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Changes of waste generation in Australia: insights from structural decomposition analysis

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Abstract

Waste generation is linked to consumption both in households (Final demand) and in the supply chain. Gaining understanding into the driving forces that change of waste generation in the supply chain can contribute to solving issues of waste management. The environmentally-extend input-output model is an effective tool with which to investigate the relationship between economic activities and waste generation. In this paper structural decomposition analysis (SDA) is employed to analyse the determinants of changes of waste generation in Australian economy from 2007–2008 to 2013–2014. Empirical results indicate that the major determinant for the increase of waste generation was change in Final demand's overall level of economic activity. Changes in the production mix of Final demand (mix effect) was responsible for a decrease of waste generation in Australian economy during the period. The Manufacturing sector was found to have the highest waste generation intensity. Meaning that each million $AUD output of the Manufacturing sector resulted in the most amount of waste generation. In addition, technological change has contributed the largest waste generation effect for the Construction sector in 2011–2012. These findings suggest that Final demand, technological changes and sectoral changes are identified as the drivers of Australian waste generation historically. To reduce waste generation, policy must be targeted at altering behaviour of consumption and waste generation, and increasing innovation of new ecological technologies for Australian industry.

Keywords: Input-output analysis, Structural decomposition analysis, waste generation

Highlights:

- Structural decomposition analysis is employed in the Australian waste input-output model.
- Determinants of changes of waste generation have been identified.
- Effect of Final demand plays an important role on Australian waste generation.
- Advice about how to lower Australian waste generation has been suggested to policy-makers.

Introduction

Waste generation occurs throughout the supply chain. Supply chains consist of different stages including the extraction of raw material, production of goods, distribution of goods, and consumption of goods. In an efficient supply chain the amount of waste generated at each stage is linked to the wider economic system and the demands of the society that the supply chain is within. Currently, sustainable production initiatives embedded throughout supply chains aim to lower waste generation, enhance the efficiency of production, and otherwise improve economic activities. In addition governmental environmental policies are aimed at reducing or eliminating future waste generation. The development of sustainable production initiatives and the design of environmental policies need measurement and analysis of the driving forces of waste generation so that they can be correctly addressed, and economic growth can be decoupled from environmental degradation (Bentley 2008, Cellura, Longo et al. 2012, Zhang and Lahr 2014).

However, the lack of information about the determinants of waste generation hinders the effectiveness of waste management policies. Therefore, before starting the design of environmental policies as well as assessing the effectiveness of the published environmental strategies and implemented measures, policy makers should identify the drivers of the development of environmental issues (energy consumption, carbon dioxide emission, water consumption, and waste generation).

The development of the economy has led to an alteration of production and consumption of patterns, and, as a consequence, to a plain change of waste generation through the supply chain. Because the amount of waste generation depend largely on production and consumption patterns (Organisation for Economic Co-operation and Development 2015).

From 1999–2000 to 2007–08, Australia’s gross domestic product (GDP) grew 3.4% on average per year (ABS 2012a). The Australian economic performance drop to 1.6% in 2009–10 due to the global financial turmoil and improved in the following years, with GDP growth averaging 2.7% from 2010–11 to 2013–14 (FOCUSECONOMICS 2018).

During the period 2006–07 to 2014–15, waste generation (including fly ash) increased from 57 megatonnes to 64 megatonnes (Department of the Environment and Energy 2017). It means that an average increase of 1.2 per cent occurs every year. Therefore, there is a need to analyse how the fluctuation of the Australian economy after the global financial turmoil drives the change of waste generation.

The identification of the driving forces (such as pollution intensity, the technology effect, and Final demand) of waste generation and pollution assists policy-makers to design environmental strategies. In this paper we use the structural decomposition analysis (SDA) methodology with an environmentally-extend input-output (EEIO) model to analyse drivers of Australian waste generation from the perspectives of economic structural change and Final demand (consumption).

The SDA method has been previously used to conduct effective analysis regarding how the economy affects the environmental issues in terms of structural decomposition components, including the changes in pollution generation per unit of output (pollution intensity); the changes between and within sectors (technology effect), the effect of changes in product mix of Final demand (mix effect); and the effect of changes in the overall level of Final demand (level effect) over long periods (Hoekstra and Van Den Bergh 2002, Muñoz and Hubacek 2008).

The SDA method mainly aims at analyzing the change of the total gross outputs between two periods by the drivers of changes in technology and changes in Final demand. This research analyses the drivers of waste generation by considering the variable of waste generation, which depends on the total gross outputs (Miller and Blair 2009, p. 606) .

