Waste Management Policies and Implications: Case Study of Taipei and Kaohsiung, Taiwan

by

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Abstract

This paper examines two waste management schemes, per-bag charge and mandatory recycling, implemented in two different cities, Taipei and Kaohsiung, respectively, of Taiwan, to assess their impacts on household waste reduction efforts. In addition, we also include a national-wide plastic bag regulation introduced in 2003,which bans retail stores offering free plastic bags, in our estimations. Our analyses suggest that with the presence of the per-bag policy, households tend to reduce their waste generation, and meanwhile increase the recycling volume; specifically, waste reduction is about 26.4% and recycling increases 68%. Mandatory recycling, on the other hand, has induced recycling by 38.6%, while it is not significant in reducing mixed waste generation. Moreover, plastic bag regulation has negative effects on both waste generation and recycling.

Chapter 1. Introduction

Garbage collection has often been considered a “free service” until recently. However, the tipping fee paid by garbage collectors to landfills as increased significantly in the past decade, due primarily to increased land prices (a result of compressed landfills) and environmental regulations. Many cities/communities have introduced a unit-pricing system in order to regulate waste disposal and to promote recycling. Waste collection charges are believed to serve as a positive incentive for consumers to reduce the waste they generate, as well as to demand less packaging on market goods and to recycle more (Choe and Fraser, 1999).[1] Notably, curbside recycling and/or drop-off recycling programs usually accompany such pricing programs; unlike regular waste collection, recycling services are generally free to customers. There have been a handful of studies on the impact of unit pricing and curbside recycling programs on garbage generation and recycling volumes. Most research on communities with different pricing systems have revealed a significant positive impact of unit pricing on recycling (Van Houtven and Morris, 1999; Hong, et al., 1993; Fullerton and Kinnamen, 1995, 2000). Evidence on the waste disposal effects of unit pricing is mixed, although some studies find an unambiguously negative

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[1] As argued in Choe and Fraser (1999), a first-best is not achievable when households engage in waste reduction efforts, and a second-best policy requires a strictly positive waste collection charge on

impact (Fullerton and Kinnamen, 1996).

In this paper, we study effects of a per-bag garbage pricing policy introduced in Taipei City, Taiwan, in July of 2000, and a mandatory recycling program introduced in Kaohsiung in January of 2001. An additional waste management policy was introduced nationwide in January of 2003: a requirement that retailers charge for all plastic bags. We are interested in the impact of these policies on both the garbage and recycling volumes generated in the provinces of Taiwan. Drawing on prior research, we construct empirical models that include as explanatory variables economic drivers of consumer waste generation and management decisions, including GDP, consumer expenditure, employment rates, and wages. Although unit pricing policies akin to that introduced in Taipei have been observed and studied in a number of communities in the U.S., mandatory recycling programs are rare and remain virtually unstudied in the literature.[2]

We first test for differences in means of waste and recycling volumes before and after introduction of the three waste management policies of interest in Taiwan. As expected, these tests reveal that after the per-bag and mandatory recycling policies were implemented, mean waste volume dropped significantly, while mean recycling volume

households.

[2] Notable exceptions are the work of Reschovsky and Stone (1994) and Jenkins, et al. (2003), which are

increased significantly, in the subject provinces. Tests results are reported in Table 1.[3] Specifically, after the introduction of the per-bag pricing policy in Taipei, general waste volumes declined by 35.1% and recycling volumes increased by 79%. Similarly, after the introduction of mandatory recycling in Kaohsiung, waste volumes fell by 23.2% and recycling increased by 88.5%. The results also suggest that after the plastic bag regulation was enacted, general waste dropped by 19.6% and recycling increased by 38.7% in the other provinces of Taiwan (other than Taipei and Kaohsiung). As the plastic bag regulation was implemented throughout Taiwan, we also test for effects of this policy in Taipei and Kaohsiung. In these cities, general waste fell by 38.6% and 20.7% after the regulation was introduced, and recycling rose by 16% and 14.2%.

While differences of means tests are clearly informative, they ignore other underlying forces driving waste and recycling decisions. In this paper, we therefore construct econometric models of waste and recycling generation that control for other relevant explanators of behavior. In doing so, we note that Taipei and Kaohsiung are located in the north and south of Taiwan, respectively, so that there is unlikely to be any cross-province impact of the policies under study. Moreover, an advantage of studying

discussed in the next section.

[3] Policy change points are defined as per-bag scheme implementation in Taipei, in July of 2000, mandatory recycling since January of 2001 in Kaohsiung, and plastic bag regulation beginning January of 2003 for Region 3.

Taiwan is that characteristics of households across the country are similar, permitting us to usefully exploit waste and recycling data for multiple regions – including those without any unit pricing or mandatory recycling programs – to understand the policies' impact on waste and recycling generation.

Chapter 2. Literature Review

There is a substantial theoretical literature on the economics of waste management and its regulation (see, for example, Fullerton and Kinnamen, 1995; Fullerton and Wu, 1998; Choe and Fraser, 1999). Arguably most relevant for our analysis is the household waste management model of Choe and Fraser (1999), who define the household utility function,

$$U = u(q) - v(e) - y \qquad (2.1)$$

where e is waste reduction effort, y the cost of waste disposal, and q the quantity of consumption on goods. Waste is generated according to the function $w(\alpha \cdot q, e)$, where α is the waste inherent in each unit of the consumption good[4]. If for each unit of waste there is a charge τ, then households face a disposal cost of $\tau \cdot w(\alpha \cdot q, e)$. Thus, households choose the quantity of consumption goods (q) and their waste reduction efforts (e) to maximize their utility, net of waste disposal costs, as follows:

$$\max\{u(q) - v(e) - \tau \cdot w(\alpha \cdot q, e)\} \qquad (2.2)$$

Choe and Fraser conclude that, in the presence of both household waste reduction efforts and the possibility of illegal disposal, a first-best optimum – requiring the legal disposal of all household wastes – cannot be achieved. The reason is that a positive

[4] Choe and Fraser also model producer packaging decisions in their characterization of market equilibrium. As our focus is on household decision making, we abstract from these decisions in our

waste charge (τ) is required to elicit optimal waste reduction efforts; however, such a charge also elicits some illegal disposal activity. In view of the infeasibility of a first-best, Choe and Fraser characterize a *second-best* optimum involving a positive waste collection charge on households as well as monitoring and fining illegal waste disposal activities.

Some positive predictions from this theory are clear; unit pricing of waste should spur reduced waste volumes, whether due to increased waste reduction efforts or increased demand for less waste-intensive products by households. Among "waste reduction efforts" are recycling activities; hence, unit pricing is expected to spur increased recycling.

A number of empirical studies have sought to test these predictions. Prior empirical research focuses principally on household-level data, rather than the community-level data available to us in this study. In this work, scholars study impacts of a number of socioeconomic variables, including income, education, race, house ownership, and age, on waste management decisions, mostly using Probit (Van Houtven and Morris, 1999[5]; Hong, et al., 1993; Jenkins, et al., 2003[6]; Reschovsky and

discussion here.

[5] For household-level recycling behavior.

[6] In this paper an ordered logit model was adopted, which was described as "virtually the same" as an ordered probit specification.

Stone, 1994) or Tobit (Van Houtven and Morris, 1999[7]) models to explain households recycling behavior, and some using OLS (Van Houtven and Morris, 1999; Fullerton and Kinnamen, 1996) or two stage estimations (Fullerton and Kinnamen, 2000[8]) to explain waste volumes. A summary of research conducted can be found in Table 2.

Income and education are found to be significant in most models, with higher incomes generally having a positive effect on garbage weight and a negative effect on recycling volumes, while higher education levels lead to reduced waste volumes (Van Houtven and Morris, 1999; Hong, et al., 1993; Fullerton and Kinnamen, 1996; Fullerton and Kinnamen, 2000). However, in Jenkins et al. (2003), higher incomes are found to have a positive effect on recycling[9]. Moreover, Hong et al. use two distinct regressors – "income" and "value of time"[10] – to explain recycling and waste disposal demand; they find that income has a significantly positive impact on waste volumes, and the "value of time" has a significant negative impact on recycling intensity.

Unit pricing of waste is found to have surprisingly little effect on household recycling behavior in some models (Fullerton and Kinnamen, 1996[11]; Fullerton and

[7] For mixed-waste and total waste (mixed-waste and recyclables) generation.
[8] They used a probit estimation to determine the probability of a curbside recycling program, and a tobit to determine a user-fee policy implementation, to deal with the endogeneity of policy choice. See discussion below.
[9] For specific material (newspaper) only.
[10] Value of time is measured primarily by the female wage in individual households.
[11] In the model the coefficient is only significant at a 10% level.

Kinnamen, 2000; Jenkins, et al., 2003), and significant effects in others (Van Houtven and Morris, 1999; Hong, et al., 1993; Fullerton and Kinnamen, 2000[12]).

Mandatory recycling, on the other hand, has rarely been implemented in the US, and been the object of almost no study. A notable exception is Reschovsky and Stone (1994), who note that the paucity of mandatory recycling policies may be due to the "excessive" burden such requirements place on households. In Reschovsky and Stone's study area, mandatory recycling was implemented for some households, but generally in conjunction with other policy measures, including curbside recycling and unit pricing (trash tags). Indeed, only 11 households in their sample (out of 1363, less than one percent) were subject only to mandatory recycling. As a result, Reschovsky and Stone were unable to identify any distinct (and significant) effects of mandatory recycling policies on waste-management decisions. Jenkins, et al. (2003) also consider impacts of mandatory recycling (MR) programs. However, in their cross-jurisdiction study, the authors note that the meaning and enforcement of mandatory recycling policies in unclear (p. 311, note 16) and likely to be heterogeneous.[13] Perhaps as a result, these authors also find that MR policies (in conjunction with curbside recycling)

[12] In the endogenous model, the effect of user fee is not significant, but in the OLS model, on the contrary, the estimate is significant.

[13] Mandatory recycling enforcement may, in some cases, be either non-existent or focus on the proper separation of recyclables, rather than assuring that ordinary garbage does not contain recyclable material, as in the case of Kaohsiung's policy.

have a statistically insignificant effect on recycling behavior.

In studying the effects of waste management policies (such as unit pricing) on waste management behavior, two issues arise. First, the policies may be endogenous. For example, more environmentally conscious communities – who tend to recycle more and produce less garbage – may be more apt to adopt unit pricing and curbside recycling programs. Alternately, such pro-environment policies may be spurred by waste management “crises,” the main symptom of which is a “large” amount of community waste. If the former source of endogeneity prevails, then estimated (negative) effects of unit pricing on waste volumes may be due to correlation, rather than causation. Conversely, if the latter source of endogeneity prevails, then estimated causal effects of unit pricing will be understated when endogeneity is not explicitly accounted for. To our knowledge, Fullerton and Kinnamen (2000) are the only scholars who, using a two stage estimation procedure, account for joint endogeneity of waste management policies in their cross-jurisdiction study of household garbage; in doing so, they find evidence that the source of endogeneity in their sample is of the second type, suggesting that estimates of unit pricing effects on waste volumes tend to understate true causal effects when endogeneity is not taken into account.

