Intervention Time Series Analysis of the Household Solid Waste Generation in Taipei City

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1. Introduction

In order to achieve the goal of waste reduction, waste charging systems have been attempted to be implemented worldwide based on the “Polluter Pays Principle (PPP)”. Several types of Waste charging systems for household solid waste (HSW) have been applied to many regions, e.g., the flat rate system and the container tag fee system. Except for considering the PPP, the waste charging system also aims at facilitating the behavior of waste generators in the context of waste reduction by using economic instruments. Theoretically the total fees would be equal to the administrative costs for MSW management services, regarding both internal and external costs. The waste charging system could aid required financial funds for maintaining MSW management systems and, simultaneously, achieve the goal of waste reduction.

In the early 1980’s, the PPP was applied to environmental regulations in Taiwan. For most local municipalities, the waste treatment and disposal fee is charged with respect to the amount of water consumption. Nevertheless, such waste charging system seemed to be failed on waste reduction while not many citizens were aware of their paying for waste treatment and disposal. To deal with such deficiency, in Taiwan the pay-as-you-throw (PAST) system, charging the fee with respect to the waste volume, has been implemented firstly in Taipei City since July, 2000. Till today, however, only 8 among over 300 municipalities adopt this system for waste charging. To modify the waste charging in Taiwan, it is imperative to examine the feasibility and policy effects of the operating PAST systems. Therefore, this study aims at analyzing the policy effect of the PAST system in Taipei City where sufficient waste data regarding the PAST is available. Meanwhile, other influencing factors of HSW generation in Taipei City would be exploited so that efficient policy measures for waste reduction could be proposed.

2. Intervention Time Series Model

Time series analysis has been widely applied in system behavior analysis. In particular, the intervention time series analysis (ITSA) is a powerful tool for analyzing the impact of a specific event, e.g., the implementation of a policy measure or an extreme climate event. Therefore, this study makes an attempt to apply the ITSA model to analyze the waste reduction effect of the PACT system in Taipei City. The general form of an ITSA model could be represented as Eq. (1).

\[ Z_t = \theta + \sum \phi_i (B) B^i \theta(B) I_{it} + \sum \delta(B) \theta(B) b_{it} + a_t \]

where \( Z_t \) is a random series of interest; \( \theta \) is the constant; \( I_{it} \) is the intervention variable (dummy); \( \delta(B) \) and \( \phi_i (B) B^i \) are the step impact function and impulse function, respectively; \( \theta(B) \) is the autoregression operator; \( \delta(B) \) is the moving average operator; \( a_t \) is a white noise.

When performing ITSA, the series of interest have to be transformed or differenced into a stationary one, and, normally, the order of autoregression and moving average could be decided by examining the autocorrelation function (ACF) and the partial autocorrelation function (PACF), respectively. The policy effect of a specific could be defined in a particular manner, a step function or an impulse function for example, and then be examined by the model.

3. The Results

In order to examine the policy effects of the PAST model in Taipei City, the monthly HSW generation data would be analyzed. In this study, the HSW generation is defined as the summation of the waste discharged by the household, the general waste directly transported to the treatment facilities (HSW collected individually), and the general disaster waste while the last term was included in the past statistics of HSW before 2005. Fig. 1 shows the time series of the historical trend of the HSW generation.

![Fig. 1 Historical time series of the monthly HSW amounts in Taipei City: Jan. 1993 – Dec. 2009. (n=204)](image)

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Apparently, several large peaks could be observed, majorly reflecting the influences of floods caused by extremely meteorological events. Meanwhile, periodical peaks could be found around the traditional Chinese New Year vacations when large housecleaning activities would be held for almost the households in Chinese society. In this sense, the disaster effect and lifestyle factors have to be considered in the development of the ITSA model. Table 1 gives the definitions of variables in this study, and the official data is collected for the model development. The activation of each intervention variable is assumed to impose an impulse impact on HSW generation at the same time period.

Two models for $HSW_t$ and $HSW_{total}$ are developed in this study using the data from Jan. 1993 to Dec. 2009. The estimation is performed by using TSP. After performing the ACF and the PACF plotting, the first-order differentiating is taken for both the series to confirming the stationarity. The optimal model structures are found, and the parameter estimators are reported in Table 2. The estimators of the two models are statistically significant and efficient according to the model diagnoses. Thereby, the two models could well quantitatively describe the system behaviors of the two series of interest, considering the policy effects, climate conditions and the lifestyle in Taipei City simultaneously.

The coefficients (parameter estimators) of the explanatory variables quantify the impacts of the explanatory variables on the explained ones. From the results of Table 2, several important policy implications could be observed:

- The PAST system is proved to be efficient in reducing HSW generation in Taipei City, and its policy effects are quantified by the developed models with statistically significances. This would be encouraging for the potential PAST municipalities. Though similar observations have been indicated by Chao, this study provides more significant evidences statistically for the arguments.
- Intensive 3R activities with particular emphases on “reuse” and “recycling” could be promoted during the Chinese New Year periods while usable goods and furniture might be replaced and discarded for New Year decoration.
- Efficient plans of natural disaster prevention would lead to HSW reduction to a great extent while flood disaster would result in a great deal of HSW discarding in Taipei City where underground spaces are intensively utilized. In addition, different impacts of the rainfall scales on HSW generation are identified.

### 4. Conclusion

In order to modifying the waste charging systems in Taiwan, this study applies an ITSA model for HSW generation in Taipei City, considering the policy effects, climate conditions and the lifestyle, simultaneously. Based on the PPP, the PACT system is proved to be efficient in waste reduction in the case study of Taipei City. However, more evidences should be found in other operating PACT systems in Taiwan given that sufficient data is available. In addition, such methodology is proved to be useful to analyze the mechanisms of HSW generation in a highly developed metropolitan area. The outcomes of this study could aid decision makers for further planning of the waste charging systems in Taiwan. Nevertheless, the consumption is excluded in the modeling due to the deficiency of monthly consumption data. A more holistic ITSA model could be established with that data. In addition, the optimal fee level for PACT systems should be further studied at the next stage.

### 5. Reference