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Assessment of solid waste generation and treatment in the Australian economic system: A Closed Waste Supply-Use model

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ABSTRACT

The Household sector (HS) is not only the major cause of waste generation in industrial sectors, but also the same function as an industrial sector to generate waste. Current researches mainly focus on waste generation caused by the demand of the HS based on the environmentally-extend input-output (EEIO) models while the effect of the HS as an industrial sector on waste flow has not been analysed. In addition, there is uncertainty around the economic cost of waste management discussed in EEIO models due to the lack of the calculation of the cost of labor.

We adjust waste supply-use table to analyse effects of the HS as an industrial sector on waste flow, resulting in closed waste supply-use table (CWSUT). The novelty of the method lies in a shift in the effect of the HS, from an exogenous factor to an endogenous factor.

Results derived from Australian CWSUT in 2009–10 illustrate waste generation effects of intermediate sectors and the mixed waste flows of the HS. The definition of "intermediate sector" is that the sector consumes intermediate inputs from producing sectors and generates intermediate outputs to Final demand. They show that: (1) the Construction sector has the largest waste generation effects, in which the amount of masonry waste has accounted for the most direct and total effects of waste generation; (2) investigations regarding the HS in CWSUT can calculate the amount of direct and total waste generation, the monetary flow, and effects of the Income for the Household sector. Base on the above results, the paper puts forwards the application of the CWSUT on other types of environmental issues and waste policies.

1. Introduction

In 2009–10, 53.7 million tonnes of waste were generated from Australian territory (ABS, 2013a). Of these, 27% came directly from the Households sector, while the others stems from industrial sectors (ABS, 2013a). From the perspective of the demand of consumers, the former part of the waste is directly derived from the Households sector, and the latter part of the waste constitutes an indirect waste generation from the goods and services produced from industrial sectors and consumed by consumers. In addition, as an indicator of the economic cost for waste treatment (Bartelings and Sterner, 1999, Yuan and Wang, 2014), the waste levy fee aims to reduce the amount of waste being placed into landfill and promote recycling and resource recovery. For example, Section 113 of the Environment Protection Act 1993 requires certain licensed waste facilities in South Australia to pay a contribution for each tonne of waste received at the facility, which is referred to as the 'waste levy' (Attoney-General's Department, 2011). The waste levy fee has increased in Australian states in recent years. For instance, the waste levy fee for the Metropolitan area in New South Wales (NSW) has increased from 58.80 AUD$ in 2009–10 to 135.70 AUD$ in 2016–17 (The NEW Environmental Protection Authority 2017). It is one of the most complex challenges for waste management to measure the amount of waste directly and indirectly caused by the demand of consumers and the costs of waste treatment due to the lack of available data regarding waste generation and treatment (Lebersorger and Beigl, 2011, Karak et al., 2012).

Environmentally-extended input-output (EEIO) model is a method– a mathematically defined procedure applying economic and environmental accounts to determine the direct and indirect effects of industrial sectors on environmental issues, such as greenhouse gas (Lenzen, 1998, Chen and Zhang, 2010, Meng and Sager, 2017), water (Lenzen and Foran, 2001, Velazquez, 2006, Deng

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et al., 2014), energy (Liang et al., 2007, Nässén et al., 2007, Liu et al., 2010), and waste (Huang et al., 1994, Nakamura and Kondo, 2002, Wang et al., 2013).

As a branch of EEIO analysis, waste input-output (WIO) connects monetary flow between industrial sectors and the Final demand with physical waste flows. It is constructed by (Nakamura and Kondo, 2002) and has been applied to tackle with a series of problems in the domain of waste management including the emission of waste (Nakamura and Kondo, 2002), material flow analysis (Nakamura and Nakajima, 2005, Nakamura et al., 2007), recycling of electrical home appliances (Nakamura and Kondo, 2006), direct and indirect emission induced by households' consumption patterns (Takase, Kondo et al., 2005), formation of a waste supply-use (WSU) format and its application in Australia (Lenzen and Reynolds, 2014, Reynolds et al., 2014), publication of an Australian Multi-Regional Waste Supply-Use framework(Fry et al., 2015), and direct and indirect waste arisings in the UK economy (Salemdeeb et al., 2016). These traditional EEIO models comprehensively capture the relationships between industrial sectors and waste treatment sectors, which are determined by all types of Final demand (Household consumption, Government expenditure, Gross Fixed Capital Formation, Changes in Inventories, and Export). The traditional EEIO model is termed the 'Open' EEIO model. However, the above-mentioned literature only analyse the effect of household consumption in the Final demand and rarely specifically focus on the mutual effect between industrial sectors and household consumption. The comparison between Open and Closed IO models applied in environmental issues have been widely discussed in CO_2 intensities (Kondo et al., 1996, Kainuma et al., 2000) and sustainability criterion (Proops et al., 1999).