With regard to the present study, data limitations prevent us from explicitly accounting for endogeneity of policy decisions. However, we infer the effects of unit pricing and other policies from time series data in three regions of Taiwan from 1997 to 2004. In the case of Taipei, for example, we study effects of a unit pricing (per bag) policy on waste management behavior over this interval. Arguably, during this short time horizon, the "environmental consciousness" of the Taipei community is unlikely to change so appreciably as to explain the timing of the unit pricing policy. However, conceivably, the acuteness of the "garbage problem" in Taipei may have some impact on policy timing. In sum, our inability to account for endogeneity of unit pricing, mandatory recycling and plastic bag policies is likely to imply that our estimates understate causal effects, if there is any bias at all.

The second issue that arises in empirical work on waste management is the potential impact of unit pricing policies on illegal dumping. Theory predicts that pricing of garbage will lead households both to reduce gross waste volumes and to increase illegal dumping. Estimated reductions in legal waste may thus be attributable to either or both of these effects. From a social welfare point of view, this confusion is potentially important. Whereas reductions in gross waste volumes, legally disposed, is likely a salutary (cost-saving) policy impact, increases in illegal waste volumes are likely to be quite costly to society. Indeed, Fullerton and Kinnamen (1995) show that when illegal dumping is possible, the optimal disposal charge may shrink to zero or even be negative. The only extant empirical study that addresses this issue (to our knowledge) is Fullerton and Kinnamen (1996). These authors attempt to measure the extent of illegal dumping caused by unit pricing in Charlottesville, VA. However, as the authors note, their measure of "dumping" includes garbage taken to worksites or otherwise legally disposed, just not presented for charge by the households themselves. Such "dumping" is found to account for roughly 28 to 43 percent of the garbage reduction attributable to unit pricing.

In our study, we cannot explicitly account for illegal dumping. Hence, our estimated effects of unit pricing incorporate illegal dumping effects. However, government records suggest that illegal dumping is not a serious problem in Taipei and can account for only a tiny portion of our estimated impacts of unit pricing. Specifically, government sources reveal that, on average, there were 423 bags found illegally disposed per month in 2002, 376 bags in 2003, and 352 bags in 2004. These quantities represent less than one-fiftieth of one percent of household garbage generated in these years, and less than one-tenth of one percent of the estimated garbage reduction attributable to unit pricing (based on our analysis).[14] Of course, illegal

[14] These calculations are likely to overstate the illegal dumping volumes, based as they are on the assumption that each "illegal bag" contains 30 kg. of waste. Effects of unit pricing are gauges from our

disposal might also take the form of illegal burning. However, our inquiries with city officials indicate that (1) the likelihood of undetected illegal burning in the densely populated city of Taipei is small, and (2) there have been no official reports of illegal burning activity in recent years in either Taipei or Kaohsiung.

Differences in estimated policy impacts across different studies may be due to different impacts of policy endogeneity, illegal dumping effects, and other demographic and geographic characteristics of the different communities studied. Ultimately, the objectives of empirical work on waste management policies are two-fold: (1) to identify and quantify policy impacts, and (2) to evaluate the implications of alternative policies for economic efficiency. For example, Palmer, et al. (1997) evaluate the relative cost-benefit efficiency of advanced disposal fees, material-specific recycling subsidies, and deposit-refund schemes for the achievement of target waste reduction. Our purpose in this paper is to further the first objective, shedding added light on the impacts of unit pricing policies, and new light on the impacts of mandatory recycling and plastic bag regulations.

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estimates in Table 11.

Chapter 3. Background

Taipei is the largest city in Taiwan, inhabited by approximately 2.6 million people. Kaohsiung is the second largest city, inhabited by a population of 1.5 million, and its per capita waste volume is slightly smaller than that of Taipei. From 1997 to June 2004, the average per capita waste volume was 30 kg in Taipei, while in Kaohsiung it was 28 kg. Other jurisdictions are also used in this research; because these jurisdictions have similar demographic and socio-economic characteristics – and are subject to common waste management policies – we treat them as a single unit in our analysis.

3.1. Waste Collection Service

Waste collection services are provided by local environmental agencies[15]. In the early 1990's, all regions in Taiwan adopted a curbside waste collection system, under which residents would set out their wastes at specific dumping sites and the agencies would pick them up at night. This traditional collection method generated some hygienic problems and complaints from residents near the dumping sites. As a result, starting with Taipei in 1994, many cities have adopted a different system for waste collection which requires households to bring their setouts to designated locations at

[15] There were other private collectors, but these were used mostly by industrial clients rather than by households.

specific times, where they wait for employees of the environmental agency to collect the garbage. This method is cumbersome, but succeeded in reducing litter and improving hygiene. In addition, garbage cans on the curbsides are all locked to avoid illegal littering or dumping.

3.2 Waste Management Policies

3.2.1 National

Waste management has been a serious issue for Taiwan since the early 1990's. Facing limited landfills and large volumes of waste (8.38 million-tons/year), the Environmental Protection Bureau of Taiwan proposed several possible solutions to the nation's waste problem. Officials turned to incineration instead of traditional tipping systems and, in 1991, started to charge a waste fee proportional to water usage[16]. Officials use the following formula to determine the fee to be collected for household waste:

$$\mathit{Waste\,Management\,Cost} \times \mathit{household\ water\ usage} \times \left[\frac{\left(\dfrac{\mathit{size\ of\ tap\ water\ client\ household}}{\mathit{total\ populations}} \right)}{\mathit{total\ water\ usage}} \right]$$

These policies, however, did not achieve garbage reduction targets, in part because

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[16] It is believed that the government chose water usage as the basis for waste charges because the water utility is the most highly subscribed.

garbage and water usage were not clearly related. In addition, finding proper sites to build incinerators was problematic for the rather small island[17].

In the late 1990's (1997), officials began to promote recycling as a means to achieve waste reduction. Most cities set up recycling sites for residents to dispose recyclable materials, and required small cash rebates for containers such as plastic bottles, iron and aluminum cans in retail outlets (convenience stores, supermarkets, etc.).[18] In January 2003, the central government introduced a plastic bag regulation, prohibiting stores from offering free plastic bags and banning the use of polyester dishes by restaurants and street vendors[19]. In view of the limited impact of the central government's waste management policies, local jurisdictions adopted other regulations on their own in the hope of addressing local waste problems.

3.2.2 Local

In July 2000, the Taipei City government introduced a user fee policy which required households to purchase official garbage bags (with official stamps) for their general waste setouts. Various sizes of official bags, with different prices, are available in all convenience stores and most supermarkets. The pricing scale is approximately

[17] The area of Taiwan is about 36185 km^2.

[18] Deposit/refund schemes were in place in Taiwan from 1998 through 2002.

linear in volume, as shown in the following chart.

Size (Liter)	5	14	33	45	76	92
Price/units[20]	$2/30	$6/30	$10/20	$13/20	$11/10	$13/10

In Kaohsiung City, officials decided to implement a mandatory recycling policy which required households to separate recyclables from general wastes in January 2001. If a household mixes recyclables in its general waste setouts, it is subject to fines ranging from $35 to $135.

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[19] A similar policy can be found in Ireland, which taxes plastic bags in retail outlets.
[20] Prices are computed using a 1:35 exchange rate; "units" indicate the total number of official bags in a package.

Chapter 4. Data

We have monthly aggregate waste and recycling volume data from Taipei, Kaohsiung, and five other local jurisdictions in Taiwan,[21] running from January 1997 to June 2004. The latter jurisdictions lacked both the unit pricing (Taipei) and the mandatory recycling (Kaohsiung) policies of interest in this paper. We treat the five other jurisdictions as one composite "region" in our analysais, which we denote "Region 3." Region-level data is obtained by taking population-weighted averages of the five jurisdictions per-capita data.

Tables 3 and 4 describe both our endogenous (waste and recycling volume) data and our explanatory variables. Unfortunately, little economic data is available at a region-level. For example, GDP and household consumption expenditure (both per capita) are available at a national level and approximately capture income effects as they vary over time. Similarly, wage rates are at a national level, capturing opportunity costs of time required in waste reduction and recycling effort. However, employment rates are available at a region-level; in an attempt to capture expected wages at a region level, we include the interaction variable ERW (employment rate times wage) as an explanatory variable. Other regressors include dummy variables for quarters, the

[21] Chiayi, Hsinchu, Keelong, Taichung and Tainan.

Chinese New Year, and the occurrence of a typhoon.

We have three policy regressors. First, for Taipei, we have the per-bag policy dummy (*bag*) that takes a value of one after the introduction of unit pricing in July, 2000. Second, for Kaohsiung, we have the mandatory recycling dummy (*MR*) that takes a value of one after the introduction of this policy in January, 2001. And third, the plastic policy dummy (*plastic*) takes a value of one after the nationwide policy charging for plastic bags was introduced in January 2003.

In principle, the effect of government waste management policies may depend upon household income. For example, as incomes rise, mandatory recycling may cause households to substitute more in favor of non-recyclables in view of the higher time costs of obligatory recycling. To account for such effects, we considered interactions between all of our policy dummies and GDP per capita. In doing so we only found statistically (and quantitatively) significant effects for the GDP_MR interaction and, hence, present results with only this interaction variable included.[22]

Our endogenous variables are recycling volume, waste volume, and total garbage volume (the sum of waste and recycling), all measured per capita.

Graphs 1, 2 and 3 indicate general trends for these variables. The charts reveal that

[22] Similar logic suggests that we consider an interaction between our policy variables and our expected wage measure ERW. We performed estimations with these alternative interactions and found no

waste volume dropped after the per-bag policy was introduced in Taipei, while recycling increased. Recycling in Kaohsiung increased after mandatory recycling was implemented, but its waste volume did not change noticably. Interestingly, there appears to have been a systematic drop in recycling after the implementation of the plastic bag regulation in all three jurisdictions, contradicting our earlier mean difference tests (which suggest that recycling rose after the plastic bag policy was implemented). This contradiction reveals a limitation of mean difference tests that fail to account for time trends and other explanatory phenomena.

There are clearly some anomalies in general waste and total garbage streams. Sharp hikes in these flows are likely to have been caused by severe tropical hurricanes attacking the island[23]; especially for the case of Taipei, the peak in waste volumes may have been exaggerated by the government's provision of free waste collection services immediately following the typhoon.

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significant effects.