It has widely been applied on environmental issues, such as energy use (Chen and Rose 1990, Alcantara and Duarte 2004, Weber 2009, Su and Ang 2017), greenhouse gas emissions (Casler and Rose 1998, Guan, Hubacek et al. 2008, Brizga, Feng et al. 2014, Wei, Huang et al. 2017), air pollutants (De Haan 2001, Liu and Liang 2017), and waste (De Haan 2001). Liao, Chen et al.

(2015) have analysed the driving forces of waste generation with 353 types of industrial waste and 26 treatment methods through a high-resolution waste input-output model.

However, the method has never been applied in economic system of Australia to analyse the drivers of waste generation due to the lack of time-series Australian input-output tables (IOTs) and corresponding waste accounts.

Environmentally-extended input-output (EEIO) is a method– a mathematically defined procedure – that is applied to 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, Zhang et al. 2014), energy (Liang, Fan et al. 2007, Nässén, Holmberg et al. 2007, Liu, Xi et al. 2010), and waste (Huang, Anderson et al. 1994, Nakamura and Kondo 2002, Wang, Huisman 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, Nakajima 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, Piantadosi et al. 2014), publication of an Australian Multi-Regional Waste Supply-Use framework (Fry, Lenzen et al. 2015), and direct and indirect waste arising in the UK economy (Salemdeeb, Al-Tabbaa et al. 2016). These models comprehensively capture the relationships between industrial sectors and waste treatment sectors. For this paper SDA is used with the most basic form of WIO (which considers waste only as a pollutant) to determine how the economic activity affects waste generation.

The purpose of this paper is to understand the changes of the drivers that affect changes of waste generation in Australian economy. Section 2 describes the SDA methodology that is used to quantify the effects of drivers of waste generation and sources of data. Results of the decomposition for Australia's waste generation from 2007-2008 to 2013-2014 are presented in Section 3. Sections 4 and 5 provide discussions and conclusions with policy implications.

2 Methodology

2.1 SDA methodology

The SDA method based on the time-series IOTs is a robust toolkit to illustrate how the determinants affect the change of environmental issues (Hoekstra 2005). We use the notation described in Hoekstra and Van Den Bergh (2002) and Chapter 13 from Miller and Blair (2009) to introduce the additive structural decomposition of the SDA methodology.We use superscripts 0 and 1 to represent IO tables for two year periods. Assuming that the matrix of IO coefficients, A, defines the basic form of IO model as

$$x^0 = A^0x^0 + f^0 \text{ and } x^1 = A^1x^1 + f^1$$

(1)

where x = gross output, f = the vector of Final demand.

The solution of Equation (1) is given by the matrix expression for the IO table with Leontief inverse:

$$x^0 = L^0f^0 \text{ and } x^1 = L^1f^1$$

(2)

where L = Leontief matrix.

Then the change in total outputs over the period is

$$\Delta x = x^1 - x^0 = L^1f^1 - L^0f^0$$

(3)

If we use year-0 weights exclusively, L^1 and f^1 are replaced by $(L^0 + \Delta L)$ and $(f^0 + \Delta f)$, then Equation 3 can becomes

$$\Delta x = (L^0 + \Delta L)(f^0 + \Delta f) - L^0f^0 = (\Delta L)f^0 + L^0(\Delta f) + (\Delta L)(\Delta f) \quad .$$

(4)

We use year-1 weights exclusively, and Equation 3 then becomes

$$\Delta x = L^1f^1 - (L^1 - \Delta L)(f^1 - \Delta f) = (\Delta L)f^1 + L^1(\Delta f) - (\Delta L)(\Delta f) \quad .$$

(5)

We calculate the average of the Equations 4 and 5, which has been examined by Dietzenbacher and Los (1998). The average result is shown as follows.

$$\Delta\mathrm{x} = \left(\frac{1}{2}\right)(\Delta L)(\mathrm{f}^0 + \mathrm{f}^1) + \left(\frac{1}{2}\right)(L^0 + L^1)(\Delta\mathrm{f})$$

(6)

The first term on the right-hand side indicates changes in the Leontief inverse matrix L when the Final demand does not change. The second term represents changes in the Final demand when the Leontief inverse matrix does not change.