Theoretically, there is a mutual effect between household consumption and waste generation of industrial sectors. The Household sector causes waste generation of industrial sectors through household consumption. The income of households from industrial sectors in turn influence the household consumption. The mutual effect between the Turkish production structure and labor income with different policy strategies has been studied through the partially closed supply-driven input-output model (Dietzenbacher and Günlük-Şenesen, 2003). This type of effect regarding how the situation of industrial sectors affects household income and how the household income influences the consumption of industrial products has also been discussed by (Miller and Blair, 2009). Chen et al. (2015) has indicates that the semi-closed model is better than the open model for analyzing the contribution of changes in labor compensation coefficients. Zhang et al. (2017) has shown that more comprehensive impacts of household consumption on carbon emissions can be analyzed by utilizing a semi-closed input-output model. Duchin (2005) has constructed a globally closed input-output model by considering different types of the final demand, such as exports and the other types of the final demand, as endogenous variables. These studies have described that some important finding can be obtained from closed IO model rather than open IO model. Moreover, the Household sector directly causes environmental pressures, including generation of GHG emissions and waste in the economic system (Choe and Fraser, 1999, Beck-Friis et al., 2001). For example, the Household sector in Australia generated the second largest volume of waste with approximately 12.4 Mt in 2009–10 and 14.27 Mt in 2010–11 (ABS, 2013a). This indicates that the Household sector is an important endogenous factor for the WSU table. Therefore, moving the Household sector and the Income into the quadrant of intermediate sectors to construct the Closed WSU (CWSU) table is significant for the analysis of the mutual effect of the Household sector on Australian waste management. The definition of "intermediate sector" is that the sector consumes intermediate inputs from producing sectors and generates intermediate outputs to Final demand (Acemoglu et al., 2003).

This study has a novel methodological contribution with no other waste management studies using the household consumption as an endogenous sector. But a semi-closed input-output model, which moves the Household sector into the intermediate use, has been applied to how different income levels affect greenhouse gas emission (Zhang et al., 2017). Other similar non waste management studies have been published by Chen et al. (2015) and Chen et al. (2016)

Effective waste management involving the recovery of materials, recycling, and disposal to landfill is provided primarily by the Waste Management Services Industry and depends on reliable data of waste flows. Currently, there are two main types of Australian waste accounts: (1) waste data generated by states and territories are published in the National Waste Report produced by the Department of the Environment and Energy (Australian Government Department of the Environment and Energy, 2009) and (2) waste data generated by intermediate sectors are published in the Waste Account, Australia, Experimental Estimates, 2013 (ABS, 2013a).

The Australian waste account in the National Waste Report was first published in 2010 to provide a one-stop shop for key national waste and recycling information in Australia. It shows the amount of total waste generated per capita over the period 2006–07 to 2010–11 generated by each jurisdiction in Australia and treated by the three waste treatment methods of disposal, recycling, and energy recovery (Australian Government Department of the Environment and Energy, 2013). The Waste Account, Australian Government Department of the Environment and Energy, 2013 was produced on the basis of an environmental-economic accounting framework, which is a subset of accounting aimed at incorporating both economic and environmental information (ABS, 2017). The Waste Account is part of a set of integrated environmental-economic accounts currently being published by the ABS that uses the System of Environmental and Economic Accounts (SEEA) adopted by the UN Statistical Commission in 2012 to provide a range of metrics on the economy and the environment. The Waste Account is composed of a series of tables displaying information on the monetary and physical flow of waste generated by intermediate sectors, the Household sector, and the Imports sector and treated by the Landfill sector, the Recovery sector, and the Exports sector over the period 2009–10 to 2010–11 (ABS, 2017). Two major advantages of the Waste Account, Australian Government Department of the Environment and Energy, 2013 are shown: (1) It can be cooperated with the Australian input-output table in 2009–10 (ABS, 2013b) to build a uniform framework for monetary and physical flow in the Australian economic system and (2) It marks an important milestone to bring international comparability of environmental statistics between Australia and other countries. Hence, the present paper will examine the direct and indirect waste generation and treatment in Australia caused by effects of the Household sector based on the data from the Waste Account, Australia, Experimental Estimates, 2013.

This article presents a new scheme called CWSU model that extends the WSU model to take account of effects of the Household sector as an industrial sector on waste generation and treatment in a national scale. The CWSUT incorporates the column of the Household sector and the row of the Household income to the WSUT to analyze effects of the Household sector as an 'endogenous' factor. In addition, the Import sector and the Export sector are considered as a column and a row treating the waste to balance the waste flow, respectively. The Section 'Results' presents a case study of Australian CWSU table to direct and total effects for each of industrial sectors and waste treatment sectors as well as mixed waste flows of the Household sector in the Australian economy.