[23] Note that cities in the northern part of Taiwan are more prone to be effected/damaged by extreme weather conditions due to the nature of their geography.

Chapter 5. Models and Results

We consider (and present) two linear models, one pooled and the other disaggregated by region.

5.1 Pooled Model

First we estimate the parameters using a fixed-effect pooled model, combining our three regions, Taipei, Kaohsiung and "Region 3." In doing so, we allow for region-specific variances (group-wise heteroskedasticity) and serial autocorrelation as revealed by a standard Durbin Watson Test (and a stepwise test for higher order autocorrelation). We find evidence for first-order (and not higher order) autocorrelation, and accordingly estimate by feasible generalized least squares (FGLS) to account for both serial correlation and heteroskedasticity.

FGLS estimations are presented in Table 5[24]. For our dependant variables *waste* and *sum* (total garbage), the coefficients on *MR* and *bag* are significant and have the expected negative signs. Similarly, for recycling, the coefficient on *MR* is significantly positive, as expected, and the coefficient on bag is positive, but insignificant. The FGLS results suggest that mandatory recycling was effective at raising recycling, while

[24] In the pooled model, the GDP interaction terms were found to have statistically insignificant coefficients; hence, these variables are excluded from the reported model.

the unit pricing policy was relatively more effective at reducing waste volumes. Coefficients on our third policy variable, *plastic* (for charges on plastic bags), are statistically insignificant in all three equations.[25]

Coefficients on our "expected wage" variable ERW are positive and statistically significant in all equations; it is expected that higher wages may spur more consumption, less waste reduction effort (due to its higher time costs), and hence, more garbage, as indicated by our estimates. For recycling, higher wages may have competing effects, raising recycling by increasing consumption (and perhaps increasing environmental consciousness as well), but lowering recycling by raising its cost in time; our estimates suggest that the former effect dominates.

Extreme weather significantly affects both waste and total garbage generation, as expected. However, the New Years holiday (NY) has a significantly negative effect on waste and recycling flows in our model, contrary to initial expectations; this seemingly paradoxical result may be due to lags in the New years' garbage set-outs that are captured by the seasonal dummy, and/or to a high propensity for travel during this holiday.

[25] This variable was only used for region 3 to avoid over-lapping effects with policies in Taipei and Kaohsiung.

5.2 Seemingly Unrelated Regressions

We next consider jurisdiction-specific waste, recycling, and total garbage equations, estimated by seemingly unrelated regressions to allow for cross-jurisdiction covariances.[26] In doing so, we test and correct for serial autocorrelation using Prais-Winston transformations.[27] Testing the SUR jurisdiction-specific equation models against pooled fixed effects counterparts leads to rejection of the pooled models in all three cases.[28] We first report SUR estimations that exclude GDP interactions with our policy variables; see Tables 6, 7 and 8. Next we report SUR estimates that include the GDP interaction with the mandatory recycling policy, GDP_MR; see Tables 9, 10, and 11.[29]

In all three jurisdictions, our estimated waste and total garbage models are qualitatively similar. Coefficients on Taipei's *bag* (unit pricing) policy are significantly negative in waste and total garbage models, and significantly positive in the recycling equation, all as predicted by economic theory. Coefficients on the *plastic* policy variable are significantly negative in both recycling and total garbage equations (for

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[26]Breusch-Pagan tests for diagonality yield the LM statistics, 9.584 for waste, 19.213 for recycling, and 11.769 for total garbage models, respectively. All lead us to reject the null that the diagonal elements are zero.

[27] A Durbin-Watson test was used to detect the presence of autocorrelation and a standard stepwise method was used to determine the degree of autocorrelation. For waste and total garbage generation, AR(1) appeared in Taipei and Kaohsiung data. For recycling, on the other hand, AR(1) occurred in Kaohsiung and region 3, but not in Taipei.

[28]The test statistics are 2.48 for the waste model, 9.54 for recycling, and 2.88 for the total garbage model.

[29]GDP was made to interact with all policy dummies; however, GDP_bag and GDP_plastic were dropped

Region 3); these effects reflect consumer demand for less packaging and bulk, in both recyclable and non-recyclable form, when costs of carrying goods – with plastic bags that are more costly under the *plastic* policy – rise.

For our three dependant variables, income and expenditure indexes, and other controlled dummies all performed somewhat better in our SUR models than in our pooled counterparts. Coefficients on *ERW* are significantly positive in all models. Some variables have different effects in Taipei and Kaohsiung. *GPD* has a negative effect on waste/total garbage volume in Taipei, and a positive effect in Kaohsiung. *Food*, on the other hand, has a negative effect on recycling volume in Taipei but a positive impact in Kaohsiung. Other variables have qualitatively similar effects across the jurisdictions.

As in the pooled models, extreme weather is found to increase trash flows, perhaps due in part to the government's offer of free waste disposal when typhoons strike. Also as before, the New Year holiday is found to have a negative impact on trash and recycling flows.

5.3 Seemingly unrelated regressions: joint estimation of waste and recycling

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because they had no statistically significant effects in any equation.

To allow for cross-equation *and* cross-jurisdiction covariances (for efficiency in estimation), we also estimated our jurisdiction-specific waste and recycling equations jointly, using SUR modified to account for serial correlation as before. Results from these joint estimations, with and without the GDP_MR interaction, are shown in Tables 12 and 13.[30] Qualitative results from these estimations are similar to those reported above, although estimated standard errors are generally smaller due to the improved efficiency in estimation.

5.4 Marginal Effects

Because the models estimated here are all linear, the estimated parameters also represent marginal impacts of regressors on our dependant variables. The following is a detailed discussion of marginal effects in the different estimations.

5.4.1 Pooled models

A. Income Proxies

In the pooled models for all three of our dependant variables, only the income proxy *ERW* is statistically significant. It is interesting that *ERW* had a positive impact

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[30]Because total garbage is the sum of waste and recycling volumes, all three equations could not be estimated jointly.

on both waste generation and recycling. In prticular, per capita waste and recycling volumes rose by approximately 10% and 35.2% per unit increase of *ERW*, respectively.

B. Expenditure

Only in the recycling model does an expenditure variable (*Food*) have a significant effect, perhaps because food products are packed with recyclables, such as paper, polystyrene, or plastic. Every additional dollar of spending on food leads to an estimated 0.054kg increase in recycling, approximately a 4% increase in the average recycling quantity.

C. Policies

The implementation of the per-bag policy led to an estimated decline in waste generation of 27.6% for Taipei city. Similarly, implementation of the mandatory recycling program is estimated to have reduced Kaohsiung's waste volumes by 8%. Among the three policies of interest in this paper, only mandatory recycling is estimated to have a significant impact on recycling, leading to an estimated 26.9% expansion in average recycling weight. The plastic bag regulation has no significant effects in our pooled estimations.

5.4.2 SUR models

A. Income Proxies

As in the pooled models, *ERW* is significant and positive in virtually all equations (the only exception being the waste model for Region 3). In Taipei, a unit rise in *ERW* is estimated to increase waste by approximately 20.3% and recycling by approximately 24%. Similarly, in Kaohsiung, a unit rise in *ERW* raised waste by an estimated 8.2% and recycling by 36.4%. Notably, in Region 3, even though its coefficient was not significant in the waste equation, *ERW* raised recycling by 43.1%, and total garbage by 10.9%.

GDP, on the other hand, behaved quite differently across regions and models. For Taipei and Kaohsiung, *GDP* had opposite impacts on waste flows: for every dollar increase in per capita *GDP*, waste in Taipei would drops by approximately 0.33%; in Kaohsiung, however, each dollar increase in *GDP* leads to a 0.2% increase in waste volume. A dollar rise in *GDP* also reduces recycling volumes in Kaohsiung by an estimated 0.5%. *GDP* was not significant in Region 3, or in the recycling equation for Taipei.

B. Expenditures

An increase in expenditures on *Drink* has a positive impact on both waste and recycling in Kaohsiung, but a negative impact on recycling in Region 3. In Kaohsiung, higher *Food* expenditures are estimated to increase recycling (as in the polled model), but they decrease recycling in Taipei. *Food* was not significant in the waste equations in the SUR estimations.

C. Controller

As in the pooled model, typhoons have the expected positive effect on waste volumes in the SUR analysis, while the Chinese New Year has negative effects that are statistically significant for Kaohsiung.

D. Policies

The per-bag policy effectively depressed waste generation and promoted recycling in our estimated models. Waste volumes are estimated to drop by 26.2%, and recycling to rise by 67.7% as a result of the policy. The mandatory recycling policy has no appreciable effect in any equation in this specification. However, the plastic bag regulation is estimated to inhibit waste generation by 11.9% and recycling activity by 47.5% for Region 3.

5.4.3 SUR models with interaction term GDP_MR

For this specification, most variables behaved similarly to the ones without the interaction term. However, in the recycling model, Kaohsiung's mandatory recycling program has a significant positive effect on household recycling volume, while the interaction term *GDP_MR* has a significant negative effect. Accounting for the GDP interaction, the estimated marginal effect of the MR policy (evaluated at mean GDP) is to raise recycling by 39.1%.

5.4.4 SUR: joint estimation of waste and recycling

Marginal effects of income proxies, expenditures and controllers are all similar to the original model. In the revised estimations, the per-bag policy depressed waste by an estimated 30.3% and increased recycling by 66.4%. Mandatory recycling leads to an estimated 36% increase in recycling when the GDP interaction is considered. The plastic bag regulation is not statistically significant in the waste equation; however, it leads to an estimated reduction in recycling of 40.2% and 45.4% in the alternative models.

Table 14 gives a summary of policy impacts on waste generation and recycling volumes, in percentage terms.

5.5 Material-specific recycling

As our regional recycling data is broken down by category of recyclable, we are able to explore the effect of our policy variables on specific classes of recyclables. Table 15 gives summary statistics for recycling by class and jurisdiction. The highest volume category is clearly paper, including newspaper. Metal and glass products are the two next largest categories. However, the “other” category includes particularly bulky products such as tires and clothing, and is responsible for a large share of Region 3’s recyclables, perhaps due to the region’s less urban (and hence, more automobile-intensive) character.

Tables 16-22 report SUR estimations of material-specific recycling. Particularly noticeable in these results is the consistent impact of mandatory recycling (*MR*) on recycling of all materials other than electronics, with significant positive coefficients on *MR* and significant negative coefficients on *GDP_MR* as in our prior SUR estimations.

The *plastic* bag policy has particularly strong negative effects on recycling of the bulky “other” recyclables, as well as metal products. However, this policy has a significant positive effect on the recycling of plastics, including the plastic bags made more valuable by the policy. The plastic policy also appears to have a positive effect on the recycling of containers, perhaps because the policy promotes the use of recyclable containers at public food establishments.