The first term on the right-hand side in Equation 6 can be further decomposed because the changes in the Leontief inverse matrix L depend on the changes in the input coefficient matrix A (Hoekstra and Van Den Bergh 2002). Therefore, the changes in the Leontief inverse matrix L cam be written as:

$$\Delta L = L^1(\Delta A)L^0$$

(7)

Here, we disaggregate the ΔA into column specific changes. For an input coefficients matrix with n-sectors (Miller and Blair 2009),

$$A^1 = A^0 + \Delta A = \begin{bmatrix} a_{11}^0 + \Delta a_{11} & \dots & a_{1n}^0 + \Delta a_{1n} \\ \vdots & & \vdots \\ a_{n1}^0 + \Delta a_{n1} & \cdots & a_{nn}^0 + \Delta a_{nn} \end{bmatrix}$$

(8)

Let $\Delta A^{(j)} = \begin{bmatrix} 0 \cdots \Delta a_{1j} \cdots 0 \\ \vdots \quad\quad \vdots \quad\quad \vdots \\ 0 \cdots \Delta n_{1j} \cdots 0 \end{bmatrix}$ represent changes in sector j’s technology. Then

[Type here]

$$\Delta A = \Delta A^{(1)} + \cdots + \Delta A^{j} + \cdots + \Delta A^{n}$$

(9)

The ΔA^{j} in the Equation 9 represents the technology change (TC) in sector j. The decomposition of ΔA can be introduced into the first term on the right-hand side of the Equation 6, which is shown like this:

$$\left(\frac{1}{2}\right)(\Delta L)(\mathrm{f}^{0} + \mathrm{f}^{1}) = \left(\frac{1}{2}\right)[L^{1}(\Delta A^{1})L^{0}](\mathrm{f}^{0} + \mathrm{f}^{1}) + \cdots + \left(\frac{1}{2}\right)[L^{1}(\Delta A^{n})L^{0}](\mathrm{f}^{0} + \mathrm{f}^{1})$$

(10)

As for the composition of changes in Final demand. If the Final demand matrix has dimension $n \times p$, where p is the number of Final demand categories. We decompose the Final demand into the following determinant effects by the method shown in Lin and Polenske (1995):

$$\Delta \mathrm{f} = (1/2)\Delta f(B^{0}\mathrm{d}^{0} + B^{1}\mathrm{d}^{1}) + (1/2)(f^{0}\mathrm{d}^{1} + f^{1}\mathrm{d}^{0})(\Delta B) + (1/2)(f^{0}B^{0} + f^{1}B^{1})(\Delta \mathrm{d})$$

(11)

The matrix B is defined as the bridge coefficients matrix, which equals the Final demand matrix elements divided by their corresponding column sums. The vector d represents the distribution of each Final demand category in the total Final demand. The first term of the right-hand side in the Equation 11 means the Final-demand level effect. The second term of the right-hand represents the Final-demand mix effect. The third term of that means the Final-demand distribution effect.

The SDA approach can not only conduct decompositions of ΔL and Δf, but also analyse decompositions of changes in some economic and environmental variables, such as employment rate, energy consumption, and CO_2 emission. For instance, if we have a set of waste generation coefficient – the amount of waste generation per dollar of output in industrial sector j at time t (e_j^t), which represents $(e_j^t)' = [e_1^t, \cdots, e_n^t]$, then the vector of waste generation, by industrial sectors, associated with the output at t will be $\varepsilon^t = \hat{e}^t \mathrm{x}^t = \hat{e}^t L^1 \mathrm{f}^1$, the changes of the vector of waste generation in two year periods is

$$\Delta\varepsilon = \varepsilon^1 - \varepsilon^0 = \hat{e}^1 L^1 f^1 - \hat{e}^0 L^0 f^0$$

(12)

The driving forces of three elements of waste generation in Equation 12 are decomposed into waste generation coefficient changes, technology change, and Final demand change based on the method in Equation 6. Here this represents

$$\Delta\varepsilon = \left(\frac{1}{2}\right)(\Delta\hat{e})(L^0\mathrm{f}^0 + L^1\mathrm{f}^1) + \left(\frac{1}{2}\right)(\Delta L)[\hat{e}^0\mathrm{f}^1 + \hat{e}^1\mathrm{f}^0] + (1/2)(\hat{e}^0 L^0 + \hat{e}^1 L^1)(\Delta\mathrm{f})$$

(13)

$$\Delta L = L^1(\Delta A)L^0$$

(14)

