyclable metal; *GLW*: weight of recyclable glass; *PTW*: weight of recyclable PET bottle; *PLW*: weight of recyclable plastic; *OTH*: weight of other recyclable waste; *TOR*: weight of total recyclable waste.
2. Source: (a.) Taiwanese cities: Environmental Database, Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) (http://edb.epa.gov.tw/); (b.) Japanese cities: Survey of Municipal Solid Waste Management of Ministry of Environment, Japan (http://www.env.go.jp/recycle/waste_tech/ippan/).
3. Descriptive statistics of this data are in Table 4.3 (pp. 55).

Appendix 2 Data on Income and Population Density

City	Year	*INC*	*PPPINC*	*DEN*
Japanese Cities				
Sapporo	1998	36986.41	19693.28	1601.89
	1999	37042.91	19723.36	1609.34
	2000	37281.58	19850.44	1618.37
	2001	37311.96	19866.62	1635.45
	2002	36832.26	19611.20	1646.60
	2003	37200.59	19807.31	1658.19
Sendai	1998	38660.80	20584.80	1245.09
	1999	38789.69	20653.43	1251.59
	2000	38810.49	20664.50	1257.62
	2001	38907.83	20716.33	1264.66
	2002	38455.18	20475.32	1270.28
	2003	38839.73	20680.07	1274.48
Chiba	1998	33899.74	18049.79	3149.74
	1999	34021.75	18114.75	3175.90
	2000	34597.35	18421.23	3202.22
	2001	33143.71	17647.24	3228.26
	2002	33630.84	17906.62	3257.53
	2003	33967.15	18085.68	3283.42
Yokohama	1998	38985.53	20757.70	7702.54
	1999	38463.28	20479.63	7757.41
	2000	38953.50	20740.65	7834.16
	2001	37644.05	20043.44	7914.61
	2002	37349.23	19886.46	7995.17
	2003	37722.72	20085.32	8064.60
Nagoya	1998	52054.74	27716.36	6437.82
	1999	51170.02	27245.29	6453.68
	2000	50837.92	27068.46	6466.37
	2001	50452.23	26863.10	6670.09
	2002	51106.46	27211.44	6696.51
	2003	51617.52	27483.56	6718.87
Kyoto	1998	40038.88	21318.56	2287.38
	1999	39845.84	21215.77	2284.80
	2000	40771.70	21708.74	2283.56
	2001	38901.24	20712.82	2282.14
	2002	38279.02	20381.52	2406.30
	2003	38661.81	20585.34	2402.13
Osaka	1998	48235.58	25682.86	11690.07
	1999	48419.35	25780.70	11151.69
	2000	48677.02	25917.90	11157.82
	2001	47504.83	25293.77	11225.09
	2002	47360.31	25216.82	11225.09
	2003	47833.91	25468.99	11245.72
Kobe	1998	37796.33	20124.52	2642.70
	1999	36832.10	19611.11	2655.29
	2000	37155.52	19783.32	2670.27
	2001	35496.05	18899.74	2686.33
	2002	35593.42	18951.58	2697.95
	2003	35949.35	19141.10	2788.96

City	Year	*INC*	*PPPINC*	*DEN*
Kitakyushu	1998	37726.24	20087.20	2083.90
	1999	37085.51	19746.04	2078.37
	2000	37498.89	19966.15	2072.35
	2001	37369.32	19897.16	2066.08
	2002	37060.52	19732.74	2060.86
	2003	37431.13	19930.06	2054.04
Fukuoka	1998	37726.24	20087.20	3739.97
	1999	37085.51	19746.04	3765.65
	2000	37498.89	19966.15	3791.96
	2001	37369.32	19897.16	3826.34
	2002	37060.52	19732.74	3864.42
	2003	37431.13	19930.06	3896.36
Nagasaki	1998	30354.40	16162.09	1266.96
	1999	30087.24	16019.84	1259.26
	2000	30639.41	16313.84	1249.31
	2001	30424.85	16199.60	1247.93
	2002	30553.96	16268.34	1244.27
	2003	30859.50	16431.03	1239.09
Naha	1998	27691.72	14744.35	7691.41
	1999	27564.47	14676.60	7729.93
	2000	27745.91	14773.21	7726.44
	2001	27809.48	14807.05	7773.38
	2002	27631.37	14712.22	7831.70
	2003	27907.69	14859.34	7894.72
Taiwanese Cities				
Taipei	1998	11858.26	27661.14	9646.81
	1999	12027.57	27394.86	9713.04
	2000	11932.76	28001.76	9735.11
	2001	11971.58	28151.05	9690.96
	2002	12630.49	30587.61	9720.39
	2003	12966.81	30608.02	9665.21
Hsinchu	1998	9162.95	21373.92	3400.69
	1999	9333.92	21259.61	3448.73
	2000	10180.86	23890.71	3535.18
	2001	10740.59	25256.40	3583.22
	2002	9845.13	23842.22	3640.86
	2003	10679.50	25208.86	3679.28
Tainan	1998	7707.02	17977.75	4093.47
	1999	8013.25	18251.56	4127.63
	2000	8263.13	19390.51	4184.56
	2001	7771.17	18273.85	4218.72
	2002	7994.63	19360.81	4241.50
	2003	8633.16	20378.48	4269.96
Kaohsiung	1998	8902.72	20766.90	9466.60
	1999	9294.20	21169.13	9564.26
	2000	9642.48	22627.32	9707.49
	2001	9828.21	23110.96	9727.02
	2002	8855.10	21444.64	9831.20
	2003	9423.94	22245.13	9824.69

City	Year	*INC*	*PPPINC*	*DEN*
Keelung	1998	7865.48	18347.38	2862.33
	1999	8672.05	19752.07	2884.93
	2000	8855.64	20780.91	2922.59
	2001	7820.74	18390.39	2945.19
	2002	7233.49	17517.54	2945.19
	2003	7483.40	17664.48	2952.72
Taichung	1998	9390.01	21903.57	5568.28
	1999	10189.31	23207.90	5690.66
	2000	9089.33	21329.29	5910.95
	2001	10206.21	23999.80	6021.09
	2002	8868.75	21477.70	6100.64
	2003	9733.09	22974.86	6174.06

Note:

1. Definition: *INC*: per capita income (1995 US dollars); *PPPINC*: PPP based income; *DEN*: population density (people per square kilometre).
2. Source: (a.) *INC* for Japanese cities is prefectural per capita GDP which is from Prefectural Account, Economic and Social Research Institute, Cabinet Office, Japan (http://www.esri.cao.go.jp/jp/sna/toukei.html#kenmin), converted to 1995 price by the General (price) Index of city area, Japanese Statistical Yearbook 2005 (http://www.stat.go.jp/data/nenkan/index.htm), and converted to US dollars by the exchange rate of 1995. (b.) *INC* for Taiwanese cities is city's per capita GDP which is converted from national per capita GDP (R.O.C. (Taiwan) Statistical Yearbook 2005 (http://eng.dgbas.gov.tw/)) by the ratio of national and cities' per capita income (PCI) (Household Income and Expenditure Survey, Directorate General of Budget, Accounting and Statistics, Executive Yuan, R.O.C. (Taiwan)). City's per capita GDP is converted to 1995 price by Consumer Price Index (R.O.C. (Taiwan) Statistical Yearbook 2005) and converted to US dollars by the exchange rate of 1995. (c.) *PPPINC* is converted to international dollars from *INC* by purchasing-power-parity (Would Economic Outlook Database, International Monetary Fund (http://www.imf.org/external/pubs/ft/weo/2005/02/data/index.htm)); (d.) population data is from Environmental Database, Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) and Survey of Municipal Solid Waste Management of Ministry of Environment, Japan, and the city territory data is from Environmental Database, Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan), and Website for Japanese Local Governments (http://uub.jp/)).
3. Descriptive statistics of this data are in Table 4.4 (pp. 57).

Appendix 3 Survey for Residential Solid Waste Management

1. Recipient: 6 waste management authorities in Taiwanese cities and 12 in Japanese cities are listed below:
   a. Mr. Li (Waste Management Section, Environmental Protection Bureau, Taipei City, Taiwan)
   b. Ms. P. Huang (Waste Management Section, Environmental Protection Bureau, Hsinchu City, Taiwan)
   c. Mr. J. Yen (Waste Management Section, Environmental Protection Bureau, Tainan City, Taiwan)
   d. Mr. C. Chang (Waste Management Section, Environmental Protection Bureau, Kaohsiung City, Taiwan)
   e. Mr. W. Liao (Waste Management Section, Environmental Protection Bureau, Keelung City, Taiwan)
   f. Mr. K. Ho (Waste Management Section, Environmental Protection Bureau, Taichung City, Taiwan)
   g. Ms. K. Uemura (General Administration Section, Cleaning Department, Environmental Affairs Bureau, Sapporo City, Japan)
   h. Mr. Okazaki (Waste Management Section, Waste Management Department, Environmental Affairs Bureau, Sendai City, Japan)
   i. Anonymous (Environmental Management Section, Environmental Management Department, Environmental Affairs Bureau, Chiba City, Japan)
   j. Mr. Sawada (Environmental Planning Section, General Administration Department, Resources Recycle Bureau, Yokohama City, Japan)
   k. Mr. Kamiya (Operations section, Management Department, Environmental Affairs Bureau, Nagoya City, Japan)
   l. Mr. K. Inoue (Recycling Society Section, Environmental Policy Department, Environmental Affairs Bureau, Kyoto City, Japan)
   m. Mr. Nakano (General Administration Department, Environmental Management Bureau, Osaka City, Japan)
   n. Mr. Fujioka (Environmental Policy Department, Environmental Affairs Bureau, Kobe City, Japan.
   o. Mr. N. Okita (Management Section, Waste Management Department,

Environmental Affairs Bureau, Kitakyushu City, Japan)

p. Anonymous (Residential Waste Management Section, Waste Management Strategy Department, Environmental Affairs Bureau, Fukuoka City, Japan)
q. Ms. Y. Kosaka (Waste Management Strategy Department, Nagasaki City, Japan)
r. Mr. Nakamoto (Environmental Policy Department, Environmental Affairs Bureau, Naha City, Japan)

2. Survey method:
   a. Contact those waste management authorities above and invite them to join this survey on January 2005.
   b. Translate the questionnaire to Japanese and Chinese and sent it to the authorities via Post, Email or Fax with a survey invitation letter.
   c. Call the authorities and ask them reply the questionnaire on February 2005.
   d. Contact with the authorities if they left some questions unanswered and explain the questions.
   e. Verify the 2004 data on their replied questionnaire with the current policies announced on authorities' websites.
   f. 100% questionnaires are retrieved on July 2005.

3. *Questionnaire:*

Questionnaire for residential solid waste management

A. Non-recyclable garbage collection	**Between 1998 and 2004** (If the change is not from the beginning of a year, please state the date)							
1. How many category do residents have to separate for non-recyclable (general) garbage collection? (excluding recyclable, bulky and hazard waste)	year	1998	1999	2000	2001	2002	2003	2004
	category							
2. What is the frequency (times per week) of each non-recyclable garbage collection? (if one category, fill in burnable only) (excluding recyclable, bulky and hazard waste)	year	1998	1999	2000	2001	2002	2003	2004
	burnable							
3. Are city's garbage collection and/or treatment fee based on the volume of garbage?	[Yes/No] If Yes, when did it start? [ ] If "Yes", go to 4. If "No", go to 5.							
4. How much is a smallest paid garbage bag and what is the volume? burnable ( )litre non-burnable ( )litre	year	1998	1999	2000	2001	2002	2003	2004
	burnable							
	non-burnable							
5. In cities without unit-pricing policy, do residents have to use specific kind of bag to throw garbage, like transparent or semi-transparent bag?	burnable	[Yes/No] If Yes, when did it start? [ ]						
	non-burnable	[Yes/No] If Yes, when did it start? [ ]						

B. Recyclable materials collection 1. Does the city provide kerbside recycle collection?	[Yes/No] If Yes, when did it start? [ ] If “Yes”, go to 2. If “No”, go to 7.							
2. How many categories of recyclable materials (including scrap paper, various bottles, cans etc.) do resident have to separate for collection? (ex. all materials collected at once is 1)	year	1998	1999	2000	2001	2002	2003	2004
	categories							
3. What is the frequency (times per week) of kerbside recycle collection for each category?	year	1998	1999	2000	2001	2002	2003	2004
4. Do residents have to pay for kerbside recycle collection by paid bag?	[Yes/No] If Yes, when did it start? [ ] If “Yes”, go to 5. If “No”, go to 6.							
5. How much is the smallest bag for recycling and what is the volume? ( )litre	year	1998	1999	2000	2001	2002	2003	2004
	price per bag							
6. Do residents have to use specific kind of bag for recycling, like transparent or semi-transparent bag?	[Yes/No] If Yes, when did it start? [ ]							
7. Does the city provide kitchen waste (compostable waste) collection?	[Yes/No] If Yes, when did it start? [ ]							

8. Besides kerbside recycle collection, in the city, how many recycle drop-off centre at which resident can drop-off most of recycle materials in any time?	year	1998	1999	2000	2001	2002	2003	2004
	number							
C. Bulky and others waste collection 1. Does the city charge for bulky waste collection?	[Yes/No] If Yes, when did it start? Year [ ]							
D. Penalty of illegal dumping 1. Do residents have to state their names or address on garbage bag?	[Yes/No] If Yes, when did it start? Year [ ]							
2. Is recycle mandatory?	[Yes/No] If Yes, when did it start? Year [ ] If "Yes", go to 3. If "No", go to 4.							
3. How much would people be fined when they put recyclable materials into non-recyclable bag?	year	1998	1999	2000	2001	2002	2003	2004
	fine							
4. Do residents have to hand in garbage bags to haulers or leave them on specific time and place in street?	[hand in/ leave in street]							
5. How much would people be fined when they dump garbage or bulky waste in unauthorised time or area?	year	1998	1999	2000	2001	2002	2003	2004
	fine							
E. correspondent detail In case of any missing answer, please state the correspondent detail	Name: Email: Tel:							

Appendix 4 Data on Recyclable Management Variables

City	Year	*MR*	*PAK*	*MEK*	*GLK*	*PTK*	*PLK*	*KWC*	*CR*	*TBG*	*PKR*
Japanese Cities											
Sapporo	1998	0	0	1	1	1	0	0	2	1	0.000
	1999	0	0	1	1	1	0	0	2	1	0.000
	2000	0	0	1	1	1	1	0	3	1	0.000
	2001	0	0	1	1	1	1	0	3	1	0.000
	2002	0	0	1	1	1	1	0	3	1	0.000
	2003	0	0	1	1	1	1	0	3	1	0.000
Sendai	1998	0	0	1	1	1	0	0	2	1	0.000
	1999	0	0	1	1	1	0	0	2	1	0.000
	2000	0	0	1	1	1	0	0	2	1	0.000
	2001	0	0	1	1	1	0	0	2	1	0.000
	2002	0	0	1	1	1	1	0	3	1	0.058
	2003	0	0	1	1	1	1	0	3	1	0.058
Chiba	1998	0	0	1	1	1	0	0	7	1	0.000
	1999	0	0	1	1	1	0	0	7	1	0.000
	2000	0	0	1	1	1	0	0	7	1	0.000
	2001	0	0	1	1	1	0	0	7	1	0.000
	2002	0	0	1	1	1	0	0	7	1	0.000
	2003	0	0	1	1	1	0	0	7	1	0.000
Yokohama	1998	0	0	1	1	1	0	0	3	0	0.000
	1999	0	0	1	1	1	0	0	3	0	0.000
	2000	0	0	1	1	1	0	0	3	1	0.000
	2001	0	0	1	1	1	0	0	3	1	0.000
	2002	0	0	1	1	1	0	0	3	1	0.000
	2003	0	0	1	1	1	0	0	3	1	0.000
Nagoya	1998	0	0	1	1	0	0	0	3	0	0.000
	1999	0	0	1	1	0	0	0	3	0	0.000
	2000	0	1	1	1	1	1	0	7	1	0.041
	2001	0	1	1	1	1	1	0	7	1	0.041
	2002	0	1	1	1	1	1	0	7	1	0.041
	2003	0	1	1	1	1	1	0	7	1	0.041
Kyoto	1998	0	0	1	1	1	0	0	2	0	0.000
	1999	0	0	1	1	1	0	0	2	0	0.000
	2000	0	0	1	1	1	0	0	2	0	0.294
	2001	0	0	1	1	1	0	0	2	0	0.294
	2002	0	0	1	1	1	0	0	3	0	0.294
	2003	0	0	1	1	1	0	0	3	0	0.294
Osaka	1998	0	0	1	1	1	0	0	2	1	0.000
	1999	0	0	1	1	1	0	0	2	1	0.000
	2000	0	0	1	1	1	0	0	2	1	0.000
	2001	0	0	1	1	1	1	0	3	1	0.000
	2002	0	0	1	1	1	1	0	3	1	0.000
	2003	0	0	1	1	1	1	0	3	1	0.000
Kobe	1998	0	0	1	1	1	0	0	2	1	0.000
	1999	0	0	1	1	1	0	0	2	1	0.000
	2000	0	0	1	1	1	0	0	2	1	0.000
	2001	0	0	1	1	1	0	0	2	1	0.000
	2002	0	0	1	1	1	0	0	2	1	0.000
	2003	0	0	1	1	1	0	0	2	1	0.000

City	Year	*MR*	*PAK*	*MEK*	*GLK*	*PTK*	*PLK*	*KWC*	*CR*	*TBG*	*PKR*
Kitakyushu	1998	0	0	1	1	1	0	0	3	1	0.000
	1999	0	0	1	1	1	0	0	3	1	0.000
	2000	0	0	1	1	1	0	0	3	1	0.000
	2001	0	0	1	1	1	0	0	3	1	0.000
	2002	0	0	1	1	1	0	0	3	1	0.000
	2003	0	0	1	1	1	0	0	3	1	0.000
Fukuoka	1998	0	0	1	1	1	0	0	2	1	0.000
	1999	0	0	1	1	1	0	0	2	1	0.000
	2000	0	0	1	1	1	0	0	2	1	0.046
	2001	0	0	1	1	1	0	0	2	1	0.046
	2002	0	0	1	1	1	0	0	2	1	0.046
	2003	0	0	1	1	1	0	0	2	1	0.046
Nagasaki	1998	0	0	1	1	1	0	0	2	0	0.000
	1999	0	0	1	1	1	0	0	2	0	0.000
	2000	0	0	1	1	1	0	0	2	0	0.000
	2001	0	0	1	1	1	0	0	5	0	0.000
	2002	0	0	1	1	1	1	0	5	1	0.028
	2003	0	0	1	1	1	1	0	5	1	0.028
Naha	1998	0	1	1	1	0	0	0	2	1	0.000
	1999	0	1	1	1	0	0	0	2	1	0.000
	2000	0	1	1	1	0	0	0	2	1	0.000
	2001	0	1	1	1	0	0	0	2	1	0.000
	2002	0	1	1	1	0	0	0	2	1	0.000
	2003	0	1	1	1	1	0	0	2	1	0.000
Taiwanese Cities											
Taipei	1998	0	1	1	1	1	1	0	3	0	0.000
	1999	0	1	1	1	1	1	0	4	0	0.000
	2000	0	1	1	1	1	1	0	5	1	0.000
	2001	0	1	1	1	1	1	0	5	1	0.000
	2002	0	1	1	1	1	1	0	5	1	0.000
	2003	0	1	1	1	1	1	0	2	1	0.000
Hsinchu	1998	0	0	0	0	0	0	0	0	0	0.000
	1999	0	0	0	0	0	0	0	0	0	0.000
	2000	0	1	1	1	1	1	0	1	0	0.000
	2001	0	1	1	1	1	1	0	1	0	0.000
	2002	0	1	1	1	1	1	0	1	0	0.000
	2003	0	1	1	1	1	1	0	1	0	0.000
Tainan	1998	0	0	0	0	0	0	0	0	0	0.000
	1999	0	0	0	0	0	0	0	0	0	0.000
	2000	0	0	0	0	0	0	0	0	0	0.000
	2001	0	0	0	0	0	0	0	0	0	0.000
	2002	0	1	1	1	1	1	0	2	0	0.000
	2003	1	1	1	1	1	1	1	2	0	0.000
Kaohsiung	1998	0	0	0	0	0	0	0	0	0	0.000
	1999	0	0	0	0	0	0	0	0	0	0.000
	2000	0	1	1	1	1	1	0	2	0	0.000
	2001	1	1	1	1	1	1	0	2	0	0.000
	2002	1	1	1	1	1	1	0	2	0	0.000
	2003	1	1	1	1	1	1	0	2	0	0.000

City	Year	*MR*	*PAK*	*MEK*	*GLK*	*PTK*	*PLK*	*KWC*	*CR*	*TBG*	*PKR*
Keelung	1998	0	0	0	0	0	0	0	0	0	0.000
	1999	0	1	1	1	1	1	0	1	0	0.000
	2000	0	1	1	1	1	1	0	1	0	0.000
	2001	1	1	1	1	1	1	0	1	0	0.000
	2002	1	1	1	1	1	1	0	1	0	0.000
	2003	1	1	1	1	1	1	1	1	0	0.000
Taichung	1998	1	1	1	1	1	1	0	2	0	0.000
	1999	1	1	1	1	1	1	0	2	0	0.000
	2000	1	1	1	1	1	1	0	2	0	0.000
	2001	1	1	1	1	1	1	0	2	0	0.000
	2002	1	1	1	1	1	1	1	2	0	0.000
	2003	1	1	1	1	1	1	1	2	0	0.000

Note:

1. Definition: *MR*: mandatory recycling policy applied; *PAK*: providing kerbside recycling for paper; *MEK*: kerbside recycling for metal; *GLK*: kerbside recycling for glass; *PTK*: kerbside recycling for PET bottle; *PLK*: kerbside recycling for plastic; *KWC*: kerbside kitchen waste collection; *CR*: category for recycling; *TBG*: using transparent bag policy; *PKR*: price of kerbside recycling collection.
2. Source: (a.) *MR* is from Question D.2. in the questionnaire; (b.) *PAK*, *MEK*, *GLK*, *PTK*, and *PLK* are from Question B.1. and 2.; (c.) *KWC* is from Question B.7.; (d.) *CR* is from Question B.2.; (e.) *TBG* is from Question A.5.; (f.) *PKR* is from Question B.4. and 5.
3. Descriptive statistics of this data are in Table 4.5 (pp. 60).

Appendix 5 Data on Non-recyclables Management Variables

City	Year	*PNR*	*FI*	*OTC*	*FNR*
Japanese Cities					
Sapporo	1998	0.005	0	0	2
	1999	0.005	0	0	2
	2000	0.005	0	0	2
	2001	0.005	0	0	2
	2002	0.005	0	0	2
	2003	0.005	0	0	2
Sendai	1998	0.057	0	0	3
	1999	0.057	0	0	3
	2000	0.057	0	0	3
	2001	0.057	0	0	3
	2002	0.057	0	0	3
	2003	0.057	0	0	3
Chiba	1998	0.051	0	0	3
	1999	0.051	0	0	3
	2000	0.051	0	0	3
	2001	0.051	0	0	3
	2002	0.051	0	0	3
	2003	0.051	0	0	3
Yokohama	1998	0.005	0	0	3
	1999	0.005	0	0	3
	2000	0.005	0	0	3
	2001	0.005	0	0	3
	2002	0.005	0	0	3
	2003	0.005	0	0	3
Nagoya	1998	0.005	1	0	2
	1999	0.005	1	0	2
	2000	0.041	1	0	2
	2001	0.041	1	0	2
	2002	0.041	1	0	2
	2003	0.041	1	0	2
Kyoto	1998	0.005	1	0	2
	1999	0.005	1	0	2
	2000	0.005	1	0	2
	2001	0.005	1	0	2
	2002	0.005	1	0	2
	2003	0.005	1	0	2
Osaka	1998	0.005	1	0	2
	1999	0.005	1	0	2
	2000	0.005	1	0	2
	2001	0.005	1	0	2
	2002	0.005	1	0	2
	2003	0.005	1	0	2
Kobe	1998	0.005	0	0	2
	1999	0.005	0	0	2
	2000	0.005	0	0	2
	2001	0.005	0	0	2
	2002	0.005	0	0	2
	2003	0.005	0	0	2

City	Year	*PNR*	*FI*	*OTC*	*FNR*
Kitakyushu	1998	0.041	1	0	2
	1999	0.041	1	0	2
	2000	0.041	1	0	2
	2001	0.041	1	0	2
	2002	0.041	1	0	2
	2003	0.041	1	0	2
Fukuoka	1998	0.046	1	0	2
	1999	0.046	1	0	2
	2000	0.046	1	0	2
	2001	0.046	1	0	2
	2002	0.046	1	0	2
	2003	0.046	1	0	2
Nagasaki	1998	0.005	0	0	2
	1999	0.005	0	0	2
	2000	0.005	0	0	2
	2001	0.005	0	0	2
	2002	0.028	0	0	2
	2003	0.028	0	0	2
Naha	1998	0.005	1	0	2
	1999	0.005	1	0	2
	2000	0.005	1	0	2
	2001	0.005	1	0	2
	2002	0.086	1	0	2
	2003	0.086	1	0	2
Taiwanese Cities					
Taipei	1998	0.010	1	1	6
	1999	0.010	1	1	6
	2000	0.080	1	1	6
	2001	0.152	1	1	6
	2002	0.144	1	1	6
	2003	0.144	1	1	5
Hsinchu	1998	0.010	0	0	6
	1999	0.010	0	0	6
	2000	0.010	1	1	6
	2001	0.010	1	1	6
	2002	0.010	1	1	6
	2003	0.010	1	1	6
Tainan	1998	0.010	1	0	6
	1999	0.010	1	0	6
	2000	0.010	1	0	6
	2001	0.010	1	0	6
	2002	0.010	1	1	6
	2003	0.010	1	1	6
Kaohsiung	1998	0.010	1	0	6
	1999	0.010	1	1	6
	2000	0.010	1	1	7
	2001	0.010	1	1	7
	2002	0.010	1	1	7
	2003	0.010	1	1	6

City	Year	*PNR*	*FI*	*OTC*	*FNR*
Keelung	1998	0.010	1	1	7
	1999	0.010	1	1	7
	2000	0.010	1	1	7
	2001	0.010	1	1	7
	2002	0.010	1	1	7
	2003	0.010	1	1	7
Taichung	1998	0.010	1	1	6
	1999	0.010	1	1	6
	2000	0.010	1	1	6
	2001	0.010	1	1	6
	2002	0.010	1	1	6
	2003	0.010	1	1	6

Note:

1. Definition: *PNR*: price of non-recyclable waste collection (per 10 litres); *FI*: if the authority enforces illegal dumping penalty; *OTC*: on-time collection policy; *FNR*: frequency of non-recyclables collection (per week).
2. Source: (a.) *PNR* is from Question A.4. in the questionnaire; (b.) *PNR* in cases without unit-pricing are 0.005 US$ in Japanese cases and 0.01 in Taiwanese cases, according to market survey; (c.) *FI* is based on Question D.3. If the authority gives any penalty to illegal dumping, the value is 1, and the value is 0 if the authority doesn't answer or zero penalty; (d.) *OTC* is from Question D.4. If the answer is "hand in", the value is 1; (e.) *FNR* is from Question A.2.
3. Descriptive statistics for *PNR* and *FNR* are in Table 4.6 (pp. 61) and that for *FI* and *OTC*: are in Table 4.7 (pp. 62).

Appendix 6 Data on Illegal Dumping Inspection

City	Year	*ENAT*	*ENAP*	*ENAF*
Taipei	1998	13.66	2.71	14.15
	1999	20.00	2.88	13.22
	2000	18.57	7.07	10.28
	2001	17.28	7.10	6.30
	2002	17.29	9.05	9.22
	2003	19.24	7.58	16.15
Hsinchu	1998	4.15	5.08	10.07
	1999	5.48	3.62	10.28
	2000	2.89	3.26	3.19
	2001	33.60	5.09	1.94
	2002	31.95	3.43	3.52
	2003	543.64	3.66	3.19
Tainan	1998	2.38	2.64	1.76
	1999	2.89	2.62	2.88
	2000	2.01	2.45	1.48
	2001	0.97	2.29	1.01
	2002	1.35	2.95	2.01
	2003	1.61	2.67	2.10
Kaohsiung	1998	18.52	4.88	7.10
	1999	19.93	5.04	10.40
	2000	28.97	5.16	6.91
	2001	25.95	4.42	6.64
	2002	23.66	3.97	5.46
	2003	38.72	4.77	5.38
Keelung	1998	4.30	3.42	5.85
	1999	6.07	1.57	10.48
	2000	4.23	0.77	5.88
	2001	6.28	14.32	10.30
	2002	2.19	0.51	1.69
	2003	5.33	0.51	4.58
Taichung	1998	14.28	4.29	11.30
	1999	22.49	3.44	7.06
	2000	9.26	3.21	4.47
	2001	9.29	4.98	4.15
	2002	18.72	2.31	5.32
	2003	11.10	2.28	3.25

Note:

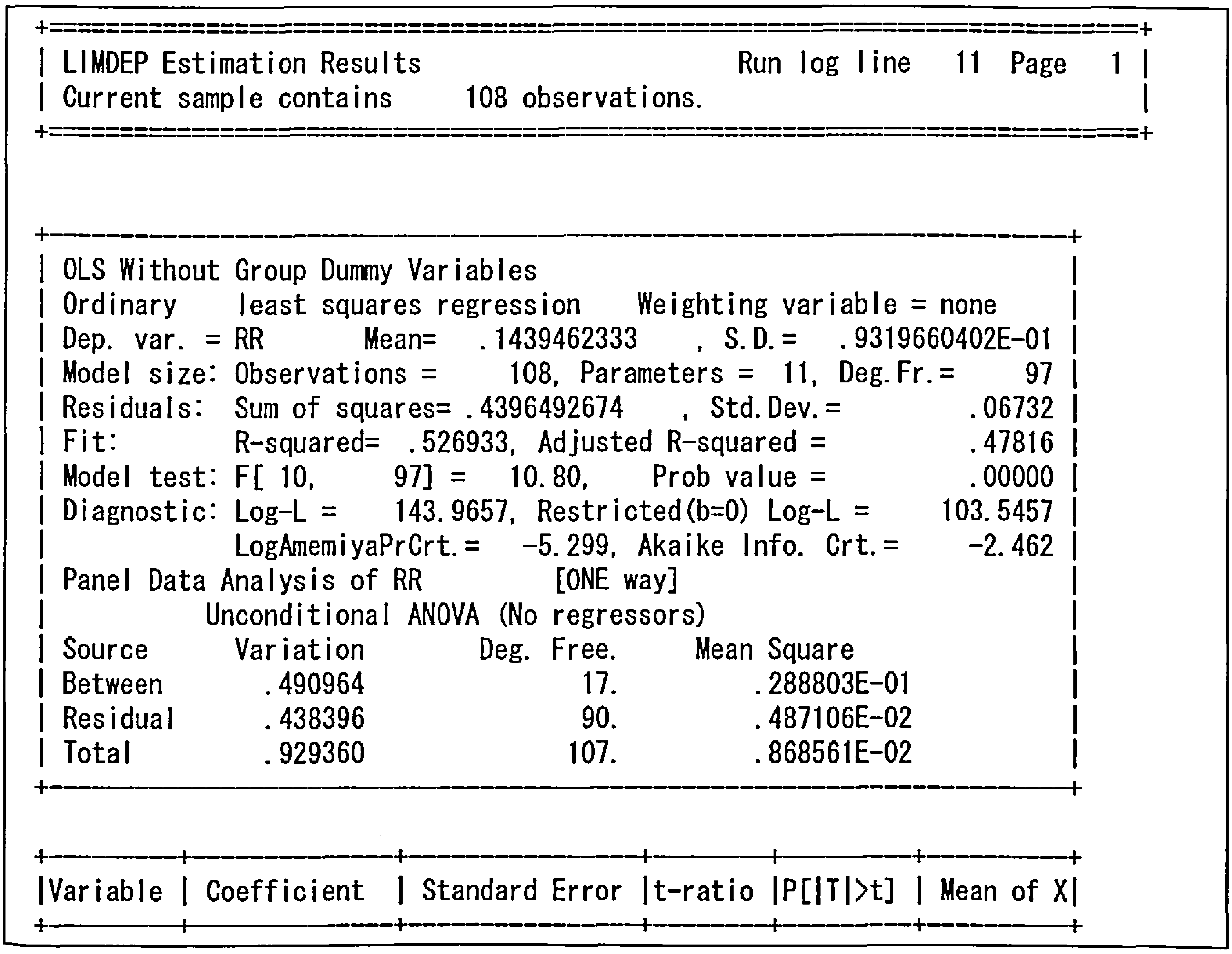
1. Definition: *ENAT*: annual inspection times per 1000 people; *ENAP*: the inspection labours per 100000 people; *ENAF*: annual prosecuted fines per 1000 people (USD).
2. Source: Environmental Database, Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) (http://edb.epa.gov.tw/)
3. Descriptive statistics of this data are in Table 4.8 (pp. 63).

