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Evaluating the impacts of waste treatment management modes on each sector's price in a macro economic system

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ABSTRACT

This paper created an Input-Occupancy-Output (IOO) table that was integrated with several alternative waste treatment management modes. Based on this table, a Ghosh price model was developed to evaluate the price changes in each sector compared with their traditional prices for the direct and indirect impacts of the costs of waste treatment management modes. The model was applied to the waste water treatment case in China. The data were sourced from the China Statistical Bureau and a survey made by Tan et al. (2015). In each waste treatment management mode, the price change of each sector was evaluated. The results revealed that different waste treatment management modes generated different ranks for the price changes by sector. There are 22 sectors whose prices increase are mainly caused by other sectors' added waste water treatment costs. An optimal combination of two waste treatment management modes for 42 sectors generates the minimum price increase for all industries. To limit the waste water discharged in China, one possible intervention would be to increase the fine imposed for unit waste water discharged, setting it at a higher level than the unit waste water discharge fee and its treatment cost. Furthermore, it is suggested that the waste water treatment cost needs to be reasonably incorporated in the products' prices. The model proposed in this paper will be particularly appropriate to evaluate these price increases and their impacts.

1. Introduction

Waste treatment and its management has become one of the most critical environmental issues of today (Lam et al., 2015; Jin, 2016; Martína et al., 2018). In many sectors, the treatment and disposal of waste contribute a large part of the production cost (Liang and Zhang, 2012; Jin et al., 2014; Song et al., 2016). Waste treatment will usually increase the production cost and lead to price differences between similar products that are and are not treated. This will result in the treated products suffering a competitive disadvantage because they cover ecological and social costs which their competitors ignore, leaving the costs to be borne by future generations (Ottaman, 1993; Val and Stewart, 2003; Olson, 2013; Ingenbleek and Paul, 2015).

The two most common modes to treat waste are (1) centralized treatment (CTM) by special organizations and (2) decentralized treatment (DTM) by the polluters themselves that are not often detailed. How to reconcile waste management ecosystem with the social and economic development provides a significant challenge (Molinos-Senante et al., 2012; Wang et al., 2016; Piao et al., 2016). Some scholars introduced a waste input-output (WIO) model to analyze the impacts of waste treatment within the whole economic system (Takase et al., 2005). Nakamura and Kondo (2002), Nakamura and Yasushi (2006), Nakamura et al. (2007) developed a WIO model that incorporated the engineering process for physical waste treatment into the input-output (IO) model. This model relaxes the strict one-to-one correspondence between treatment methods and waste types (Nakamura and Kondo, 2006). Lin (2009) proposed a hybrid IO model to analyze the generation and treatment of wastewater. It is an extension of WIO. Lenzen and Christian (2014) provided a supply-use approach to waste IO analysis. Reutter et al. (2017) presented an environmentally-extended input-output (EeIO) model to analyze the impacts of food systems on

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environment, social and economy. While these contributions have been concerned with waste treatment costs and their associated environmental benefits, the management mode of waste treatment has not been fully considered in the current WIO model formulations. Wu (2001) made technical and economic comparisons between CTM and DTM of waste water in China and found that with the same treatment technology the cost for CTM was 0.69 RMB/ton while for DTM, the average cost was 1.69 RMB/ton. Giannetti et al. (2008) found that sometimes small changes in waste treatment practice could make significant differences to the impacts on the economy and the environment. Furthermore, from the view of macro-economic system, when the management mode of waste treatment of one sector changes, it will impact the production costs of all the other sectors, and further impact their prices.

How large will be the price change by each sector when different waste treatment management modes are adopted by some industries? Which combination of waste treatment management modes has lower impacts on products' price for all industries? To the best of our knowledge, there has been no such research that has focused on these questions. Answers to these questions would help to find the optimal combination of waste treatment management modes for all industries from the view of enhancing the price competitiveness of these products in the market.

The aim of this paper is to establish a model to evaluate the price change by each sector when different waste treatment management modes are adopted by some industries. From these results, it will be possible to reveal the combination of waste treatment management modes that generates the smallest price change for all industries in a macroeconomic system. The direct and indirect impacts of costs in different waste treatment management modes will be considered. Thereafter, it will be clearer which choice of waste treatment management mode leads to smaller changes of prices for all industries. One of the innovations of the paper is the development of an IOO model that was integrated with waste treatment costs in different management modes. With this integration, a Ghosh price model was applied to evaluate changes of products' prices by sector compared with their traditional prices. The results can make clear which option of waste treatment management mode lead to smaller changes of prices for all industries.