This model applies Equations 11, 13, and 14 to assess the effect of waste intensity, technology effects, and Final demand effects (level effect and mix effect). The process of decomposition by three types of effects can be written as:

$$\Delta\varepsilon = \left(\frac{1}{2}\right)\underline{(\Delta\hat{e})(L^0\mathrm{f}^0 + L^1\mathrm{f}^1)} + \left(\frac{1}{2}\right)\underline{(L^1(\Delta A)L^0)[\hat{e}^0\mathrm{f}^1 + \hat{e}^1\mathrm{f}^0]} + (1/2)\underline{(\hat{e}^0L^0 + \hat{e}^1L^1)((1/2)\Delta f(B^0\mathrm{d}^0 + B^1\mathrm{d}^1) + (1/2)(f^0\mathrm{d}^1 + f^1\mathrm{d}^0)(\Delta B))} \quad (15)$$

The first term of the right-hand side means waste intensity change. The second term of the right-hand represents technology change. The third term of that means the Final-demand change, in which the former represents the level effect of Final demand (changes in the overall level of economic) and the latter means the mix effect (changes in the composition of Final demand).

2.2 The process of aggregated Australian IO tables and waste accounts

The Australian IOTs of 2007–2008, 2008–2009, 2009–2010, 2010–2011, 2011–2012, 2012-2013, and 2013–2014 were chosen for the structural decomposition analysis (SDA) of waste generation in the Australian economic system. The Australian IOTs of 2007–2008, 2008–2009, 2009–2010, 2012-2013, and 2013–2014 (ABS 2011, ABS 2012b, ABS 2013a, ABS 2015, ABS 2016b) have been aggregated in Appendix A, corresponding to Table A.1, Table A.2, Table A.3, Table A.6, and Table A.7. In these tables the

The Australian IOTs of 2010–2011 and 2011–2012 have been estimated based on the method described by He, Reynolds et al. (2017) and shown in Appendix A, corresponding to Tables A.4 and A.5.

The Australian waste accounts have been published for only two years (2009–2010 and 2010–2011) (ABS 2017a). Therefore, the lack of waste accounts hinders the application of SDA on waste generation in Australian economic system. The total waste accounts of 2007–2008, 2008–2009, 2011–2012, 2012-2013, and 2013–2014 were calculated from the index of waste generation (ABS 2016a). The index considers the amount of waste in 1996–1997 as a base (100). The amount of Australian waste generated in 2009–2010 with the index of 219.1 were 53753.21 (1000 tonnes). Therefore, the amount of Australian waste in other years can be calculated. The total waste accounts in Australia are shown in Table 1.

Table 1 The total amount of waste generation in Australia (1000 tonnes).

Year	The total amount of waste (1000 tonnes)
2007–2008	49533.42
2008–2009	51815.05
2009–2010	53753.21
2010–2011	57114.31
2011–2012	60671.69
2012–2013	62438.11
2013–2014	64621.61

The proportions of waste generation in different industrial sectors before 2009–2010 are estimated in terms of the proportions of waste generation in different industrial sectors in 2009–2010, while the proportions after 2010–2011 are estimated in terms of that in 2010–2011. The proportions of waste generation in different Australian industrial sectors in 2009–2010 and 2010–2011 can be obtained from Australian Environmental-Economic Accounts, 2017 (ABS 2017a). Table 2 shows the amount of estimated waste generation in each sector for the period of 2007–08, 2008–09, 2011–2012, 2012–2013, and 2013–2014.

Although the ABS has published the environment-economic accounts corresponding to the Australian IO tables, there are only two years' waste data (2009–2010 and 2010–2011) with nine types of waste and two types of waste treatment methods. In order to enhance the accuracy of the analysis, a high-resolution waste input-output model is not developed in this research.

2.3 The process of deflating IO tables

The comparative analysis of IO tables requires economic data in constant price (Wood 2011, Chang and Lahr 2016). Current prices of Australian IO tables in 2008–2009, 2009–2010, 2010–2011, 2011–2012, 2012-2013, and 2013–2014 have been converted to corresponding tables valued at constant prices for the base year of 2007–2008 by using the price index. Specifically, the producer price indices of Australia (ABS 2017b) are applied to adjust the price of intermediate sectors. The consumer price index of Australia (ABS 2017c) was used to adjust the price of Final demand and the wage price index of Australia (ABS 2017d) is used to adjust the value added. The coefficients for the deflation are shown in Table 3.

3 Results

Changes of waste generation in the Australian economy from 2007–2008 to 2013–2014 is due to a number of drivers. These include waste intensity, changes in technology effect, level effect of Final demand, and mix effect of Final demand. A summary of the decomposition of the change in waste generation over the period according to Equation 15 is presented in Figure. 1. The figure provides a cumulative representation of the total amount of waste generation in Australia in comparison with the level in 2007–2008. Regarding the total structure, the level effect of Final demand is the primary factor for the increase of waste generation during the period except the year of 2011–2012 in which the growth of waste generation was largely driven by the technology effect. The mix effect of Final demand was responsible for a large decrease of waste generation in Australia, which partly offsets the increasing amount of waste generation. From 2008–2009 to 2011–2012 the technology effect was the driver for the increase of waste generation, while since 2012–2013 it was responsible for a decrease in waste.