Appendix 7 Limdep Estimation Reports for Models in Chapter 5

A7-1. Estimation reports for the models in Table 5.1

The first part of the Limdep report is OLS estimates, the second part is FEM estimates, and the third part is REM estimates. Two tests are used to choose models: Lagrange Multiplier test and Hausman test. The methods of each kind of model estimation and arithmetic of tests are shown in section 5.1 (pp. 64). The Limdep reports of Model 1 to Model 4 are shown below. Model 2 (b.) and Model 3 (c.) have better R^2 than Model 1 (a.). The supplement regression (e.) shows that the goodness-of-fit of Model 4 (d.) isn't better than Model 2 and 3. The Lagrange multiplier test for Model 2 and 3 show that the panel data models dominate the non-panel data models (only independent variables and a constant) at 1% significance. The Hausman Test results show that FEM is better than REM at 1% significance. Both FEM of Model 2 and Model 3 may be suitable for recycling ratio estimation.

a. Lin-lin Model 1



```
+============================================================================+
| LIMDEP Estimation Results                      Run log line   11  Page   1 |
| Current sample contains     108 observations.                              |
+============================================================================+



+-----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                     |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = RR       Mean=   .1439462333    , S.D.=   .9319660402E-01 |
| Model size: Observations =     108, Parameters =  11, Deg.Fr.=     97 |
| Residuals:  Sum of squares= .4396492674    , Std.Dev.=         .06732 |
| Fit:        R-squared=  .526933, Adjusted R-squared =          .47816 |
| Model test: F[ 10,     97] =   10.80,     Prob value =         .00000 |
| Diagnostic: Log-L =     143.9657, Restricted(b=0) Log-L =    103.5457 |
|             LogAmemiyaPrCrt.=   -5.299, Akaike Info. Crt.=     -2.462 |
| Panel Data Analysis of RR          [ONE way]                          |
|           Unconditional ANOVA (No regressors)                         |
| Source      Variation         Deg. Free.      Mean Square             |
| Between       .490964               17.           .288803E-01         |
| Residual      .438396               90.           .487106E-02         |
| Total         .929360              107.           .868561E-02         |
+-----------------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
```

```
 PNR          .4231683541        .30875246    1.371   .1737  .24073777E-01
 FNR      -.4274741231E-03  .66114661E-02    -.065   .9486      3.5740741
 KR       -.6607793161E-03  .32130907E-01    -.021   .9836       .92592593
 PPPINC    .1661266026E-05  .23848025E-05     .697   .4877      20946.240
 TBG       .5286154758E-01  .24485430E-01    2.159   .0333       .57407407
 DEN      -.5636213075E-05  .27665456E-05   -2.037   .0443      4872.9226
 FI       -.2883131148E-01  .18091361E-01   -1.594   .1143       .64814815
 MR        .9876951406E-01  .27707534E-01    3.565   .0006       .12037037
 PKR      -.1265437733E-01       .13640638   -.093   .9263  .15667493E-01
 CR        .2315594993E-01  .49024462E-02    4.723   .0000      2.6944444
 Constant  .4282361923E-01  .55118505E-01     .777   .4391
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=============================================================================+
| LIMDEP Estimation Results                        Run log line   11  Page   2 |
| Current sample contains     108 observations.                                |
+=============================================================================+



+------------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                               |
| Ordinary    least squares regression    Weighting variable = none      |
| Dep. var. = RR       Mean=   .1439462333     , S.D.=    .9319660402E-01 |
| Model size: Observations =      108, Parameters =  28, Deg.Fr.=      80 |
| Residuals:  Sum of squares= .1447898883     , Std.Dev.=          .04254 |
| Fit:        R-squared=  .844205, Adjusted R-squared =            .79162 |
| Model test: F[ 27,      80] =   16.06,     Prob value =          .00000 |
| Diagnostic: Log-L =     203.9432, Restricted(b=0) Log-L =      103.5457 |
|             LogAmemiyaPrCrt.=   -6.084, Akaike Info. Crt.=       -3.258 |
| Estd. Autocorrelation of e(i,t)      .188567                           |
+------------------------------------------------------------------------+

+---------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+--------+----------+
 PNR          .6679236297        .29933720    2.231   .0279  .24073777E-01**
 FNR          -.1160725055  .30606238E-01   -3.792   .0003      3.5740741***
 KR       -.8031048834E-02  .34215523E-01    -.235   .8149       .92592593
 PPPINC    .7191755346E-05  .79130645E-05     .909   .3657      20946.240
 TBG       .1827190978E-01  .26685912E-01     .685   .4951       .57407407
 DEN       .2989539106E-03  .48822822E-04    6.123   .0000      4872.9226***
 FI       -.3563365540E-02  .48723090E-01    -.073   .9418       .64814815
 MR        .6331905934E-01  .25912546E-01    2.444   .0163       .12037037**
 PKR       .5392949256E-02       .12386789    .044   .9654  .15667493E-01
 CR        .2788469020E-01  .78896803E-02    3.534   .0006      2.6944444***
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=============================================================================+
| LIMDEP Estimation Results                        Run log line   11  Page   3 |
| Current sample contains     108 observations.                                |
+=============================================================================+

        Estimated Fixed Effects
        Group        Coefficient        Standard Error        t-ratio
            1            -.26693                .17183       -1.55342
            2            -.04807                .17965        -.26760
            3            -.71317                .21029       -3.39134
            4          -2.06313                 .40747       -5.06321
```

```
          5          -1.83564              .36360       -5.04850
          6           -.61490              .18670       -3.29344
          7          -3.32770              .56485       -5.89127
          8           -.68682              .19578       -3.50803
          9           -.54745              .16920       -3.23547
         10           -.96013              .22302       -4.30511
         11           -.21862              .14128       -1.54738
         12          -2.16160              .37846       -5.71161
         13          -2.49585              .51441       -4.85189
         14           -.47963              .28669       -1.67301
         15           -.63588              .28888       -2.20119
         16          -2.28906              .50627       -4.52140
         17           -.13607              .27059        -.50285
         18          -1.18848              .35005       -3.39516

+-----------------------------------------------------------------------------+
|                Test Statistics for the Classical Model                      |
|                                                                             |
|        Model                 Log-Likelihood    Sum of Squares    R-squared  |
| (1)  Constant term only         103.54572    .9293599491D+00     .0000000   |
| (2)  Group effects only         144.11994    .4383956039D+00     .5282822   |
| (3)  X - variables only         143.96574    .4396492674D+00     .5269333   |
| (4)  X and group effects        203.94319    .1447898883D+00     .8442047   |
|                                                                             |
|                                 Hypothesis Tests                            |
|                  Likelihood Ratio Test                F Tests               |
|              Chi-squared   d.f.  Prob.            F    num.  denom. Prob value |
| (2) vs (1)      81.148     17     .00000       5.929   17     90      .00000 |
| (3) vs (1)      80.840     10     .00000      10.805   10     97      .00000 |
| (4) vs (1)     200.795     27     .00000      16.055   27     80      .00000 |
| (4) vs (2)     119.647     10     .00000      16.222   10     80      .00000 |
| (4) vs (3)     119.955     17     .00000       9.583   17     80      .00000 |
+-----------------------------------------------------------------------------+
+=================================================================================+
| LIMDEP Estimation Results                        Run log line    11   Page    4 |
| Current sample contains      108 observations.                                  |
+=================================================================================+


              +--------------------------------------------------+
              | Random Effects Model: v(i,t) = e(i,t) + u(i)      |
              | Estimates:  Var[e]              =   .180987D-02   |
              |             Var[u]              =   .272259D-02   |
              |             Corr[v(i,t),v(i,s)] =   .600687       |
              | Lagrange Multiplier Test vs. Model (3) =   23.62  |
              | ( 1 df, prob value =  .000001)                    |
              | (High values of LM favor FEM/REM over CR model.)  |
              | Fixed vs. Random Effects (Hausman)     =   55.47  |
              | (10 df, prob value =  .000000)                    |
              | (High (low) values of H favor FEM (REM).)         |
              | Reestimated using GLS coefficients:               |
              | Estimates:  Var[e]              =   .294634D-02   |
              |             Var[u]              =   .558132D-02   |
              |             Sum of Squares          .490748D+00   |
              +--------------------------------------------------+

+--------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
```

```
+--------+--------------+----------------+--------+--------+----------+
 PNR          .8036179258      .26584476    3.023   .0025  .24073777E-01
 FNR      -.4016048962E-02  .82841303E-02   -.485   .6278    3.5740741
 KR        .2765408146E-01  .26588809E-01   1.040   .2983     .92592593
 PPPINC    .1612670698E-05  .39877344E-05    .404   .6859    20946.240
 TBG       .5056465665E-01  .22799136E-01   2.218   .0266     .57407407
 DEN      -.4687451073E-05  .49453425E-05   -.948   .3432    4872.9226
 FI       -.3767909718E-02  .27180656E-01   -.139   .8897     .64814815
 MR        .8245133186E-01  .23280971E-01   3.542   .0004     .12037037
 PKR       .5029787688E-01      .11477807    .438   .6612  .15667493E-01
 CR        .2325421463E-01  .59198645E-02   3.928   .0001    2.6944444
 Constant  .2454716306E-02  .75400506E-01    .033   .9740
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

b. Lin-lin Model 2

```
+=====================================================================+
| LIMDEP Estimation Results            Run log line   11   Page    1 |
| Current sample contains     108 observations.                       |
+=====================================================================+



+---------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                   |
| Ordinary    least squares regression    Weighting variable = none   |
| Dep. var. = RR       Mean=   .1439462333    , S.D.=   .9319660402E-01 |
| Model size: Observations =      108, Parameters =  11, Deg.Fr.=    97 |
| Residuals:  Sum of squares= .4490386390     , Std.Dev.=        .06804 |
| Fit:        R-squared=  .516830, Adjusted R-squared =          .46702 |
| Model test: F[ 10,     97] =   10.38,    Prob value =          .00000 |
| Diagnostic: Log-L =    142.8246, Restricted(b=0) Log-L =     103.5457 |
|             LogAmemiyaPrCrt.=   -5.278, Akaike Info. Crt.=     -2.441 |
| Panel Data Analysis of RR              [ONE way]                     |
|           Unconditional ANOVA (No regressors)                        |
| Source      Variation          Deg. Free.     Mean Square            |
| Between       .490964               17.          .288803E-01         |
| Residual      .438396               90.          .487106E-02         |
| Total         .929360              107.          .868561E-02         |
+---------------------------------------------------------------------+


+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR          .4454236069      .31532218    1.413   .1610  .24073777E-01
 FNR      -.5111706526E-03  .67285755E-02   -.076   .9396    3.5740741
 KR       -.3430798441E-02  .32588038E-01   -.105   .9164     .92592593
 PPPINC    .8799475857E-06  .23526238E-05    .374   .7092    20946.240
 TBG       .4992269935E-01  .24804345E-01   2.013   .0469     .57407407
 LDEN     -.1893250327E-01  .13270253E-01  -1.427   .1569    8.2698875
 FI       -.2996107616E-01  .19259663E-01  -1.556   .1231     .64814815
 MR        .9918763686E-01  .28005254E-01   3.542   .0006     .12037037
 PKR       .4870540575E-02      .13767177    .035   .9719  .15667493E-01
 CR        .2348200141E-01  .50234768E-02   4.674   .0000    2.6944444
 Constant     .1918382890   .97809911E-01   1.961   .0527
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=====================================================================+
```

```
| LIMDEP Estimation Results                      Run log line   11  Page   2 |
| Current sample contains     108 observations.                              |
+==========================================================================+



+----------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                             |
| Ordinary    least squares regression    Weighting variable = none    |
| Dep. var. = RR       Mean=   .1439462333    , S.D.=   .9319660402E-01 |
| Model size: Observations =     108, Parameters =  28, Deg.Fr.=     80 |
| Residuals:  Sum of squares= .1216988317    , Std.Dev.=         .03900 |
| Fit:        R-squared=  .869051, Adjusted R-squared =          .82486 |
| Model test: F[ 27,      80] =   19.66,    Prob value =         .00000 |
| Diagnostic: Log-L =    213.3248, Restricted(b=0) Log-L =     103.5457 |
|             LogAmemiyaPrCrt.=   -6.258, Akaike Info. Crt.=     -3.432 |
| Estd. Autocorrelation of e(i,t)     .167919                           |
+----------------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR          .6251173108        .27458809     2.277   .0250  .24073777E-01**
 FNR      -.9695039192E-01  .27902252E-01    -3.475   .0008     3.5740741***
 KR       -.1356860474E-01  .31400935E-01     -.432   .6666     .92592593
 PPPINC    .9686572562E-05  .72631286E-05     1.334   .1854     20946.240
 TBG       .3841159101E-01  .24243370E-01     1.584   .1163     .57407407
 LDEN        2.007204586       .25958946      7.732   .0000     8.2698875***
 FI       -.4994046843E-01  .45583656E-01    -1.096   .2759     .64814815
 MR        .6275122131E-01  .23693414E-01     2.648   .0094     .12037037***
 PKR        -.1006943959        .11517282     -.874   .3841  .15667493E-01
 CR        .2289127981E-01  .73055253E-02     3.133   .0023     2.6944444***
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+==========================================================================+
| LIMDEP Estimation Results                      Run log line   11  Page   3 |
| Current sample contains     108 observations.                              |
+==========================================================================+

        Estimated Fixed Effects
        Group       Coefficient        Standard Error        t-ratio
            1         -14.71247               1.92563       -7.64033
            2         -14.10858               1.86016       -7.58459
            3         -16.04140               2.09542       -7.65547
            4         -17.81678               2.33460       -7.63161
            5         -17.55044               2.27791       -7.70463
            6         -15.48371               2.00438       -7.72494
            7         -18.74126               2.42074       -7.74196
            8         -15.82501               2.05613       -7.69649
            9         -15.29310               1.97583       -7.74007
           10         -16.41295               2.13472       -7.68859
           11         -14.22044               1.85334       -7.67285
           12         -17.85098               2.31672       -7.70530
           13         -18.14324               2.38544       -7.60583
           14         -15.95942               2.13145       -7.48759
           15         -16.23383               2.16833       -7.48679
           16         -17.93502               2.38400       -7.52309
           17         -15.40261               2.07386       -7.42704
           18         -16.95795               2.25278       -7.52756
```

```
+----------------------------------------------------------------------------+
|                   Test Statistics for the Classical Model                  |
|                                                                            |
|         Model                 Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only         103.54572    .9293599491D+00     .0000000 |
| (2)  Group effects only         144.11994    .4383956039D+00     .5282822 |
| (3)  X - variables only         142.82463    .4490386390D+00     .5168302 |
| (4)  X and group effects        213.32484    .1216988317D+00     .8690509 |
|                                                                            |
|                                   Hypothesis Tests                         |
|                  Likelihood Ratio Test                 F Tests              |
|              Chi-squared    d.f.   Prob.          F     num.  denom.  Prob value |
| (2) vs (1)       81.148      17     .00000      5.929    17     90      .00000 |
| (3) vs (1)       78.558      10     .00000     10.376    10     97      .00000 |
| (4) vs (1)      219.558      27     .00000     19.664    27     80      .00000 |
| (4) vs (2)      138.410      10     .00000     20.818    10     80      .00000 |
| (4) vs (3)      141.000      17     .00000     12.658    17     80      .00000 |
+----------------------------------------------------------------------------+
+==============================================================================+
| LIMDEP Estimation Results                      Run log line    11   Page    4 |
| Current sample contains      108 observations.                               |
+==============================================================================+
```

```
            +--------------------------------------------------+
            | Random Effects Model: v(i,t) = e(i,t) + u(i)     |
            | Estimates:  Var[e]              =   .152124D-02  |
            |             Var[u]              =   .310803D-02  |
            |             Corr[v(i,t),v(i,s)] =   .671387      |
            | Lagrange Multiplier Test vs. Model (3) =    25.59 |
            | ( 1 df, prob value =  .000000)                   |
            | (High values of LM favor FEM/REM over CR model.) |
            | Fixed vs. Random Effects (Hausman)     =    79.64 |
            | (10 df, prob value =  .000000)                   |
            | (High (low) values of H favor FEM (REM).)        |
            | Reestimated using GLS coefficients:              |
            | Estimates:  Var[e]              =   .291805D-02  |
            |             Var[u]              =   .640305D-02  |
            |             Sum of Squares          .522799D+00  |
            +--------------------------------------------------+
```

```
+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient   | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR          .8379451509       .24800662      3.379   .0007  .24073777E-01
 FNR       -.6076412017E-02  .84198137E-02     -.722   .4705     3.5740741
 KR         .2760462211E-01  .25321287E-01     1.090   .2756     .92592593
 PPPINC     .1270004712E-05  .39623428E-05      .321   .7486     20946.240
 TBG        .4868637887E-01  .21433972E-01     2.271   .0231     .57407407
 LDEN      -.1268877613E-01  .24015592E-01     -.528   .5973     8.2698875
 FI         .7250311498E-03  .27839587E-01      .026   .9792     .64814815
 MR         .8150637936E-01  .21713196E-01     3.754   .0002     .12037037
 PKR        .5684940399E-01     .10677292       .532   .5944  .15667493E-01
 CR         .2354715510E-01  .56943844E-02     4.135   .0000     2.6944444
 Constant   .9569671032E-01     .18247309       .524   .6000
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

c. Lin-log Model 3

```
+=======================================================================+
| LIMDEP Estimation Results                    Run log line   26  Page   1 |
| Current sample contains     108 observations.                         |
+=======================================================================+



+-----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                     |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = RR       Mean=   .1439462333    , S.D.=   .9319660402E-01 |
| Model size: Observations =      108, Parameters =  11, Deg.Fr.=     97 |
| Residuals:  Sum of squares= .4336598653     , Std.Dev.=          .06686 |
| Fit:        R-squared=  .533378, Adjusted R-squared =            .48527 |
| Model test: F[ 10,      97] =   11.09,    Prob value =            .00000 |
| Diagnostic: Log-L =     144.7064, Restricted(b=0) Log-L =     103.5457 |
|             LogAmemiyaPrCrt.=   -5.313, Akaike Info. Crt.=      -2.476 |
| Panel Data Analysis of RR          [ONE way]                          |
|           Unconditional ANOVA (No regressors)                         |
| Source      Variation        Deg. Free.      Mean Square              |
| Between       .490964              17.          .288803E-01          |
| Residual      .438396              90.          .487106E-02          |
| Total         .929360             107.          .868561E-02          |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR      .2305260522E-01  .10324369E-01    2.233   .0279    -4.3025594
 LFNR     -.1055207446E-01  .25693529E-01    -.411   .6822     1.1380865
 KR        .8745479651E-02  .32140099E-01     .272   .7861      .92592593
 LPINC     .2231162392E-01  .47604536E-01     .469   .6403     9.9359444
 TBG       .3605235177E-01  .25759874E-01    1.400   .1648      .57407407
 LDEN     -.7668610694E-02  .14533398E-01    -.528   .5989     8.2698875
 FI       -.4600935581E-01  .21371842E-01   -2.153   .0338      .64814815
 MR        .9587936247E-01  .26857828E-01    3.570   .0006      .12037037
 PKR       .3169721358E-01     .13416981      .236   .8137  .15667493E-01
 CR        .1948738985E-01  .54227579E-02    3.594   .0005     2.6944444
 Constant  .3335325596E-01     .43942862      .076   .9397
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
| LIMDEP Estimation Results                    Run log line   26  Page   2 |
| Current sample contains     108 observations.                         |
+=======================================================================+



+-----------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                              |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = RR       Mean=   .1439462333    , S.D.=   .9319660402E-01 |
| Model size: Observations =      108, Parameters =  28, Deg.Fr.=     80 |
| Residuals:  Sum of squares= .1179371848     , Std.Dev.=          .03840 |
| Fit:        R-squared=  .873098, Adjusted R-squared =            .83027 |
| Model test: F[ 27,      80] =   20.39,    Prob value =            .00000 |
```

```
| Diagnostic: Log-L =    215.0203, Restricted(b=0) Log-L =     103.5457 |
|             LogAmemiyaPrCrt.=   -6.289, Akaike Info. Crt.=     -3.463 |
| Estd. Autocorrelation of e(i,t)     .147951                          |
+---------------------------------------------------------------------+


+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 LPNR      .2844541748E-01  .10025489E-01     2.837   .0055    -4.3025594***
 LFNR        -.6334649096        .16793688    -3.772   .0003     1.1380865***
 KR       -.4695787411E-02  .31454297E-01     -.149   .8816      .92592593
 LPINC        .1596571030        .15433223     1.035   .3034     9.9359444
 TBG       .2836062180E-01  .24678785E-01     1.149   .2533      .57407407
 LDEN         2.017642270        .25554224     7.896   .0000     8.2698875***
 FI       -.4564745180E-01  .44238958E-01    -1.032   .3047      .64814815
 MR        .6251553631E-01  .23493444E-01     2.661   .0091      .12037037***
 PKR         -.1060094813        .11344937     -.934   .3524  .15667493E-01
 CR        .1898615420E-01  .73784434E-02     2.573   .0116     2.6944444**
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
| LIMDEP Estimation Results                     Run log line   26 Page   3 |
| Current sample contains     108 observations.                          |
+=======================================================================+


          Estimated Fixed Effects
          Group          Coefficient            Standard Error        t-ratio
             1             -15.76723                   2.49021       -6.33168
             2             -15.03673                   2.44279       -6.15555
             3             -16.96552                   2.61983       -6.47580
             4             -18.72914                   2.82484       -6.63017
             5             -18.61888                   2.79436       -6.66302
             6             -16.55448                   2.55363       -6.48273
             7             -19.80607                   2.90672       -6.81389
             8             -16.88809                   2.59128       -6.51727
             9             -16.39009                   2.52317       -6.49583
            10             -17.52025                   2.64963       -6.61233
            11             -15.29002                   2.41665       -6.32695
            12             -18.94077                   2.77635       -6.82217
            13             -18.90095                   2.89169       -6.53629
            14             -16.73866                   2.67294       -6.26228
            15             -17.02378                   2.68685       -6.33597
            16             -18.72838                   2.87392       -6.51667
            17             -16.19124                   2.60800       -6.20830
            18             -17.74377                   2.76786       -6.41063

+---------------------------------------------------------------------+
|                Test Statistics for the Classical Model              |
|                                                                     |
|         Model              Log-Likelihood    Sum of Squares  R-squared |
| (1)  Constant term only        103.54572   .9293599491D+00   .0000000 |
| (2)  Group effects only        144.11994   .4383956039D+00   .5282822 |
| (3)  X - variables only        144.70644   .4336598653D+00   .5333779 |
| (4)  X and group effects       215.02029   .1179371848D+00   .8730985 |
|                                                                     |
|                              Hypothesis Tests                       |
|               Likelihood Ratio Test                 F Tests         |
|            Chi-squared   d.f.  Prob.          F    num. denom. Prob value |
```

```
| (2) vs (1)     81.148      17      .00000      5.929   17     90      .00000 |
| (3) vs (1)     82.321      10      .00000     11.088   10     97      .00000 |
| (4) vs (1)    222.949      27      .00000     20.386   27     80      .00000 |
| (4) vs (2)    141.801      10      .00000     21.738   10     80      .00000 |
| (4) vs (3)    140.628      17      .00000     12.598   17     80      .00000 |
+-----------------------------------------------------------------------------+

+=================================================================================+
| LIMDEP Estimation Results                          Run log line    26  Page    4 |
| Current sample contains       108 observations.                                 |
+=================================================================================+


            +----------------------------------------------------+
            | Random Effects Model: v(i,t) = e(i,t) + u(i)       |
            | Estimates:  Var[e]              =   .147421D-02    |
            |             Var[u]              =   .299651D-02    |
            |             Corr[v(i,t),v(i,s)] =   .670251        |
            | Lagrange Multiplier Test vs. Model (3) =    22.50  |
            | ( 1 df, prob value =  .000002)                     |
            | (High values of LM favor FEM/REM over CR model.)   |
            | Fixed vs. Random Effects (Hausman)     =    84.85  |
            | (10 df, prob value =  .000000)                     |
            | (High (low) values of H favor FEM (REM).)          |
            | Reestimated using GLS coefficients:                |
            | Estimates:  Var[e]              =   .292680D-02    |
            |             Var[u]              =   .577772D-02    |
            |             Sum of Squares          .497296D+00    |
            +----------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 LPNR      .3287121626E-01  .89380163E-02     3.678   .0002     -4.3025594
 LFNR     -.2012577919E-01  .32438365E-01     -.620   .5350      1.1380865
 KR        .4267710642E-01  .25182179E-01     1.695   .0901      .92592593
 LPINC     .2133881946E-01  .81504372E-01      .262   .7935      9.9359444
 TBG       .4389468714E-01  .21931420E-01     2.001   .0453      .57407407
 LDEN     -.1528149636E-02  .23856326E-01     -.064   .9489      8.2698875
 FI       -.1299276604E-01  .27423298E-01     -.474   .6357      .64814815
 MR        .7693235456E-01  .21255409E-01     3.619   .0003      .12037037
 PKR       .6592883248E-01       .10508028      .627   .5304  .15667493E-01
 CR        .1840292394E-01  .57495988E-02     3.201   .0014      2.6944444
 Constant -.7274601571E-02       .76658510     -.009   .9924
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

d. Log-log Model 4

```
+=================================================================================+
| LIMDEP Estimation Results                          Run log line    11  Page    1 |
| Current sample contains       108 observations.                                 |
+=================================================================================+



+-----------------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                           |
| Ordinary    least squares regression    Weighting variable = none           |
| Dep. var. = LRR       Mean=  -2.240670358     , S.D.=   .9371663314         |
```

```
| Model size: Observations =      108, Parameters =  11, Deg.Fr.=     97 |
| Residuals:  Sum of squares= 41.60161038    , Std.Dev.=          .65489 |
| Fit:        R-squared= .557317, Adjusted R-squared =            .51168 |
| Model test: F[ 10,     97] =   12.21,     Prob value =          .00000 |
| Diagnostic: Log-L =   -101.7298, Restricted(b=0) Log-L =     -145.7344 |
|             LogAmemiyaPrCrt.=    -.750, Akaike Info. Crt.=      2.088 |
| Panel Data Analysis of LRR        [ONE way]                           |
|           Unconditional ANOVA (No regressors)                         |
| Source      Variation         Deg. Free.     Mean Square             |
| Between       38.0660               17.         2.23918              |
| Residual      55.9101               90.         .621223              |
| Total         93.9760              107.         .878281              |
+---------------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 LPNR          .1846262822       .10112161     1.826   .0710    -4.3025594
 LFNR         -.1670447633       .25165421     -.664   .5084     1.1380865
 KR           1.412344153        .31479488     4.487   .0000     .92592593
 LPINC        -.1772092644       .46626068     -.380   .7047     9.9359444
 TBG           .2629537693       .25230403     1.042   .2999     .57407407
 LDEN      -.6243075630E-01      .14234677     -.439   .6619     8.2698875
 FI           -.3451212134       .20932563    -1.649   .1024     .64814815
 MR            .7750652674       .26305789     2.946   .0040     .12037037
 PKR          -.3130048883      1.3141207      -.238   .8122  .15667493E-01
 CR          .8922622425E-01  .53112980E-01    1.680   .0962     2.6944444
 Constant     -.5429540262      4.3039656      -.126   .8999
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=====================================================================+
| LIMDEP Estimation Results                      Run log line   11  Page   2 |
| Current sample contains     108 observations.                       |
+=====================================================================+


+---------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                            |
| Ordinary    least squares regression    Weighting variable = none   |
| Dep. var. = LRR      Mean=  -2.240670358    , S.D.=   .9371663314   |
| Model size: Observations =      108, Parameters =  28, Deg.Fr.=     80 |
| Residuals:  Sum of squares= 17.40687936    , Std.Dev.=          .46646 |
| Fit:        R-squared= .814773, Adjusted R-squared =            .75226 |
| Model test: F[ 27,     80] =   13.03,     Prob value =          .00000 |
| Diagnostic: Log-L =    -54.6810, Restricted(b=0) Log-L =     -145.7344 |
|             LogAmemiyaPrCrt.=   -1.295, Akaike Info. Crt.=      1.531 |
| Estd. Autocorrelation of e(i,t)     .296780                          |
+---------------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 LPNR          .2728129722       .12179814     2.240   .0274    -4.3025594**
 LFNR        -4.829011975       2.0402396     -2.367   .0199     1.1380865**
 KR            .7599052539       .38213346     1.989   .0495     .92592593**
 LPINC        4.225094629       1.8749587      2.253   .0265     9.9359444**
 TBG           .1508304054       .29981880      .503   .6160     .57407407
 LDEN        17.85602364        3.1045437      5.752   .0000     8.2698875***
```

```
FI          .2022009977      .53745235     .376   .7076     .64814815
MR          .7588142433      .28541827    2.659   .0092     .12037037***
PKR       -1.074697932      1.3782791     -.780   .4374  .15667493E-01
CR      .7752195503E-01  .89639584E-01     .865   .3893    2.6944444
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=====================================================================+
| LIMDEP Estimation Results                  Run log line   11  Page   3 |
| Current sample contains     108 observations.                        |
+=====================================================================+

        Estimated Fixed Effects
        Group        Coefficient          Standard Error        t-ratio
            1         -171.71355                30.25321       -5.67588
            2         -165.88344                29.67711       -5.58961
            3         -182.27462                31.82797       -5.72687
            4         -198.19877                34.31851       -5.77527
            5         -198.64360                33.94826       -5.85136
            6         -179.47154                31.02366       -5.78499
            7         -208.65412                35.31327       -5.90866
            8         -181.45662                31.48111       -5.76398
            9         -177.67362                30.65363       -5.79617
           10         -187.82597                32.18998       -5.83492
           11         -166.74547                29.35951       -5.67944
           12         -199.50937                33.72950       -5.91498
           13         -202.14438                35.13072       -5.75406
           14         -182.39049                32.47308       -5.61667
           15         -184.59292                32.64208       -5.65506
           16         -199.86659                34.91479       -5.72441
           17         -177.08828                31.68419       -5.58917
           18         -191.48594                33.62637       -5.69452

+-----------------------------------------------------------------+
|               Test Statistics for the Classical Model           |
|                                                                 |
|        Model              Log-Likelihood   Sum of Squares    R-squared |
| (1)  Constant term only     -145.73443   .9397603840D+02    .0000000 |
| (2)  Group effects only     -117.69247   .5591005663D+02    .4050605 |
| (3)  X - variables only     -101.72977   .4160161038D+02    .5573168 |
| (4)  X and group effects     -54.68101   .1740687936D+02    .8147732 |
|                                                                 |
|                          Hypothesis Tests                       |
|              Likelihood Ratio Test               F Tests        |
|           Chi-squared   d.f.   Prob.          F    num.  denom.  Prob value |
| (2) vs (1)    56.084    17     .00000      3.604   17     90     .00004 |
| (3) vs (1)    88.009    10     .00000     12.212   10     97     .00000 |
| (4) vs (1)   182.107    27     .00000     13.033   27     80     .00000 |
| (4) vs (2)   126.023    10     .00000     17.696   10     80     .00000 |
| (4) vs (3)    94.098    17     .00000      6.541   17     80     .00000 |
+-----------------------------------------------------------------+
+=====================================================================+
| LIMDEP Estimation Results                  Run log line   11  Page   4 |
| Current sample contains     108 observations.                        |
+=====================================================================+


             +------------------------------------------------+
             | Random Effects Model: v(i,t) = e(i,t) + u(i)   |
```

```
| Estimates:  Var[e]              =   .217586D+00  |
|             Var[u]              =   .211297D+00  |
|             Corr[v(i,t),v(i,s)] =   .492668      |
| Lagrange Multiplier Test vs. Model (3) =    3.81 |
| ( 1 df, prob value =  .050917)                   |
| (High values of LM favor FEM/REM over CR model.) |
| Fixed vs. Random Effects (Hausman)     =   55.25 |
| (10 df, prob value =  .000000)                   |
| (High (low) values of H favor FEM (REM).)        |
| Reestimated using GLS coefficients:              |
| Estimates:  Var[e]              =   .350102D+00  |
|             Var[u]              =   .378648D+00  |
|             Sum of Squares          .463621D+02  |
+--------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 LPNR        .2701976837       .10229634     2.641   .0083   -4.3025594
 LFNR       -.2089372806       .31181466     -.670   .5028    1.1380865
 KR         1.629809122        .28534257     5.712   .0000    .92592593
 LPINC       .2832104932       .77222729      .367   .7138    9.9359444
 TBG         .3581874551       .24893574     1.439   .1502    .57407407
 LDEN       -.1279040352       .21943466     -.583   .5600    8.2698875
 FI       -.4407842598E-01     .27583865     -.160   .8730    .64814815
 MR          .7001726202       .24679119     2.837   .0046    .12037037
 PKR       .5532302280E-01    1.2257750       .045   .9640  .15667493E-01
 CR        .6956483509E-01  .62990897E-01    1.104   .2694    2.6944444
 Constant   -4.555276495      7.2289315      -.630   .5286
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

e. Measure of the Goodness-of-fit in Model 4

Since dependant variable is logged in Model 4, adjusted R^2 cannot be compared with other models directly. According to the method suggested in Wooldridge (2003), the following steps can find the goodness-of-fit of Model 4. Firstly, run the regression of the actual recycling ratios (*RR*) on the exponential fitted values in Model 4 (MHT, $\exp\left(\widehat{\log RR}\right)$).

```
+=====================================================================+
| LIMDEP Estimation Results                 Run log line   18  Page  1 |
| Current sample contains    108 observations.                         |
+=====================================================================+



+-----------------------------------------------------------------+
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = RR       Mean=   .1439462333    , S.D.=   .9319660402E-01 |
| Model size: Observations =     108, Parameters =   1, Deg.Fr.=    107 |
| Residuals:  Sum of squares= .5131394504    , Std.Dev.=          .06925 |
| Fit:        R-squared=  .447857, Adjusted R-squared =           .44786 |
| Model test: F[  1,     107] =   86.79,    Prob value =          .00000 |
```

```
| Diagnostic: Log-L =     135.6189, Restricted(b=0) Log-L =     103.5457 |
|             LogAmemiyaPrCrt.=    -5.331, Akaike Info. Crt.=     -2.493 |
| Model does not contain ONE. R-squared and F can be negative!          |
| Autocorrel: Durbin-Watson Statistic =    .72942,    Rho =      .63529 |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 MHT          1.051492034   .44696998E-01    23.525   .0000     .13149532
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

Secondly, the correlation between actual recycling ratio (RR) and the fitted value of above regression ($\hat{RR}$) is 0.68.