Interestingly, the per-bag (unit pricing) policy has rather uneven effects. While it has a significantly positive effect on recycling of plastics and the bulky "other" recyclables, the unit pricing policy has a significant negative effect on the recycling of metals.

Chapter 6. Conclusion

In all of our estimations, the per-bag (unit pricing) policy has a greater impact on households' waste generation than does either of the other policies investigated here. When garbage is prices, Taiwanese households engage in more waste reduction effort, whether in the form of recycling, commmposting, or demanding less bulky packaging. These conclusions conform with those of prior empirical work on unit-pricing policies in U.S. jurisdictions.

Unlike prior work, our study of Taiwanese waste management behavior permits us to evaluate effects of a mandatory recycling program implemented as a stand-alone policy. In theory, the effects of this policy on garbage generation are ambiguous. Our empirical results provide some evidence that, by raising the cost of garbage overall and by requiring that all recyclables be sorted, the MR policy leads to less net waste; however, these effects are not statistically significant in all models. We obtain stronger results on the impact of the MR policy on recycling itself. In all of our estimations, MR spurs higher recycling volumes, despite incentives that are created to substitute consumption away from recyclables. Our results also provide evidence that such substitution incentives are indeed created by the MR policy, with higher incomes creating higher costs of sorting recyclables and thereby leading to a reduced impact of the MR policy on recycling flows. These effects of the MR policy are not necessarily salutary. Unlike a user-fee program, mandatory recycling does not offer households an opportunity to choose between recycling or not, and thus as Reschovsky and Stone noted, this policy may elicit recycling that is “excessive” from a cost-benefit point of view

Taiwan also provides us a unique opportunity to study effects of a plastic bag regulation introduced in 2003. The regulation, similar to one in Ireland, requires consumer payment for all plastic bags used to carry retail products. In theory, such a regulation should spur consumer efforts to avoid products and packaging, both recyclables and non-recyclables, in order to reduce the cost of carrying bags. Our empirical results provide some support for these impacts.

Table 1: Test of Mean Differences: Before and After Policy Implementations

Waste

	Taipei Before	After		**Kaohsiung** Before	After		**Region 3** Before	After		**Taipei** Before	After		**Kaohsiung** Before	After
Mean	37.582	24.407	Mean	32.245	24.767	Mean	26.555	21.337	Mean	33.108	20.343	Mean	29.997	23.791
Variance	10.249	69.206	Variance	4.467	5.542	Variance	15.311	2.560	Variance	72.127	5.503	Variance	15.045	3.936
Observations	42	48	Observations	48	42	Observations	72	18	Observations	72	18	Observations	72	18
df	62		df	83		df	69		df	87		df	53	
t Stat	10.147		t Stat	15.764		t Stat	8.759		t Stat	11.164		t Stat	9.491	
P one-tail	0.000		P one-tail	0.000		P one-tail	0.000		P one-tail	0.000		P one-tail	0.000	

Recycling

	Taipei Before	After		**Kaohsiung** Before	After		**Region 3** Before	After		**Taipei** Before	After		**Kaohsiung** Before	After
Mean	0.776	1.389	Mean	1.081	2.038	Mean	1.324	1.836	Mean	1.069	1.240	Mean	1.485	1.696
Variance	0.040	0.050	Variance	0.512	0.181	Variance	0.656	0.096	Variance	0.158	0.048	Variance	0.695	0.116
Observations	42	48	Observations	48	42	Observations	72	18	Observations	72	18	Observations	72	18
df	88		df	78		df	73		df	48		df	69	
t Stat	-13.691		t Stat	-7.818		t Stat	-4.255		t Stat	-2.448		t Stat	-1.664	
P one-tail	0.000		P one-tail	0.000		P one-tail	0.000		P one-tail	0.009		P one-tail	0.050	

Total Garbage

	Taipei Before	After		**Kaohsiung** Before	After		**Region 3** Before	After		**Taipei** Before	After		**Kaohsiung** Before	After
Mean	38.358	25.796	Mean	33.326	26.805	Mean	27.879	23.173	Mean	34.177	21.583	Mean	31.482	25.487
Variance	10.384	69.810	Variance	4.284	6.952	Variance	12.685	3.297	Variance	68.366	6.089	Variance	11.861	4.666
Observations	42	48	Observations	48	42	Observations	72	18	Observations	72	18	Observations	72	18
df	62		df	77		df	54		df	85		df	41	
t Stat	9.630		t Stat	12.920		t Stat	7.851		t Stat	11.098		t Stat	9.208	
P one-tail	0.000		P one-tail	0.000		P one-tail	0.000		P one-tail	0.000		P one-tail	0.000	

Note: per-bag policy in July 2000

Note: mandatory recycling in January 2001

Note: plastic bag regulation in January 2003

Note: these two colums show tests results for difference of means before and after plastic regulation, for Taipei and Kaohsiung

Table 2: Literature Summary

Author(s)	Reschovsky and Stone [ix]	Hong, Adams and Love [iii]	Kinnaman & Fullerton [iv]	Kinnaman & Fullerton [v]	Jenkins, Martinez, Palmer and Podolsky [vii]	Van Houtven and Morris [ii]
Survey Place	Tompkins County, NY	Portland, OR	Charlottesville, VA	113 communities	20 MSA in US	Marietta, GA
Target Policy	various measurements*	block payment	per-bag	user fee	curbside recycling	block payment and per-bag
Survey Time	Sept 1990	1990	1991	1991	1992	1994
supplement policy	N/A	free curbside recycling	free curbside recycling	curbside recycling assessed	unit-price program assessed	fixed price curbside recycling
Sample	1422 households	4306 households	75 households, using May and September waste setout data, when the implemen-tation was July 1	cross community to assess endogeneity problem	1049 households, using data of 1992	400 households, before and (5 months) after

*Includin curbside recycling, trash tag(unit pricing), and mandatory recycling.

Table 3: Variables Summary

Dependent Variable		Description
Waste		general waste volume, per capita, kg/month
Recycling		recycling volume, per capita, kg/month
Sum		total garbage volume, per capita, kg/month

Source	Regressor	Description
national data*	GDP	Gross domestic income, per capita, thousand dollar/month
	PC	private consumption, per capita, thousand dollar/month
	wage	wage rate, per capita, thousand dollar/month
	RW	rent and water expenditure, per capita, thousand dollar/month
	Food	expenditure on food, per capita, thousand dollar/month
	Drink	expenditure on drink, per capita, thousand dollar/month
regional data	ERW	employment rate * wage rate
	ER	employment rate
	GDP_MR	interaction term: GDP * MR
policy dummy	bag	per-bag policy (=1 if there's such policy)
	MR	mandatory recycling policy (=1 if there's such policy)
	plastic	plastic bag ban (=1 for region 3 since Jan 2003)
other controller	NY	Chinese New Year month dummy
	typhoon	extreme weather (=1 if typhoon attacts)
	Si	seasonal dummies, i=2, 3, 4
	Di	regional dummies (for pooled models only, D1=1 if Taipei, D2=1 if Kaohsiung)

*These statistics are real, using the price of 1995 as base.

Table 4: Descriptive Statistics

Source	Variable	Mean	Std Dev	Min	Max
National Statistics	GDP	1.005	0.060	0.877	1.126
	PC	0.606	0.046	0.504	0.690
	wage	1.181	0.271	0.987	2.200
	RW	0.099	0.003	0.091	0.101
	food	0.129	0.008	0.113	0.140
	drink	0.017	0.002	0.014	0.019
Aggregate	waste	28.274	6.665	17.183	70.018
	recycling	1.353	0.682	0.178	3.029
	sum	29.627	6.400	18.295	71.193
	ERW	68.036	15.455	56.112	128.824
	ER	54.960	3.936	48.566	61.000
Taipei	population	2629125.14	16858.36	2590766	2646753
	waste	30.555	9.217	17.183	70.018
	recycling	1.103	0.374	0.223	1.912
	sum	31.658	9.020	18.295	71.193
	ERW	66.125	15.123	56.112	124.727
	ER	56.013	0.558	54.8	57.1
Kaohsiung	population	1476428.2	30266.14	1427000	1510873
	waste	28.756	4.357	19.833	36.696
	recycling	1.528	0.764	0.178	3.029
	sum	30.283	4.021	21.544	38.812
	ERW	69.614	15.562	58.447	127.878
	ER	59.023	1.384	55.4	61
	GDP_MR	0.486	0.524	0.000	1.126
Region 3	population	538266.09	16748.22	508891.6	562067.6
	waste	25.512	4.136	18.264	47.131
	recycling	1.428	0.763	0.376	2.978
	sum	26.938	3.786	20.122	48.372
	ERW	68.370	15.644	57.507	128.824
	ER	57.451	0.628	56.14	58.32

Note: sample size=90

Table 5: Pooled Model Results

Variable (standard error)	Waste	Recycling	Total Garbage
intercept	9.121 (21.524)	-7.859** (3.098)	-3.034 (22.672)
month	-0.133*** (0.044)	0.005 (0.005)	-0.131*** (0.045)
MR	-2.291** (0.961)	0.411** (0.162)	-2.255** (1.015)
bag	-8.433*** (1.770)	0.247 (0.200)	-8.767*** (1.832)
plastic	-0.582 (1.424)	-0.241 (0.223)	-0.618 (1.499)
ERW	0.041*** (0.012)	0.007*** (0.001)	0.049*** (0.012)
ER	0.150 (0.238)	0.043 (0.031)	0.182 (0.250)
PC	37.188 (53.395)	-6.524 (6.245)	38.991 (56.028)
GDP	16.522 (14.216)	-1.638 (1.995)	6.407 (14.978)
RW	-238.283 (325.011)	45.916 (34.368)	-204.755 (339.109)
Food	-95.529 (216.780)	53.809** (26.356)	30.595 (226.747)
Drink	500.523 (453.557)	61.713 (49.680)	527.334 (473.785)
typhoon	0.890** (0.364)	-0.013 (0.027)	0.876** (0.371)
NY	-1.515*** (0.541)	-0.147*** (0.039)	-1.686*** (0.549)
S2	3.237 (4.590)	-0.559 (0.523)	3.589 (4.812)
S3	-1.578 (2.805)	-0.111 (0.299)	-0.847 (2.930)
S4	0.621 (4.084)	-0.423 (0.480)	1.213 (4.287)
D1	8.641*** (2.015)	-0.792*** (0.273)	8.322*** (2.109)
D2	2.774 (2.410)	-0.746 (0.326)	2.530 (2.538)
rho	0.324 (0.058)	0.771 (0.039)	0.349 (0.057)

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level
rho= estimated serial correlation coefficient