The waste intensity effect for the largest positive contributing industrial sector has been found to be the Manufacturing sector, which contributed to the change of waste generation from 770.6kt in 2009–10 to 3755.1kt in 2013–14 (Figure. 2). Although the amount of waste generated in the Construction sector increased from 2007–2008 to 2013–2014 in Table 2, the waste intensity effect of the Construction sector has decreased during the period. However, the negative contribution of the Construction sector is unable to offset the positive contribution of the Manufacturing sector on waste generation.

The changes of waste generation among different sectors due to the contribution of technology effect are displayed in Figure. 3. The largest positive effect on waste generation caused by the technology effect occurred in the Construction sector in 2011–2012. There had been a decrease trend for waste generation in the Construction sector since 2011–2012. The technology effect contributed to the largest negative effect on waste generation in the Manufacturing sector during the period. This result indicates that that new technologies have been applied to this industrial sector to reduce waste generation.

The level effect of Final demand (effect of changes in the overall level of Final demand) showed an important force for the growth of waste generation from 2007–2008 to 2013–2014 (Figure. 4). The changes of Final demand in the Construction sector contributes the most waste generation, followed by the AOI sector and the Manufacturing. This means that from 2007–2008 to 2013–2014, waste generation in the Construction sector, the AOI sector, and the Manufacturing sector (along with other sectors) grew due to the growth of Final demand. With the rise in economy wide waste generation corresponding to the increase in the total of Final demand.

Figure. 5 shows the mix effect of Final demand on waste generation. The mix effect of Final demand (effect of changes in product mix of Final demand) for the Manufacturing sector mainly contributed to decreased of waste generation during the period. This indicates that the change of the proportion of the Manufacturing sector's Final demand in the total of Final demand results in the decrease of waste generation. The mix effects of Final demand for other industrial sectors showed no significant contribution to the changes of waste generation.

4 Discussions

The analysis contributes to the growing streams of literature on the analysis of environmental issues embodied in the economy. Even though the SDA method has becoming the dominant method to analyse the drivers for carbon emission and energy consumption studies (De Haan 2001, Baiocchi and Minx 2010, Okushima and Tamura 2010), the method has not been applied in Australian waste domain. This paper applies the SDA method to analyse the driving forces of waste generation in Australian economy.

In the SDA model the main driving force for increasing waste generation in Australia is the level effect of Final demand (effect of changes in the overall level of Final demand), meaning that the growth of total consumption plays the most significant role on the increase of waste generation. The decrease of waste generation caused by mix effect of Final demand (effect of changes in product mix of Final demand) shows that the amount of waste generation decreases due to the drop of the proportion of each variable of Final demand in their corresponding total output, the Manufacturing sector in particular. Although the mix effect of Final demand offsets part of the increasing waste generation, the continuing increase of waste generation form the level effect of Final demand implies that the consumption of Final demand has always been the main driver of waste generation from 2007–2008 and 2013–2014.

The contribution of effects of waste intensity on waste generation is mainly due to the sharp increase of the effects of waste intensity in the Manufacturing sector, which diminished the negative contribution of the Construction sector on waste generation.

The waste intensities in the All other industry sector, the Construction sector, the Electricity, gas, and water sector, and the Public administration sector have a decreased trend since 2009–10. It indicates the proportions of the increase of waste generation are lower than that of the total outputs in these industrial sector. It is corresponding to the background of the Australian waste generation with average increase of 1.2 per cent and GDP growth averaging 2.7% from 2010–11 to 2013–14.

The change of technology effect from the positive contribution to the negative contribution during the period for the waste generation manifests that the consumption of the Australian material flow has been diminished via the improvement of technology. Our results confirms the relationship between innovation, technology and waste reduction in Australia. This was relationship was previously discussed via practical case studies in ‘Construction and demolition waste guide – recycling and re-use across the supply chain’ (Australian Government Department of Sustainability, Environment, Water, Population and Communities 2011). However, our results also provide economic evidence of the historic impact of innovation, technology upon waste generation. This should enable further investment in waste reduction via innovation and technology schemes.