```
+=========================================================================+
| LIMDEP Estimation Results                     Run log line   21  Page   1 |
| Current sample contains     108 observations.                             |
+=========================================================================+

Descriptive Statistics
All results based on nonmissing observations.
===========================================================================
Variable        Mean          Std.Dev.         Minimum          Maximum     Cases
===========================================================================
---------------------------------------------------------------------------
All observations in current sample
---------------------------------------------------------------------------
RR        .143946233     .931966040E-01  .181721144E-02  .410937087       108
RRHT      .138266280     .742148629E-01  .108518826E-01  .268610387       108

Correlation Matrix for Listed Variables

              RR      RRHT
      RR 1.00000   .68172
    RRHT  .68172  1.00000
```

Thirdly, the squared of the correlation is 0.46 which can be compared with adjusted R^2 obtained from model without logged dependant.

A7-2. Estimation reports for Regression Specification Error Test

Regression Specification Error Test (RESET) is suggested by Ramsey (1969). The arithmetic of the test are shown in the main contest section 5.1 (pp. 70). The Limdep reports of RESET for Model 2 and Model 3 are shown below. The *P*-value of RESET for Model 2 and 3 are 0.06 and 0.42, respectively. Those means that the unrestricted model of Model 3 cannot reject the null hypothesis of correct functional form, but Model 2 can do. Therefore, Model 3 is chosen for recycling ratio estimation.

a. Estimation report for Model 2 Regression Specification Error Test

```
+=============================================================================+
| LIMDEP Estimation Results                          Run log line   16  Page   5 |
| Current sample contains     108 observations.                                |
+=============================================================================+



+------------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                      |
| Ordinary    least squares regression    Weighting variable = none      |
| Dep. var. = RR        Mean=   .1439462333     , S.D.=   .9319660402E-01 |
| Model size: Observations =      108, Parameters =  13, Deg.Fr.=      95 |
| Residuals:  Sum of squares= .3971960589     , Std.Dev.=          .06466 |
| Fit:        R-squared=  .572613, Adjusted R-squared =            .51863 |
| Model test: F[ 12,      95] =    10.61,     Prob value =         .00000 |
| Diagnostic: Log-L =     149.4493, Restricted(b=0) Log-L =      103.5457 |
|             LogAmemiyaPrCrt.=   -5.364, Akaike Info. Crt.=       -2.527 |
| Panel Data Analysis of RR               [ONE way]                      |
|           Unconditional ANOVA (No regressors)                          |
| Source      Variation          Deg. Free.      Mean Square             |
| Between       .490964                 17.          .288803E-01         |
| Residual      .438396                 90.          .487106E-02         |
| Total         .929360                107.          .868561E-02         |
+------------------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR         -5.812683347       1.8137468     -3.205   .0018  .24073777E-01
 FNR        .2517468897E-01  .10526155E-01     2.392   .0187     3.5740741
 KR           .2141731285    .69519081E-01     3.081   .0027    .92592593
 PPPINC    -.7174319766E-05  .32331320E-05    -2.219   .0289    20946.240
 TBG         -.3227032377       .11050844     -2.920   .0044    .57407407
 LDEN       .9855384840E-01  .361137494E-01    2.727   .0076    8.2698875
 FI        -.6743827109E-01  .21172873E-01    -3.185   .0020    .64814815
 MR          -.4191144240       .15433916     -2.716   .0079    .12037037
 PKR         -.3290041295       .16285399     -2.020   .0462  .15667493E-01
 CR          -.1622702297    .53007841E-01    -3.061   .0029    2.6944444
 YHATSQ      45.07471575       13.468600       3.347   .0012  .26536489E-01
 YHATQB     -79.58667708       25.626946      -3.106   .0025  .54799416E-02
```

```
Constant    -.7073564337        .27898293   -2.535   .0129
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+==============================================================================+
| LIMDEP Estimation Results                        Run log line   16  Page    6 |
| Current sample contains     108 observations.                                |
+==============================================================================+



+-----------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                              |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = RR       Mean=   .1439462333     , S.D.=   .9319660402E-01 |
| Model size: Observations =      108, Parameters =  30, Deg.Fr.=     78 |
| Residuals:  Sum of squares= .1163629079     , Std.Dev.=          .03862 |
| Fit:        R-squared=  .874792, Adjusted R-squared =            .82824 |
| Model test: F[ 29,      78] =    18.79,     Prob value =          .00000 |
| Diagnostic: Log-L =     215.7460, Restricted(b=0) Log-L =      103.5457 |
|             LogAmemiyaPrCrt.=   -6.263, Akaike Info. Crt.=      -3.440 |
| Estd. Autocorrelation of e(i,t)      .152674                          |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR        -2.892527645      1.8941471     -1.527   .1300  .24073777E-01
 FNR     -.6321349040E-01  .33358645E-01    -1.895   .0611     3.5740741
 KR          .1003018968   .68829082E-01     1.457   .1483     .92592593
 PPPINC   .3264320598E-05  .79614042E-05      .410   .6827     20946.240
 TBG        -.1686896121     .11230827      -1.502   .1364     .57407407
 LDEN        2.094768789     .26357589       7.947   .0000     8.2698875
 FI      -.8458560834E-01  .48844053E-01    -1.732   .0865     .64814815
 MR         -.2001280135     .14103100      -1.419   .1591     .12037037
 PKR        -.3164103411     .16136232      -1.961   .0528  .15667493E-01
 CR      -.7635109296E-01  .53278193E-01    -1.433   .1551     2.6944444
 YHATSQ      24.23884786      12.862969      1.884   .0625  .26536489E-01
 YHATQB     -42.63540209      23.258381     -1.833   .0699  .54799416E-02
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+==============================================================================+
| LIMDEP Estimation Results                        Run log line   16  Page    7 |
| Current sample contains     108 observations.                                |
+==============================================================================+

        Estimated Fixed Effects
        Group        Coefficient        Standard Error       t-ratio
            1         -15.36295               1.95099        -7.87445
            2         -14.77016               1.88647        -7.82950
            3         -16.73736               2.12299        -7.88385
            4         -18.53086               2.35883        -7.85595
            5         -18.21718               2.30047        -7.91889
            6         -16.12363               2.02833        -7.94920
            7         -19.41715               2.44100        -7.95459
            8         -16.48926               2.08102        -7.92364
            9         -15.93209               1.99854        -7.97185
           10         -17.06441               2.15630        -7.91375
           11         -14.88124               1.88156        -7.90898
           12         -18.53085               2.33884        -7.92310
```

```
          13          -18.85610              2.40658       -7.83522
          14          -16.70424              2.16098       -7.72994
          15          -16.98279              2.19749       -7.72825
          16          -18.72954              2.41343       -7.76056
          17          -16.16968              2.10634       -7.67669
          18          -17.73134              2.28261       -7.76800

+------------------------------------------------------------------------+
|                  Test Statistics for the Classical Model               |
|                                                                        |
|         Model                Log-Likelihood    Sum of Squares  R-squared |
| (1)  Constant term only       103.54572    .9293599491D+00    .0000000 |
| (2)  Group effects only       144.11994    .4383956039D+00    .5282822 |
| (3)  X - variables only       149.44929    .3971960589D+00    .5726133 |
| (4)  X and group effects      215.74596    .1163629079D+00    .8747924 |
|                                                                        |
|                                 Hypothesis Tests                       |
|                Likelihood Ratio Test              F Tests              |
|            Chi-squared   d.f.  Prob.          F     num. denom. Prob value |
| (2) vs (1)    81.148     17     .00000      5.929   17     90     .00000 |
| (3) vs (1)    91.807     12     .00000     10.607   12     95     .00000 |
| (4) vs (1)   224.400     29     .00000     18.792   29     78     .00000 |
| (4) vs (2)   143.252     12     .00000     17.989   12     78     .00000 |
| (4) vs (3)   132.593     17     .00000     11.073   17     78     .00000 |
+------------------------------------------------------------------------+
+===========================================================================+
| LIMDEP Estimation Results                    Run log line    16  Page    8 |
| Current sample contains      108 observations.                           |
+===========================================================================+


             +----------------------------------------------------+
             | Random Effects Model: v(i,t) = e(i,t) + u(i)       |
             | Estimates:  Var[e]              =   .149183D-02    |
             |             Var[u]              =   .268918D-02    |
             |             Corr[v(i,t),v(i,s)] =   .643189        |
             | Lagrange Multiplier Test vs. Model (3) =    23.33   |
             | ( 1 df, prob value =  .000001)                     |
             | (High values of LM favor FEM/REM over CR model.)   |
             | Fixed vs. Random Effects (Hausman)     =    73.45   |
             | (12 df, prob value =  .000000)                     |
             | (High (low) values of H favor FEM (REM).)          |
             | Reestimated using GLS coefficients:                |
             | Estimates:  Var[e]              =   .281651D-02    |
             |             Var[u]              =   .658322D-02    |
             |             Sum of Squares          .431267D+00    |
             +----------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR       -4.441773310      1.5464004      -2.872   .0041  .24073777E-01
 FNR      .1810103813E-01  .10215373E-01    1.772   .0764     3.5740741
 KR        .1878632074     .54855360E-01    3.425   .0006     .92592593
 PPPINC  -.6136151990E-05  .43126288E-05   -1.423   .1548     20946.240
 TBG       -.2669572481    .91434284E-01   -2.920   .0035     .57407407
 LDEN     .8603809506E-01  .36214512E-01    2.376   .0175     8.2698875
 FI      -.4272512913E-01  .29260871E-01   -1.460   .1443     .64814815
```

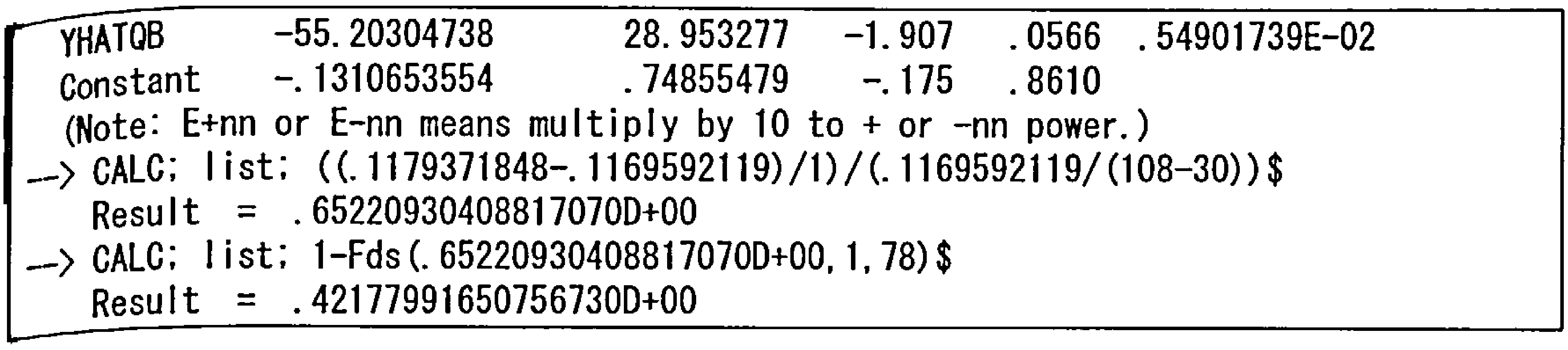
```
 MR          -.3329295465       .11647993    -2.858   .0043     .12037037
 PKR         -.2718638244       .13844303    -1.964   .0496  .15667493E-01
 CR          -.1228750741    .42860604E-01   -2.867   .0041    2.6944444
 YHATSQ       38.74383210      10.598165      3.656   .0003  .26536489E-01
 YHATQB      -71.90936667      19.519694     -3.684   .0002  .54799416E-02
 Constant    -.6484677697       .26978720    -2.404   .0162
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
--> CALC; list; ((.1216988317-.1163629079)/1)/(.1163629079/(108-30))$
   Result  = .35767588135359780D+01
--> CALC; list; 1-Fds(.35767588135359780D+01,1,78)$
   Result  = .62305990187015550D-01
```

b. Estimation reports for Model 3 Regression Specification Error Test

```
+=============================================================================+
| LIMDEP Estimation Results                        Run log line   23   Page   5 |
| Current sample contains     108 observations.                               |
+=============================================================================+



+-----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                     |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = RR         Mean=   .1439462333    , S.D.=   .9319660402E-01 |
| Model size: Observations =      108, Parameters =  13, Deg.Fr.=     95 |
| Residuals:  Sum of squares= .4020357216    , Std.Dev.=          .06505 |
| Fit:        R-squared=  .567406, Adjusted R-squared =           .51276 |
| Model test: F[ 12,     95] =   10.38,     Prob value =          .00000 |
| Diagnostic: Log-L =     148.7953, Restricted(b=0) Log-L =     103.5457 |
|             LogAmemiyaPrCrt.=   -5.351, Akaike Info. Crt.=      -2.515 |
| Panel Data Analysis of RR          [ONE way]                          |
|           Unconditional ANOVA (No regressors)                         |
| Source      Variation        Deg. Free.     Mean Square               |
| Between       .490964              17.        .288803E-01             |
| Residual      .438396              90.        .487106E-02             |
| Total         .929360             107.        .868561E-02             |
+-----------------------------------------------------------------------+


+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR        -.1947929821    .93506057E-01   -2.083   .0399    -4.3025594
 LFNR       .7993095704E-01  .51131631E-01    1.563   .1213     1.1380865
 KR         .7781663769E-01  .41344659E-01    1.882   .0629     .92592593
 LPINC     -.8296476313E-01  .68372385E-01   -1.213   .2280     9.9359444
 TBG         -.2334310407       .12075404    -1.933   .0562     .57407407
 LDEN       .2068713307E-01  .18307041E-01    1.130   .2613     8.2698875
 FI         .2665536639E-02  .31021102E-01     .086   .9317     .64814815
 MR          -.3269634456       .19184658    -1.704   .0916     .12037037
 PKR         -.3001646795       .19522838    -1.538   .1275  .15667493E-01
 CR          -.1066505118    .50330426E-01   -2.119   .0367     2.6944444
 YHATSQ       36.54948220      17.230464      2.121   .0365  .26482443E-01
 YHATQB      -61.40501164      33.322372     -1.843   .0685  .54901739E-02
 Constant    -.3710228340       .45253761     -.820   .4143
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=============================================================================+
```

```
| LIMDEP Estimation Results                     Run log line   23  Page    6 |
| Current sample contains     108 observations.                               |
+==========================================================================+



+-----------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                              |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = RR       Mean=   .1439462333     , S.D.=   .9319660402E-01 |
| Model size: Observations =      108, Parameters =  30, Deg.Fr.=     78 |
| Residuals:  Sum of squares= .1169592119    , Std.Dev.=         .03872 |
| Fit:        R-squared=  .874151, Adjusted R-squared =          .82736 |
| Model test: F[ 29,      78] =   18.68,     Prob value =         .00000 |
| Diagnostic: Log-L =     215.4699, Restricted(b=0) Log-L =    103.5457 |
|             LogAmemiyaPrCrt.=   -6.258, Akaike Info. Crt.=     -3.435 |
| Estd. Autocorrelation of e(i,t)     .140258                           |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR     -.1626479301E-01      .12235406     -.133   .8945    -4.3025594
 LFNR       -.6340530878        .17771471    -3.568   .0006     1.1380865
 KR        .1718252677E-01  .48870734E-01      .352   .7259     .92592593
 LPINC       .1156066469        .19056820      .607   .5455     9.9359444
 TBG      -.2832418859E-01      .15509898     -.183   .8555     .57407407
 LDEN        2.041493399        .25941001     7.870   .0000     8.2698875
 FI       -.5268585154E-01  .46962535E-01    -1.122   .2647     .64814815
 MR       -.1076184413E-01      .23761159     -.045   .9640     .12037037
 PKR        -.1613700154        .21792572     -.740   .4608  .15667493E-01
 CR       -.5380065013E-02  .62732238E-01     -.086   .9318     2.6944444
 YHATSQ      5.921265908        21.837182      .271   .7869  .26482443E-01
 YHATQB     -7.445196130        41.777603     -.178   .8589  .54901739E-02
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+==========================================================================+
| LIMDEP Estimation Results                     Run log line   23  Page    7 |
| Current sample contains     108 observations.                               |
+==========================================================================+


          Estimated Fixed Effects
          Group         Coefficient        Standard Error       t-ratio
              1           -15.74040               2.52842      -6.22539
              2           -14.99391               2.48128      -6.04281
              3           -16.96200               2.66055      -6.37538
              4           -18.72879               2.86485      -6.53744
              5           -18.60914               2.84194      -6.54804
              6           -16.52840               2.59776      -6.36255
              7           -19.79512               2.95371      -6.70179
              8           -16.87416               2.63025      -6.41541
              9           -16.34401               2.56761      -6.36546
             10           -17.48652               2.69486      -6.48884
             11           -15.27117               2.45297      -6.22557
             12           -18.93245               2.82119      -6.71080
             13           -18.86106               2.94071      -6.41378
             14           -16.69874               2.71864      -6.14232
             15           -16.98789               2.73199      -6.21814
             16           -18.70628               2.91991      -6.40646
```

```
        17          -16.14992                 2.65233       -6.08896
        18          -17.71427                 2.81257       -6.29826

+------------------------------------------------------------------------+
|                Test Statistics for the Classical Model                 |
|                                                                        |
|       Model                Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only       103.54572   .9293599491D+00    .0000000 |
| (2)  Group effects only       144.11994   .4383956039D+00    .5282822 |
| (3)  X - variables only       148.79530   .4020357216D+00    .5674058 |
| (4)  X and group effects      215.46995   .1169592119D+00    .8741508 |
|                                                                        |
|                             Hypothesis Tests                           |
|              Likelihood Ratio Test                 F Tests             |
|           Chi-squared    d.f.  Prob.          F     num.  denom. Prob value |
| (2) vs (1)     81.148     17     .00000     5.929   17     90      .00000 |
| (3) vs (1)     90.499     12     .00000    10.384   12     95      .00000 |
| (4) vs (1)    223.848     29     .00000    18.682   29     78      .00000 |
| (4) vs (2)    142.700     12     .00000    17.864   12     78      .00000 |
| (4) vs (3)    133.349     17     .00000    11.183   17     78      .00000 |
+------------------------------------------------------------------------+
+==========================================================================+
| LIMDEP Estimation Results                         Run log line   23  Page   8 |
| Current sample contains      108 observations.                             |
+==========================================================================+


                +-------------------------------------------------+
                | Random Effects Model: v(i,t) = e(i,t) + u(i)    |
                | Estimates:  Var[e]              =   .149948D-02 |
                |             Var[u]              =   .273248D-02 |
                |             Corr[v(i,t),v(i,s)] =   .645677     |
                | Lagrange Multiplier Test vs. Model (3) =   17.83 |
                | ( 1 df, prob value =  .000024)                  |
                | (High values of LM favor FEM/REM over CR model.) |
                | Fixed vs. Random Effects (Hausman)     =   81.32 |
                | (12 df, prob value =  .000000)                  |
                | (High (low) values of H favor FEM (REM).)       |
                | Reestimated using GLS coefficients:             |
                | Estimates:  Var[e]              =   .297941D-02 |
                |             Var[u]              =   .643549D-02 |
                |             Sum of Squares          .440355D+00 |
                +-------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR       -.1324237939   .80891690E-01   -1.637   .1016    -4.3025594
 LFNR      .5575874533E-01 .48898872E-01    1.140   .2542     1.1380865
 KR        .7386867232E-01 .31728284E-01    2.328   .0199     .92592593
 LPINC    -.8210386310E-01 .93811878E-01    -.875   .3815     9.9359444
 TBG        -.1686315708     .10614997     -1.589   .1121     .57407407
 LDEN      .2622422543E-01 .26965966E-01     .972   .3308     8.2698875
 FI        .2089168780E-02 .28263746E-01     .074   .9411     .64814815
 MR         -.2405955001     .15819957     -1.521   .1283     .12037037
 PKR        -.1784658521     .16059493     -1.111   .2664   .15667493E-01
 CR       -.6759049731E-01 .42197106E-01   -1.602   .1092     2.6944444
 YHATSQ      29.63117712     14.815480      2.000   .0455   .26482443E-01
```



```
 YHATQB       -55.20304738        28.953277    -1.907    .0566  .54901739E-02
 Constant     -.1310653554        .74855479     -.175    .8610
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
--> CALC; list; ((.1179371848-.1169592119)/1)/(.1169592119/(108-30))$
    Result  =  .65220930408817070D+00
--> CALC; list; 1-Fds(.65220930408817070D+00,1,78)$
    Result  =  .42177991650756730D+00
```

A7-3. Estimation report for the model in Table 5.2

The LM test and Hausman test results show that FEM estimates can reject non-penal model and REM are better at 1% significance, respectively. Therefore, FEM estimates are chosen.

```
+=====================================================================+
| LIMDEP Estimation Results                   Run log line   28  Page   1 |
| Current sample contains     108 observations.                        |
+=====================================================================+



+------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                |
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = TOR       Mean=    139.5495552    , S.D.=    94.43354965 |
| Model size: Observations =      108, Parameters =  11, Deg.Fr.=      97 |
| Residuals:  Sum of squares= 420811.6843     , Std.Dev.=       65.86551 |
| Fit:        R-squared=  .558987, Adjusted R-squared =           .51352 |
| Model test: F[ 10,      97] =   12.29,      Prob value =         .00000 |
| Diagnostic: Log-L =    -599.7071, Restricted(b=0) Log-L =   -643.9158 |
|             LogAmemiyaPrCrt.=     8.472, Akaike Info. Crt.=     11.309 |
| Panel Data Analysis of TOR          [ONE way]                    |
|           Unconditional ANOVA (No regressors)                    |
| Source      Variation         Deg. Free.      Mean Square        |
| Between       538973.               17.          31704.3         |
| Residual      415221.               90.          4613.56         |
| Total         954193.              107.          8917.70         |
+------------------------------------------------------------------+


+--------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+---------+----------+
 LPNR       17.68902231       10.170277     1.739   .0852    -4.3025594
 LFNR       14.16891058       25.310052      .560   .5769     1.1380865
 KR         13.41602045       31.660407      .424   .6727     .92592593
 LPINC      25.83236964       46.894037      .551   .5830     9.9359444
 TBG        42.44949979       25.375407     1.673   .0976     .57407407
 LDEN      -17.94087986       14.316486    -1.253   .2132     8.2698875
 FI        -46.06633897       21.052866    -2.188   .0311     .64814815
 MR         59.32486016       26.456974     2.242   .0272     .12037037
 PKR       -23.24991662       132.16732     -.176   .8607  .15667493E-01
 CR         23.03926427       5.3418230     4.313   .0000     2.6944444
 Constant   15.44395675       432.87013      .036   .9716

+=====================================================================+
| LIMDEP Estimation Results                   Run log line   28  Page   2 |
| Current sample contains     108 observations.                        |
+=====================================================================+


+------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                         |
```

```
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = TOR       Mean=   139.5495552    , S.D.=    94.43354965    |
| Model size: Observations =      108, Parameters =  28, Deg.Fr.=     80 |
| Residuals:  Sum of squares= 138993.4538    , Std.Dev.=       41.68235 |
| Fit:        R-squared= .854334, Adjusted R-squared =            .80517 |
| Model test: F[ 27,      80] =   17.38,     Prob value =         .00000 |
| Diagnostic: Log-L =    -539.8881, Restricted(b=0) Log-L =    -643.9158 |
|             LogAmemiyaPrCrt.=     7.691, Akaike Info. Crt.=     10.516 |
| Estd. Autocorrelation of e(i,t)      .200415                          |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR       20.48962854       10.883720      1.883   .0627     -4.3025594*
 LFNR     -574.5636446       182.31310      -3.152   .0022      1.1380865***
 KR         11.43872778       34.146939       .335   .7384      .92592593
 LPINC     193.5626952       167.54382      1.155   .2508      9.9359444
 TBG        41.21266217       26.791410      1.538   .1272      .57407407
 LDEN     1791.065533        277.41791      6.456   .0000      8.2698875***
 FI        -47.71348274       48.026029      -.993   .3229      .64814815
 MR         44.40289985       25.504598      1.741   .0848      .12037037*
 PKR       -91.01400817      123.16120       -.739   .4617  .15667493E-01
 CR         18.43853377        8.0100743     2.302   .0235      2.6944444**

+==========================================================================+
| LIMDEP Estimation Results                    Run log line    28  Page   3 |
| Current sample contains      108 observations.                           |
+==========================================================================+

           Estimated Fixed Effects
           Group        Coefficient          Standard Error       t-ratio
               1       -14551.21625              2703.38701      -5.38259
               2       -13864.13808              2651.90732      -5.22799
               3       -15560.96177              2844.10493      -5.47130
               4       -17169.30242              3066.65689      -5.59870
               5       -17060.66473              3033.57111      -5.62395
               6       -15252.27538              2772.23296      -5.50180
               7       -18156.39286              3155.54668      -5.75380
               8       -15522.16197              2813.11040      -5.51779
               9       -15084.32536              2739.16788      -5.50690
              10       -16105.88604              2876.45398      -5.59922
              11       -14100.80123              2623.52655      -5.37475
              12       -17359.88421              3014.02358      -5.75970
              13       -17315.92865              3139.23480      -5.51597
              14       -15374.51275              2901.75141      -5.29836
              15       -15608.49657              2916.85257      -5.35114
              16       -17136.92592              3119.93920      -5.49271
              17       -14861.91522              2831.25690      -5.24923
              18       -16302.37549              3004.80760      -5.42543

+-----------------------------------------------------------------------+
|                Test Statistics for the Classical Model                |
|                                                                       |
|         Model               Log-Likelihood    Sum of Squares   R-squared |
| (1)  Constant term only       -643.91584   .9541933971D+06    .0000000 |
| (2)  Group effects only       -598.98481   .4152206617D+06    .5648464 |
| (3)  X - variables only       -599.70707   .4208116843D+06    .5589870 |
```

```
| (4)  X and group effects     -539.88811   .1389934538D+06     .8543341  |
|                                                                        |
|                              Hypothesis Tests                          |
|             Likelihood Ratio Test                     F Tests          |
|         Chi-squared    d.f.   Prob.          F     num.  denom.  Prob value |
| (2) vs (1)    89.862     17     .00000      6.872   17     90     .00000 |
| (3) vs (1)    88.418     10     .00000     12.295   10     97     .00000 |
| (4) vs (1)   208.055     27     .00000     17.378   27     80     .00000 |
| (4) vs (2)   118.193     10     .00000     15.899   10     80     .00000 |
| (4) vs (3)   119.638     17     .00000      9.541   17     80     .00000 |
+------------------------------------------------------------------------+

+==========================================================================+
| LIMDEP Estimation Results                      Run log line   28  Page   4 |
| Current sample contains      108 observations.                            |
+==========================================================================+


          +-----------------------------------------------+
          | Random Effects Model: v(i,t) = e(i,t) + u(i)   |
          | Estimates:  Var[e]              =   .173742D+04 |
          |             Var[u]              =   .260085D+04 |
          |             Corr[v(i,t),v(i,s)] =   .599513     |
          | Lagrange Multiplier Test vs. Model (3) =   19.91 |
          | ( 1 df, prob value =  .000008)                  |
          | (High values of LM favor FEM/REM over CR model.) |
          | Fixed vs. Random Effects (Hausman)     =   60.93 |
          | (10 df, prob value =  .000000)                  |
          | (High (low) values of H favor FEM (REM).)        |
          | Reestimated using GLS coefficients:              |
          | Estimates:  Var[e]              =   .294225D+04 |
          |             Var[u]              =   .489972D+04 |
          |             Sum of Squares          .461764D+06 |
          +-----------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 LPNR       25.05029076       9.4893915     2.640   .0083    -4.3025594
 LFNR       8.590247519       31.801912      .270   .7871     1.1380865
 KR         54.55984206       26.555830     2.055   .0399     .92592593
 LPINC      38.38610980       79.967863      .480   .6312     9.9359444
 TBG        52.71824262       23.197932     2.273   .0231     .57407407
 LDEN      -14.43073812       23.001723     -.627   .5304     8.2698875
 FI        -24.30771523       27.564659     -.882   .3779     .64814815
 MR         52.97936553       22.678144     2.336   .0195     .12037037
 PKR        45.06228561       112.38937      .401   .6885  .15667493E-01
 CR         19.06250748       6.0004928     3.177   .0015     2.6944444
 Constant  -147.9817714       750.47759     -.197   .8437
```

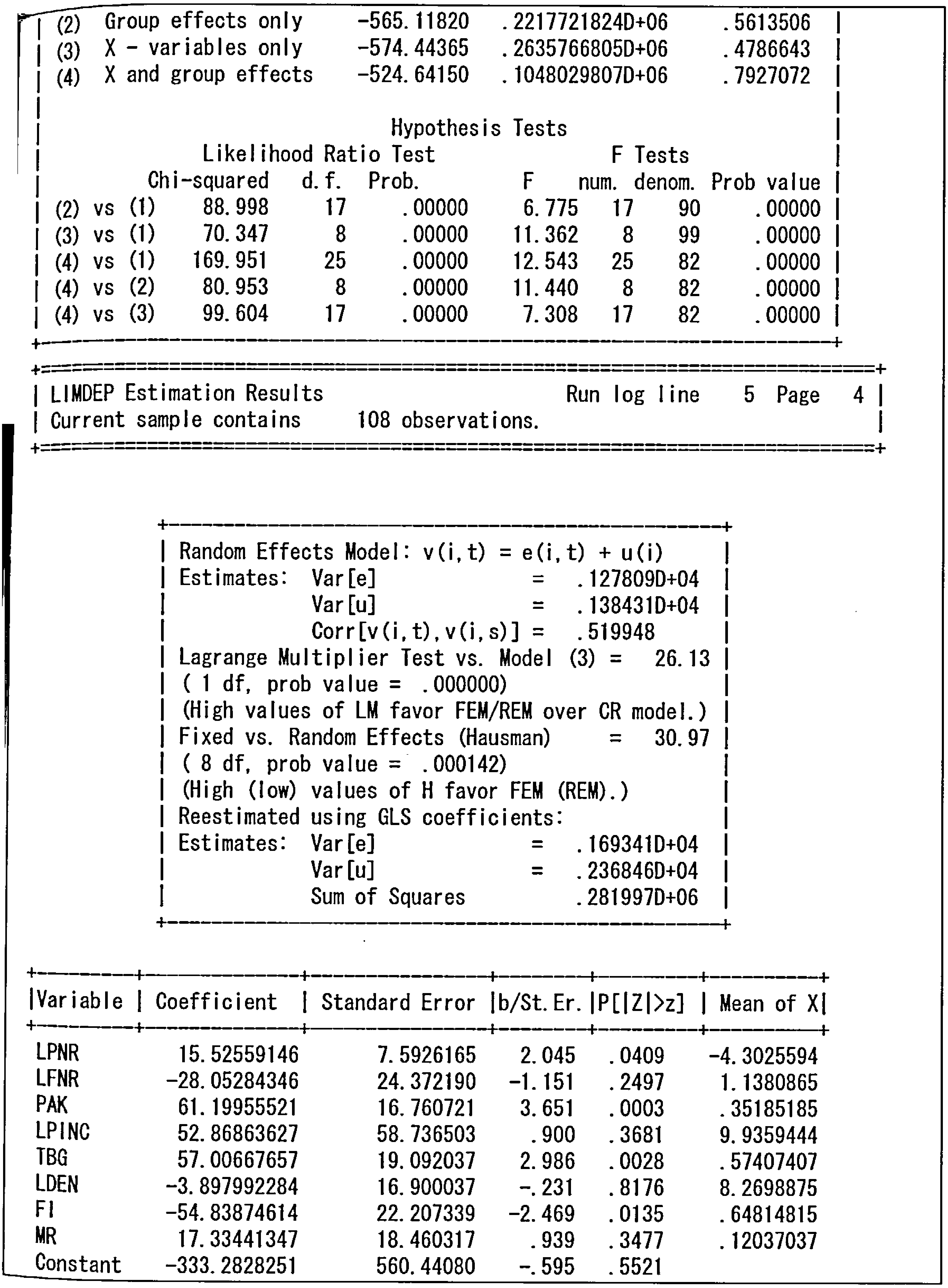
A7-4. Estimation reports for the models in Table 5.3

The estimations of each kind of recyclable are shown below. The LM Test of shows that these panel data models are better than non-panel data models at the 1% significance level. The Hausman Test shows that these FEMs are better than REMs at 1% significance except for the plastics (5% significance) and glass models (15% significance). Therefore, FEM estimates of all models are chosen.

a. Estimation report for recyclable paper model (*PAW*)

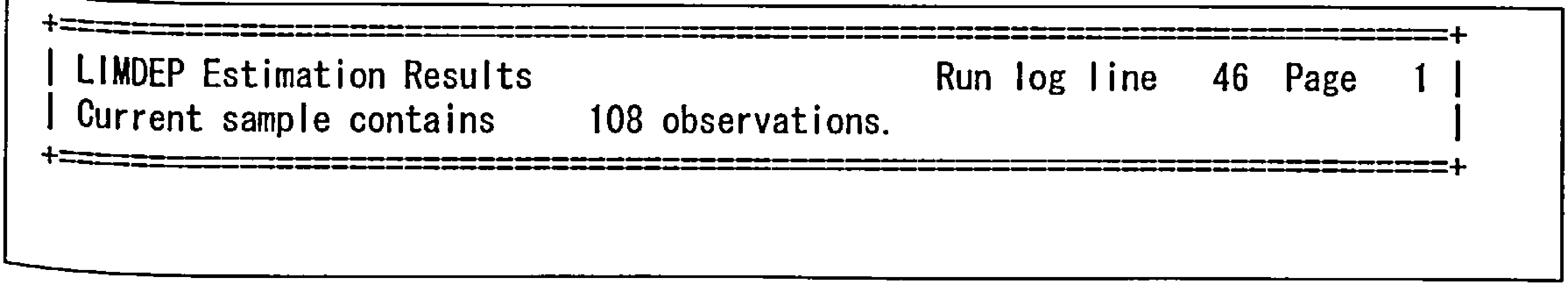
```
+=========================================================================+
| LIMDEP Estimation Results                        Run log line     5 Page    1 |
| Current sample contains    108 observations.                              |
+=========================================================================+


+-----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                     |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = PAW       Mean=   81.85685369     , S.D.=   68.73894496   |
| Model size: Observations =      108, Parameters =    9, Deg.Fr.=   99 |
| Residuals:  Sum of squares= 263576.6805     , Std.Dev.=      51.59836 |
| Fit:        R-squared=  .478664, Adjusted R-squared =          .43654 |
| Model test: F[  8,      99] =    11.36,     Prob value =       .00000 |
| Diagnostic: Log-L =   -574.4437, Restricted(b=0) Log-L =    -609.6172 |
|             LogAmemiyaPrCrt.=    7.967, Akaike Info. Crt.=     10.805 |
| Panel Data Analysis of PAW          [ONE way]                         |
|           Unconditional ANOVA (No regressors)                         |
| Source      Variation          Deg. Free.      Mean Square            |
| Between      283807.                 17.          16694.6             |
| Residual     221772.                 90.          2464.14             |
| Total        505580.                107.          4725.04             |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR       24.34129149       6.8555244      3.551   .0006    -4.3025594
 LFNR      -42.89642303       17.629723     -2.433   .0168     1.1380865
 PAK        47.38872857       15.759519      3.007   .0033     .35185185
 LPINC      71.75250407       34.878737      2.057   .0423     9.9359444
 TBG        20.97055190       18.794208      1.116   .2672     .57407407
 LDEN       5.220503490       10.585262       .493   .6230     8.2698875
 FI        -78.89164638       15.281148     -5.163   .0000     .64814815
 MR         27.85008738       19.331937      1.441   .1528     .12037037
 Constant  -501.6266312       327.87659     -1.530   .1292

+=========================================================================+
| LIMDEP Estimation Results                        Run log line     5 Page    2 |
| Current sample contains    108 observations.                              |
+=========================================================================+
```

```
+------------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                               |
| Ordinary    least squares regression    Weighting variable = none      |
| Dep. var. = PAW      Mean=   81.85685369    , S.D.=   68.73894496      |
| Model size: Observations =      108, Parameters =  26, Deg.Fr.=     82 |
| Residuals:  Sum of squares= 104802.9807     , Std.Dev.=       35.75032 |
| Fit:        R-squared=  .792707, Adjusted R-squared =          .72951 |
| Model test: F[ 25,      82] =   12.54,     Prob value =         .00000 |
| Diagnostic: Log-L =    -524.6415, Restricted(b=0) Log-L =    -609.6172 |
|             LogAmemiyaPrCrt.=    7.369, Akaike Info. Crt.=      10.197 |
| Estd. Autocorrelation of e(i,t)     .279372                            |
+------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR       10.58975566       9.1137687      1.162   .2480    -4.3025594
 LFNR     -246.1972231      146.82469      -1.677   .0967     1.1380865*
 PAK        44.80343127      21.375506      2.096   .0386     .35185185**
 LPINC     -12.39166150     133.03966       -.093   .9260     9.9359444
 TBG        62.53126309      21.439476      2.917   .0044     .57407407***
 LDEN     1095.597037       231.33751       4.736   .0000     8.2698875***
 FI        -54.10605617      40.140686     -1.348   .1807     .64814815
 MR          3.543240417     20.657648       .172   .8642     .12037037

+=============================================================================+
| LIMDEP Estimation Results                           Run log line    5 Page   3 |
| Current sample contains     108 observations.                               |
+=============================================================================+