Table 6: SUR Model Results, Waste

Variable (standard error)	Taipei	Kaohsiung	Region 3
intercept	104.252 (146.860)	-22.041 (19.388)	-5.437 (60.978)
month	-0.038 (0.166)	-0.183*** (0.041)	-0.051 (0.065)
bag	-8.006** (3.153)	--	--
MR	--	-1.296 (0.999)	--
plastic	--	--	-3.028* (1.725)
ERW	0.094** (0.045)	0.034*** (0.012)	0.034 (0.024)
ER	-0.382 (2.033)	0.315 (0.190)	0.591 (1.145)
PC	190.671 (183.153)	23.615 (44.567)	-102.466 (88.435)
GDP	-99.538** (47.647)	49.616*** (14.695)	23.074 (23.418)
RW	-285.267 (1230.655)	-271.645 (281.252)	393.401 (510.933)
Food	-410.707 (788.084)	-93.601 (189.634)	39.086 (404.952)
Drink	255.578 (1671.448)	861.065** (395.980)	93.992 (721.314)
typhoon	1.830 (1.333)	0.809** (0.388)	1.634** (0.764)
NY	-2.071 (1.989)	-1.368** (0.605)	-1.119 (1.222)
S2	13.366 (15.980)	2.442 (3.849)	-7.689 (7.612)
S3	4.948 (10.379)	-3.836 (2.524)	-3.521 (5.061)
S4	16.433 (13.880)	-2.152 (3.447)	-8.704 (6.782)
rho	0.279 (0.102)	0.106 (0.108)	DW=2.1987

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level
rho= estimated serial correlation coefficient
DW=Durbin-Watson statistics

Table 7: SUR Model Results, Recycling

Variable (standard error)	**Taipei**	**Kaohsiung**	**Region 3**
intercept	2.111 (4.130)	-17.148*** (3.409)	30.756*** (7.057)
month	-0.003 (0.005)	-0.001 (0.006)	0.038*** (0.007)
bag	0.747*** (0.083)	--	--
MR	--	0.054 (0.166)	--
plastic	--	--	-0.679*** (0.203)
ERW	0.004** (0.002)	0.008*** (0.001)	0.009*** (0.002)
ER	-0.012 (0.058)	-0.016 (0.033)	-0.430*** (0.130)
PC	15.414*** (5.140)	-8.261 (7.561)	1.160 (9.943)
GDP	-1.584 (1.326)	-8.176*** (2.585)	-0.550 (2.796)
RW	-32.150 (35.633)	121.127*** (40.729)	2.292 (56.686)
Food	-45.021** (22.420)	142.020*** (30.876)	-54.530 (45.739)
Drink	-8.552 (48.080)	134.551** (58.733)	-223.969*** (78.443)
typhoon	-0.033 (0.051)	0.007 (0.034)	-0.011 (0.060)
NY	-0.140* (0.082)	-0.206*** (0.049)	-0.096 (0.088)
S2	1.121** (0.451)	-0.683 (0.632)	0.123 (0.844)
S3	0.256 (0.297)	0.002 (0.366)	0.742 (0.535)
S4	1.084*** (0.388)	-0.368 (0.584)	0.330 (0.759)
rho	DW=2.2344	0.714 (0.075)	0.374 (0.099)

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level
rho= estimated serial correlation coefficient
DW=Durbin-Watson statistics

Table 8: SUR Model Results, Total Garbag

Variable **(standard error)**	**Taipei**	**Kaohsiung**	**Region 3**
intercept	108.845 (146.352)	-45.967** (19.814)	36.389 (61.179)
month	-0.040 (0.165)	-0.198*** (0.042)	-0.017 (0.066)
bag	-7.569** (3.148)	--	--
MR	--	-1.016 (1.015)	--
plastic	--	--	-3.558** (1.727)
ERW	0.098** (0.044)	0.042*** (0.013)	0.043* (0.024)
ER	-0.433 (2.023)	0.336* (0.193)	-0.037 (1.147)
PC	199.714 (183.103)	17.127 (45.643)	-101.599 (89.042)
GDP	-101.255** (47.620)	43.337*** (14.994)	23.954 (23.537)
RW	-334.393 (1228.297)	-172.764 (288.165)	367.411 (515.027)
Food	-412.636 (787.368)	75.033 (194.245)	-12.827 (407.422)
Drink	245.871 (1668.973)	1050.019** (405.625)	-124.505 (726.963)
typhoon	1.847 (1.323)	0.861** (0.399)	1.616** (0.771)
NY	-2.209 (1.973)	-1.574** (0.623)	-1.234 (1.233)
S2	14.210 (15.971)	2.009 (3.942)	-7.521 (7.663)
S3	5.333 (10.363)	-3.907 (2.584)	-2.732 (5.092)
S4	17.166 (13.877)	-2.449 (3.529)	-8.340 (6.826)
rho	0.285 (0.102)	0.102 (0.108)	DW=2.1686

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level
rho= estimated serial correlation coefficient
DW=Durbin-Watson statistics

Table 9: SUR Model Results (with GDP_MR), Waste

Variable **(standard error)**	**Taipei**	**Kaohsiung**	**Region 3**
intercept	105.369 (146.870)	-26.675 (20.527)	-2.698 (61.091)
month	-0.037 (0.166)	-0.181*** (0.041)	-0.052 (0.065)
bag	-8.061** (3.154)	--	--
MR	--	-11.456 (15.007)	--
plastic	--	--	-2.928* (1.731)
GDP_MR	--	9.712 (14.312)	--
ERW	0.094** (0.045)	0.034*** (0.012)	0.034 (0.024)
ER	-0.398 (2.033)	0.336* (0.192)	0.531 (1.147)
PC	190.566 (183.153)	28.583 (45.103)	-100.150 (88.489)
GDP	-99.623** (47.647)	37.393 (23.233)	23.179 (23.411)
RW	-289.341 (1230.669)	-185.126 (308.287)	394.027 (510.903)
Food	-407.563 (788.098)	-61.890 (194.969)	27.498 (405.243)
Drink	250.645 (1671.464)	840.046** (396.568)	100.476 (721.326)
typhoon	1.834 (1.333)	0.862** (0.395)	1.632** (0.764)
NY	-2.071 (1.989)	-1.376** (0.604)	-1.123 (1.222)
S2	13.383 (15.980)	2.826 (3.884)	-7.566 (7.613)
S3	4.994 (10.379)	-3.549 (2.555)	-3.562 (5.060)
S4	16.447 (13.880)	-1.707 (3.504)	-8.557 (6.784)
rho	0.279 (0.102)	0.106 (0.108)	DW=2.1987

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level
rho= estimated serial correlation coefficient
DW=Durbin-Watson statistics

Table 10: SUR Model Results (with GDP_MR), Recycling

Variable **(standard error)**	**Taipei**	**Kaohsiung**	**Region 3**
intercept	1.467 (4.114)	-15.911*** (3.013)	24.869*** (7.530)
month	-0.004 (0.005)	-0.011* (0.006)	0.032*** (0.008)
bag	0.750*** (0.082)	--	--
MR	--	12.289*** (2.287)	
plastic	--		-0.546** (0.216)
GDP_MR	--	-11.668*** (2.171)	--
ERW	0.003 (0.002)	0.006*** (0.001)	0.039** (0.017)
ER	-0.010 (0.058)	-0.044 (0.029)	-0.379*** (0.139)
PC	15.228*** (5.140)	-11.259 (6.880)	7.422 (10.881)
GDP	-1.490 (1.325)	5.990 (3.608)	-2.407 (3.022)
RW	-26.597 (35.581)	31.592 (42.638)	-0.032 (61.684)
Food	-44.282* (22.407)	116.510*** (28.803)	-45.349 (49.514)
Drink	-7.944 (48.028)	195.982*** (55.782)	-234.02*** (85.340)
typhoon	-0.031 (0.051)	-0.013 (0.036)	-0.019 (0.065)
NY	-0.123 (0.082)	-0.181*** (0.051)	0.064 (0.093)
S2	1.077** (0.451)	-0.965 (0.583)	0.589 (0.921)
S3	0.214 (0.297)	-0.461 (0.359)	0.871 (0.580)
S4	1.029** (0.389)	-0.805 (0.537)	0.643 (0.829)
rho	DW=2.2344	0.566 (0.088)	0.374 (0.099)

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level
rho= estimated serial correlation coefficient
DW=Durbin-Watson statistics

Table 11: SUR Model Results (with GDP_MR), Total Garbage

Variable (standard error)	Taipei	Kaohsiung	Region 3
intercept	108.085 (146.374)	-43.946** (20.924)	35.170 (61.352)
month	-0.040 (0.165)	-0.199*** (0.042)	-0.016 (0.066)
bag	-7.533** (3.150)	--	--
MR	--	3.637 (15.219)	
plastic	--	--	-3.607** (1.735)
GDP_MR	--	-4.442 (14.515)	--
ERW	0.098** (0.044)	0.041*** (0.013)	0.043* (0.024)
ER	-0.422 (2.023)	0.327* (0.195)	-0.011 (1.151)
PC	199.758 (183.102)	14.732 (46.046)	-102.768 (89.129)
GDP	-101.187** (47.621)	49.074** (23.577)	23.967 (23.541)
RW	-331.790 (1228.327)	-212.828 (314.619)	367.230 (515.053)
Food	-414.616 (787.397)	60.674 (199.039)	-7.603 (407.922)
Drink	249.793 (1669.006)	1061.286** (405.136)	-126.297 (727.075)
typhoon	1.845 (1.323)	0.839** (0.407)	1.617** (0.771)
NY	-2.208 (1.973)	-1.568** (0.625)	-1.231 (1.233)
S2	14.199 (15.971)	1.834 (3.966)	-7.584 (7.667)
S3	5.301 (10.364)	-4.043 (2.609)	-2.720 (5.093)
S4	17.155 (13.877)	-2.666 (3.576)	-8.417 (6.831)
rho	0.102 (0.106)	0.097 (0.109)	DW=2.1686

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level
rho= estimated serial correlation coefficient
DW=Durbin-Watson statistics