5 Conclusions and policy implications

The research presented here applies the additive decomposition of the SDA method on time-series waste IO tables for Australian economy. It is the first application of the SDA method in Australian waste management. It aims at assessing the trend of waste generation affected by four types of drivers: waste intensity, technology effect, level effect and mix effect of Final demand.

The results of the research identify that the level effect of Final demand always play an important role on the growth of waste generation in the examined period, especially Final demand of the Construction sector, the AOI sector, and the Manufacturing sector. A sector level analysis leads to allocating the impact of technology effect to different industrial sectors and also to identify which sectors are the most important on waste generation and reduction. The results of this chapter shows that a series of novel technologies in the Construction sector for enhancing the efficiency of resource and reducing the waste generation from the origins to a large extent can lessen the environmental pressure. For example, steel piling on construction sites as a temporary structure to hold back soil or water can be reused 5–6 times per year in the UK. The application of steel piling diminishes the waste generation in the Construction sector (Allwood, Cullen et al. 2012). Zero Waste SA's Industry program supports a series of projects to improve the productivity and competiveness of companies to better use resource and reduce waste generation (Zero Waste South Australia 2016). The shift of technology effect benefits the development of the Australian economy towards a circular economy from the perspective of waste management.

The results suggest to policy makers that the most important way to reduce indirect waste generation is to ensure a reduction of Final demand because Final demand is the main driver of the growth of waste generation. The reduction of Final demand mainly focuses on the reduction of household consumption. The best way to reduce direct waste from the consumption by households is to adjust the human behaviour of waste management. Therefore, local, state and federal government bodies must invest in interventions that alter human behaviour of consumption and waste generation as a priority. Dual consumption and waste generation reduction focused initiatives — such as Container Deposit Schemes in Australia (Recycling Near You 2017) and Compostable and Reusable Coffee Cup Pilot in the City of

Adelaide (City of Adelaide 2017) — must be introduced to tackle both waste generation of consumers and the supply chain effects of their purchases. To be effective these interventions must be evidence based according to state of the art research.

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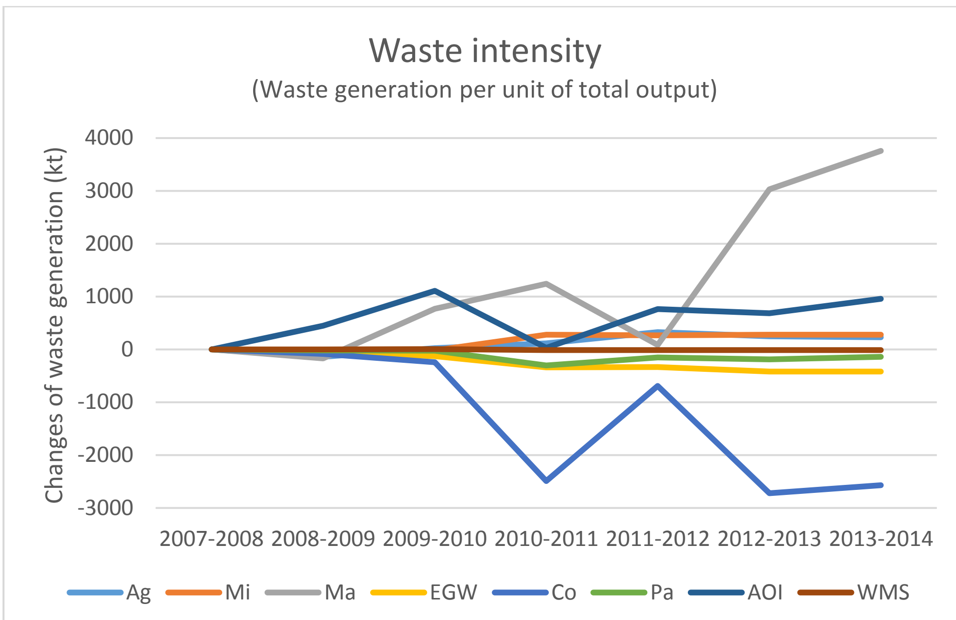

Figure. 2. Changes of Australian waste generation due to changes of waste intensity from 2007–2008 to 2013–2014.