        Estimated Fixed Effects
        Group        Coefficient        Standard Error        t-ratio
            1        -7706.96197            2262.06745       -3.40704
            2        -7325.97705            2218.14969       -3.30274
            3        -8308.82875            2383.55477       -3.48590
            4        -9294.76616            2570.24985       -3.61629
            5        -9106.92532            2536.24591       -3.59071
            6        -8087.32784            2319.57937       -3.48655
            7        -9844.99008            2643.94216       -3.72360
            8        -8267.67214            2355.66942       -3.50969
            9        -7979.19116            2291.26563       -3.48244
           10        -8621.08036            2408.50206       -3.57944
           11        -7413.05828            2194.66612       -3.37776
           12        -9478.55204            2518.92583       -3.76293
           13        -9433.75093            2620.59839       -3.59985
           14        -8296.86313            2417.56006       -3.43192
           15        -8445.10449            2429.61208       -3.47591
           16        -9375.38267            2602.29825       -3.60273
           17        -8016.19643            2357.27921       -3.40061
           18        -8838.82098            2504.71601       -3.52887

+-------------------------------------------------------------------------+
|                Test Statistics for the Classical Model                 |
|                                                                         |
|        Model               Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only      -609.61715    .5055795534D+06    .0000000 |
```



```
| (2)  Group effects only      -565.11820   .2217721824D+06       .5613506 |
| (3)  X - variables only      -574.44365   .2635766805D+06       .4786643 |
| (4)  X and group effects     -524.64150   .1048029807D+06       .7927072 |
|                                                                          |
|                            Hypothesis Tests                              |
|                Likelihood Ratio Test                F Tests              |
|            Chi-squared  d.f.  Prob.           F    num.  denom. Prob value |
| (2) vs (1)     88.998    17     .00000      6.775   17     90     .00000 |
| (3) vs (1)     70.347     8     .00000     11.362    8     99     .00000 |
| (4) vs (1)    169.951    25     .00000     12.543   25     82     .00000 |
| (4) vs (2)     80.953     8     .00000     11.440    8     82     .00000 |
| (4) vs (3)     99.604    17     .00000      7.308   17     82     .00000 |
+--------------------------------------------------------------------------+

+=============================================================================+
| LIMDEP Estimation Results                        Run log line     5  Page   4 |
| Current sample contains      108 observations.                              |
+=============================================================================+


             +----------------------------------------------------+
             | Random Effects Model: v(i,t) = e(i,t) + u(i)       |
             | Estimates:  Var[e]              =   .127809D+04    |
             |             Var[u]              =   .138431D+04    |
             |             Corr[v(i,t),v(i,s)] =   .519948        |
             | Lagrange Multiplier Test vs. Model (3) =   26.13   |
             | ( 1 df, prob value =  .000000)                     |
             | (High values of LM favor FEM/REM over CR model.)   |
             | Fixed vs. Random Effects (Hausman)     =   30.97   |
             | ( 8 df, prob value =  .000142)                     |
             | (High (low) values of H favor FEM (REM).)          |
             | Reestimated using GLS coefficients:                |
             | Estimates:  Var[e]              =   .169341D+04    |
             |             Var[u]              =   .236846D+04    |
             |             Sum of Squares          .281997D+06    |
             +----------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 LPNR        15.52559146      7.5926165      2.045   .0409   -4.3025594
 LFNR       -28.05284346     24.372190      -1.151   .2497    1.1380865
 PAK         61.19955521     16.760721       3.651   .0003    .35185185
 LPINC       52.86863627     58.736503        .900   .3681    9.9359444
 TBG         57.00667657     19.092037       2.986   .0028    .57407407
 LDEN       -3.897992284     16.900037       -.231   .8176    8.2698875
 FI         -54.83874614     22.207339      -2.469   .0135    .64814815
 MR          17.33441347     18.460317        .939   .3477    .12037037
 Constant   -333.2828251    560.44080       -.595   .5521
```

b. Estimation report for recyclable metal model (*MEW*)



```
+=============================================================================+
| LIMDEP Estimation Results                        Run log line    46  Page   1 |
| Current sample contains      108 observations.                              |
+=============================================================================+
```

```
+----------------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                          |
| Ordinary    least squares regression    Weighting variable = none          |
| Dep. var. = MEW      Mean=   22.14363827    , S.D.=   13.64356089          |
| Model size: Observations =      108, Parameters =  10, Deg.Fr.=      98    |
| Residuals:  Sum of squares= 10291.81120     , Std.Dev.=         10.24785   |
| Fit:        R-squared=  .483283, Adjusted R-squared =              .43583  |
| Model test: F[  9,      98] =   10.18,      Prob value =           .00000  |
| Diagnostic: Log-L =   -399.3219, Restricted(b=0) Log-L =     -434.9759    |
|             LogAmemiyaPrCrt.=    4.743, Akaike Info. Crt.=        7.580    |
| Panel Data Analysis of MEW          [ONE way]                              |
|           Unconditional ANOVA (No regressors)                              |
| Source      Variation        Deg. Free.      Mean Square                   |
| Between       10163.3               17.          597.841                    |
| Residual      9754.41               90.          108.382                    |
| Total         19917.7              107.          186.147                    |
+----------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          272.1391809       45.210457     6.019   .0000  .24073777E-01
 FNR         -.3594738282       .99731652     -.360   .7193     3.5740741
 MEK          19.50740306       4.7347821     4.120   .0001     .92592593
 PPPINC  -.6448150432E-03  .34898457E-03    -1.848   .0677     20946.240
 TBG         -6.017402933       3.7641093    -1.599   .1131     .57407407
 LDEN        -2.960024786       1.9496170    -1.518   .1322     8.2698875
 FI          -3.514502825       2.7438759    -1.281   .2033     .64814815
 MR           2.574462234       4.2121130      .611   .5425     .12037037
 PKRME       -36.08168219       20.756974    -1.738   .0853  .13100068E-01
 Constant     42.69525548       14.393890     2.966   .0038
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=====================================================================+
| LIMDEP Estimation Results                    Run log line   46   Page    2 |
| Current sample contains     108 observations.                       |
+=====================================================================+


+----------------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                                   |
| Ordinary    least squares regression    Weighting variable = none          |
| Dep. var. = MEW      Mean=   22.14363827    , S.D.=   13.64356089          |
| Model size: Observations =      108, Parameters =  27, Deg.Fr.=      81    |
| Residuals:  Sum of squares= 4205.241132     , Std.Dev.=          7.20531   |
| Fit:        R-squared=  .788869, Adjusted R-squared =              .72110  |
| Model test: F[ 26,      81] =   11.64,      Prob value =           .00000  |
| Diagnostic: Log-L =   -350.9910, Restricted(b=0) Log-L =     -434.9759    |
|             LogAmemiyaPrCrt.=    4.173, Akaike Info. Crt.=        7.000    |
| Estd. Autocorrelation of e(i,t)     -.051514                               |
+----------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          171.6813704       50.711793     3.385   .0010  .24073777E-01***+
 FNR         -16.55293666       4.9279795    -3.359   .0011     3.5740741***-
 MEK          6.218146282       5.2919617     1.175   .2428     .92592593
```

```
PPPINC    .4654564535E-02  .13145361E-02    3.541   .0006     20946.240***+
TBG          -5.055488247      3.8162869   -1.325   .1883      .57407407
LDEN          114.5341575      46.979018    2.438   .0166     8.2698875**+
FI           -.1620124427      8.4164769    -.019   .9847      .64814815
MR            12.46093348      4.3691898    2.852   .0053      .12037037***+
PKRME        -25.54755019      21.328551   -1.198   .2339   .13100068E-01
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=============================================================================+
| LIMDEP Estimation Results                         Run log line   46  Page   3 |
| Current sample contains     108 observations.                                |
+=============================================================================+

          Estimated Fixed Effects
          Group          Coefficient          Standard Error        t-ratio
              1           -892.60402               348.79238       -2.55913
              2           -837.83893               336.72473       -2.48820
              3           -921.70977               380.08172       -2.42503
              4          -1059.08323               422.79914       -2.50493
              5          -1088.46939               413.77333       -2.63059
              6           -941.11802               363.43011       -2.58954
              7          -1139.50030               438.64680       -2.59776
              8           -950.28752               372.24204       -2.55288
              9           -921.10803               357.91779       -2.57352
             10           -978.33972               386.44671       -2.53163
             11           -832.21612               335.97731       -2.47700
             12          -1048.68349               419.09659       -2.50225
             13          -1083.50205               431.94185       -2.50844
             14           -932.91662               385.40079       -2.42064
             15           -940.52491               391.91370       -2.39983
             16          -1042.98114               430.99943       -2.41991
             17           -870.30967               374.40270       -2.32453
             18          -1004.43439               407.51344       -2.46479

+-------------------------------------------------------------------------+
|                Test Statistics for the Classical Model                  |
|                                                                         |
|         Model                Log-Likelihood    Sum of Squares   R-squared |
| (1)  Constant term only        -434.97594    .1991770266D+05     .0000000 |
| (2)  Group effects only        -396.42591    .9754409147D+04     .5102643 |
| (3)  X - variables only        -399.32188    .1029181120D+05     .4832832 |
| (4)  X and group effects       -350.99097    .4205241132D+04     .7888692 |
|                                                                         |
|                                 Hypothesis Tests                        |
|                  Likelihood Ratio Test             F Tests              |
|             Chi-squared   d.f.  Prob.         F    num.  denom.  Prob value |
| (2) vs (1)      77.100    17     .00000     5.516   17     90      .00000 |
| (3) vs (1)      71.308     9     .00000    10.184    9     98      .00000 |
| (4) vs (1)     167.970    26     .00000    11.640   26     81      .00000 |
| (4) vs (2)      90.870     9     .00000    11.876    9     81      .00000 |
| (4) vs (3)      96.662    17     .00000     6.896   17     81      .00000 |
+-------------------------------------------------------------------------+
+=============================================================================+
| LIMDEP Estimation Results                         Run log line   46  Page   4 |
| Current sample contains     108 observations.                                |
+=============================================================================+
```

```
+--------------------------------------------------------+
| Random Effects Model: v(i,t) = e(i,t) + u(i)           |
| Estimates:  Var[e]              =   .519166D+02        |
|             Var[u]              =   .531019D+02        |
|             Corr[v(i,t),v(i,s)] =   .505644            |
| Lagrange Multiplier Test vs. Model (3) =    20.10      |
| ( 1 df, prob value =  .000007)                         |
| (High values of LM favor FEM/REM over CR model.)       |
| Fixed vs. Random Effects (Hausman)     =    33.82      |
| ( 9 df, prob value =  .000096)                         |
| (High (low) values of H favor FEM (REM).)              |
| Reestimated using GLS coefficients:                    |
| Estimates:  Var[e]              =   .698143D+02        |
|             Var[u]              =   .114568D+03        |
|             Sum of Squares          .117127D+05        |
+--------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR         252.9795604        43.815639     5.774   .0000  .24073777E-01
 FNR        -1.725286298        1.2500634    -1.380   .1675   3.5740741
 MEK         16.97655867        4.0104176     4.233   .0000   .92592593
 PPPINC    .3241337714E-03  .58374489E-03      .555   .5787   20946.240
 TBG        -5.258099134        3.4435767    -1.527   .1268   .57407407
 LDEN       -5.411955888        3.3505406    -1.615   .1063   8.2698875
 FI         -.1380242952        4.1694705     -.033   .9736   .64814815
 MR          7.806267256        3.8569873     2.024   .0430   .12037037
 PKRME      -29.97565473        19.032326    -1.575   .1153  .13100068E-01
 Constant    47.02865096        25.133918     1.871   .0613
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

c. Estimation report for recyclable glass model (*GLW*)

```
+=====================================================================+
| LIMDEP Estimation Results                  Run log line   50  Page  1 |
| Current sample contains      108 observations.                     |
+=====================================================================+



+-----------------------------------------------------------------+
| OLS Without Group Dummy Variables                               |
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = GLW      Mean=   11.34223604    , S.D.=   11.02621364 |
| Model size: Observations =       108, Parameters =  10, Deg.Fr.=     98 |
| Residuals:  Sum of squares= 7084.472219    , Std.Dev.=        8.50238 |
| Fit:        R-squared=  .455408, Adjusted R-squared =          .40539 |
| Model test: F[  9,     98] =    9.11,     Prob value =         .00000 |
| Diagnostic: Log-L =    -379.1560, Restricted(b=0) Log-L =   -411.9728 |
|             LogAmemiyaPrCrt.=     4.369, Akaike Info. Crt.=      7.207 |
| Panel Data Analysis of GLW          [ONE way]                   |
|             Unconditional ANOVA (No regressors)                 |
| Source       Variation          Deg. Free.      Mean Square     |
| Between        12021.7                 17.          707.160     |
| Residual       987.067                 90.          10.9674     |
| Total          13008.8                107.          121.577     |
+-----------------------------------------------------------------+
```

```
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR         159.2442937       37.509972     4.245   .0000  .24073777E-01
 FNR        -2.814843185       .82744828    -3.402   .0010     3.5740741
 GLK         4.024436389       3.9283289     1.024   .3081     .92592593
 PPPINC  -.1287008597E-03  .28954367E-03     -.444   .6577     20946.240
 TBG        -5.981648518       3.1229862    -1.915   .0584     .57407407
 LDEN     .8989081964E-01      1.6175479      .056   .9558     8.2698875
 FI         -8.882147601       2.2765244    -3.902   .0002     .64814815
 MR          1.177905367       3.4946836      .337   .7368     .12037037
 PKRGL      -20.73179890       17.221536    -1.204   .2316  .13100068E-01
 Constant    25.11582450       11.942247     2.103   .0380
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
| LIMDEP Estimation Results                  Run log line   50  Page   2 |
| Current sample contains     108 observations.                         |
+=======================================================================+


+-----------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                              |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = GLW      Mean=   11.34223604    , S.D.=   11.02621364     |
| Model size: Observations =     108, Parameters =  27, Deg.Fr.=     81 |
| Residuals:  Sum of squares= 765.2230484    , Std.Dev.=         3.07363 |
| Fit:        R-squared=  .941176, Adjusted R-squared =           .92229 |
| Model test: F[ 26,      81] =   49.85,     Prob value =         .00000 |
| Diagnostic: Log-L =    -258.9793, Restricted(b=0) Log-L =    -411.9728 |
|             LogAmemiyaPrCrt.=    2.469, Akaike Info. Crt.=       5.296 |
| Estd. Autocorrelation of e(i,t)     .102251                           |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR         60.63697515       21.632541     2.803   .0061  .24073777E-01***
 FNR        -.8248489082       2.1021682     -.392   .6956     3.5740741
 GLK         2.012190820       2.2574351      .891   .3749     .92592593
 PPPINC  -.2928133295E-03  .56075232E-03     -.522   .6027     20946.240
 TBG        -1.323206380       1.6279445     -.813   .4183     .57407407
 LDEN        47.20572446       20.040221     2.356   .0205     8.2698875**
 FI          .3939671943       3.5902848      .110   .9128     .64814815
 MR          .8634621282       1.8638007      .463   .6442     .12037037
 PKRGL      -11.28777719       9.0982929    -1.241   .2177  .13100068E-01
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
| LIMDEP Estimation Results                  Run log line   50  Page   3 |
| Current sample contains     108 observations.                         |
+=======================================================================+

        Estimated Fixed Effects
        Group       Coefficient         Standard Error       t-ratio
            1        -332.83543              148.78719      -2.23699
            2        -300.01215              143.63940      -2.08865
```

```
       3         -340.35368             162.13454       -2.09921
       4         -399.67055             180.35686       -2.21600
       5         -383.98937             176.50665       -2.17550
       6         -349.73479             155.03133       -2.25590
       7         -423.24099             187.11713       -2.26190
       8         -365.71859             158.79031       -2.30315
       9         -344.84787             152.67989       -2.25863
      10         -377.31051             164.84971       -2.28882
      11         -313.22867             143.32057       -2.18551
      12         -408.50653             178.77743       -2.28500
      13         -426.04896             184.25694       -2.31225
      14         -373.51504             164.40354       -2.27194
      15         -381.79036             167.18181       -2.28368
      16         -422.58660             183.85492       -2.29848
      17         -365.66779             159.71200       -2.28954
      18         -400.20958             173.83631       -2.30222

+--------------------------------------------------------------------+
|              Test Statistics for the Classical Model               |
|                                                                    |
|       Model              Log-Likelihood   Sum of Squares  R-squared |
| (1)  Constant term only     -411.97279   .1300878043D+05   .0000000 |
| (2)  Group effects only     -272.72611   .9870667064D+03   .9241230 |
| (3)  X - variables only     -379.15595   .7084472219D+04   .4554084 |
| (4)  X and group effects    -258.97931   .7652230484D+03   .9411764 |
|                                                                    |
|                          Hypothesis Tests                          |
|             Likelihood Ratio Test              F Tests             |
|         Chi-squared  d.f.  Prob.         F    num.  denom. Prob value |
| (2) vs (1)  278.493   17    .00000   64.478   17     90     .00000 |
| (3) vs (1)   65.634    9    .00000    9.106    9     98     .00000 |
| (4) vs (1)  305.987   26    .00000   49.846   26     81     .00000 |
| (4) vs (2)   27.494    9    .00116    2.609    9     81     .01067 |
| (4) vs (3)  240.353   17    .00000   39.347   17     81     .00000 |
+--------------------------------------------------------------------+
+=======================================================================+
| LIMDEP Estimation Results                  Run log line   50  Page   4 |
| Current sample contains     108 observations.                         |
+=======================================================================+


          +--------------------------------------------------+
          | Random Effects Model: v(i,t) = e(i,t) + u(i)     |
          | Estimates:  Var[e]            =  .944720D+01     |
          |             Var[u]            =  .628433D+02     |
          |             Corr[v(i,t),v(i,s)] =  .869316       |
          | Lagrange Multiplier Test vs. Model (3) =  169.70 |
          | ( 1 df, prob value =  .000000)                   |
          | (High values of LM favor FEM/REM over CR model.) |
          | Fixed vs. Random Effects (Hausman)     =   13.82 |
          | ( 9 df, prob value =  .129004)                   |
          | (High (low) values of H favor FEM (REM).)        |
          | Reestimated using GLS coefficients:              |
          | Estimates:  Var[e]            =  .103514D+02     |
          |             Var[u]            =  .154240D+03     |
          |             Sum of Squares       .832480D+04     |
          +--------------------------------------------------+
```

```
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          62.71013762       20.506554     3.058   .0022  .24073777E-01
 FNR         -1.943074284       .97996289    -1.983   .0474    3.5740741
 GLK          4.495509841       1.9682188     2.284   .0224    .92592593
 PPPINC   -.2748814103E-03  .42461652E-03     -.647   .5174    20946.240
 TBG         -.7244950943       1.5737157     -.460   .6452    .57407407
 LDEN        -1.160888983       3.0896141     -.376   .7071    8.2698875
 FI          -1.893551587       2.8107010     -.674   .5005    .64814815
 MR           .7727909235       1.7886589      .432   .6657    .12037037
 PKRGL       -8.224709167       8.7477404     -.940   .3471  .13100068E-01
 Constant     29.63084054       24.064651     1.231   .2182
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

d. Estimation report for recyclable PET bottles model (*PTW*)

```
+=======================================================================+
| LIMDEP Estimation Results                     Run log line    54  Page    1 |
| Current sample contains     108 observations.                              |
+=======================================================================+



+-----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                     |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = PTW        Mean=   4.025185333     , S.D.=    3.066788096 |
| Model size: Observations =      108, Parameters =  10, Deg.Fr.=     98 |
| Residuals:  Sum of squares= 603.6105950     , Std.Dev.=        2.48179 |
| Fit:        R-squared=  .400201, Adjusted R-squared =           .34512 |
| Model test: F[  9,      98] =    7.27,     Prob value =         .00000 |
| Diagnostic: Log-L =    -246.1685, Restricted(b=0) Log-L =    -273.7712 |
|             LogAmemiyaPrCrt.=     1.907, Akaike Info. Crt.=      4.744 |
| Panel Data Analysis of PTW        [ONE way]                           |
|           Unconditional ANOVA (No regressors)                         |
| Source      Variation         Deg. Free.      Mean Square             |
| Between       326.878               17.          19.2281              |
| Residual      679.477               90.          7.54974              |
| Total         1006.36              107.          9.40519              |
+-----------------------------------------------------------------------+


+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          32.98893604       10.890632     3.029   .0031  .24073777E-01
 FNR          .2730949855       .22534963     1.212   .2285    3.5740741
 PTK          2.284307999       .86708664     2.634   .0098    .86111111
 PPPINC    .1335254862E-03  .91489754E-04     1.459   .1476    20946.240
 TBG       .3701574581E-01      .92183989      .040   .9681    .57407407
 LDEN        -.2482271948       .49309966     -.503   .6158    8.2698875
 FI          -.4465801283       .68054471     -.656   .5132    .64814815
 MR           2.925004993       .99247045     2.947   .0040    .12037037
 PKRPT        2.446974563       5.1180184      .478   .6336  .14602584E-01
 Constant    -.5757492982       3.4946253     -.165   .8695
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
```

```
| LIMDEP Estimation Results                        Run log line   54  Page   2 |
| Current sample contains     108 observations.                               |
+===========================================================================+



+-----------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                              |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = PTW       Mean=   4.025185333    , S.D.=    3.066788096    |
| Model size: Observations =       108, Parameters =  27, Deg.Fr.=     81 |
| Residuals:  Sum of squares= 201.5344294     , Std.Dev.=         1.57736 |
| Fit:        R-squared=  .799738, Adjusted R-squared =             .73546 |
| Model test: F[ 26,       81] =   12.44,     Prob value =          .00000 |
| Diagnostic: Log-L =   -186.9321, Restricted(b=0) Log-L =     -273.7712 |
|             LogAmemiyaPrCrt.=    1.135, Akaike Info. Crt.=       3.962 |
| Estd. Autocorrelation of e(i,t)      .090527                          |
+-----------------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR          40.80697446        11.091224     3.679    .0004  .24073777E-01***
 FNR          .4437543901        1.0809186      .411    .6823     3.5740741
 PTK          1.845354251        .83176602     2.219    .0288     .86111111**
 PPPINC    .5262834595E-03  .27041531E-03     1.946    .0545     20946.240*
 TBG          1.341993187        .84634823     1.586    .1160     .57407407
 LDEN         58.04680875        10.442814     5.559    .0000     8.2698875***
 FI           .5718895630        1.7860030      .320    .7495     .64814815
 MR           3.367330511        .89266242     3.772    .0003     .12037037***
 PKRPT        .4392239396        4.6734996      .094    .9253  .14602584E-01
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+===========================================================================+
| LIMDEP Estimation Results                        Run log line   54  Page   3 |
| Current sample contains     108 observations.                               |
+===========================================================================+


       Estimated Fixed Effects
       Group        Coefficient           Standard Error        t-ratio
          1           -438.14012               77.42162        -5.65914
          2           -426.64586               74.76708        -5.70633
          3           -481.00694               84.43145        -5.69701
          4           -532.94834               93.86732        -5.67768
          5           -524.61642               91.83369        -5.71268
          6           -461.76503               80.62250        -5.72750
          7           -557.56784               97.34012        -5.72804
          8           -472.07633               82.63883        -5.71252
          9           -457.12412               79.47472        -5.75182
         10           -492.54129               85.81969        -5.73926
         11           -421.59670               74.58734        -5.65239
         12           -530.56621               93.30043        -5.68664
         13           -551.32464               95.88444        -5.74989
         14           -486.50266               85.51623        -5.68901
         15           -494.57103               87.00646        -5.68430
         16           -543.69763               95.68016        -5.68245
         17           -477.77556               83.13690        -5.74685
         18           -519.02083               90.44176        -5.73873
```

```
+---------------------------------------------------------------------------+
|                Test Statistics for the Classical Model                     |
|                                                                            |
|      Model                  Log-Likelihood    Sum of Squares    R-squared  |
| (1)  Constant term only       -273.77116    .1006355247D+04      .0000000  |
| (2)  Group effects only       -252.56174    .6794770046D+03      .3248140  |
| (3)  X - variables only       -246.16846    .6036105950D+03      .4002013  |
| (4)  X and group effects      -186.93213    .2015344294D+03      .7997383  |
|                                                                            |
|                              Hypothesis Tests                              |
|               Likelihood Ratio Test                F Tests                 |
|           Chi-squared   d.f.  Prob.          F     num.  denom.  Prob value |
| (2) vs (1)     42.419     17    .00058      2.547   17     90       .00234 |
| (3) vs (1)     55.205      9    .00000      7.265    9     98       .00000 |
| (4) vs (1)    173.678     26    .00000     12.441   26     81       .00000 |
| (4) vs (2)    131.259      9    .00000     21.344    9     81       .00000 |
| (4) vs (3)    118.473     17    .00000      9.506   17     81       .00000 |
+---------------------------------------------------------------------------+

+===============================================================================+
| LIMDEP Estimation Results                         Run log line   54   Page   4 |
| Current sample contains      108 observations.                                 |
+===============================================================================+


             +---------------------------------------------------+
             | Random Effects Model: v(i,t) = e(i,t) + u(i)      |
             | Estimates:  Var[e]              =  .248808D+01    |
             |             Var[u]              =  .367121D+01    |
             |             Corr[v(i,t),v(i,s)] =  .596045        |
             | Lagrange Multiplier Test vs. Model (3) =   21.98  |
             | ( 1 df, prob value =  .000003)                    |
             | (High values of LM favor FEM/REM over CR model.)  |
             | Fixed vs. Random Effects (Hausman)     =   47.09  |
             | ( 9 df, prob value =  .000000)                    |
             | (High (low) values of H favor FEM (REM).)         |
             | Reestimated using GLS coefficients:               |
             | Estimates:  Var[e]              =  .358869D+01    |
             |             Var[u]              =  .813801D+01    |
             |             Sum of Squares         .710017D+03    |
             +---------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          38.54512094      9.7991900      3.934   .0001  .24073777E-01
 FNR          .3741571332      .29366332      1.274   .2026     3.5740741
 PTK          3.526693635      .69929611      5.043   .0000     .86111111
 PPPINC    .1724257692E-03  .14366987E-03     1.200   .2301     20946.240
 TBG          1.365080416      .78176355      1.746   .0808     .57407407
 LDEN        -.5369665744      .85860918      -.625   .5317     8.2698875
 FI           .9650942792      .99117582       .974   .3302     .64814815
 MR           3.651242246      .83047387      4.397   .0000     .12037037
 PKRPT        4.459217035      4.2267049      1.055   .2914  .14602584E-01
 Constant    -2.361698838      6.3847968      -.370   .7115
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

e. Estimation report for recyclable plastics model (*PLW*)

```
+=============================================================================+
| LIMDEP Estimation Results                      Run log line    25  Page    1 |
| Current sample contains     108 observations.                               |
+=============================================================================+



+--------------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                        |
| Ordinary    least squares regression    Weighting variable = none        |
| Dep. var. = PLW      Mean=   5.772585243     , S.D.=   8.947573514       |
| Model size: Observations =     108, Parameters =   9, Deg.Fr.=       99  |
| Residuals:  Sum of squares= 3472.472262     , Std.Dev.=          5.92246 |
| Fit:        R-squared=  .594637, Adjusted R-squared =            .56188 |
| Model test: F[  8,      99] =    18.15,     Prob value =           .00000 |
| Diagnostic: Log-L =   -340.6519, Restricted(b=0) Log-L =      -389.4123  |
|             LogAmemiyaPrCrt.=    3.638, Akaike Info. Crt.=        6.475  |
| Panel Data Analysis of PLW         [ONE way]                             |
|           Unconditional ANOVA (No regressors)                            |
| Source      Variation        Deg. Free.      Mean Square                 |
| Between       3697.11              17.          217.477                  |
| Residual      4869.22              90.          54.1024                  |
| Total         8566.32             107.          80.0591                  |
+--------------------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 LPNR        .9747766953       .79327050     1.229   .2221    -4.3025594
 LFNR      -2.403028297       2.0678968    -1.162   .2480     1.1380865
 PLK        14.78872313       1.6251531     9.100   .0000     .39814815
 LPINC     -1.827728177       4.4716469     -.409   .6836     9.9359444
 TBG       -1.104056570       2.2238416     -.496   .6207     .57407407
 LDEN      -1.318615590       1.2160024    -1.084   .2808     8.2698875
 FI        -1.268277397       1.6796895     -.755   .4520     .64814815
 MR         2.156564601       2.2624618      .953   .3428     .12037037
 Constant   37.07463471       42.228606      .878   .3821

+=============================================================================+
| LIMDEP Estimation Results                      Run log line    25  Page    2 |
| Current sample contains     108 observations.                               |
+=============================================================================+



+--------------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                                 |
| Ordinary    least squares regression    Weighting variable = none        |
| Dep. var. = PLW      Mean=   5.772585243     , S.D.=   8.947573514       |
| Model size: Observations =     108, Parameters =  26, Deg.Fr.=       82  |
| Residuals:  Sum of squares= 1819.170268     , Std.Dev.=          4.71010 |
| Fit:        R-squared=  .787637, Adjusted R-squared =            .72289 |
| Model test: F[ 25,      82] =    12.17,     Prob value =           .00000 |
| Diagnostic: Log-L =   -305.7416, Restricted(b=0) Log-L =      -389.4123  |
|             LogAmemiyaPrCrt.=    3.315, Akaike Info. Crt.=        6.143  |
| Estd. Autocorrelation of e(i,t)      .181151                             |
+--------------------------------------------------------------------------+
```

```
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR        .7012539094      1.2006656       .584   .5605    -4.3025594
 LFNR      -11.18274689      19.286416      -.580   .5633     1.1380865
 PLK        13.37900052       1.7396295      7.691   .0000      .39814815***
 LPINC     -10.42644322      16.962591      -.615   .5402     9.9359444
 TBG         1.352138767      2.8702844       .471   .6386      .57407407
 LDEN      111.4235491       30.024352      3.711   .0003     8.2698875***
 FI         -4.706481064      5.1254247      -.918   .3607      .64814815
 MR          1.595757950      2.5904316       .616   .5393      .12037037


+=============================================================================+
| LIMDEP Estimation Results                       Run log line   25  Page   3 |
| Current sample contains     108 observations.                             |
+=============================================================================+


        Estimated Fixed Effects
        Group        Coefficient         Standard Error       t-ratio
            1         -708.19623             285.75405       -2.47834
            2         -671.28388             279.94789       -2.39789
            3         -784.63485             301.51013       -2.60235
            4         -880.62858             325.63252       -2.70436
            5         -850.01187             321.09436       -2.64723
            6         -743.66649             292.89518       -2.53902
            7         -924.40848             334.52944       -2.76331
            8         -766.88541             298.08322       -2.57272
            9         -734.15668             289.19960       -2.53858
           10         -802.36646             304.35574       -2.63628
           11         -683.32195             277.29233       -2.46427
           12         -883.95561             319.79885       -2.76410
           13         -898.50472             331.69918       -2.70879
           14         -779.62071             305.57718       -2.55131
           15         -798.04318             306.86417       -2.60064
           16         -888.04952             329.29834       -2.69679
           17         -755.00848             297.67354       -2.53636
           18         -839.90540             316.65387       -2.65244


+-------------------------------------------------------------------------+
|                 Test Statistics for the Classical Model                 |
|                                                                         |
|        Model                Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only       -389.41233     .8566320681D+04    .0000000 |
| (2)  Group effects only       -358.90743     .4869215236D+04    .4315862 |
| (3)  X - variables only       -340.65187     .3472472262D+04    .5946367 |
| (4)  X and group effects      -305.74161     .1819170268D+04    .7876369 |
|                                                                         |
|                              Hypothesis Tests                           |
|                 Likelihood Ratio Test               F Tests              |
|             Chi-squared   d.f.   Prob.        F    num.  denom.  Prob value |
| (2) vs (1)     61.010     17     .00000     4.020   17     90     .00001 |
| (3) vs (1)     97.521      8     .00000    18.153    8     99     .00000 |
| (4) vs (1)    167.341     25     .00000    12.165   25     82     .00000 |
| (4) vs (2)    106.332      8     .00000    17.185    8     82     .00000 |
| (4) vs (3)     69.821     17     .00000     4.384   17     82     .00000 |
+-------------------------------------------------------------------------+
+=============================================================================+
| LIMDEP Estimation Results                       Run log line   25  Page   4 |
```

```
| Current sample contains      108 observations.                          |
+=========================================================================+


          +------------------------------------------------------+
          | Random Effects Model: v(i,t) = e(i,t) + u(i)         |
          | Estimates:  Var[e]              =   .221850D+02      |
          |             Var[u]              =   .128905D+02      |
          |             Corr[v(i,t),v(i,s)] =   .367507          |
          | Lagrange Multiplier Test vs. Model (3) =    15.85    |
          | ( 1 df, prob value =  .000069)                       |
          | (High values of LM favor FEM/REM over CR model.)     |
          | Fixed vs. Random Effects (Hausman)      =    16.20   |
          | ( 8 df, prob value =  .039567)                       |
          | (High (low) values of H favor FEM (REM).)            |
          | Reestimated using GLS coefficients:                  |
          | Estimates:  Var[e]              =   .262487D+02      |
          |             Var[u]              =   .209032D+02      |
          |             Sum of Squares          .351740D+04      |
          +------------------------------------------------------+

+--------+--------------+----------------+---------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+---------+---------+----------+
 LPNR        .9164403972       .92607107      .990   .3224    -4.3025594
 LFNR      -1.612869804       2.7094416     -.595   .5517     1.1380865
 PLK        14.57869501       1.5361673     9.490   .0000     .39814815
 LPINC     -3.260258095       6.5802043     -.495   .6203     9.9359444
 TBG         .5837723513      2.4392131      .239   .8109     .57407407
 LDEN      -1.220949065       1.8216556     -.670   .5027     8.2698875
 FI         -.9424758104      2.3371257     -.403   .6868     .64814815
 MR         2.994138103       2.2803922     1.313   .1892     .12037037
 Constant   48.15291375       62.239715      .774   .4391
```

A7-5. Estimation reports for the models in Table 5.4

The estimations of non-recyclables and total waste generation are shown below. The LM Test shows that panel data models are better than the non-panel models at the 99% confidence level. The Hausman Test shows that two FEM models of non-recyclables are better than REM models at the 99% confidence level and that two FEM models of total waste are better than REM models at the 80% confidence level. Therefore, FEM estimates of all models are chosen.