Table 12: SUR, joint estimation for waste and recycling

Variable (standard error)	Waste: Taipei	Waste: Kaohsiung	Waste: Region 3	Recycling: Taipei	Recycling: Kaohsiung	Recycling: Region 3
intercept	114.122	-22.373	-18.771	2.524	-17.673***	30.726***
	(146.044)	(19.174)	(59.525)	(4.006)	(3.382)	(7.015)
month	-0.001	-0.179***	-0.056	-0.003	-0.001	0.037***
	(0.165)	(0.040)	(0.065)	(0.005)	(0.006)	(0.007)
bag	-9.246***	--	--	0.732***	--	--
	(3.134)			(0.080)		
MR	--	-1.175	--	--	0.021	--
		(0.985)			(0.164)	
plastic	--	--	-2.622	--	--	-0.649***
			(1.691)			(0.201)
ERW	0.095**	0.034***	0.034	0.004**	0.008***	0.009***
	(0.045)	(0.012)	(0.024)	(0.002)	(0.001)	(0.002)
ER	-0.458	0.308	0.841	-0.019	-0.013	-0.431***
	(2.019)	(0.186)	(1.112)	(0.056)	(0.033)	(0.129)
PC	171.585	17.794	-97.281	15.403***	-9.606	2.033
	(182.728)	(44.169)	(87.781)	(5.133)	(7.497)	(9.922)
GDP	-103.813**	49.729***	15.531	-1.620	-7.891***	-0.765
	(47.516)	(14.509)	(23.097)	(1.313)	(2.560)	(2.785)
RW	-221.029	-205.317	410.625	-32.907	125.014***	1.014
	(1227.094)	(278.835)	(508.283)	(35.382)	(40.413)	(56.620)
Food	-380.144	-110.616	77.161	-44.721**	144.545***	-55.557
	(786.010)	(187.881)	(399.751)	(22.328)	(30.651)	(45.613)
Drink	225.227	851.656**	-9.226	-7.505	147.287**	-222.678***
	(1667.144)	(392.298)	(716.681)	(47.812)	(58.263)	(78.353)
typhoon	1.826	0.805**	1.551**	-0.036	0.007	-0.016
	(1.331)	(0.386)	(0.763)	(0.051)	(0.034)	(0.060)
NY	-2.011	-1.370**	-1.091	-0.141*	-0.201***	-0.098
	(1.988)	(0.604)	(1.221)	(0.082)	(0.049)	(0.088)
S2	11.835	1.787	-6.986	1.118**	-0.790	0.187
	(15.941)	(3.814)	(7.555)	(0.450)	(0.627)	(0.842)
S3	4.858	-4.140	-2.657	0.262	-0.073	0.761
	(10.349)	(2.499)	(5.003)	(0.295)	(0.363)	(0.533)
S4	15.489	-2.621	-7.942	1.084***	-0.488	0.394
	(13.848)	(3.415)	(6.729)	(0.388)	(0.579)	(0.757)
rho	0.279	0.106	DW=2.1987	DW=2.2344	0.714	0.374
	(0.102)	(0.018)			(0.075)	(0.099)

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level
rho= estimated serial correlation coefficient
DW=Durbin-Watson statistics

Table 13: SUR, joint estimation for waste and recycling, with GDP_MR

	Waste			Recycling		
Variable (standard error)	**Taipei**	**Kaohsiung**	**Region 3**	**Taipei**	**Kaohsiung**	**Region 3**
intercept	103.353 (145.977)	-30.288 (20.319)	-20.903 (59.604)	1.866 (3.985)	-16.366*** (2.990)	29.650*** (6.923)
month	-0.007 (0.165)	-0.180*** (0.041)	-0.063 (0.065)	-0.003 (0.005)	-0.010* (0.006)	0.035*** (0.007)
bag	-9.238*** (3.135)	--	--	0.718*** (0.080)	--	--
MR	--	-12.562 (14.857)	--	--	11.756*** (2.256)	--
plastic	--	--	-2.443 (1.695)	--	--	-0.574*** (0.196)
GDP_MR	--	10.840 (14.164)	--	--	-11.200*** (2.142)	--
ERW	0.095** (0.045)	0.034*** (0.012)	0.034 (0.024)	0.004** (0.002)	0.008*** (0.001)	0.009*** (0.002)
ER	-0.389 (2.018)	0.321* (0.188)	0.783 (1.113)	-0.017 (0.056)	-0.043 (0.028)	-0.432*** (0.127)
PC	171.508 (182.890)	22.936 (44.817)	-94.661 (87.835)	15.046*** (5.131)	-12.166* (6.844)	3.317 (9.917)
GDP	-102.791** (47.547)	36.172 (23.042)	15.838 (23.096)	-1.600 (1.312)	5.360 (3.567)	-1.068 (2.767)
RW	-172.712 (1227.682)	-78.842 (305.967)	457.100 (508.219)	-25.355 (35.302)	41.383 (42.326)	3.740 (56.697)
Food	-373.415 (786.600)	-69.256 (193.645)	66.943 (399.903)	-44.374* (22.304)	119.190*** (28.647)	-52.415 (45.400)
Drink	268.653 (1668.108)	828.615** (393.756)	-3.938 (716.629)	-6.256 (47.734)	203.528*** (55.473)	-222.537*** (78.536)
typhoon	1.832 (1.331)	0.874** (0.393)	1.556** (0.762)	-0.033 (0.051)	-0.012 (0.036)	-0.017 (0.060)
NY	-2.020 (1.989)	-1.389** (0.603)	-1.114 (1.221)	-0.143* (0.082)	-0.195*** (0.052)	-0.098 (0.088)
S2	11.689 (15.954)	2.144 (3.859)	-6.925 (7.557)	1.072** (0.449)	-1.032* (0.580)	0.296 (0.842)
S3	4.550 (10.355)	-3.887 (2.536)	-2.820 (5.001)	0.230 (0.295)	-0.482 (0.357)	0.797 (0.532)
S4	15.260 (13.860)	-2.240 (3.482)	-7.905 (6.732)	1.040*** -0.388	-0.848 (0.534)	0.484 (0.757)
rho	0.279 (0.102)	0.106 (0.108)	DW=2.1987	DW=2.2344	0.566 (0.088)	0.374 (0.099)

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level
rho= estimated serial correlation coefficient
DW=Durbin-Watson statistics

Table 14: Policy Impact on Waste and Recycling Summary

Pooled Model (%)

Policy	bag	MR	plastic
waste	-27.6***	-8**	-2.3
recycling	22.4	26.9***	16.9

SUR: without GDP_MR (%)

Policy	bag	MR	plastic
waste	-26.2**	-4.5	-11.9*
recycling	67.7***	3.5	47.5***

SUR: with GDP_MR (%)

Policy	bag	MR	plastic
waste	-26.4**	-5.9	-11.5*
recycling	68.0***	36.8***	-38.2**

SUR: joint estimation, without GDP_MR (%)

Policy	bag	MR	plastic
waste	-30.3***	-4.1	-10.3
recycling	66.4***	1.4	-45.4***

SUR: joint estimation, with GDP_MR (%)

Policy	bag	MR	plastic
waste	-30.2***	-5.8	-9.6
recycling	66.4***	32.7***	-40.2***

Note: *, **, *** represent 0.1, 0.05 and 0.01 significance level

Table 15: Descriptive statistics for different categories of recyclables

	(per capita, g/month)	mean	s.d.	min	max
Taipei	paper	614.516	441.783	34.137	4289.08
	metal	180.194	191.171	24.648	1834.74
	plastic product	139.946	96.127	6.746	399.470
	glass	150.442	88.194	0	354.037
	electronics	3.387	4.492	0	17.584
	containers	2.999	8.690	0	44.339
	other	67.117	120.688	0	703.129
Kaohsiung	paper	568.261	338.423	59.087	1770.52
	metal	243.250	153.510	31.518	1261.26
	plastic product	225.293	130.430	16.861	459.941
	glass	364.133	167.082	26.357	670.829
	electronics	12.527	11.546	0	93.632
	containers	21.660	16.597	0	52.027
	other	109.578	67.610	3.299	262.419
Region 3	paper	607.842	227.957	231.675	1812.99
	metal	188.067	114.201	46.730	586.670
	plastic product	100.087	70.287	9.739	393.513
	glass	177.915	166.929	14.933	955.229
	electronics	13.172	12.250	0	72.932
	containers	7.167	10.731	0.008	81.884
	other	348.635	417.443	1.209	1440.940

Note 1: metal includes aluminum and iron cans
Note 2: plastic product includes plastic bottles
Note 3: containers include paper and aluminum foil container
Note 4: others include tires, clothes, fluorescent tubes and other recyclables

Table 16: SUR Results, Paper

Variable (standard error)	Taipei	Kaohsiung	Region 3
Intercept	5218.542 (6621.45)	-9760.19*** (1892.216)	1886.149 (2602.065)
month	-16.215* (8.903)	-11.262*** (3.660)	-1.315 (3.171)
bag	148.444 (126.498)	--	--
MR	--	5222.268*** (1099.066)	--
plastic	--	--	-69.373 (69.272)
GDP_MR	--	-1662.54*** (347.031)	--
ERW	1.979 (3.521)	2.901** (1.122)	3.427*** (1.242)
ER	-159.913* (82.930)	-9.999 (12.834)	-100.84** (45.595)
PC	-10640.1 (11075.43)	-8630.73* (4822.402)	-8141.63* (4416.135)
GDP	880.544 (2674.647)	2698.231 (1948.288)	1195.816 (1109.128)
RW	12829.95 (72737.9)	22545.7 (30210.35)	36182.19 (26144.27)
Food	82056.43* (47106.06)	82103.58*** (20147.82)	37032.72* (19288.01)
Drink	-80983.5 (99650.82)	72791.22* (40941.11)	-50346.9 (36635.25)
typhoon	-26.395 (107.527)	-18.557 (34.541)	-28.333 (39.523)
NY	-90.431 (177.028)	-32.353 (53.191)	-79.228 (64.312)
S2	-402.848 (959.953)	-581.38 (413.369)	-479.486 (380.567)
S3	535.371 (610.219)	-76.208 (257.338)	201.104 (244.702)
S4	-399.063 (836.885)	-533.98 (371.385)	-495.797 (337.550)
rho	DW=2.2848	0.266 (0.103)	DW=2.2001

Table 17: SUR Results, Plastic Products (including plastic bottles)

Variable (standard error)	**Taipei**	**Kaohsiung**	**Region 3**
Intercept	4870.992*** (1090.232)	-2711.57*** (618.505)	268.205 (761.912)
month	0.221 (1.292)	-0.418 (1.150)	0.960 (0.837)
bag	49.404** (21.936)	--	--
MR	--	1376.384*** (489.881)	--
plastic	--	--	52.460** (21.806)
GDP_MR	--	-407.471** (155.025)	--
ERW	-0.421 (0.445)	0.990*** (0.239)	0.298 (0.308)
ER	-47.389*** (15.278)	-2.465 (6.116)	-20.185 (14.192)
PC	2553.494* (1395.122)	-3208.82** (1391.904)	-2934.99** (1134.188)
GDP	-587.729 (356.976)	786.993 (760.327)	364.741 (297.777)
RW	-41194.4*** (9618.973)	20750.86** (8714.503)	5522.516 (6554.351)
Food	8157.459 (6071.175)	13889.81** (5841.316)	10988.03** (5126.113)
Drink	-13548.1 (12981.17)	28205.24** (11266.5)	20863.42** (9238.193)
typhoon	-24.826* (13.697)	2.496 (7.201)	-13.235 (9.865)
NY	-24.507 (22.136)	-32.017*** (10.329)	-24.315 (15.828)
S2	326.688*** (122.224)	-307.061** (117.998)	-239.784** (97.673)
S3	249.120*** (80.213)	-128.701* (72.93)	-79.816 (64.412)
S4	280.357** (105.434)	-259.021** (108.849)	-196.47** (87.016)
rho	DW=2.0161	0.571 (0.087)	DW=2.0790