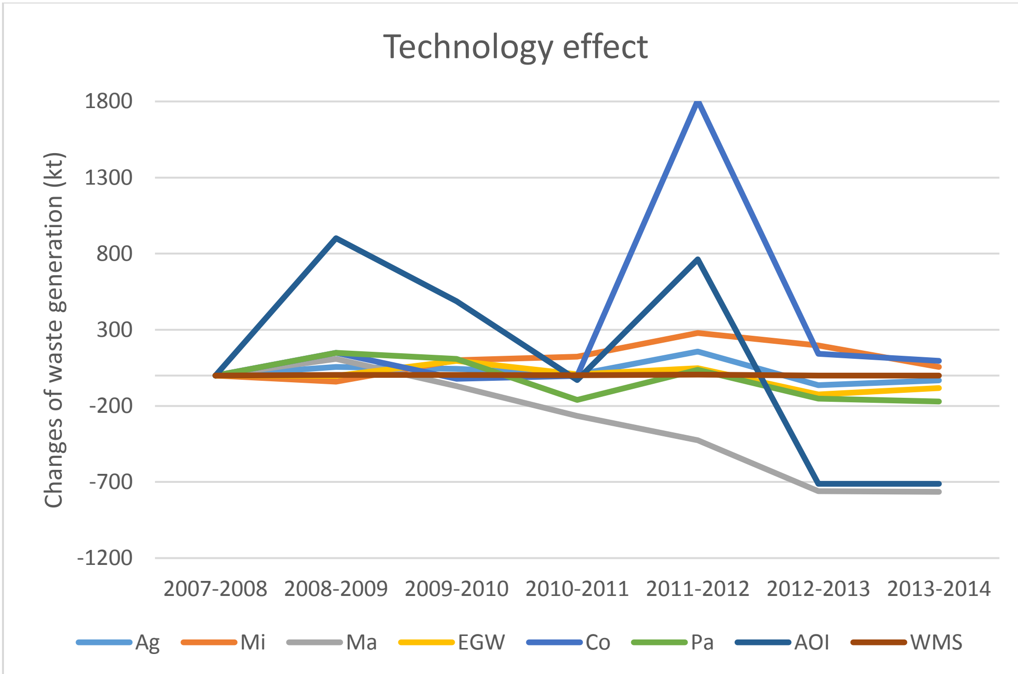

Figure. 3. Changes of Australian waste generation due to changes of technology effect from 2007–2008 to 2013–2014.

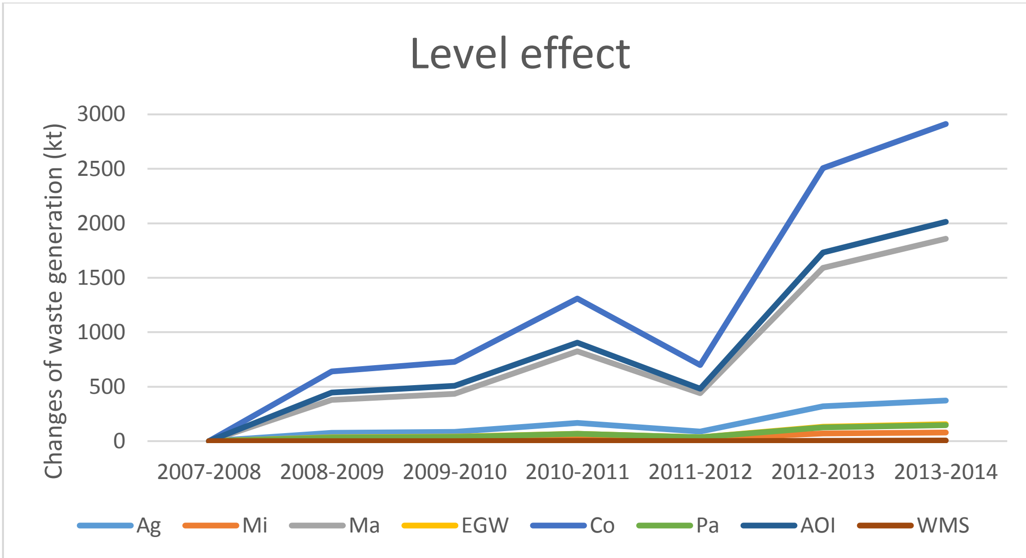

Figure. 4. Changes of Australian waste generation due to changes of Final demand (Level effect) from 2007–2008 to 2013–2014.