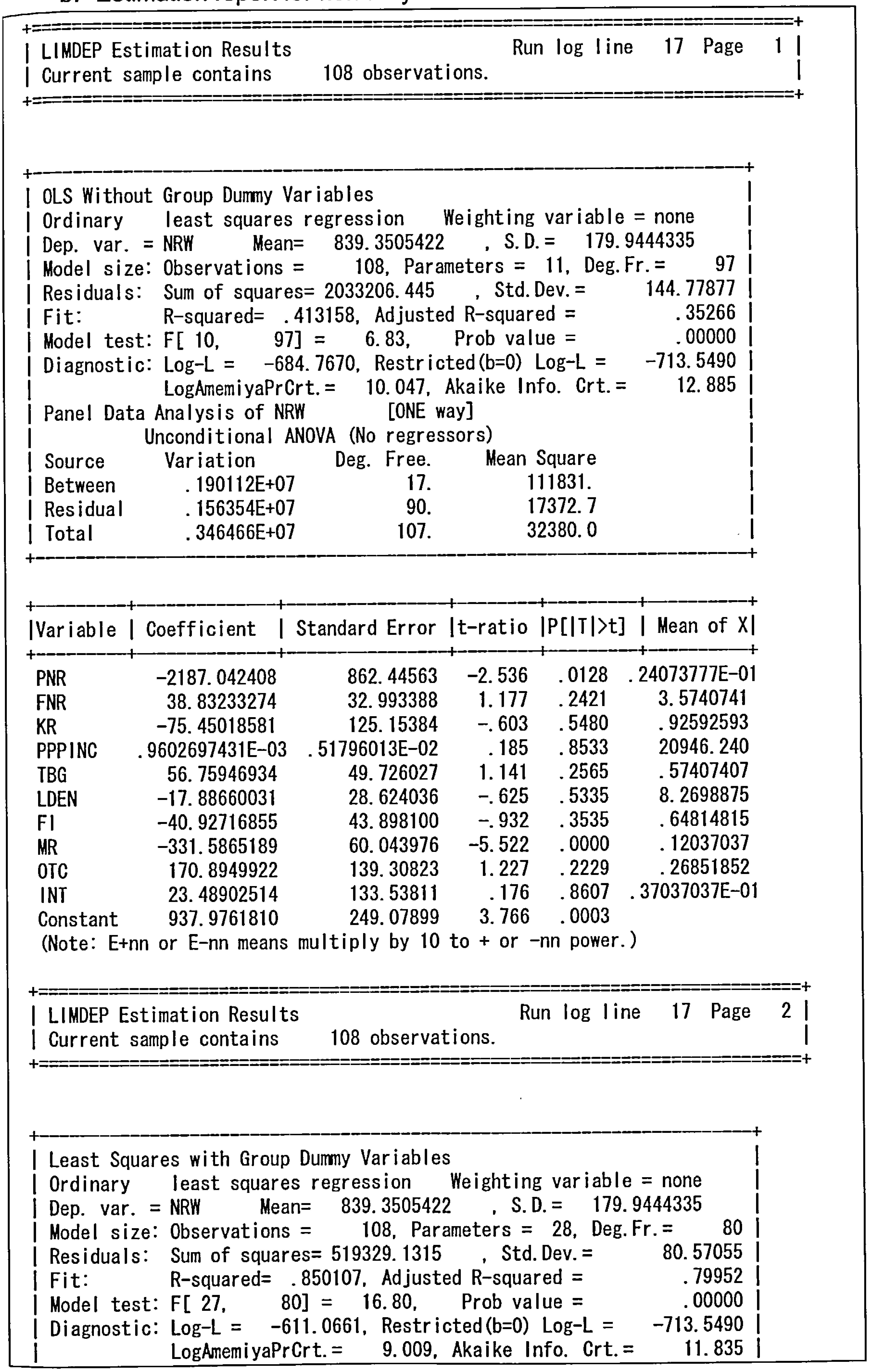
a. Estimation report for non-recyclables model without interaction term

```
+=============================================================================+
| LIMDEP Estimation Results                        Run log line   13  Page   1 |
| Current sample contains      108 observations.                              |
+=============================================================================+


+------------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                      |
| Ordinary    least squares regression    Weighting variable = none      |
| Dep. var. = NRW       Mean=   839.3505422    , S.D.=    179.9444335    |
| Model size: Observations =      108, Parameters =  10, Deg.Fr.=     98 |
| Residuals:  Sum of squares= 2033854.974    , Std.Dev.=       144.06118 |
| Fit:        R-squared= .412971, Adjusted R-squared =            .35906 |
| Model test: F[  9,     98] =    7.66,    Prob value =           .00000 |
| Diagnostic: Log-L =   -684.7842, Restricted(b=0) Log-L =     -713.5490 |
|             LogAmemiyaPrCrt.=   10.029, Akaike Info. Crt.=      12.866 |
| Panel Data Analysis of NRW          [ONE way]                          |
|           Unconditional ANOVA (No regressors)                          |
| Source      Variation        Deg. Free.      Mean Square               |
| Between       .190112E+07          17.           111831.               |
| Residual      .156354E+07          90.           17372.7               |
| Total         .346466E+07         107.           32380.0               |
+------------------------------------------------------------------------+

+---------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+--------+----------+
 PNR        -2084.477409       632.31279    -3.297   .0014  .24073777E-01
 FNR         37.16916419       31.452828     1.182   .2402     3.5740741
 KR         -82.01736480       118.86320     -.690   .4918     .92592593
 PPPINC    .1169834782E-02  .50157326E-02     .233   .8161     20946.240
 TBG         56.08538781       49.332405     1.137   .2584     .57407407
 LDEN       -16.63453050       27.587427     -.603   .5479     8.2698875
 FI         -43.24577345       41.664761    -1.038   .3018     .64814815
 MR         -333.0634244       59.159330    -5.630   .0000     .12037037
 OTC         180.4319130       127.68826     1.413   .1608     .26851852
 Constant    933.1646590       246.34532     3.788   .0003
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

```
+=========================================================================+
| LIMDEP Estimation Results                    Run log line   13  Page   2 |
| Current sample contains     108 observations.                            |
+=========================================================================+



+-----------------------------------------------------------------+
| Least Squares with Group Dummy Variables                        |
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = NRW      Mean=   839.3505422     , S.D.=   179.9444335   |
| Model size: Observations =      108, Parameters =  27, Deg.Fr.=     81 |
| Residuals:  Sum of squares= 538041.3795     , Std.Dev.=      81.50145 |
| Fit:        R-squared=  .844706, Adjusted R-squared =          .79486 |
| Model test: F[ 26,     81] =   16.95,     Prob value =          .00000 |
| Diagnostic: Log-L =   -612.9776, Restricted(b=0) Log-L =   -713.5490 |
|             LogAmemiyaPrCrt.=    9.024, Akaike Info. Crt.=     11.851 |
| Estd. Autocorrelation of e(i,t)     .022495                        |
+-----------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR         -2424.148086       573.72486    -4.225   .0001  .24073777E-01***
 FNR           118.2880812      56.197517     2.105   .0378      3.5740741**
 KR            106.2406882      95.152651     1.117   .2669       .92592593
 PPPINC    .4811723753E-02  .14956453E-01     .322   .7483      20946.240
 TBG          -82.61071481      43.162496    -1.914   .0585       .57407407*
 LDEN        -3078.226095       522.67362    -5.889   .0000      8.2698875***
 FI            11.40523729      98.713916      .116   .9083       .64814815
 MR          -264.9584484       49.386844    -5.365   .0000       .12037037***
 OTC          -48.34895137     106.78806      -.453   .6517       .26851852
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=========================================================================+
| LIMDEP Estimation Results                    Run log line   13  Page   3 |
| Current sample contains     108 observations.                            |
+=========================================================================+

          Estimated Fixed Effects
          Group        Coefficient         Standard Error        t-ratio
              1         23144.39209            3889.19014        5.95095
              2         22413.39481            3755.66240        5.96789
              3         25291.12047            4236.84656        5.96933
              4         27905.12730            4712.83434        5.92109
              5         27450.55593            4615.35735        5.94766
              6         24064.80357            4061.57128        5.92500
              7         29129.35390            4891.26605        5.95538
              8         25086.56844            4149.82037        6.04522
              9         24146.57437            3991.64774        6.04927
             10         25817.61900            4310.07780        5.99006
             11         22441.08446            3746.02459        5.99064
             12         28035.49761            4670.12009        6.00316
             13         28666.53735            4814.43425        5.95429
             14         25284.34765            4295.83234        5.88579
             15         25846.80324            4367.61004        5.91784
             16         28418.97760            4802.69054        5.91730
             17         24750.69373            4171.76433        5.93291
             18         26817.43695            4541.26192        5.90528
```

```
+-----------------------------------------------------------------------------+
|                   Test Statistics for the Classical Model                   |
|                                                                             |
|          Model              Log-Likelihood    Sum of Squares     R-squared |
| (1)  Constant term only       -713.54903    .3464659909D+07      .0000000 |
| (2)  Group effects only       -670.58331    .1563540868D+07      .5487174 |
| (3)  X - variables only       -684.78423    .2033854974D+07      .4129713 |
| (4)  X and group effects      -612.97758    .5380413795D+06      .8447059 |
|                                                                             |
|                                Hypothesis Tests                            |
|                Likelihood Ratio Test                  F Tests               |
|            Chi-squared   d.f.   Prob.           F    num.  denom. Prob value |
| (2) vs (1)     85.931    17      .00000      6.437   17     90      .00000 |
| (3) vs (1)     57.530     9      .00000      7.660    9     98      .00000 |
| (4) vs (1)    201.143    26      .00000     16.946   26     81      .00000 |
| (4) vs (2)    115.211     9      .00000     17.154    9     81      .00000 |
| (4) vs (3)    143.613    17      .00000     13.246   17     81      .00000 |
+-----------------------------------------------------------------------------+
+=================================================================================+
| LIMDEP Estimation Results                        Run log line    13   Page    4 |
| Current sample contains      108 observations.                                  |
+=================================================================================+


             +---------------------------------------------------+
             | Random Effects Model: v(i,t) = e(i,t) + u(i)      |
             | Estimates:  Var[e]              =   .664249D+04   |
             |             Var[u]              =   .141111D+05   |
             |             Corr[v(i,t),v(i,s)] =   .679936       |
             | Lagrange Multiplier Test vs. Model (3) =    40.14 |
             | ( 1 df, prob value =  .000000)                    |
             | (High values of LM favor FEM/REM over CR model.)  |
             | Fixed vs. Random Effects (Hausman)     =    46.46 |
             | ( 9 df, prob value =  .000000)                    |
             | (High (low) values of H favor FEM (REM).)         |
             | Reestimated using GLS coefficients:               |
             | Estimates:  Var[e]              =   .958663D+04   |
             |             Var[u]              =   .350043D+05   |
             |             Sum of Squares          .253341D+07   |
             +---------------------------------------------------+

+---------+---------------+-----------------+--------+---------+-----------+
|Variable | Coefficient   | Standard Error  |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+---------------+-----------------+--------+---------+-----------+
 PNR        -2492.856655       519.51131      -4.798   .0000  .24073777E-01
 FNR         68.29808719       26.828818       2.546   .0109    3.5740741
 KR          60.12596176       84.590239        .711   .4772    .92592593
 PPPINC    .8134026422E-02  .84600709E-02       .961   .3363    20946.240
 TBG        -84.55958904       40.406402      -2.093   .0364    .57407407
 LDEN       -27.89949947       50.939369      -.548    .5839    8.2698875
 FI         -68.45090319       61.002065      -1.122   .2618    .64814815
 MR         -307.0406355       45.475401      -6.752   .0000    .12037037
 OTC        -57.26292150       98.041784      -.584    .5592    .26851852
 Constant    805.1814061       397.44750       2.026   .0428
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

b. Estimation report for non-recyclables model with interaction term



```
+=====================================================================+
| LIMDEP Estimation Results            Run log line    17   Page    1 |
| Current sample contains      108 observations.                      |
+=====================================================================+


+---------------------------------------------------------------+
| OLS Without Group Dummy Variables                             |
| Ordinary    least squares regression    Weighting variable = none  |
| Dep. var. = NRW      Mean=    839.3505422    , S.D.=    179.9444335 |
| Model size: Observations =      108, Parameters =  11, Deg.Fr.=    97 |
| Residuals:  Sum of squares= 2033206.445    , Std.Dev.=      144.77877 |
| Fit:        R-squared=  .413158, Adjusted R-squared =          .35266 |
| Model test: F[ 10,      97] =     6.83,     Prob value =       .00000 |
| Diagnostic: Log-L =    -684.7670, Restricted(b=0) Log-L =    -713.5490 |
|             LogAmemiyaPrCrt.=    10.047, Akaike Info. Crt.=    12.885 |
| Panel Data Analysis of NRW        [ONE way]                   |
|            Unconditional ANOVA (No regressors)                |
| Source      Variation        Deg. Free.      Mean Square      |
| Between      .190112E+07           17.           111831.      |
| Residual     .156354E+07           90.           17372.7      |
| Total        .346466E+07          107.           32380.0      |
+---------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR        -2187.042408       862.44563    -2.536   .0128  .24073777E-01
 FNR         38.83233274       32.993388     1.177   .2421     3.5740741
 KR         -75.45018581       125.15384     -.603   .5480     .92592593
 PPPINC    .9602697431E-03  .51796013E-02     .185   .8533     20946.240
 TBG         56.75946934       49.726027     1.141   .2565     .57407407
 LDEN       -17.88660031       28.624036     -.625   .5335     8.2698875
 FI         -40.92716855       43.898100     -.932   .3535     .64814815
 MR         -331.5865189       60.043976    -5.522   .0000     .12037037
 OTC         170.8949922       139.30823     1.227   .2229     .26851852
 INT         23.48902514       133.53811      .176   .8607  .37037037E-01
 Constant    937.9761810       249.07899     3.766   .0003
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=====================================================================+
| LIMDEP Estimation Results            Run log line    17   Page    2 |
| Current sample contains      108 observations.                      |
+=====================================================================+


+---------------------------------------------------------------+
| Least Squares with Group Dummy Variables                      |
| Ordinary    least squares regression    Weighting variable = none  |
| Dep. var. = NRW      Mean=    839.3505422    , S.D.=    179.9444335 |
| Model size: Observations =      108, Parameters =  28, Deg.Fr.=    80 |
| Residuals:  Sum of squares= 519329.1315    , Std.Dev.=       80.57055 |
| Fit:        R-squared=  .850107, Adjusted R-squared =          .79952 |
| Model test: F[ 27,      80] =    16.80,     Prob value =       .00000 |
| Diagnostic: Log-L =    -611.0661, Restricted(b=0) Log-L =    -713.5490 |
|             LogAmemiyaPrCrt.=     9.009, Akaike Info. Crt.=    11.835 |
```

```
| Estd. Autocorrelation of e(i,t)      .040276                             |
+--------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR         -1675.410594       718.44891    -2.332   .0217  .24073777E-01**
 FNR          112.4184875       55.663104     2.020   .0462     3.5740741**
 KR           103.3813539       94.080909     1.099   .2745     .92592593
 PPPINC    .9192817710E-02  .15009110E-01      .612   .5416     20946.240
 TBG         -69.98587963       43.312590    -1.616   .1093     .57407407
 LDEN        -3162.477871       519.08120    -6.092   .0000     8.2698875***
 FI           6.702555726       97.625725      .069   .9454     .64814815
 MR          -260.3698464       48.897505    -5.325   .0000     .12037037***
 OTC         -50.52695297       105.57614     -.479   .6333     .26851852
 INT         -186.8416050       110.04922    -1.698   .0927  .37037037E-01*
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=============================================================================+
| LIMDEP Estimation Results                          Run log line   17  Page   3 |
| Current sample contains     108 observations.                               |
+=============================================================================+

        Estimated Fixed Effects
        Group        Coefficient         Standard Error        t-ratio
            1        23679.06457             3857.64434        6.13822
            2        22889.33017             3723.33351        6.14754
            3        25862.37559             4201.94692        6.15486
            4        28580.18719             4675.94074        6.11218
            5        28061.10697             4576.79140        6.13117
            6        24641.38997             4029.51733        6.11522
            7        29806.39531             4851.81454        6.14335
            8        25665.02673             4116.54573        6.23460
            9        24678.97893             3958.49621        6.23443
           10        26397.74039             4274.52747        6.17559
           11        22971.73177             3716.40422        6.18117
           12        28708.22905             4633.75122        6.19546
           13        29406.72617             4779.37051        6.15285
           14        25904.39101             4262.44018        6.07736
           15        26499.85269             4334.82314        6.11325
           16        29133.62830             4766.45756        6.11222
           17        25381.38550             4140.81154        6.12957
           18        27483.45414             4506.49863        6.09863

+----------------------------------------------------------------------------+
|                Test Statistics for the Classical Model                    |
|                                                                            |
|      Model               Log-Likelihood    Sum of Squares      R-squared  |
| (1)  Constant term only      -713.54903   .3464659909D+07       .0000000  |
| (2)  Group effects only      -670.58331   .1563540868D+07       .5487174  |
| (3)  X - variables only      -684.76701   .2033206445D+07       .4131584  |
| (4)  X and group effects     -611.06610   .5193291315D+06       .8501068  |
|                                                                            |
|                            Hypothesis Tests                               |
|              Likelihood Ratio Test                 F Tests                |
|          Chi-squared   d.f.   Prob.          F     num.  denom.  Prob value |
| (2) vs (1)   85.931    17     .00000       6.437   17     90       .00000 |
| (3) vs (1)   57.564    10     .00000       6.829   10     97       .00000 |
```

```
| (4) vs (1)    204.966     27      .00000      16.804   27     80      .00000 |
| (4) vs (2)    119.034     10      .00000      16.086   10     80      .00000 |
| (4) vs (3)    147.402     17      .00000      13.718   17     80      .00000 |
+----------------------------------------------------------------------------+
+==============================================================================+
| LIMDEP Estimation Results                      Run log line    17   Page    4 |
| Current sample contains      108 observations.                               |
+==============================================================================+


          +--------------------------------------------------+
          | Random Effects Model: v(i,t) = e(i,t) + u(i)      |
          | Estimates:  Var[e]              =   .649161D+04   |
          |             Var[u]              =   .144693D+05   |
          |             Corr[v(i,t),v(i,s)] =   .690299       |
          | Lagrange Multiplier Test vs. Model (3) =    39.71  |
          | ( 1 df, prob value =  .000000)                    |
          | (High values of LM favor FEM/REM over CR model.)  |
          | Fixed vs. Random Effects (Hausman)     =    49.01  |
          | (10 df, prob value =  .000000)                    |
          | (High (low) values of H favor FEM (REM).)         |
          | Reestimated using GLS coefficients:               |
          | Estimates:  Var[e]              =   .959070D+04   |
          |             Var[u]              =   .411734D+05   |
          |             Sum of Squares          .256367D+07   |
          +--------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR       -2067.539490       671.41951     -3.079   .0021  .24073777E-01
 FNR        68.90008820       26.690468      2.581   .0098    3.5740741
 KR         52.59978987       84.141005       .625   .5319     .92592593
 PPPINC   .1000090138E-01  .86574688E-02    1.155   .2480    20946.240
 TBG       -81.10462643       40.276808     -2.014   .0440     .57407407
 LDEN      -27.11009345       51.397571      -.527   .5979    8.2698875
 FI        -73.16413090       61.223338     -1.195   .2321     .64814815
 MR        -305.7016950       45.069500     -6.783   .0000     .12037037
 OTC       -51.41840497       97.362423      -.528   .5974     .26851852
 INT       -102.9859458       102.97256     -1.000   .3172  .37037037E-01
 Constant   757.2824180       404.31270      1.873   .0611
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

c. Estimation report for total waste model without interaction term

```
+==============================================================================+
| LIMDEP Estimation Results                      Run log line    29   Page    1 |
| Current sample contains      108 observations.                               |
+==============================================================================+


+----------------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                          |
| Ordinary    least squares regression    Weighting variable = none          |
| Dep. var. = TOW      Mean=   978.9000974    , S.D.=    162.7061772         |
| Model size: Observations =      108, Parameters =  10, Deg.Fr.=      98    |
| Residuals:  Sum of squares= 1671797.571     , Std.Dev.=       130.61072    |
```

```
| Fit:         R-squared= .409810, Adjusted R-squared =          .35561 |
| Model test: F[  9,      98] =     7.56,     Prob value =         .00000 |
| Diagnostic: Log-L =    -674.1984, Restricted(b=0) Log-L =    -702.6732 |
|             LogAmemiyaPrCrt.=     9.833, Akaike Info. Crt.=     12.670 |
| Panel Data Analysis of TOW          [ONE way]                          |
|           Unconditional ANOVA (No regressors)                          |
| Source       Variation        Deg. Free.     Mean Square               |
| Between       .187443E+07           17.          110260.               |
| Residual      958215.               90.          10646.8               |
| Total         .283264E+07          107.          26473.3               |
+------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR         -1335.742549       573.27608   -2.330   .0219  .24073777E-01
 FNR          67.95762819       28.516194    2.383   .0191     3.5740741
 KR           71.37263050       107.76538     .662   .5093     .92592593
 PPPINC    .5413898248E-02  .45474322E-02    1.191   .2367     20946.240
 TBG          113.9161468       44.726420    2.547   .0124     .57407407
 LDEN        -35.89834237       25.011691   -1.435   .1544     8.2698875
 FI          -90.74610972       37.774676   -2.402   .0182     .64814815
 MR          -262.4864437       53.635842   -4.894   .0000     .12037037
 OTC          46.58787626       115.76648     .402   .6882     .26851852
 Constant     898.0660408       223.34497    4.021   .0001
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=============================================================================+
| LIMDEP Estimation Results                          Run log line    29 Page    2 |
| Current sample contains      108 observations.                               |
+=============================================================================+


+------------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                               |
| Ordinary    least squares regression    Weighting variable = none      |
| Dep. var. = TOW      Mean=   978.9000974     , S.D.=    162.7061772    |
| Model size: Observations =       108, Parameters =  27, Deg.Fr.=     81 |
| Residuals:  Sum of squares= 597707.4360     , Std.Dev.=        85.90171 |
| Fit:        R-squared=  .788993, Adjusted R-squared =           .72126 |
| Model test: F[ 26,      81] =    11.65,     Prob value =         .00000 |
| Diagnostic: Log-L =    -618.6565, Restricted(b=0) Log-L =    -702.6732 |
|             LogAmemiyaPrCrt.=     9.130, Akaike Info. Crt.=     11.957 |
| Estd. Autocorrelation of e(i,t)      .060645                           |
+------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR         -1980.189474       604.70026   -3.275   .0015  .24073777E-01***
 FNR          54.07068771       59.231621     .913   .3635     3.5740741
 KR           150.3121490       100.28994    1.499   .1371     .92592593
 PPPINC    .1248085470E-01  .15763952E-01     .792   .4304     20946.240
 TBG          2.747031740       45.492840     .060   .9520     .57407407
 LDEN        -1182.998164       550.89277   -2.147   .0342     8.2698875**
 FI          -45.35186400       104.04348    -.436   .6639     .64814815
 MR          -223.5793813       52.053240   -4.295   .0000     .12037037***
 OTC         -51.89428865       112.55355    -.461   .6458     .26851852
```

```
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
| LIMDEP Estimation Results                   Run log line    29  Page    3 |
| Current sample contains     108 observations.                          |
+=======================================================================+

       Estimated Fixed Effects
       Group        Coefficient        Standard Error       t-ratio
          1          9177.98038           4099.16752         2.23899
          2          9012.22661           3958.43061         2.27672
          3         10177.68161           4465.59391         2.27913
          4         11009.64575           4967.28026         2.21643
          5         10928.60638           4864.54050         2.24659
          6          9391.68785           4280.85552         2.19388
          7         11367.44409           5155.34551         2.20498
          8         10083.82455           4373.86918         2.30547
          9          9664.40157           4207.15681         2.29713
         10         10229.15228           4542.77890         2.25174
         11          8993.73236           3948.27246         2.27789
         12         11083.56032           4922.25988         2.25172
         13         11448.11491           5074.36556         2.25607
         14         10084.91599           4527.76433         2.22735
         15         10399.70223           4603.41731         2.25913
         16         11354.31402           5061.98780         2.24305
         17         10055.97319           4396.99788         2.28701
         18         10660.54745           4786.44465         2.22724

+--------------------------------------------------------------------+
|                Test Statistics for the Classical Model              |
|                                                                    |
|       Model               Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only     -702.67320    .2832643110D+07   .0000000 |
| (2)  Group effects only     -644.14295    .9582148082D+06   .6617241 |
| (3)  X - variables only     -674.19842    .1671797571D+07   .4098100 |
| (4)  X and group effects    -618.65654    .5977074360D+06   .7889930 |
|                                                                    |
|                          Hypothesis Tests                          |
|            Likelihood Ratio Test                F Tests            |
|         Chi-squared   d.f.   Prob.          F    num.  denom.  Prob value |
| (2) vs (1)   117.061    17     .00000     10.356   17    90     .00000 |
| (3) vs (1)    56.950     9     .00000      7.561    9    98     .00000 |
| (4) vs (1)   168.033    26     .00000     11.649   26    81     .00000 |
| (4) vs (2)    50.973     9     .00000      5.428    9    81     .00001 |
| (4) vs (3)   111.084    17     .00000      8.562   17    81     .00000 |
+--------------------------------------------------------------------+
+=======================================================================+
| LIMDEP Estimation Results                   Run log line    29  Page    4 |
| Current sample contains     108 observations.                          |
+=======================================================================+


                +----------------------------------------------------+
                | Random Effects Model: v(i,t) = e(i,t) + u(i)        |
                | Estimates:  Var[e]              =   .737910D+04  |
                |             Var[u]              =   .968005D+04  |
                |             Corr[v(i,t),v(i,s)] =   .567440      |
                | Lagrange Multiplier Test vs. Model (3) =   54.15 |
```

```
          | ( 1 df, prob value =  .000000)                  |
          | (High values of LM favor FEM/REM over CR model.) |
          | Fixed vs. Random Effects (Hausman)     =   12.66 |
          | ( 9 df, prob value =  .178560)                  |
          | (High (low) values of H favor FEM (REM).)       |
          | Reestimated using GLS coefficients:             |
          | Estimates:  Var[e]              =   .791619D+04 |
          |             Var[u]              =   .244557D+05 |
          |             Sum of Squares          .187841D+07 |
          +-------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR        -1769.970031      531.80925     -3.328   .0009  .24073777E-01***
 FNR          67.70383637      26.678783     2.538   .0112    3.5740741**
 KR          128.9540080       87.541067     1.473   .1407     .92592593
 PPPINC    .9102955838E-02  .76423161E-02    1.191   .2336    20946.240
 TBG          19.56492176      41.583105      .471   .6380     .57407407
 LDEN        -35.31231669      44.197684     -.799   .4243    8.2698875
 FI          -97.73633797      56.219429    -1.738   .0821     .64814815*
 MR         -253.5899593       46.712928    -5.429   .0000     .12037037***
 OTC         -30.03929211     101.10776      -.297   .7664     .26851852
 Constant    852.1925025      346.78112      2.457   .0140
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

d. Estimation report for total waste model with interaction term

```
+=======================================================================+
| LIMDEP Estimation Results                       Run log line   33  Page   1 |
| Current sample contains      108 observations.                          |
+=======================================================================+



+----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                    |
| Ordinary    least squares regression    Weighting variable = none    |
| Dep. var. = TOW      Mean=   978.9000974    , S.D.=    162.7061772   |
| Model size: Observations =     108, Parameters =  11, Deg.Fr.=     97 |
| Residuals:  Sum of squares= 1613792.947     , Std.Dev.=     128.98465 |
| Fit:        R-squared=  .430287, Adjusted R-squared =          .37155 |
| Model test: F[ 10,      97] =    7.33,     Prob value =        .00000 |
| Diagnostic: Log-L =    -672.2916, Restricted(b=0) Log-L =   -702.6732 |
|             LogAmemiyaPrCrt.=     9.816, Akaike Info. Crt.=    12.654 |
| Panel Data Analysis of TOW          [ONE way]                        |
|           Unconditional ANOVA (No regressors)                        |
| Source      Variation         Deg. Free.     Mean Square             |
| Between       .187443E+07          17.          110260.              |
| Residual      958215.              90.          10646.8              |
| Total         .283264E+07         107.          26473.3              |
+----------------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR        -365.7556595      768.36025      -.476   .6351  .24073777E-01
 FNR          52.22856171      29.394094     1.777   .0787    3.5740741
```

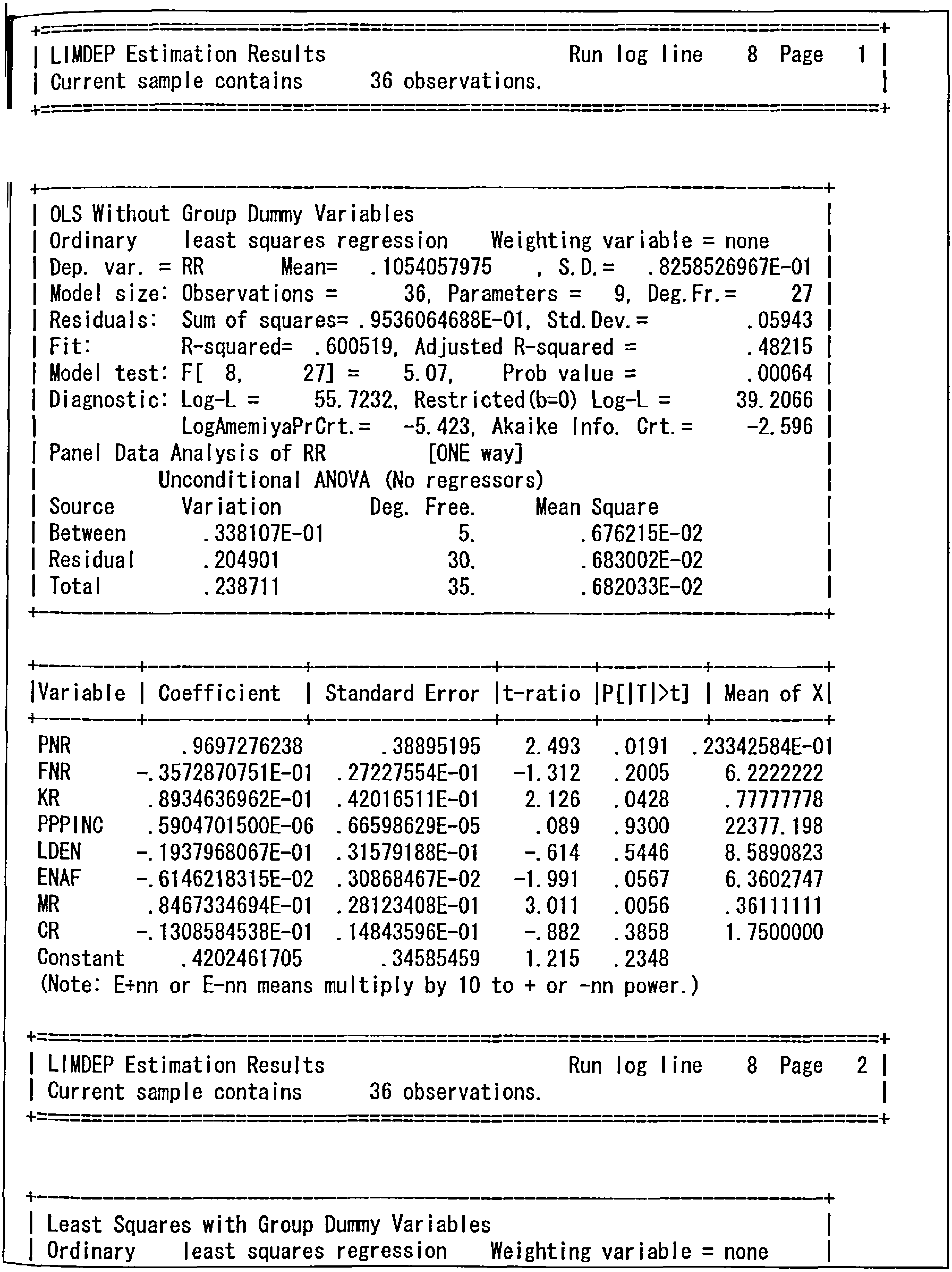
```
 KR          9.264917610       111.50064      .083    .9339     .92592593
 PPPINC    .7395815489E-02  .46145515E-02    1.603    .1122     20946.240
 TBG        107.5411626       44.301347      2.427    .0170     .57407407
 LDEN      -24.05715573       25.501401      -.943    .3478     8.2698875
 FI        -112.6738274       39.109196     -2.881    .0049     .64814815
 MR        -276.4539665       53.493697     -5.168    .0000     .12037037
 OTC        136.7812964       124.11091      1.102    .2731     .26851852
 INT       -222.1425108       118.97026     -1.867    .0649   .37037037E-01
 Constant   852.5620842       221.90662      3.842    .0002
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
| LIMDEP Estimation Results                     Run log line   33  Page  2 |
| Current sample contains     108 observations.                          |
+=======================================================================+


+------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                         |
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = TOW      Mean=   978.9000974    , S.D.=   162.7061772 |
| Model size: Observations =     108, Parameters =  28, Deg.Fr.=   80 |
| Residuals:  Sum of squares= 542330.6011    , Std.Dev.=     82.33549 |
| Fit:        R-squared=  .808543, Adjusted R-squared =        .74393 |
| Model test: F[ 27,     80] =   12.51,    Prob value =        .00000 |
| Diagnostic: Log-L =   -613.4064, Restricted(b=0) Log-L =  -702.6732 |
|             LogAmemiyaPrCrt.=    9.052, Akaike Info. Crt.=   11.878 |
| Estd. Autocorrelation of e(i,t)     .038463                      |
+------------------------------------------------------------------+

+---------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+--------+----------+
 PNR       -692.1455830       734.18685      -.943    .3481   .24073777E-01
 FNR        43.97329784       56.882429       .773    .4413     3.5740741
 KR         145.3932714       96.141793      1.512    .1337     .92592593
 PPPINC    .2001759670E-01  .15337892E-01    1.305    .1949     20946.240
 TBG        24.46538030       44.261371       .553    .5817     .57407407
 LDEN      -1327.935456       530.45191     -2.503    .0140     8.2698875**
 FI        -53.44182921       99.764260      -.536    .5934     .64814815
 MR        -215.6856659       49.968627     -4.316    .0000     .12037037***
 OTC       -55.64107799       107.88884      -.516    .6072     .26851852
 INT       -321.4213132       112.45989     -2.858    .0052   .37037037E-01***
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
| LIMDEP Estimation Results                     Run log line   33  Page  3 |
| Current sample contains     108 observations.                          |
+=======================================================================+

       Estimated Fixed Effects
       Group       Coefficient        Standard Error        t-ratio
           1       10097.77088            3942.14776        2.56149
           2        9830.97235            3804.89479        2.58377
           3       11160.40475            4293.99243        2.59907
           4       12170.94297            4778.36930        2.54709
           5       11978.92981            4677.04804        2.56122
           6       10383.58233            4117.78569        2.52164
```

```
        7          12532.15009          4958.09569       2.52761
        8          11078.93924          4206.72049       2.63363
        9          10580.29059          4045.20883       2.61551
       10          11227.12797          4368.16289       2.57022
       11           9906.59841          3797.81371       2.60850
       12          12240.85194          4735.25560       2.58505
       13          12721.45263          4884.06475       2.60469
       14          11151.56895          4355.81082       2.56016
       15          11523.13516          4429.77936       2.60129
       16          12583.71882          4870.86892       2.58346
       17          11140.94447          4231.51786       2.63285
       18          11806.28863          4605.21548       2.56368

+----------------------------------------------------------------------------+
|                 Test Statistics for the Classical Model                    |
|                                                                            |
|        Model                 Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only        -702.67320    .2832643110D+07      .0000000 |
| (2)  Group effects only        -644.14295    .9582148082D+06      .6617241 |
| (3)  X - variables only        -672.29156    .1613792947D+07      .4302872 |
| (4)  X and group effects       -613.40635    .5423306011D+06      .8085426 |
|                                                                            |
|                              Hypothesis Tests                              |
|                Likelihood Ratio Test                F Tests                |
|             Chi-squared   d.f.  Prob.         F     num.  denom.  Prob value |
| (2) vs (1)    117.061     17     .00000     10.356   17     90       .00000 |
| (3) vs (1)     60.763     10     .00000      7.326   10     97       .00000 |
| (4) vs (1)    178.534     27     .00000     12.513   27     80       .00000 |
| (4) vs (2)     61.473     10     .00000      6.135   10     80       .00000 |
| (4) vs (3)    117.770     17     .00000      9.297   17     80       .00000 |
+----------------------------------------------------------------------------+
+=============================================================================+
| LIMDEP Estimation Results                      Run log line   33  Page    4 |
| Current sample contains      108 observations.                              |
+=============================================================================+


            +--------------------------------------------------+
            | Random Effects Model: v(i,t) = e(i,t) + u(i)     |
            | Estimates:  Var[e]              =   .677913D+04  |
            |             Var[u]              =   .985791D+04  |
            |             Corr[v(i,t),v(i,s)] =   .592528      |
            | Lagrange Multiplier Test vs. Model (3) =    57.85 |
            | ( 1 df, prob value =  .000000)                   |
            | (High values of LM favor FEM/REM over CR model.) |
            | Fixed vs. Random Effects (Hausman)     =    14.63 |
            | (10 df, prob value =  .145992)                   |
            | (High (low) values of H favor FEM (REM).)        |
            | Reestimated using GLS coefficients:              |
            | Estimates:  Var[e]              =   .744060D+04  |
            |             Var[u]              =   .280592D+05  |
            |             Sum of Squares          .182582D+07  |
            +--------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR        -650.5786532      671.25041     -.969    .3324  .24073777E-01
```

```
FNR         67.24447974        25.876435    2.599   .0094     3.5740741***
KR          104.8421636        84.766564    1.237   .2161     .92592593
PPPINC    .1346085716E-01  .77389503E-02    1.739   .0820     20946.240*
TBG         27.62602913        40.280266     .686   .4928     .57407407
LDEN       -29.71402768        44.202660    -.672   .5014     8.2698875
FI         -109.9791342        55.706750   -1.974   .0484     .64814815
MR         -251.2570014        45.043535   -5.578   .0000     .12037037***
OTC        -6.721024326        97.858420    -.069   .9452     .26851852
INT        -269.7236316        102.89797   -2.621   .0088   .37037037E-01***
Constant    718.3882469        349.68710    2.054   .0399
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

A7-6. Estimation reports for the model in Table 5.6

The estimations for recycling ratio is shown below. LM test shows that this panel data model (FEM) is better than OLS model at 90% confidence level. FEM estimates are chosen.