Table 18: SUR Results, Glass

Variable **(standard error)**	**Taipei**	**Kaohsiung**	**Region 3**
Intercept	5316.589*** (1009.966)	-3198.01*** (821.128)	2624.886 (3161.053)
month	3.061** (1.160)	-2.429 (1.644)	4.801 (3.267)
bag	-7.153 (20.675)	--	--
MR	--	1875.728*** (620.759)	--
plastic	--	--	-63.59 (91.630)
GDP_MR	--	-554.579*** (197.154)	--
ERW	0.204 (0.357)	2.062*** (0.462)	2.201** (0.873)
ER	-46.233*** (14.231)	0.976 (7.791)	-3.772 (58.896)
PC	2987.226** (1238.308)	-4129.53** (1792.31)	-13076.6*** (4369.683)
GDP	-40.297 (321.108)	1675.763* (957.408)	2623.133** (1229.869)
RW	-31088*** (8537.362)	-1830.47 (12285.94)	-14878.4 (24839.55)
Food	-8411.480 (5387.077)	28160.88*** (7750.979)	34110.82* (20242.3)
Drink	-31527.2*** (11510.59)	58309.95*** (15686.55)	13123.73 (34388.86)
typhoon	-18.017 (10.875)	-16.604 (14.833)	2.422 (26.462)
NY	-24.887 (16.929)	-90.912*** (22.381)	15.384 (39.088)
S2	301.782*** (108.524)	-304.78* (154.328)	-900.608** (370.972)
S3	209.994*** (71.354)	-178.812* (101.521)	-152.64 (236.870)
S4	277.653*** (93.677)	-261.579* (139.686)	-857.826** (333.810)
rho	0.108 (0.106)	0.158 (0.105)	0.351 (0.083)

Table 19: SUR Results, Metal (including aluminum and iron cans, and other recyclable metal)

Variable (standard error)	**Taipei**	**Kaohsiung**	**Region 3**
Intercept	-2307.46 (2267.499)	-2045.21* (1141.627)	5922.989*** (1194.407)
month	2.903 (3.726)	-1.656 (2.270)	3.700*** (1.371)
bag	-104.893*** (36.080)	--	--
MR	--	953.694** (445.504)	--
plastic	--	--	-167.262*** (32.896)
GDP_MR	--	-357.488** (140.098)	--
ERW	-0.551 (1.619)	0.478 (0.948)	1.140** (0.520)
ER	28.483 (21.507)	-11.239** (4.430)	-103.261*** (21.719)
PC	-4412.56 (5118.069)	-4430.37 (3129.463)	-2516.25 (1878.241)
GDP	-1710.48 (1161.578)	-465.394 (953.273)	686.280 (482.154)
RW	9387.537 (32984.25)	-2581.96 (20212.18)	13727.39 (11078.2)
Food	34589.84 (21559.15)	49654.07*** (13181.22)	-3225.93 (8457.811)
Drink	-3975.95 (45388.29)	6362.124 (27527.46)	-51563.6*** (15558.61)
typhoon	-71.274 (49.768)	-33.062 (30.401)	-1.721 (16.648)
NY	-4.509 (80.812)	-23.187 (49.201)	2.416 (26.721)
S2	-268.541 (442.146)	-187.107 (269.782)	-168.742 (161.694)
S3	140.514 (276.241)	195.603 (168.780)	115.141 (105.995)
S4	-112.771 (386.270)	-118.37 (237.457)	-153.264 (143.592)
rho	DW=2.3559	DW=2.1701	DW=2.1060

Table 20: SUR Results, Paper and Aluminum Foiled Containers

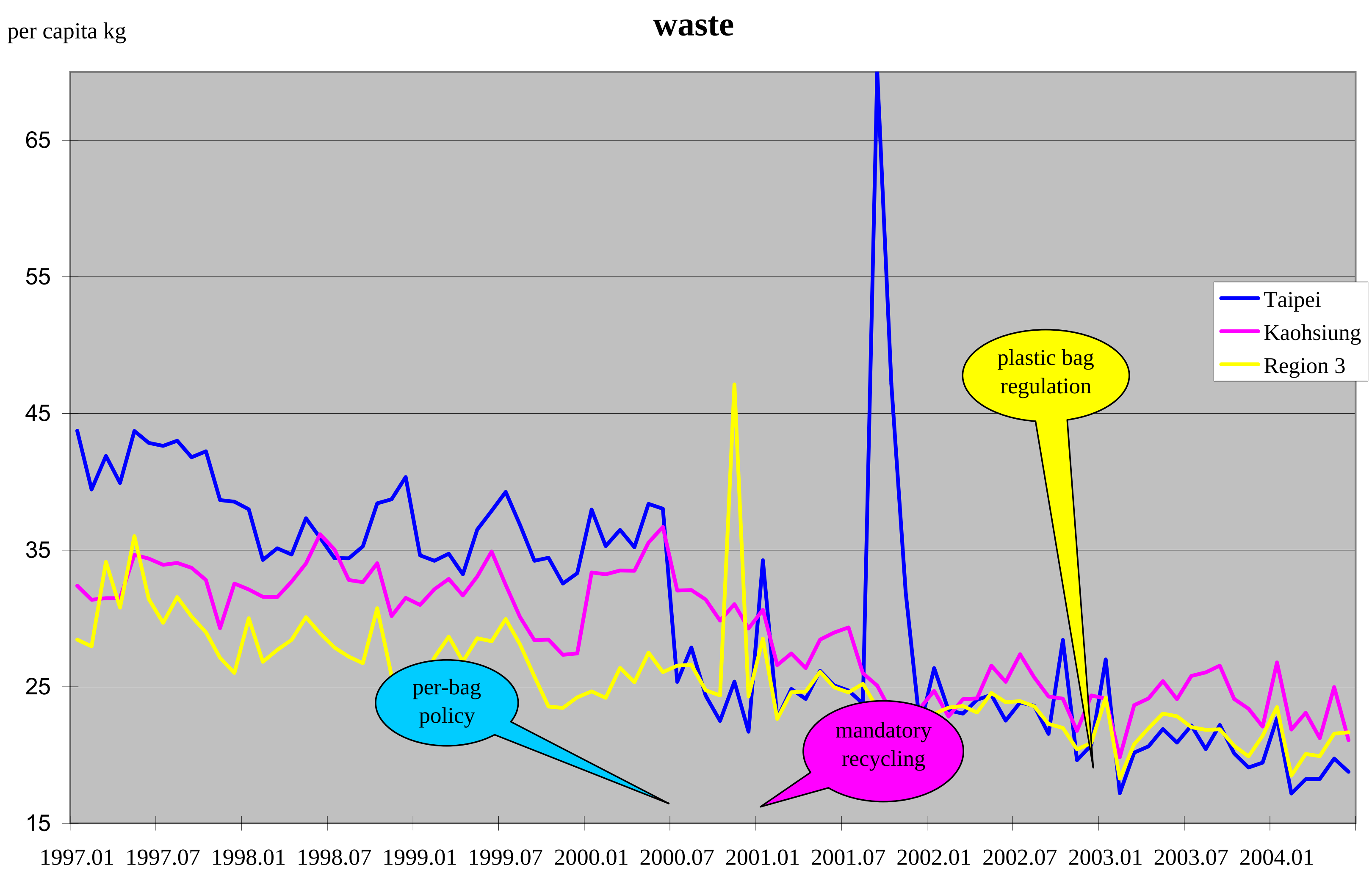
Variable **(standard error)**	**Taipei**	**Kaohsiung**	**Region 3**
Intercept	-13.565 (126.027)	-117.696 (92.664)	747.129*** (163.269)
month	0.537*** (0.163)	0.083 (0.182)	0.216 (0.199)
bag	-4.045 (2.641)	--	--
MR	--	214.919*** (72.397)	--
plastic	--	--	9.020* (4.610)
GDP_MR	--	-62.833*** (22.921)	--
ERW	0.050 (0.049)	0.006 (0.043)	0.078 (0.061)
ER	2.059 (1.609)	0.586 (0.896)	-14.042*** (2.844)
PC	11.226 (199.691)	49.269 (207.082)	-88.882 (274.991)
GDP	120.539** (49.668)	146.400 (112.528)	137.159* (71.008)
RW	-83.202 (1293.784)	-1218.47 (1376.401)	797.29 (1612.972)
Food	-1912.81** (844.871)	-117.112 (882.167)	-1578.19 (1208.946)
Drink	557.136 (1773.052)	3261.567* (1757.364)	-498.067 (2240.38)
typhoon	-1.032 (1.468)	1.779 (1.349)	-1.063 (1.885)
NY	-1.116 (2.205)	-3.615* (1.968)	-1.807 (2.832)
S2	-5.715 (17.281)	-0.612 (17.761)	-12.379 (23.459)
S3	-13.330 (10.900)	-13.138 (11.399)	-11.451 (14.733)
S4	-4.013 (15.114)	-0.814 (16.192)	-4.783 (20.942)
rho	0.267 (0.103)	0.365 (0.099)	0.265 (0.102)