The paper is organized as follows. Section 2 provides the framework of the Input-Occupancy-Output (IOO) table that is integrated with costs of different waste treatment management modes. Section 3 applies the model to waste water treatment case in China. Section 4 presents some conclusions while Section 5 presents some suggestions.

2. Model

2.1. The framework of the IOO table integrated with costs of different waste treatment management modes

The classical input–output (IO) model fails to incorporate some production factors such as arable land, water, energy resources and capital. Chen (1990) proposed an IOO model that highlighted occupancy factors in the classical IO model. The IOO model not only reflects the relations between inputs and outputs but also the quantitative relations between occupancy and output as well as occupancy and input. Occupancy is a necessary part of the production process that is as important as the use of inputs in the model. Thus, a series of new methods such as the direct and total occupancy coefficient, the total consumption coefficient that takes occupancy into consideration have been formulated (Liu et al., 2009a, b, c; Liang et al., 2010; Liang and Zhang, 2012; Zou and Liu, 2016).

In this research, it is assumed that in one economy, n kinds of products are produced, from which m kinds of waste are discharged. Drawing on the IOO model of Chen (1990), it has been shown that it is possible to establish a framework of an IOO table integrated with costs of different waste treatment management modes (see Table 1). In Table 1, Z is a matrix with elements of intermediate inputs, Y is final demand matrix, X is a vector with elements of total outputs, D denotes depreciation of fixed asset vector, W denotes the employee compensation vector, T is the net taxes vector, S is the operating surplus vector, C is a matrix with the element of waste treatment cost that is internal to the organization if the industry carry out any type of waste treatment (requiring some sort of investment), R is the matrix of discharged m kinds of waste volume from n sectors, P is a matrix with the element representing the payment that an industry must make to have the waste dealt with externally.

The intermediate input section $Z_{n\times n}$ of the integrated table is the same as that of the classical IO table. The costs of different waste treatment management mode, matrix $C_{m\times n}$ which describes waste treatment costs by producer in decentralized treatment mode and matrix $P_{m\times n}$ which records payments for discharged waste in centralized treatment mode, are integrated in the primary input section. This is different from the IOO model proposed by Chen (1990) and some extended IOO models established by Liu et al. (2009a, b, c), Liang et al. (2010), Liang and Zhang (2012) and Zou and Liu (2016).

With the framework in Table 1, three scenarios of typical options for waste treatment management modes can be designed. The first considers that the producers treat waste voluntarily during the production process (scenario 1). In this scenario, some investment in infrastructure and equipment, operating costs *etc.* would be added to the costs for producers. So $P=0$ with $C>0$ at the same time in Table 1. Scenario 2 considers the case in which the producers do not take any measure to treat waste internally and thus they pay charges for disposing pollutants to an organization that will perform this task. The waste would be treated centrally by some special organization and the average treatment cost would probably be smaller than that of decentralized treatment by the producers. Then $P>0$ and $C=0$ in Table 1 in this scenario. In scenario 3, some producers choose a centralized waste treatment management mode (in this case, $P_i>0$ and $C_i=0$) while the other producers choose decentralized treatment mode (where now $P_i=0$ and $C_i>0$). In this way, the model reflects waste treatment costs with several different options for the waste treatment management mode, considerations that were ignored in the existing IOO model and its extensions. In fact, if the waste treatment costs in different waste treatment management modes by all sectors were not included, the calculated prices of all industries could not be determined, potentially leading to a series of economic and ecological problems. Accordingly, the IOO table integrated with costs of waste treatment management modes provides a more realistic approach compared to a standard IOO model and its extensions to date.

2.2. Price model based on waste treatment management modes in an IOO model

From Table 1, a Ghosh price model to evaluate the rate of changes of price for these products before and after waste treatment in the three scenarios was estimated. It is assumed that the economic system has n sectors, and the typical input coefficient showing the use of i by sector j can be defines as:

$$A_{ij}=Z_{ij}/X_i\cdot(i=1,2\ldots n;\ j=1,2\ldots n) \qquad (1)$$