```
+=============================================================================+
| LIMDEP Estimation Results                           Run log line     8  Page    1 |
| Current sample contains       36 observations.                                |
+=============================================================================+


+-----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                     |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = RR       Mean=   .1054057975     , S.D.=   .8258526967E-01 |
| Model size: Observations =       36, Parameters =   9, Deg.Fr.=     27 |
| Residuals:  Sum of squares= .9536064688E-01, Std.Dev.=          .05943 |
| Fit:        R-squared=  .600519, Adjusted R-squared =          .48215 |
| Model test: F[  8,     27] =    5.07,     Prob value =          .00064 |
| Diagnostic: Log-L =      55.7232, Restricted(b=0) Log-L =     39.2066 |
|             LogAmemiyaPrCrt.=   -5.423, Akaike Info. Crt.=     -2.596 |
| Panel Data Analysis of RR          [ONE way]                          |
|           Unconditional ANOVA (No regressors)                         |
| Source      Variation        Deg. Free.     Mean Square               |
| Between      .338107E-01             5.          .676215E-02          |
| Residual     .204901                30.          .683002E-02          |
| Total        .238711                35.          .682033E-02          |
+-----------------------------------------------------------------------+


+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR           .9697276238       .38895195     2.493   .0191  .23342584E-01
 FNR        -.3572870751E-01  .27227554E-01   -1.312   .2005     6.2222222
 KR          .8934636962E-01  .42016511E-01    2.126   .0428     .77777778
 PPPINC      .5904701500E-06  .66598629E-05     .089   .9300     22377.198
 LDEN       -.1937968067E-01  .31579188E-01    -.614   .5446     8.5890823
 ENAF       -.6146218315E-02  .30868467E-02   -1.991   .0567     6.3602747
 MR          .8467334694E-01  .28123408E-01    3.011   .0056     .36111111
 CR         -.1308584538E-01  .14843596E-01    -.882   .3858     1.7500000
 Constant      .4202461705       .34585459     1.215   .2348
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=============================================================================+
| LIMDEP Estimation Results                           Run log line     8  Page    2 |
| Current sample contains       36 observations.                                |
+=============================================================================+


+-----------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                              |
| Ordinary    least squares regression    Weighting variable = none     |
```

```
| Dep. var. = RR        Mean=   .1054057975     , S.D.=   .8258526967E-01 |
| Model size: Observations =       36, Parameters =  14, Deg.Fr.=      22 |
| Residuals:  Sum of squares= .2811725203E-01, Std.Dev.=            .03575 |
| Fit:        R-squared=  .882212, Adjusted R-squared =             .81261 |
| Model test: F[ 13,      22] =   12.68,     Prob value =           .00000 |
| Diagnostic: Log-L =      77.7062, Restricted(b=0) Log-L =        39.2066 |
|             LogAmemiyaPrCrt.=   -6.334, Akaike Info. Crt.=        -3.539 |
| Estd. Autocorrelation of e(i,t)     -.155857                            |
+-------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          1.128378903        .30913656    3.650   .0011  .23342584E-01
 FNR       -.4681827384E-01  .29398085E-01   -1.593   .1225    6.2222222
 KR         .1998856803E-01  .33738654E-01     .592   .5583    .77777778
 PPPINC     .2980363271E-05  .76281816E-05     .391   .6990    22377.198
 LDEN         2.842158846        .43902007    6.474   .0000    8.5890823
 ENAF       .3969229477E-02  .31521247E-02    1.259   .2183    6.3602747
 MR         .6366956034E-01  .21754518E-01    2.927   .0067    .36111111
 CR        -.1604101128E-01  .13955419E-01   -1.149   .2601    1.7500000
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=============================================================================+
| LIMDEP Estimation Results                         Run log line    8  Page   3 |
| Current sample contains        36 observations.                              |
+=============================================================================+

         Estimated Fixed Effects
         Group         Coefficient        Standard Error        t-ratio
             1           -25.90069               4.03852        -6.41341
             2           -22.97705               3.60100        -6.38075
             3           -23.41907               3.67627        -6.37034
             4           -25.82385               4.04594        -6.38265
             5           -22.35995               3.53169        -6.33123
             6           -24.38074               3.81737        -6.38679

+--------------------------------------------------------------------------+
|                 Test Statistics for the Classical Model                  |
|                                                                          |
|           Model              Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only          39.20655    .2387114368D+00     .0000000 |
| (2)  Group effects only          41.95569    .2049006976D+00     .1416385 |
| (3)  X - variables only          55.72316    .9536064688D-01     .6005192 |
| (4)  X and group effects         77.70625    .2811725203D-01     .8822124 |
|                                                                          |
|                              Hypothesis Tests                            |
|                Likelihood Ratio Test                 F Tests              |
|            Chi-squared   d.f.   Prob.          F    num.  denom.  Prob value |
| (2) vs (1)      5.498     5      .35813       .990    5     30      .44029 |
| (3) vs (1)     33.033     8      .00006      5.073    8     27      .00064 |
| (4) vs (1)     76.999    13      .00000     12.675   13     22      .00000 |
| (4) vs (2)     71.501     8      .00000     17.290    8     22      .00000 |
| (4) vs (3)     43.966     5      .00000     10.523    5     22      .00003 |
+--------------------------------------------------------------------------+
+=============================================================================+
| LIMDEP Estimation Results                         Run log line    8  Page   4 |
| Current sample contains        36 observations.                              |
```

```
=================================================================+

        +--------------------------------------------------------+
        | Random Effects Model: v(i,t) = e(i,t) + u(i)           |
        | Estimates:  Var[e]              =  .127806D-02         |
        |             Var[u]              =  .225382D-02         |
        |             Corr[v(i,t),v(i,s)] =  .638137             |
        | Lagrange Multiplier Test vs. Model (3) =     2.73      |
        | ( 1 df, prob value =  .098495)                         |
        | (High values of LM favor FEM/REM over CR model.)       |
        | Fixed vs. Random Effects (Hausman)     =      .00      |
        | ( 8 df, prob value = 1.000000)                         |
        | (High (low) values of H favor FEM (REM).)              |
        | Reestimated using GLS coefficients:                    |
        | Estimates:  Var[e]              =  .390005D-02         |
        |             Var[u]              =  .493970D-02         |
        |             Sum of Squares         .119339D+00         |
        +--------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          .6964689875       .27787987     2.506   .0122  .23342584E-01
 FNR       -.6740251497E-01  .24869878E-01   -2.710   .0067   6.2222222
 KR         .6887031161E-01  .29343226E-01    2.347   .0189   .77777778
 PPPINC     .6161307363E-05  .59870140E-05    1.029   .3034   22377.198
 LDEN      -.1396425107E-01  .54196615E-01    -.258   .7967   8.5890823
 ENAF      -.7863994960E-02  .23649861E-02   -3.325   .0009   6.3602747
 MR         .8510565214E-01  .20690599E-01    4.113   .0000   .36111111
 CR        -.9386493208E-02  .11711697E-01    -.801   .4229   1.7500000
 Constant     .4727542825       .47923824      .986   .3239
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

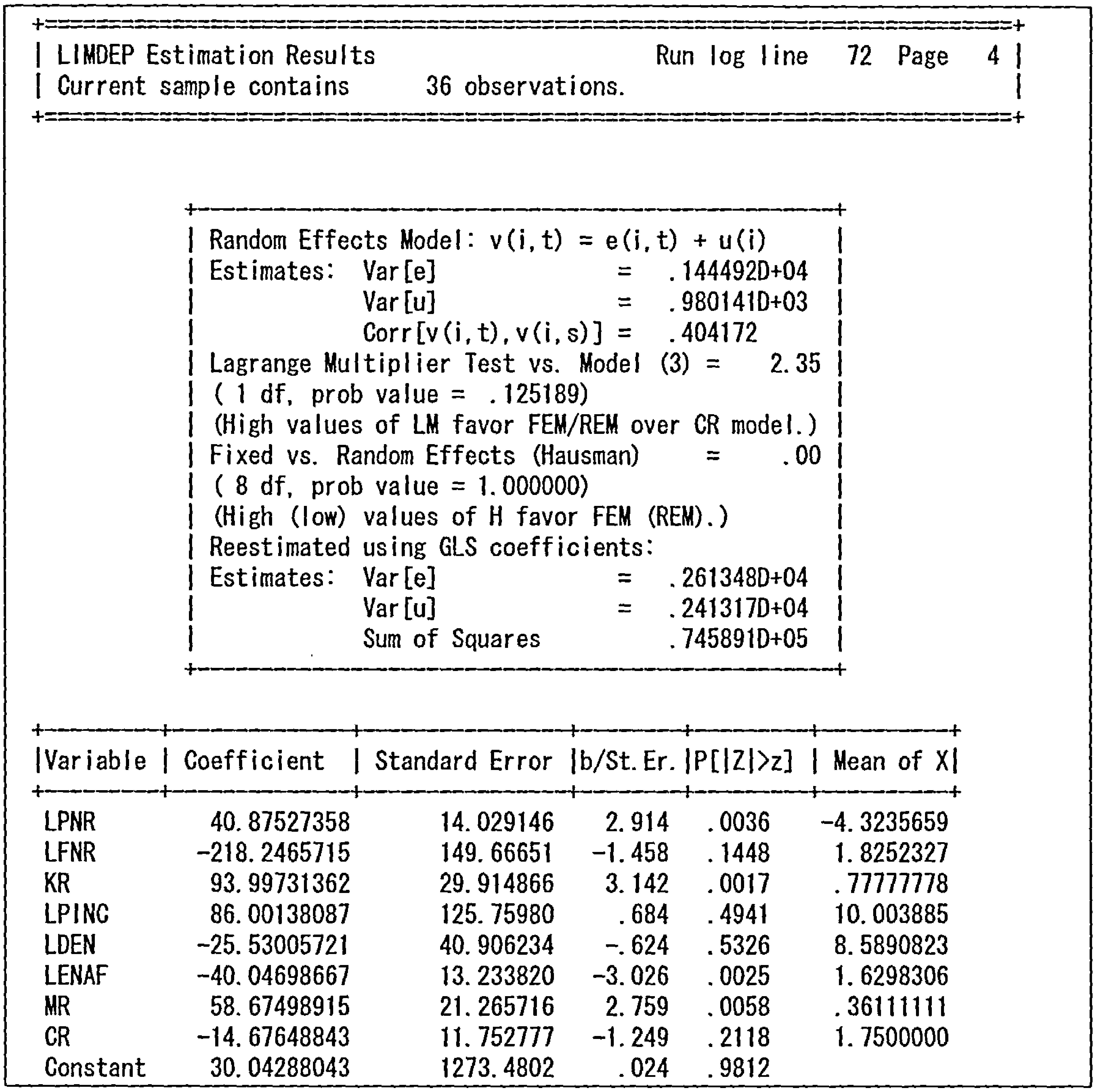
A7-7. Estimation reports for the models in Table 5.7

The estimations for total recyclables, recyclable paper, metal, glass, PET bottles, plastics, non-recyclables, and total waste generation are shown below. LM test shows that their panel data models aren't better than OLS models at 90% confidence level. Therefore, OLS estimates of these models are chosen.

a. Estimation report for total recyclables model

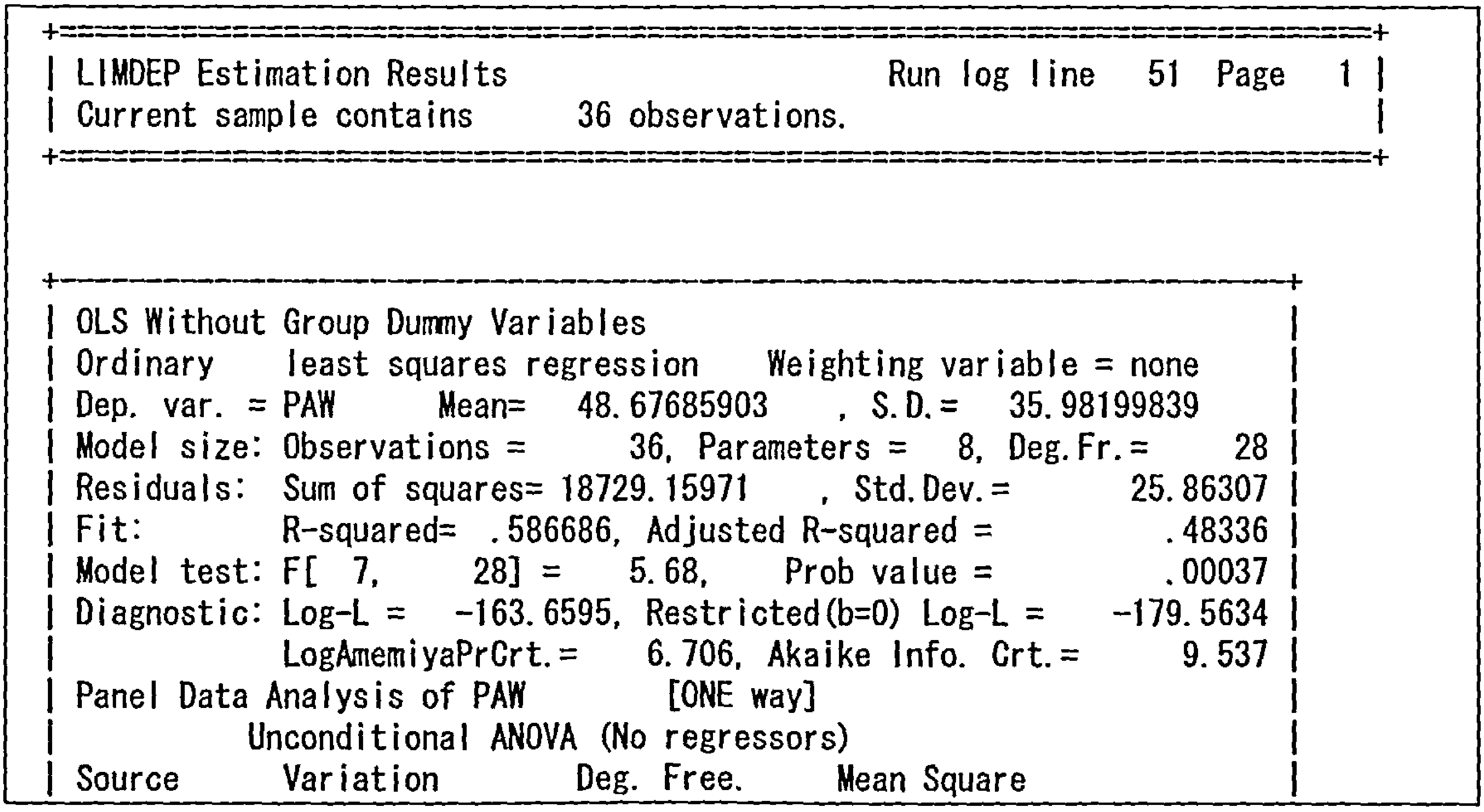
```
+=============================================================================+
| LIMDEP Estimation Results                      Run log line    72  Page    1 |
| Current sample contains      36 observations.                               |
+=============================================================================+



+-----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                     |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = TOR       Mean=   99.37692909     , S.D.=    69.89294736  |
| Model size: Observations =       36, Parameters =   9, Deg.Fr.=    27 |
| Residuals:  Sum of squares= 65476.53947     , Std.Dev.=      49.24487 |
| Fit:        R-squared=  .617042, Adjusted R-squared =          .50357 |
| Model test: F[  8,     27] =    5.44,    Prob value =          .00039 |
| Diagnostic: Log-L =   -186.1885, Restricted(b=0) Log-L =   -203.4654 |
|             LogAmemiyaPrCrt.=    8.017, Akaike Info. Crt.=     10.844 |
| Panel Data Analysis of TOR          [ONE way]                         |
|           Unconditional ANOVA (No regressors)                         |
| Source      Variation       Deg. Free.      Mean Square               |
| Between       10185.6               5.          2037.12               |
| Residual      160790.              30.          5359.68               |
| Total         170976.              35.          4885.02               |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR        51.67907046       15.880023     3.254   .0031    -4.3235659
 LFNR       -67.57554579       148.98197     -.454   .6538     1.8252327
 KR          113.2071235       35.053749     3.230   .0032     .77777778
 LPINC       3.769199825       123.13429      .031   .9758     10.003885
 LDEN       -12.91936010       26.440266     -.489   .6291     8.5890823
 LENAF      -35.17168253       14.373351    -2.447   .0212     1.6298306
 MR          48.99648853       23.238376     2.108   .0444     .36111111
 CR         -20.62800197       12.674277    -1.628   .1152     1.7500000
 Constant    507.0944192       1354.0075      .375   .7109

+=============================================================================+
| LIMDEP Estimation Results                      Run log line    72  Page    2 |
| Current sample contains      36 observations.                               |
+=============================================================================+
```

```
+------------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                               |
| Ordinary    least squares regression    Weighting variable = none      |
| Dep. var. = TOR      Mean=   99.37692909    , S.D.=    69.89294736     |
| Model size: Observations =       36, Parameters =  14, Deg.Fr.=     22 |
| Residuals:  Sum of squares= 31788.15376     , Std.Dev.=       38.01205 |
| Fit:        R-squared=  .814078, Adjusted R-squared =           .70422 |
| Model test: F[ 13,     22] =    7.41,     Prob value =          .00002 |
| Diagnostic: Log-L =    -173.1817, Restricted(b=0) Log-L =    -203.4654 |
|             LogAmemiyaPrCrt.=    7.604, Akaike Info. Crt.=      10.399 |
| Estd. Autocorrelation of e(i,t)     -.108710                           |
+------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR         42.89351468       16.279482     2.635   .0136    -4.3235659
 LFNR       -321.2139243        197.73473    -1.624   .1155     1.8252327
 KR           49.40455765       36.305242     1.361   .1844      .77777778
 LPINC       163.9913764        178.79088      .917   .3669     10.003885
 LDEN       1714.027304         475.82565     3.602   .0012     8.5890823
 LENAF        -2.255079807      18.605485     -.121   .9044     1.6298306
 MR           54.24597210       23.350361     2.323   .0277      .36111111
 CR          -16.67409655       15.528586    -1.074   .2921     1.7500000

+=============================================================================+
| LIMDEP Estimation Results                            Run log line   72  Page   3 |
| Current sample contains       36 observations.                              |
+=============================================================================+

        Estimated Fixed Effects
        Group         Coefficient          Standard Error        t-ratio
            1       -16598.48497              4300.27569        -3.85987
            2       -14822.59073              3866.53521        -3.83356
            3       -15062.83357              3925.51014        -3.83717
            4       -16526.04359              4301.55748        -3.84187
            5       -14391.47926              3785.29841        -3.80194
            6       -15697.63967              4076.87301        -3.85041

+-------------------------------------------------------------------------+
|                 Test Statistics for the Classical Model                 |
|                                                                         |
|        Model              Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only     -203.46544   .1709758432D+06     .0000000   |
| (2)  Group effects only     -202.35986   .1607902561D+06     .0595733   |
| (3)  X - variables only     -186.18850   .6547653947D+05     .6170422   |
| (4)  X and group effects    -173.18173   .3178815376D+05     .8140781   |
|                                                                         |
|                               Hypothesis Tests                          |
|                Likelihood Ratio Test               F Tests              |
|            Chi-squared   d.f.  Prob.          F    num. denom. Prob value |
| (2) vs (1)      2.211      5     .81922      .380    5     30     .85839 |
| (3) vs (1)     34.554      8     .00003     5.438    8     27     .00039 |
| (4) vs (1)     60.567     13     .00000     7.410   13     22     .00002 |
| (4) vs (2)     58.356      8     .00000    11.160    8     22     .00000 |
| (4) vs (3)     26.014      5     .00009     4.663    5     22     .00471 |
+-------------------------------------------------------------------------+
```



```
+=====================================================================+
| LIMDEP Estimation Results                 Run log line   72  Page   4 |
| Current sample contains      36 observations.                        |
+=====================================================================+


            +----------------------------------------------+
            | Random Effects Model: v(i,t) = e(i,t) + u(i)  |
            | Estimates:  Var[e]              =  .144492D+04 |
            |             Var[u]              =  .980141D+03 |
            |             Corr[v(i,t),v(i,s)] =  .404172     |
            | Lagrange Multiplier Test vs. Model (3) =  2.35 |
            | ( 1 df, prob value =  .125189)               |
            | (High values of LM favor FEM/REM over CR model.) |
            | Fixed vs. Random Effects (Hausman)    =    .00 |
            | ( 8 df, prob value = 1.000000)               |
            | (High (low) values of H favor FEM (REM).)    |
            | Reestimated using GLS coefficients:          |
            | Estimates:  Var[e]              =  .261348D+04 |
            |             Var[u]              =  .241317D+04 |
            |             Sum of Squares         .745891D+05 |
            +----------------------------------------------+

+--------+----------------+----------------+--------+--------+----------+
|Variable | Coefficient   | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+----------------+----------------+--------+--------+----------+
 LPNR        40.87527358      14.029146      2.914   .0036    -4.3235659
 LFNR      -218.2465715      149.66651     -1.458   .1448     1.8252327
 KR          93.99731362      29.914866      3.142   .0017     .77777778
 LPINC       86.00138087     125.75980       .684   .4941    10.003885
 LDEN       -25.53005721      40.906234     -.624   .5326     8.5890823
 LENAF      -40.04698667      13.233820    -3.026   .0025     1.6298306
 MR          58.67498915      21.265716      2.759   .0058     .36111111
 CR         -14.67648843      11.752777    -1.249   .2118     1.7500000
 Constant    30.04288043    1273.4802        .024   .9812
```

b. Estimation report for recyclable paper model (*PAW*)



```
+=====================================================================+
| LIMDEP Estimation Results                 Run log line   51  Page   1 |
| Current sample contains      36 observations.                        |
+=====================================================================+


+-----------------------------------------------------------------+
| OLS Without Group Dummy Variables                               |
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = PAW      Mean=   48.67685903    , S.D.=   35.98199839 |
| Model size: Observations =      36, Parameters =   8, Deg.Fr.=    28 |
| Residuals:  Sum of squares= 18729.15971     , Std.Dev.=      25.86307 |
| Fit:        R-squared=  .586686, Adjusted R-squared =         .48336 |
| Model test: F[  7,      28] =    5.68,    Prob value =        .00037 |
| Diagnostic: Log-L =   -163.6595, Restricted(b=0) Log-L =   -179.5634 |
|             LogAmemiyaPrCrt.=    6.706, Akaike Info. Crt.=     9.537 |
| Panel Data Analysis of PAW          [ONE way]                   |
|           Unconditional ANOVA (No regressors)                   |
| Source      Variation        Deg. Free.     Mean Square         |
```

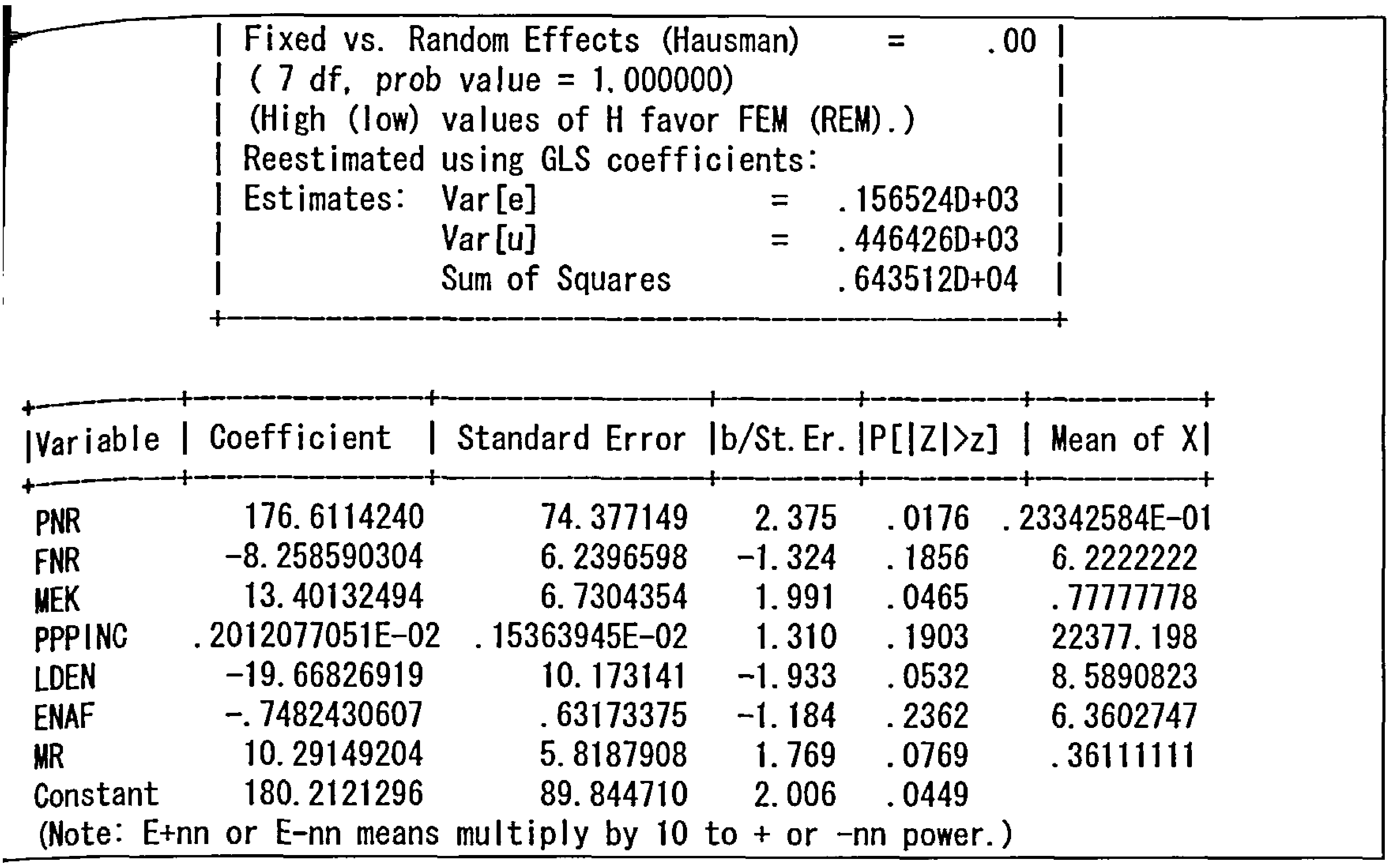
```
| Between       5058.24              5.          1011.65               |
| Residual      40256.4             30.          1341.88               |
| Total         45314.6             35.          1294.70               |
+--------------------------------------------------------------------+

+---------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+--------+----------+
 LPNR        26.14296960       7.2551359     3.603   .0012    -4.3235659
 LFNR       -71.92015452       77.105442     -.933   .3589     1.8252327
 PAK         39.86401668       16.180461     2.464   .0202     .77777778
 LPINC      -13.91698588       63.249798     -.220   .8274     10.003885
 LDEN       -22.97567334       12.684274    -1.811   .0808     8.5890823
 LENAF      -11.10980853       7.5125751    -1.479   .1503     1.6298306
 MR          21.46473663       12.108711     1.773   .0872     .36111111
 Constant    608.8932115       686.80003      .887   .3829

+=======================================================================+
| LIMDEP Estimation Results                 Run log line   51   Page   2 |
| Current sample contains      36 observations.                         |
+=======================================================================+


+--------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                           |
| Ordinary    least squares regression    Weighting variable = none  |
| Dep. var. = PAW      Mean=   48.67685903    , S.D.=   35.98199839  |
| Model size: Observations =       36, Parameters =  13, Deg.Fr.=     23 |
| Residuals:  Sum of squares= 10689.73148    , Std.Dev.=       21.55855 |
| Fit:        R-squared=  .764100, Adjusted R-squared =          .64102 |
| Model test: F[ 12,      23] =    6.21,    Prob value =         .00009 |
| Diagnostic: Log-L =   -153.5651, Restricted(b=0) Log-L =   -179.5634 |
|             LogAmemiyaPrCrt.=    6.450, Akaike Info. Crt.=      9.254 |
| Estd. Autocorrelation of e(i,t)      .012235                       |
+--------------------------------------------------------------------+

+---------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+--------+----------+
 LPNR        20.87339082       8.0536815     2.592   .0148    -4.3235659
 LFNR       -230.1972998       91.025977    -2.529   .0171     1.8252327
 PAK         9.845457113       15.471172      .636   .5295     .77777778
 LPINC       175.2974878       94.894638     1.847   .0749     10.003885
 LDEN        554.4793027       248.37332     2.232   .0335     8.5890823
 LENAF       .9362145730       10.455232      .090   .9293     1.6298306
 MR          30.99848031       13.150218     2.357   .0254     .36111111

+=======================================================================+
| LIMDEP Estimation Results                 Run log line   51   Page   3 |
| Current sample contains      36 observations.                         |
+=======================================================================+

         Estimated Fixed Effects
         Group        Coefficient          Standard Error        t-ratio
             1        -6371.11616              2340.46774       -2.72216
             2        -5757.72853              2108.24153       -2.73106
             3        -5809.32423              2137.11140       -2.71831
             4        -6307.43551              2333.50364       -2.70299
```

```
           5        -5569.00176              2060.89059        -2.70223
           6        -6049.87607              2219.29833        -2.72603

+--------------------------------------------------------------------------+
|                 Test Statistics for the Classical Model                  |
|                                                                          |
|         Model                 Log-Likelihood    Sum of Squares   R-squared |
| (1)  Constant term only        -179.56339    .4531464729D+05    .0000000 |
| (2)  Group effects only        -177.43289    .4025640802D+05    .1116248 |
| (3)  X - variables only        -163.65951    .1872915971D+05    .5866864 |
| (4)  X and group effects       -153.56515    .1068973148D+05    .7640999 |
|                                                                          |
|                                   Hypothesis Tests                       |
|                Likelihood Ratio Test                  F Tests            |
|            Chi-squared   d.f.   Prob.           F    num.  denom.  Prob value |
| (2) vs (1)      4.261      5     .51248        .754    5     30      .58990 |
| (3) vs (1)     31.808      7     .00004       5.678    7     28      .00037 |
| (4) vs (1)     51.996     12     .00000       6.208   12     23      .00009 |
| (4) vs (2)     47.735      7     .00000       9.088    7     23      .00002 |
| (4) vs (3)     20.189      5     .00115       3.460    5     23      .01777 |
+--------------------------------------------------------------------------+

+=============================================================================+
| LIMDEP Estimation Results                       Run log line   51   Page    4 |
| Current sample contains        36 observations.                               |
+=============================================================================+


             +--------------------------------------------------+
             | Random Effects Model: v(i,t) = e(i,t) + u(i)     |
             | Estimates:  Var[e]            =   .464771D+03    |
             |             Var[u]            =   .204128D+03    |
             |             Corr[v(i,t),v(i,s)] =  .305170       |
             | Lagrange Multiplier Test vs. Model (3) =     1.59 |
             | ( 1 df, prob value =  .207438)                   |
             | (High values of LM favor FEM/REM over CR model.) |
             | Fixed vs. Random Effects (Hausman)    =      .00 |
             | ( 7 df, prob value = 1.000000)                   |
             | (High (low) values of H favor FEM (REM).)        |
             | Reestimated using GLS coefficients:              |
             | Estimates:  Var[e]            =   .674855D+03    |
             |             Var[u]            =   .799934D+03    |
             |             Sum of Squares        .209961D+05    |
             +--------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 LPNR       22.89868703       7.1348034      3.209    .0013   -4.3235659
 LFNR     -134.4480755       76.066051     -1.768    .0771    1.8252327
 PAK        34.12398007      13.931612      2.449    .0143    .77777778
 LPINC      45.42822454      67.162482       .676    .4988    10.003885
 LDEN      -31.98279908      18.483605     -1.730    .0836    8.5890823
 LENAF     -12.48454019       7.2449635     -1.723    .0849    1.6298306
 MR         27.90600459      11.763333      2.372    .0177    .36111111
 Constant  197.0536392      675.89953        .292    .7706
```

c. Estimation report for recyclable metal model (*MEW*)