Table 21: SUR Results, Electronics

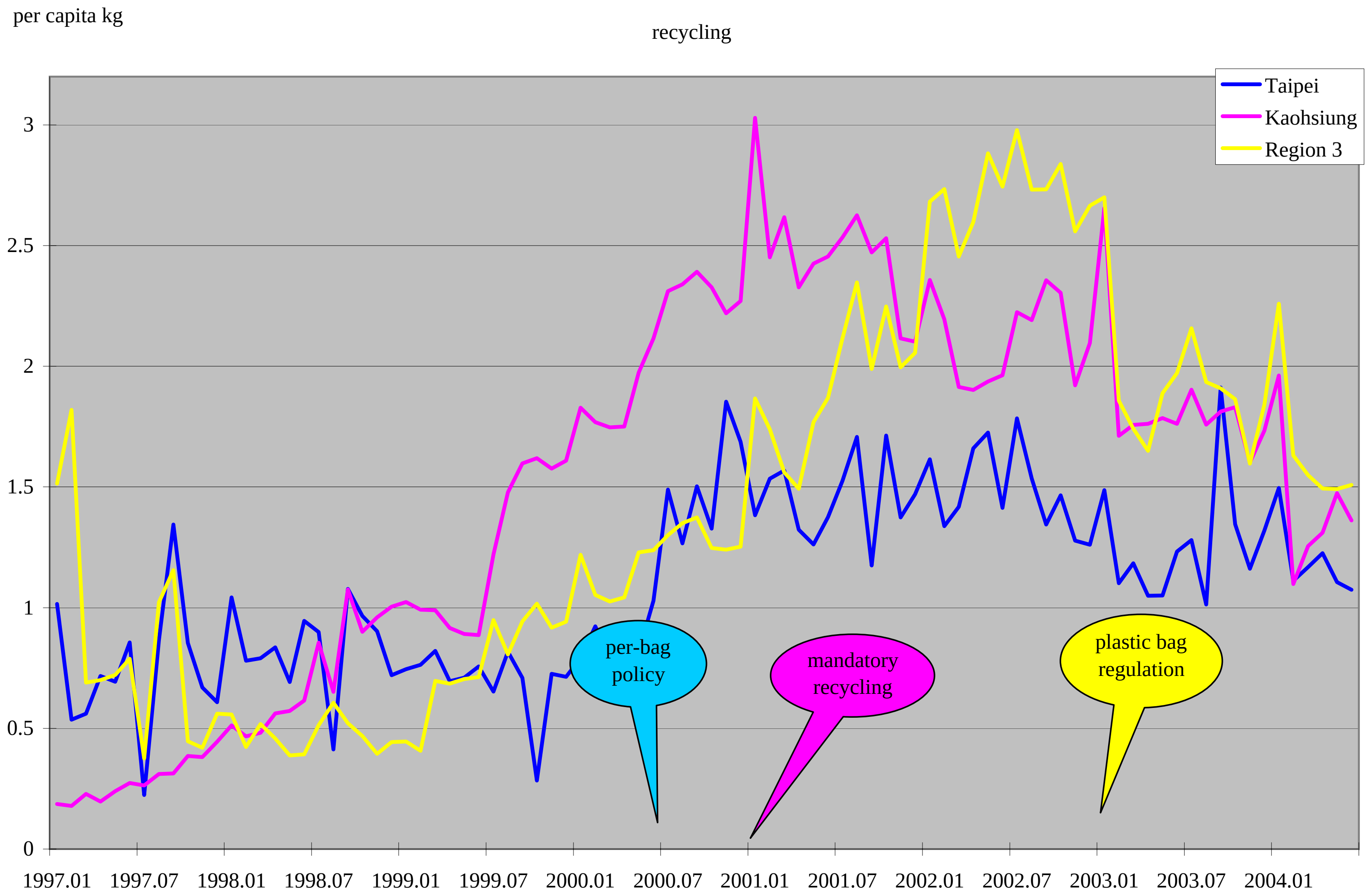
Variable (standard error)	**Taipei**	**Kaohsiung**	**Region 3**
Intercept	147.793** (58.767)	-81.576 (108.904)	101.612 (145.423)
month	0.133* (0.067)	-0.163 (0.214)	0.174 (0.161)
bag	1.000 (1.225)	--	--
MR	--	69.109 (69.239)	--
plastic	--	--	-5.082 (3.893)
GDP_MR	--	-24.937 (22.055)	--
ERW	0.087*** (0.020)	0.118 (0.075)	0.107* (0.057)
ER	-1.372 (0.823)	-1.422 (0.943)	-3.164 (2.663)
PC	194.203*** (72.478)	-359.762 (249.852)	-4.530 (223.152)
GDP	-30.941 (18.810)	101.053 (109.946)	-67.431 (57.503)
RW	-446.905 (495.256)	-565.694 (1681.621)	780.018 (1318.856)
Food	-722.277** (313.993)	2820.785** (1074.421)	831.398 (1018.962)
Drink	-2381.3*** (669.213)	-300.154 (2208.713)	-4010.49** (1843.637)
typhoon	-1.189** (0.590)	-3.492 (2.444)	-1.691 (1.797)
NY	-1.325 (0.902)	-1.307 (3.881)	0.628 (2.806)
S2	16.699** (6.342)	-14.738 (21.502)	4.558 (19.047)
S3	11.717*** (4.151)	11.360 (13.971)	19.304 (12.407)
S4	15.748*** (5.486)	-14.131 (19.175)	8.108 (16.953)
rho	0.178 (0.105)	DW=2.1449	0.103 (0.106)

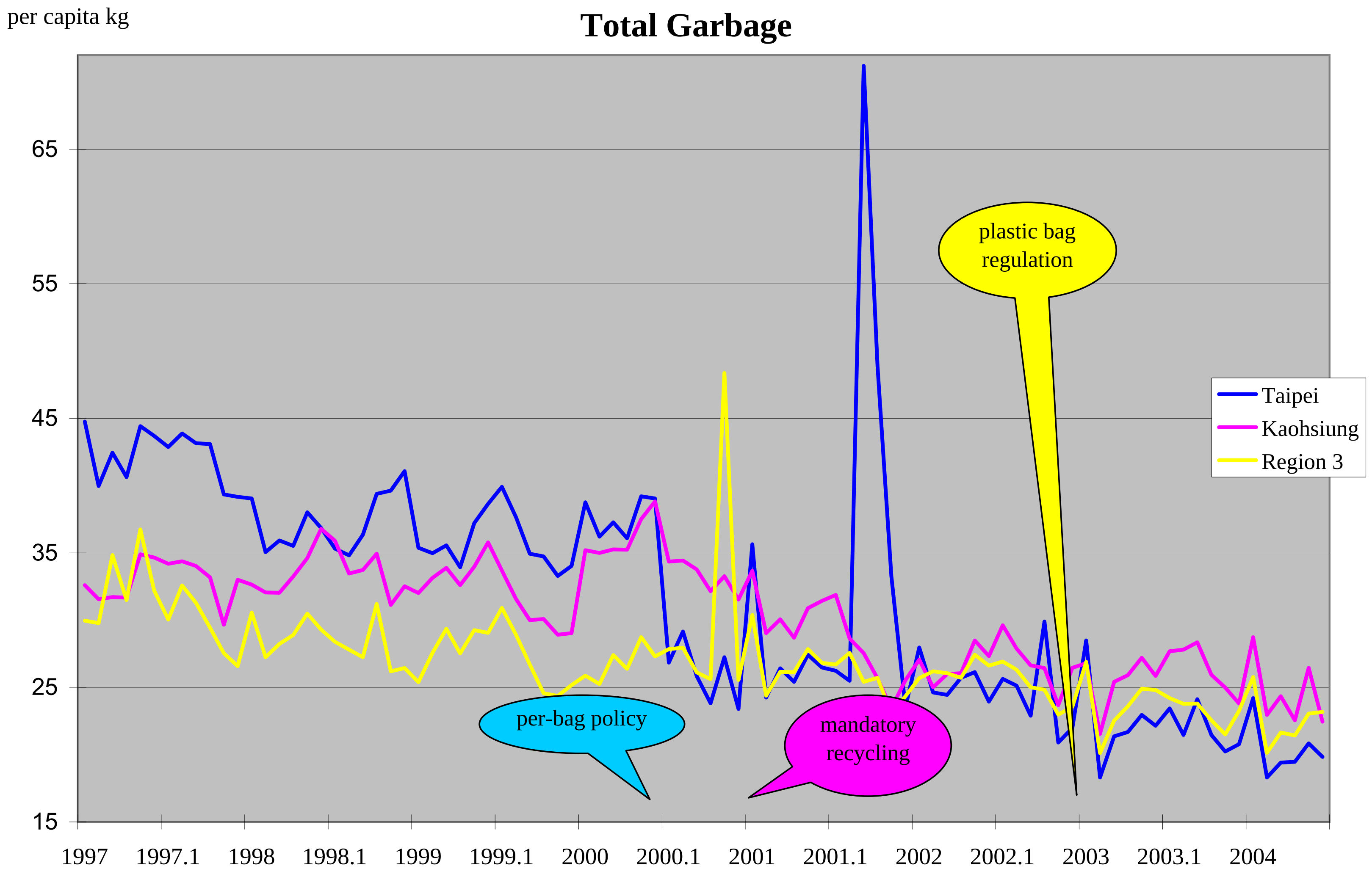
Table 22: SUR Results, Others (including tires, clothes, fluorescent tubes and others)

Variable (standard error)	**Taipei**	**Kaohsiung**	**Region 3**
Intercept	-5210.37* (2871.998)	-672.325 (487.625)	19851.43*** (3058.868)
month	1.515 (3.248)	-0.429 (0.953)	24.265*** (3.088)
bag	126.415** (61.297)	--	--
MR	--	766.904** (375.631)	--
plastic	--	--	-591.438*** (87.370)
GDP_MR	--	-244.083** (118.987)	--
ERW	0.201 (0.884)	0.761*** (0.228)	0.953 (0.714)
ER	74.616* (39.870)	-3.675 (4.713)	-254.49*** (55.483)
PC	-898.341 (3565.802)	-708.022 (1087.512)	10849.65** (4078.648)
GDP	458.998 (927.544)	249.707 (583.238)	-1058.76 (1201.423)
RW	13856.67 (24050.81)	-3393.71 (7222.964)	-24876.5 (22876.23)
Food	-6644.71 (15365.12)	10968.63** (4632.359)	-71058.2*** (19354.26)
Drink	38174.01 (32629.84)	3412.292 (9231.863)	-137082*** (31667.43)
typhoon	-6.869 (26.482)	-12.050* (7.090)	-14.290 (21.011)
NY	-13.842 (39.676)	-16.802 (10.341)	-23.454 (30.406)
S2	-148.811 (311.334)	-10.171 (93.258)	793.772** (341.597)
S3	-210.574 (202.592)	46.036 (59.756)	466.303** (211.375)
S4	-78.070 (270.178)	2.562 (84.934)	901.740*** (309.783)
rho	0.261 (0.103)	0.366 (0.100)	0.527 (0.093)



waste
per capita kg
65
55
45
35
25
15
1997.01
1997.07
1998.01
1998.07
1999.01
1999.07
2000.01
2000.07
2001.01
2001.07
2002.01
2002.07
2003.01
2003.07
2004.01
Taipei
Kaohsiung
Region 3
plastic bag regulation
per-bag policy
mandatory recycling


per capita kg
recycling
Taipei
Kaohsiung
Region 3
3
2.5
2
1.5
1
0.5
0
per-bag policy
mandatory recycling
plastic bag regulation
1997.01
1997.07
1998.01
1998.07
1999.01
1999.07
2000.01
2000.07
2001.01
2001.07
2002.01
2002.07
2003.01
2003.07
2004.01


per capita kg
Total Garbage
65
55
45
35
25
15
1997
1997.1
1998
1998.1
1999
1999.1
2000
2000.1
2001
2001.1
2002
2002.1
2003
2003.1
2004
plastic bag regulation
per-bag policy
mandatory recycling
Taipei
Kaohsiung
Region 3

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