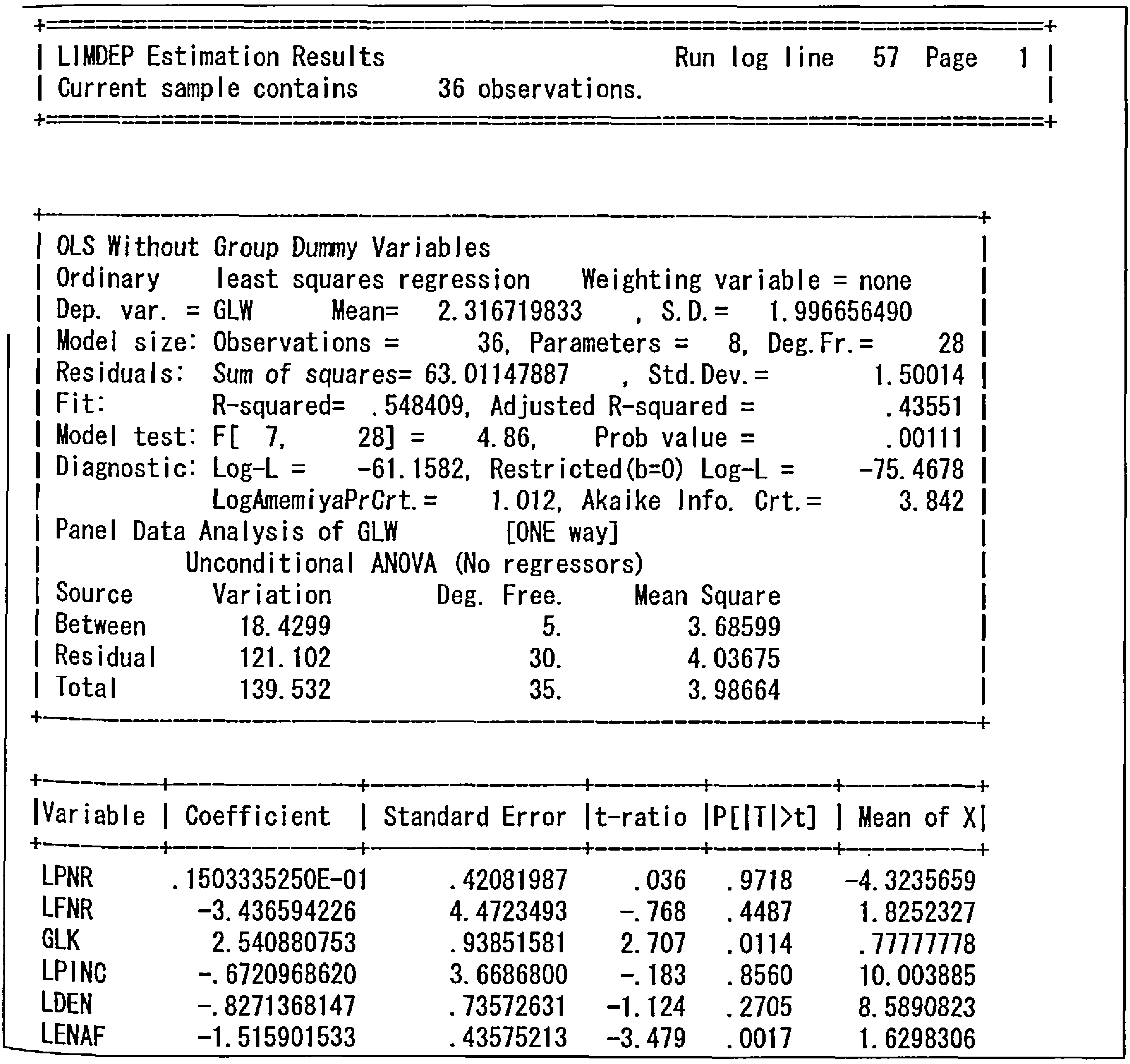
```
+=========================================================================+
| LIMDEP Estimation Results                   Run log line    14  Page   1 |
| Current sample contains        36 observations.                          |
+=========================================================================+


+----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                    |
| Ordinary    least squares regression    Weighting variable = none    |
| Dep. var. = MEW      Mean=   18.42077024    , S.D.=   16.51089708    |
| Model size: Observations =       36, Parameters =   8, Deg.Fr.=    28 |
| Residuals:  Sum of squares= 5102.099467    , Std.Dev.=       13.49881 |
| Fit:        R-squared=  .465264, Adjusted R-squared =          .33158 |
| Model test: F[  7,      28] =     3.48,     Prob value =       .00827 |
| Diagnostic: Log-L =   -140.2518, Restricted(b=0) Log-L =    -151.5195 |
|             LogAmemiyaPrCrt.=    5.406, Akaike Info. Crt.=      8.236 |
| Panel Data Analysis of MEW         [ONE way]                         |
|           Unconditional ANOVA (No regressors)                        |
| Source      Variation        Deg. Free.      Mean Square             |
| Between       1272.11               5.          254.422              |
| Residual      8269.23              30.          275.641              |
| Total         9541.34              35.          272.610              |
+----------------------------------------------------------------------+

+---------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+--------+----------+
 PNR          201.5084774       81.263676    2.480   .0194  .23342584E-01
 FNR          1.190502783       6.1287216     .194   .8474     6.2222222
 MEK          16.54188848       8.4324039    1.962   .0598     .77777778
 PPPINC     .4966485166E-03  .14722251E-02    .337   .7384     22377.198
 LDEN        -13.05921400       6.5400650   -1.997   .0557     8.5890823
 ENAF        -.5412848866       .69571146    -.778   .4431     6.3602747
 MR           5.291418145       6.3515235     .833   .4118     .36111111
 Constant     96.02854748       69.660761    1.379   .1790
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=========================================================================+
| LIMDEP Estimation Results                   Run log line    14  Page   2 |
| Current sample contains        36 observations.                          |
+=========================================================================+


+----------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                             |
| Ordinary    least squares regression    Weighting variable = none    |
| Dep. var. = MEW      Mean=   18.42077024    , S.D.=   16.51089708    |
| Model size: Observations =       36, Parameters =  13, Deg.Fr.=    23 |
| Residuals:  Sum of squares= 2505.131182    , Std.Dev.=       10.43641 |
| Fit:        R-squared=  .737445, Adjusted R-squared =          .60046 |
| Model test: F[ 12,      23] =     5.38,     Prob value =       .00028 |
| Diagnostic: Log-L =   -127.4482, Restricted(b=0) Log-L =    -151.5195 |
|             LogAmemiyaPrCrt.=    4.999, Akaike Info. Crt.=      7.803 |
| Estd. Autocorrelation of e(i,t)     -.230607                         |
+----------------------------------------------------------------------+
```

```
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          169.9482283       83.977871     2.024   .0523  .23342584E-01
 FNR         -15.39129089       7.6382325    -2.015   .0533    6.2222222
 MEK          2.442244004       7.3805281      .331   .7431    .77777778
 PPPINC    .4604713708E-02  .20741539E-02     2.220   .0344    22377.198
 LDEN         258.2200388       124.27619     2.078   .0467    8.5890823
 ENAF         .3419382702       .90966727      .376   .7097    6.3602747
 MR           11.40758728       6.3103765     1.808   .0810    .36111111
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=============================================================================+
| LIMDEP Estimation Results                   Run log line    14  Page    3 |
| Current sample contains       36 observations.                           |
+=============================================================================+

        Estimated Fixed Effects
        Group         Coefficient        Standard Error        t-ratio
            1         -2411.34557           1145.55667        -2.10496
            2         -2112.57602           1018.31567        -2.07458
            3         -2144.26767           1039.00827        -2.06376
            4         -2367.11077           1144.25326        -2.06869
            5         -2022.63848            997.01117        -2.02870
            6         -2255.37583           1080.42871        -2.08748

+--------------------------------------------------------------------------+
|                 Test Statistics for the Classical Model                  |
|                                                                          |
|        Model              Log-Likelihood    Sum of Squares    R-squared  |
| (1)  Constant term only       -151.51945    .9541340280D+04     .0000000 |
| (2)  Group effects only       -148.94379    .8269232730D+04     .1333259 |
| (3)  X - variables only       -140.25178    .5102099467D+04     .4652639 |
| (4)  X and group effects      -127.44818    .2505131182D+04     .7374445 |
|                                                                          |
|                            Hypothesis Tests                              |
|               Likelihood Ratio Test                  F Tests             |
|            Chi-squared   d.f.  Prob.           F    num.  denom.  Prob value |
| (2) vs (1)      5.151      5     .39769      .923    5     30      .47977 |
| (3) vs (1)     22.535      7     .00205     3.480    7     28      .00827 |
| (4) vs (1)     48.143     12     .00000     5.383   12     23      .00028 |
| (4) vs (2)     42.991      7     .00000     7.560    7     23      .00009 |
| (4) vs (3)     25.607      5     .00011     4.769    5     23      .00390 |
+--------------------------------------------------------------------------+
+=============================================================================+
| LIMDEP Estimation Results                   Run log line    14  Page    4 |
| Current sample contains       36 observations.                           |
+=============================================================================+


            +----------------------------------------------------+
            | Random Effects Model: v(i,t) = e(i,t) + u(i)       |
            | Estimates:  Var[e]              =   .108919D+03    |
            |             Var[u]              =   .732991D+02    |
            |             Corr[v(i,t),v(i,s)] =   .402261        |
            | Lagrange Multiplier Test vs. Model (3) =      .41  |
            | ( 1 df, prob value =  .522658)                     |
            | (High values of LM favor FEM/REM over CR model.)   |
```



```
          | Fixed vs. Random Effects (Hausman)       =    .00 |
          | ( 7 df, prob value = 1.000000)                   |
          | (High (low) values of H favor FEM (REM).)        |
          | Reestimated using GLS coefficients:              |
          | Estimates:  Var[e]              =  .156524D+03   |
          |             Var[u]              =  .446426D+03   |
          |             Sum of Squares         .643512D+04   |
          +--------------------------------------------------+

+--------+--------------+----------------+--------+--------+---------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+---------+
 PNR        176.6114240      74.377149     2.375   .0176  .23342584E-01
 FNR       -8.258590304      6.2396598    -1.324   .1856    6.2222222
 MEK        13.40132494      6.7304354     1.991   .0465    .77777778
 PPPINC  .2012077051E-02  .15363945E-02    1.310   .1903    22377.198
 LDEN      -19.66826919      10.173141    -1.933   .0532    8.5890823
 ENAF      -.7482430607      .63173375    -1.184   .2362    6.3602747
 MR         10.29149204      5.8187908     1.769   .0769    .36111111
 Constant   180.2121296      89.844710     2.006   .0449
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

d. Estimation report for recyclable glass model (*GLW*)



```
+=======================================================================+
| LIMDEP Estimation Results                    Run log line   57  Page   1 |
| Current sample contains      36 observations.                         |
+=======================================================================+


+----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                    |
| Ordinary    least squares regression    Weighting variable = none    |
| Dep. var. = GLW       Mean=   2.316719833    , S.D.=    1.996656490  |
| Model size: Observations =       36, Parameters =    8, Deg.Fr.=   28 |
| Residuals:  Sum of squares= 63.01147887     , Std.Dev.=      1.50014 |
| Fit:        R-squared=  .548409, Adjusted R-squared =          .43551 |
| Model test: F[  7,      28] =    4.86,     Prob value =        .00111 |
| Diagnostic: Log-L =     -61.1582, Restricted(b=0) Log-L =    -75.4678 |
|             LogAmemiyaPrCrt.=     1.012, Akaike Info. Crt.=     3.842 |
| Panel Data Analysis of GLW         [ONE way]                         |
|           Unconditional ANOVA (No regressors)                        |
| Source      Variation        Deg. Free.      Mean Square             |
| Between       18.4299               5.          3.68599              |
| Residual      121.102              30.          4.03675              |
| Total         139.532              35.          3.98664              |
+----------------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+---------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+---------+
 LPNR     .1503335250E-01    .42081987      .036   .9718   -4.3235659
 LFNR      -3.436594226      4.4723493     -.768   .4487    1.8252327
 GLK        2.540880753      .93851581     2.707   .0114    .77777778
 LPINC     -.6720968620      3.6686800     -.183   .8560    10.003885
 LDEN      -.8271368147      .73572631    -1.124   .2705    8.5890823
 LENAF     -1.515901533      .43575213    -3.479   .0017    1.6298306
```

```
MR              .3582024830       .70234193      .510   .6140      .36111111
Constant      22.84729895       39.836484       .574   .5709
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=====================================================================+
| LIMDEP Estimation Results                     Run log line   57  Page    2 |
| Current sample contains      36 observations.                          |
+=====================================================================+


+---------------------------------------------------------------+
| Least Squares with Group Dummy Variables                      |
| Ordinary    least squares regression    Weighting variable = none   |
| Dep. var. = GLW      Mean=   2.316719833     , S.D.=    1.996656490 |
| Model size: Observations =       36, Parameters =  13, Deg.Fr.=     23 |
| Residuals:  Sum of squares= 25.88321916     , Std.Dev.=        1.06083 |
| Fit:        R-squared=  .814500, Adjusted R-squared =          .71772 |
| Model test: F[ 12,      23] =    8.42,     Prob value =        .00001 |
| Diagnostic: Log-L =    -45.1432, Restricted(b=0) Log-L =    -75.4678 |
|             LogAmemiyaPrCrt.=     .426, Akaike Info. Crt.=      3.230 |
| Estd. Autocorrelation of e(i,t)     .001922                     |
+---------------------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
LPNR     -.9590473577E-01      .39629646     -.242   .8105     -4.3235659
LFNR       -11.94267701       4.4791035    -2.666   .0124      1.8252327
GLK          .9390292727      .76128797     1.233   .2273      .77777778
LPINC       7.246566395       4.6694682     1.552   .1315     10.003885
LDEN       42.20796261       12.221674      3.454   .0017      8.5890823
LENAF      -.3239833070      .51446924     -.630   .5338      1.6298306
MR          1.513827467       .64708107     2.339   .0264      .36111111
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=====================================================================+
| LIMDEP Estimation Results                     Run log line   57  Page    3 |
| Current sample contains      36 observations.                          |
+=====================================================================+

         Estimated Fixed Effects
         Group        Coefficient          Standard Error        t-ratio
             1         -440.20277              115.16709       -3.82230
             2         -394.37450              103.73997       -3.80157
             3         -399.57346              105.16056       -3.79965
             4         -436.83595              114.82441       -3.80438
             5         -383.41368              101.40998       -3.78083
             6         -418.02102              109.20473       -3.82787

+----------------------------------------------------------------+
|                 Test Statistics for the Classical Model         |
|                                                                |
|        Model              Log-Likelihood    Sum of Squares     R-squared |
| (1)  Constant term only         -75.46778   .1395322999D+03    .0000000 |
| (2)  Group effects only         -72.91790   .1211023729D+03    .1320836 |
| (3)  X - variables only         -61.15815   .6301147887D+02    .5484094 |
| (4)  X and group effects        -45.14315   .2588321916D+02    .8145002 |
|                                                                |
```

```
|                            Hypothesis Tests                            |
|             Likelihood Ratio Test                 F Tests              |
|          Chi-squared   d.f.   Prob.         F    num.  denom.  Prob value |
| (2) vs (1)      5.100     5     .40383      .913    5     30       .48581 |
| (3) vs (1)     28.619     7     .00017     4.858    7     28       .00111 |
| (4) vs (1)     60.649    12     .00000     8.416   12     23       .00001 |
| (4) vs (2)     55.549     7     .00000    12.087    7     23       .00000 |
| (4) vs (3)     32.030     5     .00001     6.598    5     23       .00061 |
+-----------------------------------------------------------------------+
+=============================================================================+
| LIMDEP Estimation Results                         Run log line    57  Page   4 |
| Current sample contains      36 observations.                              |
+=============================================================================+


             +--------------------------------------------------+
             | Random Effects Model: v(i,t) = e(i,t) + u(i)     |
             | Estimates:  Var[e]              =   .112536D+01  |
             |             Var[u]              =   .112505D+01  |
             |             Corr[v(i,t),v(i,s)] =   .499932      |
             | Lagrange Multiplier Test vs. Model (3) =      .13 |
             | ( 1 df, prob value =  .714908)                   |
             | (High values of LM favor FEM/REM over CR model.) |
             | Fixed vs. Random Effects (Hausman)     =      .00 |
             | ( 7 df, prob value = 1.000000)                   |
             | (High (low) values of H favor FEM (REM).)        |
             | Reestimated using GLS coefficients:              |
             | Estimates:  Var[e]              =   .189345D+01  |
             |             Var[u]              =   .590968D+01  |
             |             Sum of Squares          .809008D+02  |
             +--------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR      -.1522826956      .36761120      -.414   .6787    -4.3235659
 LFNR      -9.154994306     3.9985079      -2.290   .0220     1.8252327
 GLK        2.175749718      .69767269      3.119   .0018      .77777778
 LPINC      3.796724664     3.6941155       1.028   .3041     10.003885
 LDEN      -1.623580810     1.1927790      -1.361   .1735     8.5890823
 LENAF     -1.451977427      .37885702     -3.833   .0001     1.6298306
 MR         1.393167998      .60479818      2.304   .0212      .36111111
 Constant  -5.497480468     36.180926       -.152   .8792
```

e. Estimation report for recyclable PET bottles model (*PTW*)

```
+=============================================================================+
| LIMDEP Estimation Results                         Run log line    26  Page   1 |
| Current sample contains      36 observations.                              |
+=============================================================================+


+-----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                     |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = PTW      Mean=   5.251003166     , S.D.=    3.789667555   |
| Model size: Observations =       36, Parameters =   8, Deg.Fr.=     28 |
```

```
| Residuals:  Sum of squares= 179.2849951     , Std.Dev.=         2.53042 |
| Fit:        R-squared=  .643324, Adjusted R-squared =             .55416 |
| Model test: F[  7,      28] =     7.21,    Prob value =           .00006 |
| Diagnostic: Log-L =    -79.9800, Restricted(b=0) Log-L =       -98.5367 |
|             LogAmemiyaPrCrt.=    2.057, Akaike Info. Crt.=        4.888 |
| Panel Data Analysis of PTW          [ONE way]                           |
|           Unconditional ANOVA (No regressors)                           |
| Source      Variation         Deg. Free.      Mean Square               |
| Between       91.9854                5.          18.3971                |
| Residual      410.670               30.          13.6890                |
| Total         502.655               35.          14.3616                |
+-------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          24.31529636       15.233299     1.596   .1217  .23342584E-01
 FNR          .2412799453       1.1488608      .210   .8352    6.2222222
 PTK          2.273872003       1.5806980     1.439   .1614    .77777778
 PPPINC     .3162211651E-03  .27597626E-03    1.146   .2616    22377.198
 LDEN         2.189351807       1.2259693     1.786   .0850    8.5890823
 ENAF        -.5204749678       .13041474    -3.991   .0004    6.3602747
 MR           2.122895573       1.1906262     1.783   .0854    .36111111
 Constant   -21.92334695       13.058273    -1.679   .1043
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=========================================================================+
| LIMDEP Estimation Results                       Run log line   26  Page   2 |
| Current sample contains       36 observations.                          |
+=========================================================================+


+-------------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                                |
| Ordinary    least squares regression    Weighting variable = none       |
| Dep. var. = PTW       Mean=   5.251003166     , S.D.=    3.789667555    |
| Model size: Observations =       36, Parameters =  13, Deg.Fr.=      23 |
| Residuals:  Sum of squares= 71.63835640     , Std.Dev.=         1.76485 |
| Fit:        R-squared=  .857480, Adjusted R-squared =             .78312 |
| Model test: F[ 12,      23] =    11.53,    Prob value =           .00000 |
| Diagnostic: Log-L =    -63.4678, Restricted(b=0) Log-L =       -98.5367 |
|             LogAmemiyaPrCrt.=    1.444, Akaike Info. Crt.=        4.248 |
| Estd. Autocorrelation of e(i,t)      .078555                            |
+-------------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR          48.83598940       14.201114     3.439   .0018  .23342584E-01
 FNR          .5325127143       1.2916666      .412   .6832    6.2222222
 PTK          .8104839677       1.2480874      .649   .5212    .77777778
 PPPINC     .7477836093E-03  .35075071E-03    2.132   .0416    22377.198
 LDEN         63.48416527       21.015779     3.021   .0052    8.5890823
 ENAF      -.1446249479E-01     .15382968     -.094   .9257    6.3602747
 MR           3.671698860       1.0671190     3.441   .0018    .36111111
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=========================================================================+
```

```
| LIMDEP Estimation Results                        Run log line   26  Page   3 |
| Current sample contains      36 observations.                              |
+============================================================================+


       Estimated Fixed Effects
       Group      Coefficient       Standard Error       t-ratio
           1        -606.17311           193.71986       -3.12912
           2        -535.60936           172.20272       -3.11034
           3        -543.83416           175.70195       -3.09521
           4        -597.72770           193.49945       -3.08904
           5        -524.63695           168.60001       -3.11173
           6        -570.44273           182.70637       -3.12218

+------------------------------------------------------------------------+
|                Test Statistics for the Classical Model                 |
|                                                                        |
|         Model                Log-Likelihood    Sum of Squares   R-squared |
| (1)  Constant term only         -98.53673   .5026553063D+03    .0000000 |
| (2)  Group effects only         -94.89866   .4106698958D+03    .1829990 |
| (3)  X - variables only         -79.98003   .1792849951D+03    .6433242 |
| (4)  X and group effects        -63.46780   .7163835640D+02    .8574802 |
|                                                                        |
|                             Hypothesis Tests                           |
|              Likelihood Ratio Test               F Tests               |
|           Chi-squared   d.f.  Prob.          F    num. denom. Prob value |
| (2) vs (1)      7.276     5    .20090     1.344    5    30     .27311 |
| (3) vs (1)     37.113     7    .00000     7.215    7    28     .00006 |
| (4) vs (1)     70.138    12    .00000    11.532   12    23     .00000 |
| (4) vs (2)     62.862     7    .00000    15.550    7    23     .00000 |
| (4) vs (3)     33.024     5    .00000     6.912    5    23     .00045 |
+------------------------------------------------------------------------+
+============================================================================+
| LIMDEP Estimation Results                        Run log line   26  Page   4 |
| Current sample contains      36 observations.                              |
+============================================================================+


            +--------------------------------------------------+
            | Random Effects Model: v(i,t) = e(i,t) + u(i)     |
            | Estimates:  Var[e]              =   .311471D+01  |
            |             Var[u]              =   .328832D+01  |
            |             Corr[v(i,t),v(i,s)] =   .513557      |
            | Lagrange Multiplier Test vs. Model (3) =     .45 |
            | ( 1 df, prob value =  .501433)                   |
            | (High values of LM favor FEM/REM over CR model.) |
            | Fixed vs. Random Effects (Hausman)      =    .00 |
            | ( 7 df, prob value = 1.000000)                   |
            | (High (low) values of H favor FEM (REM).)        |
            | Reestimated using GLS coefficients:              |
            | Estimates:  Var[e]              =   .467155D+01  |
            |             Var[u]              =   .192863D+02  |
            |             Sum of Squares          .227835D+03  |
            +--------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR         35.68732032      12.864023     2.774   .0055  .23342584E-01
```

```
 FNR        -.1064195682       1.1049438    -.096   .9233     6.2222222
 PTK         2.287296379       1.1475421    1.993   .0462     .77777778
 PPPINC   .5368468478E-03  .27624271E-03    1.943   .0520     22377.198
 LDEN        .4521527085       2.0119132     .225   .8222     8.5890823
 ENAF       -.3868566945       .11020175   -3.510   .0004     6.3602747
 MR          3.674039782       1.0035476    3.661   .0003     .36111111
 Constant   -11.46179986       17.457680    -.657   .5115
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

f. Estimation report for recyclable plastics model (*PLW*)

```
+=======================================================================+
| LIMDEP Estimation Results                    Run log line   63  Page   1 |
| Current sample contains      36 observations.                          |
+=======================================================================+



+-------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                 |
| Ordinary    least squares regression   Weighting variable = none  |
| Dep. var. = PLW      Mean=   9.443412126    , S.D.=   7.180708038 |
| Model size: Observations =      36, Parameters =   8, Deg.Fr.=  28 |
| Residuals:  Sum of squares= 710.8930820    , Std.Dev.=      5.03875 |
| Fit:        R-squared=  .606086, Adjusted R-squared =        .50761 |
| Model test: F[  7,     28] =    6.15,   Prob value =         .00020 |
| Diagnostic: Log-L =   -104.7758, Restricted(b=0) Log-L =  -121.5450 |
|             LogAmemiyaPrCrt.=    3.435, Akaike Info. Crt.=     6.265 |
| Panel Data Analysis of PLW        [ONE way]                       |
|           Unconditional ANOVA (No regressors)                     |
| Source      Variation       Deg. Free.     Mean Square            |
| Between      432.751               5.        86.5503              |
| Residual     1371.94              30.        45.7313              |
| Total        1804.69              35.        51.5626              |
+-------------------------------------------------------------------+


+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR        .1530131989       1.4134764     .108   .9146    -4.3235659
 LFNR        30.80883217       15.022009    2.051   .0497     1.8252327
 PLK         7.829999149       3.1523461    2.484   .0192     .77777778
 LPINC       3.765776721       12.322594     .306   .7622     10.003885
 LDEN        .9399180658       2.4712040     .380   .7066     8.5890823
 LENAF      -4.505391110       1.4636318   -3.078   .0046     1.6298306
 MR          3.520249224       2.3590704    1.492   .1468     .36111111
 Constant   -91.89192035       133.80530    -.687   .4979

+=======================================================================+
| LIMDEP Estimation Results                    Run log line   63  Page   2 |
| Current sample contains      36 observations.                          |
+=======================================================================+



+-------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                          |
| Ordinary    least squares regression   Weighting variable = none  |
| Dep. var. = PLW      Mean=   9.443412126    , S.D.=   7.180708038 |
```

```
| Model size: Observations =       36, Parameters =  13, Deg.Fr.=      23 |
| Residuals:  Sum of squares= 321.6650840     , Std.Dev.=          3.73971 |
| Fit:        R-squared=  .821762, Adjusted R-squared =             .72877 |
| Model test: F[ 12,      23] =    8.84,     Prob value =           .00001 |
| Diagnostic: Log-L =    -90.5016, Restricted(b=0) Log-L =      -121.5450 |
|             LogAmemiyaPrCrt.=     2.946, Akaike Info. Crt.=       5.750 |
| Estd. Autocorrelation of e(i,t)      .043500                             |
+--------------------------------------------------------------------------+

+--------+-------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+-------------+----------------+--------+--------+----------+
 LPNR          .4859789809       1.3970534      .348   .7305   -4.3235659
 LFNR       -13.20623249        15.790065     -.836   .4098    1.8252327
 PLK          4.548867924        2.6837483     1.695   .1008     .77777778
 LPINC   -.6443330451E-01       16.461152     -.004   .9969   10.003885
 LDEN        90.41759825        43.084743     2.099   .0447    8.5890823
 LENAF       -5.326887697        1.8136448    -2.937   .0064    1.6298306
 MR           4.476253999        2.2811377     1.962   .0594     .36111111
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=================================================================================+
| LIMDEP Estimation Results                          Run log line   63   Page    3 |
| Current sample contains       36 observations.                                 |
+=================================================================================+

          Estimated Fixed Effects
          Group        Coefficient          Standard Error        t-ratio
              1          -791.29488              405.99550        -1.94902
              2          -698.90986              365.71176        -1.91109
              3          -721.42973              370.71975        -1.94602
              4          -784.57791              404.78746        -1.93825
              5          -676.06111              357.49790        -1.89109
              6          -748.42507              384.97653        -1.94408

+----------------------------------------------------------------------------+
|                 Test Statistics for the Classical Model                    |
|                                                                            |
|        Model                 Log-Likelihood    Sum of Squares    R-squared  |
| (1)  Constant term only       -121.54504     .1804689877D+04    .0000000  |
| (2)  Group effects only       -116.61008     .1371938399D+04    .2397927  |
| (3)  X - variables only       -104.77584     .7108930820D+03    .6060857  |
| (4)  X and group effects       -90.50164     .3216650840D+03    .8217616  |
|                                                                            |
|                                   Hypothesis Tests                         |
|                 Likelihood Ratio Test                  F Tests              |
|            Chi-squared   d.f.   Prob.           F     num.  denom. Prob value |
| (2) vs (1)      9.870     5     .07901      1.893     5     30      .12525 |
| (3) vs (1)     33.538     7     .00002      6.154     7     28      .00020 |
| (4) vs (1)     62.087    12     .00000      8.837    12     23      .00001 |
| (4) vs (2)     52.217     7     .00000     10.728     7     23      .00001 |
| (4) vs (3)     28.548     5     .00003      5.566     5     23      .00167 |
+----------------------------------------------------------------------------+
+=================================================================================+
| LIMDEP Estimation Results                          Run log line   63   Page    4 |
| Current sample contains       36 observations.                                 |
+=================================================================================+
```

```
+--------------------------------------------------------+
| Random Effects Model: v(i,t) = e(i,t) + u(i)           |
| Estimates:  Var[e]              =   .139854D+02        |
|             Var[u]              =   .114036D+02        |
|             Corr[v(i,t),v(i,s)] =   .449154            |
| Lagrange Multiplier Test vs. Model (3) =       .35     |
| ( 1 df, prob value =  .552499)                         |
| (High values of LM favor FEM/REM over CR model.)       |
| Fixed vs. Random Effects (Hausman)     =       .00     |
| ( 7 df, prob value = 1.000000)                         |
| (High (low) values of H favor FEM (REM).)              |
| Reestimated using GLS coefficients:                    |
| Estimates:  Var[e]              =   .178691D+02        |
|             Var[u]              =   .796021D+02        |
|             Sum of Squares          .906471D+03        |
+--------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 LPNR        .5356301551       1.2828370      .418   .6763    -4.3235659
 LFNR       4.123429200       13.879753       .297   .7664     1.8252327
 PLK        7.191218809       2.4485256      2.937   .0033     .77777778
 LPINC       .8806255027      12.672693       .069   .9446     10.003885
 LDEN       1.592605206       3.9177555       .407   .6844     8.5890823
 LENAF     -6.131796992       1.3165319     -4.658   .0000     1.6298306
 MR         4.651430721       2.1117579      2.203   .0276     .36111111
 Constant  -15.53473000       124.82148      -.124   .9010
```

g. Estimation report for non-recyclables model (*NRW*)

```
+=============================================================================+
| LIMDEP Estimation Results                          Run log line    9 Page   1 |
| Current sample contains        36 observations.                             |
+=============================================================================+


+-----------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                     |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = NRW       Mean=    928.3611111    , S.D.=    224.5779728  |
| Model size: Observations =        36, Parameters =   8, Deg.Fr.=    28 |
| Residuals:  Sum of squares= 697735.2438     , Std.Dev.=      157.85790 |
| Fit:        R-squared=  .604735, Adjusted R-squared =          .50592 |
| Model test: F[  7,      28] =     6.12,     Prob value =          .00021 |
| Diagnostic: Log-L =   -228.7792, Restricted(b=0) Log-L =    -245.4867 |
|             LogAmemiyaPrCrt.=    10.324, Akaike Info. Crt.=      13.154 |
| Panel Data Analysis of NRW          [ONE way]                         |
|           Unconditional ANOVA (No regressors)                         |
| Source       Variation          Deg. Free.       Mean Square          |
| Between        469119.                 5.           93823.8           |
| Residual      .129612E+07             30.           43203.8           |
| Total         .176523E+07             35.           50435.3           |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
```

```
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR       -2003.721167      950.31445     -2.108   .0441  .23342584E-01
 FNR        141.8977771      71.670554      1.980   .0576    6.2222222
 KR         7.069400642      98.610297       .072   .9434    .77777778
 PPPINC   .3159139562E-02  .17216508E-01     .183   .8557    22377.198
 LDEN       27.09711700      76.480891       .354   .7258    8.5890823
 ENAF       17.93092647      8.1357956      2.204   .0359    6.3602747
 MR        -326.0787158      74.276046     -4.390   .0001    .36111111
 Constant  -213.0118139      814.62754      -.261   .7956
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
| LIMDEP Estimation Results                     Run log line    9  Page    2 |
| Current sample contains      36 observations.                          |
+=======================================================================+


+-----------------------------------------------------------------+
| Least Squares with Group Dummy Variables                        |
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = NRW      Mean=   928.3611111    , S.D.=   224.5779728 |
| Model size: Observations =       36, Parameters =  13, Deg.Fr.=     23 |
| Residuals:  Sum of squares= 278823.5472    , Std.Dev.=       110.10342 |
| Fit:        R-squared=  .842047, Adjusted R-squared =          .75964 |
| Model test: F[ 12,      23] =   10.22,     Prob value =          .00000 |
| Diagnostic: Log-L =   -212.2685, Restricted(b=0) Log-L =    -245.4867 |
|             LogAmemiyaPrCrt.=    9.711, Akaike Info. Crt.=     12.515 |
| Estd. Autocorrelation of e(i,t)    -.258087                     |
+-----------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR       -4248.551378      885.96047     -4.795   .0000  .23342584E-01
 FNR        68.63807531      80.582801       .852   .4013    6.2222222
 KR         117.1774166      77.864039      1.505   .1432    .77777778
 PPPINC   .2643342435E-01  .21882174E-01    1.208   .2368    22377.198
 LDEN      -6852.379284      1311.1048     -5.226   .0000    8.5890823
 ENAF      -14.13840229      9.5969241     -1.473   .1515    6.3602747
 MR        -218.7878518      66.574016     -3.286   .0027    .36111111
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=======================================================================+
| LIMDEP Estimation Results                     Run log line    9  Page    3 |
| Current sample contains      36 observations.                          |
+=======================================================================+

         Estimated Fixed Effects
         Group       Coefficient        Standard Error       t-ratio
             1       63204.00532          12085.54011        5.22972
             2       55985.88117          10743.15677        5.21131
             3       57241.00060          10961.46227        5.22202
             4       62965.01470          12071.78928        5.21588
             5       54846.93468          10518.39586        5.21438
             6       59411.49232          11398.44493        5.21225

+------------------------------------------------------------------+
```

```
|                 Test Statistics for the Classical Model                |
|                                                                        |
|       Model                Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only       -245.48674    .1765234306D+07     .0000000 |
| (2)  Group effects only       -239.92632    .1296115167D+07     .2657546 |
| (3)  X - variables only       -228.77916    .6977352438D+06     .6047351 |
| (4)  X and group effects      -212.26847    .2788235472D+06     .8420473 |
|                                                                        |
|                              Hypothesis Tests                          |
|                 Likelihood Ratio Test              F Tests            |
|            Chi-squared   d.f.   Prob.          F    num.  denom.  Prob value |
| (2) vs (1)     11.121      5     .04904      2.172    5     30      .08387 |
| (3) vs (1)     33.415      7     .00002      6.120    7     28      .00021 |
| (4) vs (1)     66.437     12     .00000     10.218   12     23      .00000 |
| (4) vs (2)     55.316      7     .00000     11.988    7     23      .00000 |
| (4) vs (3)     33.021      5     .00000      6.911    5     23      .00045 |
+------------------------------------------------------------------------+

+==========================================================================+
| LIMDEP Estimation Results                      Run log line     9  Page    4 |
| Current sample contains       36 observations.                           |
+==========================================================================+


            +-------------------------------------------------+
            | Random Effects Model: v(i,t) = e(i,t) + u(i)    |
            | Estimates:  Var[e]              =   .121228D+05 |
            |             Var[u]              =   .127964D+05 |
            |             Corr[v(i,t),v(i,s)] =   .513516     |
            | Lagrange Multiplier Test vs. Model (3) =    1.07 |
            | ( 1 df, prob value =  .301408)                  |
            | (High values of LM favor FEM/REM over CR model.) |
            | Fixed vs. Random Effects (Hausman)    =      .00 |
            | ( 7 df, prob value = 1.000000)                  |
            | (High (low) values of H favor FEM (REM).)       |
            | Reestimated using GLS coefficients:             |
            | Estimates:  Var[e]              =   .266441D+05 |
            |             Var[u]              =   .171123D+05 |
            |             Sum of Squares          .742132D+06 |
            +-------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 PNR        -2851.625729       802.53764    -3.553   .0004  .23342584E-01
 FNR         144.4877656       68.932687     2.096   .0361     6.2222222
 KR         -4.697436477       71.591130     -.066   .9477     .77777778
 PPPINC    .1131154702E-01  .17233487E-01     .656   .5116     22377.198
 LDEN       -13.58218601       125.50910     -.108   .9138     8.5890823
 ENAF        17.26789837       6.8750463     2.512   .0120     6.3602747
 MR         -286.2614053       62.607602    -4.572   .0000     .36111111
 Constant   -43.37461807       1089.0675     -.040   .9682
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

h. Estimation report for total waste generation model (*TOW*)

```
+==========================================================================+
| LIMDEP Estimation Results                      Run log line    84  Page    1 |
```

```
| Current sample contains       36 observations.                      |
+=====================================================================+



+-----------------------------------------------------------------+
| OLS Without Group Dummy Variables                               |
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = TOW       Mean=   1027.738040     , S.D.=    189.9931266 |
| Model size: Observations =       36, Parameters =   8, Deg.Fr.=     28 |
| Residuals:  Sum of squares= 575400.4910     , Std.Dev.=       143.35277 |
| Fit:        R-squared=  .544565, Adjusted R-squared =          .43071 |
| Model test: F[  7,      28] =     4.78,     Prob value =          .00123 |
| Diagnostic: Log-L =   -225.3092, Restricted(b=0) Log-L =     -239.4663 |
|             LogAmemiyaPrCrt.=    10.131, Akaike Info. Crt.=     12.962 |
| Panel Data Analysis of TOW          [ONE way]                   |
|           Unconditional ANOVA (No regressors)                   |
| Source      Variation        Deg. Free.      Mean Square        |
| Between       440422.                5.          88084.4        |
| Residual      822986.               30.          27432.9        |
| Total       .126341E+07             35.          36097.4        |
+-----------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR         -1148.657978       862.99269   -1.331   .1939  .23342584E-01
 FNR          121.3151490       65.084946    1.864   .0728    6.2222222
 KR           90.80299015       89.549271    1.014   .3193    .77777778
 PPPINC    .1207202183E-02  .15634531E-01     .077   .9390    22377.198
 LDEN        -7.791638516       69.453274    -.112   .9115    8.5890823
 ENAF         12.99800759       7.3882199    1.759   .0895    6.3602747
 MR          -284.0842072       67.451026   -4.212   .0002    .36111111
 Constant     288.9006078       739.77367     .391   .6991
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+=====================================================================+
| LIMDEP Estimation Results                     Run log line   84  Page    2 |
| Current sample contains       36 observations.                      |
+=====================================================================+



+-----------------------------------------------------------------+
| Least Squares with Group Dummy Variables                        |
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = TOW       Mean=   1027.738040     , S.D.=    189.9931266 |
| Model size: Observations =       36, Parameters =  13, Deg.Fr.=     23 |
| Residuals:  Sum of squares= 280466.4868     , Std.Dev.=       110.42733 |
| Fit:        R-squared=  .778008, Adjusted R-squared =          .66219 |
| Model test: F[ 12,      23] =     6.72,     Prob value =          .00005 |
| Diagnostic: Log-L =   -212.3742, Restricted(b=0) Log-L =     -239.4663 |
|             LogAmemiyaPrCrt.=     9.717, Akaike Info. Crt.=     12.521 |
| Estd. Autocorrelation of e(i,t)     -.310768                    |
+-----------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 PNR         -3458.450425       888.56686   -3.892   .0005  .23342584E-01
```

```
FNR          10.17951125      80.819866      .126    .9006      6.2222222
KR          136.3961660       78.093105     1.747    .0913      .77777778
PPPINC   .3825794746E-01  .21946549E-01    1.743    .0919      22377.198
LDEN      -5104.718365       1314.9619    -3.882    .0006      8.5890823
ENAF      -11.78728968       9.6251570    -1.225    .2306      6.3602747
MR        -161.4468957       66.769869    -2.418    .0221      .36111111
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+====================================================================+
| LIMDEP Estimation Results                 Run log line   84  Page   3 |
| Current sample contains        36 observations.                      |
+====================================================================+

      Estimated Fixed Effects
      Group       Coefficient        Standard Error        t-ratio
          1       47150.27941          12121.09423         3.88994
          2       41820.83021          10774.76176         3.88137
          3       42851.20479          10993.70949         3.89779
          4       47059.51374          12107.30294         3.88687
          5       41145.21355          10549.33963         3.90026
          6       44339.27668          11431.97770         3.87853

+-----------------------------------------------------------------+
|                Test Statistics for the Classical Model          |
|                                                                 |
|        Model              Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only     -239.46628   .1263408585D+07    .0000000 |
| (2)  Group effects only     -231.75096   .8229864749D+06    .3485983 |
| (3)  X - variables only     -225.30923   .5754004910D+06    .5445650 |
| (4)  X and group effects    -212.37422   .2804664868D+06    .7780081 |
|                                                                 |
|                            Hypothesis Tests                     |
|              Likelihood Ratio Test              F Tests         |
|           Chi-squared   d.f.  Prob.         F     num.  denom.  Prob value |
| (2) vs (1)    15.431      5    .00867     3.211    5     30      .01937 |
| (3) vs (1)    28.314      7    .00019     4.783    7     28      .00123 |
| (4) vs (1)    54.184     12    .00000     6.717   12     23      .00005 |
| (4) vs (2)    38.753      7    .00000     6.356    7     23      .00032 |
| (4) vs (3)    25.870      5    .00009     4.837    5     23      .00362 |
+-----------------------------------------------------------------+
+====================================================================+
| LIMDEP Estimation Results                 Run log line   84  Page   4 |
| Current sample contains        36 observations.                      |
+====================================================================+


          +----------------------------------------------+
          | Random Effects Model: v(i,t) = e(i,t) + u(i)  |
          | Estimates:  Var[e]              =  .121942D+05 |
          |             Var[u]              =  .835582D+04 |
          |             Corr[v(i,t),v(i,s)] =  .406609     |
          | Lagrange Multiplier Test vs. Model (3) =   .45 |
          | ( 1 df, prob value =  .503845)                 |
          | (High values of LM favor FEM/REM over CR model.) |
          | Fixed vs. Random Effects (Hausman)    =    .00 |
          | ( 7 df, prob value = 1.000000)                 |
          | (High (low) values of H favor FEM (REM).)      |
          | Reestimated using GLS coefficients:            |
```

```
          | Estimates:  Var[e]             =   .203033D+05  |
          |             Var[u]             =   .232377D+05  |
          |             Sum of Squares         .626705D+06  |
          +-------------------------------------------------+

+--------+----------------+------------------+----------+----------+------------+
|Variable | Coefficient   | Standard Error |b/St.Er. |P[|Z|>z] | Mean of X|
+--------+----------------+------------------+----------+----------+------------+
 PNR        -2081.443868       787.74192    -2.642    .0082  .23342584E-01
 FNR         98.44379561       66.150187     1.488    .1367     6.2222222
 KR          67.98010068       71.237426      .954    .3399     .77777778
 PPPINC    .1519375651E-01  .16297076E-01    .932    .3512     22377.198
 LDEN       -56.42229765       108.29660     -.521    .6024     8.5890823
 ENAF        11.98328502       6.6929477     1.790    .0734     6.3602747
 MR         -231.4165536       61.622119    -3.755    .0002     .36111111
 Constant    562.8838971       955.62795      .589    .5558
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

Appendix 8 Unit-pricing in Taipei City

Taipei City Council announced ‘Autonomous Ordinance for Taipei City Waste Collection and Treatment Fee’ on 28th April, 2000. That authorises the city government to sell specific garbage bag for collecting waste collection and treatment costs by Article 2, named ‘Per Bag Garbage Collection Fee Policy’, and the price should be calculated by following equation by Article 7.

$$\begin{array}{c}\text{unit-price}\\ \text{(per litre)}\end{array} = \frac{\begin{array}{c}\text{total cost of waste collection}\\ \text{and treatment (NTD)}\end{array} \times \begin{array}{c}\text{weight per litre}\\ \text{(kg/litre)}\end{array}}{\begin{array}{c}\text{total waste treatment capacity}\\ \text{of incinerators (ton)}\end{array} \times \begin{array}{c}1000\\ \text{(kg/ton)}\end{array}}$$

and total waste treatment capacity of incinerators (ton) =
total incinerators designed capacity (ton/day) × 365 × 85%

In the “Statement of Price Calculation for Per Bag Garbage Collection Fee’ announced by Taipei City government, the total cost of waste collection and treatment includes labour, management and operation costs of residential garbage collection and treatment, but excludes land use and external costs. According to the equation above, the unit-price is 0.5 NTD/litre. Unit-pricing started to apply and the garbage collection fee on the basis of each household’s bi-monthly consumption of tap water was terminated on July 2000. The city government provided a simulation for a·household. The average garbage fee collected from water consumption bill per household is 144 NTD per month, and the household’s payment for waste collection under unit-pricing will be 140 NTD when it has 3 people in house and each of them generates 0.75 kg waste per day in house. Therefore, a household’s payment will not be increased subjected to the unit-pricing scheme even when it doesn’t reduce waste, but unit-pricing provides an incentive of waste reduction.

After one year adoption, Taipei City government reduced garbage bag price by 10% to 0.45 NTD/litre and 0.144 USD/10l on July 2001 (Statement of Per Bag Garbage Collection Fee Reduction, Taipei City government). The reason for reduction is that recycling increased dramatically after unit-pricing adopted which increases the revenue from selling recycling materials.

Appendix 9 Limdep Estimation Reports for Models in Chapter 6

Two policy variables, whether adopting mandatory recycling (*MR*) and unit-pricing (*NRU*), are tested to explain each three inspection variables: inspection labours (*ENAP*, A9-1), prosecuted fine (*ENAF*, A9-2), and inspection times (*ENAT*, A9-3). The estimation reports are shown below.

A9-1. Estimation report for the regression of inspection labours

Based on the LM test result, OLS estimates are chosen. Inspection labour (*ENAP*) is significantly increased by adopting unit-pricing (*NRU*).

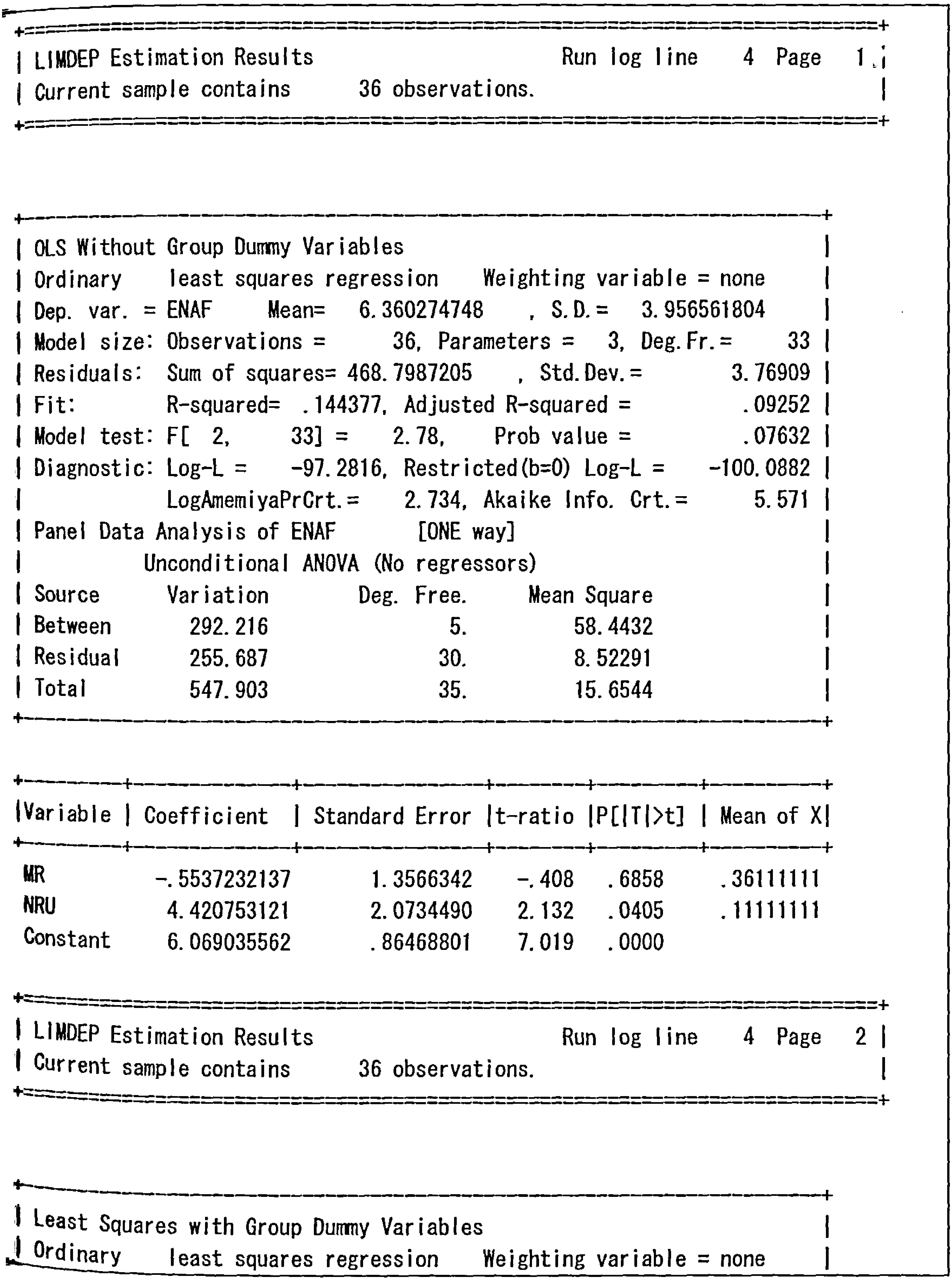
```
+=====================================================================+
| LIMDEP Estimation Results                   Run log line    7  Page    1 |
| Current sample contains      36 observations.                        |
+=====================================================================+



+----------------------------------------------------------------+
| OLS Without Group Dummy Variables                              |
| Ordinary    least squares regression    Weighting variable = none    |
| Dep. var. = ENAP     Mean=   4.055579294    , S.D.=    2.590485542   |
| Model size: Observations =       36, Parameters =    3, Deg.Fr.=      33 |
| Residuals:  Sum of squares= 172.1286464     , Std.Dev.=        2.28386 |
| Fit:        R-squared=  .267137, Adjusted R-squared =          .22272 |
| Model test: F[  2,      33] =     6.01,     Prob value =         .00593 |
| Diagnostic: Log-L =     -79.2468, Restricted(b=0) Log-L =      -84.8411 |
|             LogAmemiyaPrCrt.=     1.732, Akaike Info. Crt.=      4.569 |
| Panel Data Analysis of ENAP        [ONE way]                   |
|           Unconditional ANOVA (No regressors)                  |
| Source      Variation        Deg. Free.      Mean Square       |
| Between       43.5451                5.          8.70902       |
| Residual     191.326                30.          6.37755       |
| Total        234.872                35.          6.71062       |
+----------------------------------------------------------------+


+--------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+---------+----------+
 MR           .6309006906       .82204600      .767   .4483      .36111111
 NRU         4.352929204       1.2563965     3.465   .0015      .11111111
 Constant    3.344095244        .52395357    6.382   .0000

+=====================================================================+
```

```
| LIMDEP Estimation Results                    Run log line    7  Page    2 |
| Current sample contains       36 observations.                            |
+===========================================================================+



+-----------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                              |
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = ENAP     Mean=   4.055579294     , S.D.=   2.590485542    |
| Model size: Observations =       36, Parameters =    8, Deg.Fr.=    28 |
| Residuals:  Sum of squares= 155.3116513     , Std.Dev.=        2.35517 |
| Fit:        R-squared=  .338738, Adjusted R-squared =          .17342 |
| Model test: F[  7,      28] =     2.05,     Prob value =          .08375 |
| Diagnostic: Log-L =    -77.3963, Restricted(b=0) Log-L =    -84.8411 |
|             LogAmemiyaPrCrt.=     1.914, Akaike Info. Crt.=      4.744 |
| Estd. Autocorrelation of e(i,t)     -.350019                          |
+-----------------------------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 MR             1.015496915       1.2029144      .844   .4045      .36111111
 NRU            4.903702210       2.0396405     2.404   .0218      .11111111

+===========================================================================+
| LIMDEP Estimation Results                    Run log line    7  Page    3 |
| Current sample contains       36 observations.                            |
+===========================================================================+

        Estimated Fixed Effects
        Group        Coefficient        Standard Error        t-ratio
            1            2.79332               1.66536        1.67731
            2            4.02434                .96150        4.18550
            3            2.43510                .98218        2.47929
            4            4.20015               1.13412        3.70345
            5            3.00972               1.13412        2.65379
            6            2.40146               1.53996        1.55943

+-------------------------------------------------------------------------+
|                 Test Statistics for the Classical Model                 |
|                                                                         |
|        Model                Log-Likelihood    Sum of Squares   R-squared |
| (1)  Constant term only         -84.84114   .2348715370D+03    .0000000 |
| (2)  Group effects only         -81.15011   .1913264421D+03    .1853996 |
| (3)  X - variables only         -79.24680   .1721286464D+03    .2671371 |
| (4)  X and group effects        -77.39625   .1553116513D+03    .3387379 |
|                                                                         |
|                                 Hypothesis Tests                        |
|                  Likelihood Ratio Test                  F Tests         |
```

```
|          Chi-squared  d.f.  Prob.         F     num.  denom. Prob value |
| (2) vs (1)     7.382     5     .19374     1.366    5     30     .26500 |
| (3) vs (1)    11.189     2     .00372     6.014    2     33     .00593 |
| (4) vs (1)    14.890     7     .03744     2.049    7     28     .08375 |
| (4) vs (2)     7.508     2     .02343     3.246    2     28     .05395 |
| (4) vs (3)     3.701     5     .59320      .606    5     28     .69560 |
+-----------------------------------------------------------------------+

+=========================================================================+
| LIMDEP Estimation Results                      Run log line    7  Page   4 |
| Current sample contains       36 observations.                          |
+=========================================================================+


          +----------------------------------------------------+
          | Random Effects Model: v(i,t) = e(i,t) + u(i)        |
          | Estimates:  Var[e]              =   .431421D+01    |
          |             Var[u]              =   .467139D+00    |
          |             Corr[v(i,t),v(i,s)] =   .097700        |
          | Lagrange Multiplier Test vs. Model (3) =      .72 |
          | ( 1 df, prob value =  .395670)                     |
          | (High values of LM favor FEM/REM over CR model.)   |
          | Fixed vs. Random Effects (Hausman)     =      .20 |
          | ( 2 df, prob value =  .904543)                     |
          | (High (low) values of H favor FEM (REM).)          |
          | Reestimated using GLS coefficients:                |
          | Estimates:  Var[e]              =   .556524D+01    |
          |             Var[u]              =  -.149419D-01    |
          |             Sum of Squares          .172254D+03    |
          +----------------------------------------------------+

+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 MR          .7387700296       .83027749      .890   .3736      .36111111
 NRU        4.496063302       1.2973442      3.466   .0005      .11111111
 Constant   3.289238639        .57134844     5.757   .0000
```

A9-2. Estimation report for the regression of prosecuted fine

Based on the LM test and Hausman test results, FEM estimates are chosen for *ENAF* model. Both whether adopting mandatory recycling (*MR*) and unit-pricing (*NRU*) are insignificant to prosecuted fine (*ENAF*).



```
+=====================================================================+
| LIMDEP Estimation Results                  Run log line     4  Page   1 |
| Current sample contains       36 observations.                       |
+=====================================================================+


+------------------------------------------------------------------+
| OLS Without Group Dummy Variables                                 |
| Ordinary    least squares regression    Weighting variable = none |
| Dep. var. = ENAF     Mean=   6.360274748    , S.D.=   3.956561804 |
| Model size: Observations =       36, Parameters =   3, Deg.Fr.=     33 |
| Residuals:  Sum of squares= 468.7987205     , Std.Dev.=       3.76909 |
| Fit:        R-squared=  .144377, Adjusted R-squared =          .09252 |
| Model test: F[  2,     33] =     2.78,    Prob value =          .07632 |
| Diagnostic: Log-L =     -97.2816, Restricted(b=0) Log-L =    -100.0882 |
|             LogAmemiyaPrCrt.=    2.734, Akaike Info. Crt.=      5.571 |
| Panel Data Analysis of ENAF        [ONE way]                       |
|           Unconditional ANOVA (No regressors)                     |
| Source      Variation       Deg. Free.     Mean Square            |
| Between       292.216               5.        58.4432              |
| Residual      255.687              30.        8.52291              |
| Total         547.903              35.        15.6544              |
+------------------------------------------------------------------+

+--------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+---------+----------+
MR          -.5537232137       1.3566342    -.408   .6858     .36111111
NRU         4.420753121        2.0734490    2.132   .0405     .11111111
Constant    6.069035562        .86468801    7.019   .0000

+=====================================================================+
| LIMDEP Estimation Results                  Run log line     4  Page   2 |
| Current sample contains       36 observations.                       |
+=====================================================================+


+------------------------------------------------------------------+
| Least Squares with Group Dummy Variables                          |
| Ordinary    least squares regression    Weighting variable = none |
```

```
| Dep. var. = ENAF     Mean=   6.360274748    , S.D.=    3.956561804      |
| Model size: Observations =       36, Parameters =   8, Deg.Fr.=     28 |
| Residuals:  Sum of squares= 232.4926194    , Std.Dev.=         2.88155 |
| Fit:        R-squared=  .575669, Adjusted R-squared =          .46959 |
| Model test: F[  7,      28] =    5.43,     Prob value =         .00052 |
| Diagnostic: Log-L =    -84.6579, Restricted(b=0) Log-L =    -100.0882 |
|             LogAmemiyaPrCrt.=    2.317, Akaike Info. Crt.=      5.148 |
| Estd. Autocorrelation of e(i,t)      .027006                          |
+-----------------------------------------------------------------------+


+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 MR         -1.580853251       1.4717610   -1.074   .2903      .36111111
 NRU        -3.195499151       2.4954921   -1.281   .2090      .11111111


+=============================================================================+
| LIMDEP Estimation Results                          Run log line    4  Page   3 |
| Current sample contains      36 observations.                              |
+=============================================================================+


        Estimated Fixed Effects
        Group        Coefficient       Standard Error       t-ratio
            1          13.68529             2.03756         6.71651
            2           5.36424             1.17639         4.55993
            3           2.13609             1.20169         1.77757
            4           7.77325             1.38759         5.60198
            5           7.25183             1.38759         5.22621
            6           7.50647             1.88414         3.98404


+-----------------------------------------------------------------------+
|                 Test Statistics for the Classical Model               |
|                                                                       |
|         Model              Log-Likelihood    Sum of Squares    R-squared |
| (1)  Constant term only       -100.08823   .5479033458D+03     .0000000 |
| (2)  Group effects only        -86.36965   .2556874443D+03     .5333348 |
| (3)  X - variables only        -97.28157   .4687987205D+03     .1443770 |
| (4)  X and group effects       -84.65790   .2324926194D+03     .5756686 |
|                                                                       |
|                                 Hypothesis Tests                      |
|                 Likelihood Ratio Test                  F Tests        |
|             Chi-squared   d.f.   Prob.          F     num.  denom.  Prob value |
| (2) vs (1)     27.437      5      .00005      6.857    5     30      .00023 |
| (3) vs (1)      5.613      2      .06041      2.784    2     33      .07632 |
| (4) vs (1)     30.861      7      .00007      5.427    7     28      .00052 |
| (4) vs (2)      3.424      2      .18055      1.397    2     28      .26412 |
| (4) vs (3)     25.247      5      .00012      5.692    5     28      .00096 |
+-----------------------------------------------------------------------+
+=============================================================================+
```

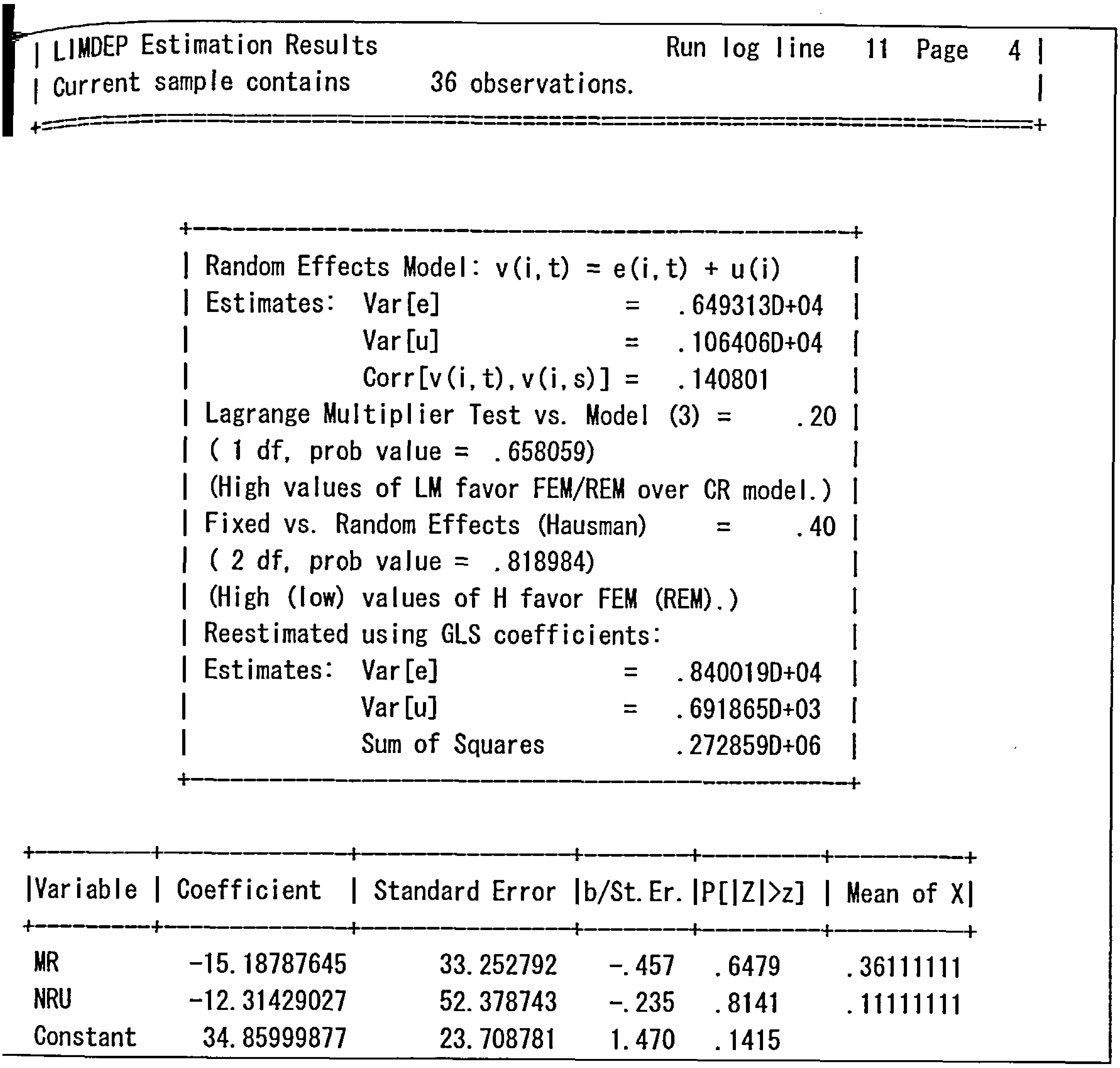
```
| LIMDEP Estimation Results                    Run log line    4  Page    4 |
| Current sample contains      36 observations.                            |
+==========================================================================+


           +-----------------------------------------------------+
           | Random Effects Model: v(i,t) = e(i,t) + u(i)         |
           | Estimates:  Var[e]              =   .830331D+01      |
           |             Var[u]              =   .590271D+01      |
           |             Corr[v(i,t),v(i,s)] =   .415508          |
           | Lagrange Multiplier Test vs. Model (3) =    3.48     |
           | ( 1 df, prob value =  .062231)                       |
           | (High values of LM favor FEM/REM over CR model.)     |
           | Fixed vs. Random Effects (Hausman)     =    6.42     |
           | ( 2 df, prob value =  .040369)                       |
           | (High (low) values of H favor FEM (REM).)            |
           | Reestimated using GLS coefficients:                  |
           | Estimates:  Var[e]              =   .867164D+01      |
           |             Var[u]              =   .154121D+02      |
           |             Sum of Squares          .546238D+03      |
           +-----------------------------------------------------+

+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 MR         -1.518232378      1.3377482     -1.135   .2564     .36111111
 NRU        -.4163370304      2.1849274      -.191   .8489     .11111111
 Constant    6.954784999      1.2365983      5.624   .0000
```

A9-3. Estimation report for the regression of inspection times

Based on the LM test result, OLS estimates are chosen for *ENAT* model. Both whether adopting mandatory recycling (*MR*) and unit-pricing (*NRU*) are insignificant to inspection times (*ENAT*).

```
+=================================================================+
| LIMDEP Estimation Results                  Run log line  11  Page  1 |
| Current sample contains     36 observations.                      |
+=================================================================+



+-------------------------------------------------------------+
| OLS Without Group Dummy Variables                           |
| Ordinary   least squares regression   Weighting variable = none    |
| Dep. var. = ENAT    Mean=   28.00723336    , S.D.=   89.00141452   |
| Model size: Observations =       36, Parameters =   3, Deg.Fr.=    33 |
| Residuals:  Sum of squares= 272058.7746    , Std.Dev.=      90.79761 |
| Fit:        R-squared= .018702, Adjusted R-squared =        -.04077 |
| Model test: F[  2,     33] =     .31,    Prob value =        .73234 |
| Diagnostic: Log-L =   -211.8264, Restricted(b=0) Log-L =   -212.1662 |
|             LogAmemiyaPrCrt.=    9.097, Akaike Info. Crt.=    11.935 |
| Panel Data Analysis of ENAT        [ONE way]                 |
|           Unconditional ANOVA (No regressors)               |
| Source      Variation       Deg. Free.     Mean Square      |
| Between       43464.0             5.          8692.80       |
| Residual      233780.            30.          7792.66       |
| Total         277244.            35.          7921.25       |
+-------------------------------------------------------------+


+--------+--------------+----------------+--------+--------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 MR        -24.78844195      32.681419     -.758   .4535     .36111111
 NRU       -21.22139312      49.949543     -.425   .6737     .11111111
 Constant   39.31654774      20.830399     1.887   .0679


+=================================================================+
| LIMDEP Estimation Results                  Run log line  11  Page  2 |
| Current sample contains     36 observations.                      |
+=================================================================+



+-------------------------------------------------------------+
| Least Squares with Group Dummy Variables                    |
| Ordinary   least squares regression   Weighting variable = none    |
```

```
| Dep. var. = ENAT     Mean=    28.00723336     , S.D.=    89.00141452     |
| Model size: Observations =        36, Parameters =    8, Deg.Fr.=     28 |
| Residuals:  Sum of squares= 233752.6826     , Std.Dev.=        91.36909 |
| Fit:        R-squared=  .156870, Adjusted R-squared =            -.05391 |
| Model test: F[  7,      28] =     .74,    Prob value =            .63706 |
| Diagnostic: Log-L =    -209.0948, Restricted(b=0) Log-L =     -212.1662 |
|             LogAmemiyaPrCrt.=     9.230, Akaike Info. Crt.=       12.061 |
| Estd. Autocorrelation of e(i,t)     .000492                               |
+-------------------------------------------------------------------------+


+---------+---------------+-----------------+--------+---------+---------+
|Variable | Coefficient   | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+---------------+-----------------+--------+---------+---------+
 MR          2.554289168       46.667119      .055    .9567      .36111111
 NRU         1.264867196       79.127951      .016    .9873      .11111111


+=============================================================================+
| LIMDEP Estimation Results                        Run log line    11  Page    3 |
| Current sample contains       36 observations.                              |
+=============================================================================+


          Estimated Fixed Effects
          Group         Coefficient          Standard Error          t-ratio
              1            16.83029                64.60770           .26050
              2           103.61975                37.30127          2.77791
              3             1.44468                38.10354           .03791
              4            24.68076                43.99818           .56095
              5             3.45654                43.99818           .07856
              6            11.63384                59.74282           .19473


+--------------------------------------------------------------------------+
|                  Test Statistics for the Classical Model                  |
|                                                                           |
|          Model                Log-Likelihood    Sum of Squares   R-squared |
| (1)  Constant term only        -212.16619    .2772438125D+06    .0000000 |
| (2)  Group effects only        -209.09688    .2337798260D+06    .1567717 |
| (3)  X - variables only        -211.82637    .2720587746D+06    .0187021 |
| (4)  X and group effects       -209.09479    .2337526826D+06    .1568696 |
|                                                                           |
|                                Hypothesis Tests                           |
|                 Likelihood Ratio Test                  F Tests            |
|             Chi-squared   d.f.   Prob.          F     num.  denom.  Prob value |
| (2) vs (1)      6.139      5     .29296       1.116    5     30      .37321 |
| (3) vs (1)       .680      2     .71189        .314    2     33      .73234 |
| (4) vs (1)      6.143      7     .52318        .744    7     28      .63706 |
| (4) vs (2)       .004      2     .99791        .002    2     28      .99838 |
| (4) vs (3)      5.463      5     .36200        .918    5     28      .48399 |
+--------------------------------------------------------------------------+
+=============================================================================+
```



```
| LIMDEP Estimation Results                        Run log line   11  Page    4 |
| Current sample contains       36 observations.                              |
+=============================================================================+


              +--------------------------------------------------+
              | Random Effects Model: v(i,t) = e(i,t) + u(i)     |
              | Estimates:  Var[e]              =  .649313D+04   |
              |             Var[u]              =  .106406D+04   |
              |             Corr[v(i,t),v(i,s)] =  .140801       |
              | Lagrange Multiplier Test vs. Model (3) =     .20 |
              | ( 1 df, prob value =  .658059)                   |
              | (High values of LM favor FEM/REM over CR model.) |
              | Fixed vs. Random Effects (Hausman)     =     .40 |
              | ( 2 df, prob value =  .818984)                   |
              | (High (low) values of H favor FEM (REM).)        |
              | Reestimated using GLS coefficients:              |
              | Estimates:  Var[e]              =  .840019D+04   |
              |             Var[u]              =  .691865D+03   |
              |             Sum of Squares         .272859D+06   |
              +--------------------------------------------------+

+--------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+--------+--------------+----------------+--------+---------+----------+
 MR          -15.18787645       33.252792    -.457   .6479     .36111111
 NRU         -12.31429027       52.378743    -.235   .8141     .11111111
 Constant     34.85999877       23.708781    1.470   .1415
```