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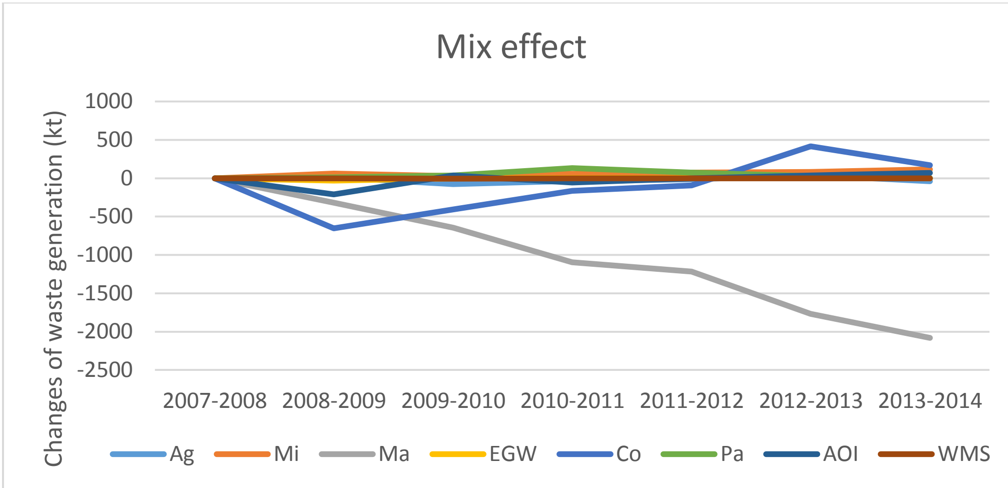

Figure. 5. Changes of Australian waste generation due to changes of Final demand (Mix effect) from 2007–2008 to 2013–2014.

Appendix A Australian aggregated input-output tables

The Appendix shows the Australian aggregated input-output (IO) tables with value added from 2007–08 and 2013–14.

Table A.1 The Australian aggregated IO table, 2007–2008

	Ag	Mi	Ma	EGW	Co	Pa	AOI	WMS	Final demand	Total output
(Million $AUD)										
Ag	10861.86	85.73	25693.53	17.10	396.61	151.53	4903.53	0.18	18762.91	60873.00
Mi	59.77	13012.57	34736.14	4181.95	909.27	216.33	3310.47	0.54	81231.96	137659.00
Ma	5329.43	8379.22	73522.17	2337.57	39721.47	4456.56	63981.86	138.05	181107.67	378974.00
EGW	892.34	1779.14	6296.29	6650.07	1232.88	867.60	10757.65	14.02	21815.01	50305.00
Co	889.95	4742.00	2411.60	3797.79	72756.96	3868.77	18038.42	4.26	173039.25	279549.00
Pa	52.71	441.61	1199.41	132.42	987.71	2539.11	7145.88	2.07	88544.07	101045.00
AOI	11868.35	18684.54	66168.64	8700.41	64178.34	27053.59	391799.24	231.84	686587.04	1275272.00
WMS	1.49	47.28	107.58	56.04	1736.72	22.75	314.19	0	970.95	3257.00
Primary input	30917.1	90486.91	168838.6	24431.64	97629.04	61868.76	775020.8	2866.04	191594.13	1443653.00
Total input	60873.00	137659.00	378974.00	50305.00	279549.00	101045.00	1275272.00	3257.00	1443653.00	3730587.00

Table A.2 The Australian aggregated IO table, 2008–2009

	Ag	Mi	Ma	EGW	Co	Pa	AOI	WMS	Final demand	Total output
(Million $AUD)										
Ag	12726.19	159.57	28384.09	20.93	375.32	166.10	6046.16	0.26	21392.36	69271.00
Mi	77.88	16732.28	32547.65	4047.23	856.05	115.40	2927.03	1.52	124860.96	182166.00
Ma	5731.21	9268.14	76710.72	1890.07	42653.67	5469.56	69195.52	115.75	182361.36	393396.00
EGW	955.64	2192.07	5626.39	13840.27	1286.48	590.19	10013.97	13.05	21668.94	56187.00
Co	1459.84	6410.60	3289.25	2644.74	77006.71	5595.63	26663.40	10.06	174031.77	297112.00
Pa	60.85	526.85	1108.12	121.17	1024.00	3211.59	8417.25	2.72	95828.44	110301.00
AOI	13917.13	25188.85	70445.94	6723.02	67057.29	29732.45	398989.62	427.55	712848.15	1325330.00
WMS	2.58	44.24	125.96	48.70	1771.88	26.42	314.92	0.00	1010.31	3345.00
Primary input	34339.68	121643.39	175157.87	26850.88	105080.59	65393.66	802762.13	2774.08	195433.72	1529436.00
Total input	69271.00	182166.00	393396.00	56187.00	297112.00	110301.00	1325330.00	3345.00	1529436.00	3966544.00

Table A.3 The Australian aggregated IO table, 2009–2010

	Ag	Mi	Ma	EGW	Co	Pa	AOI	WMS	Final demand	Total output
(Million $AUD)										
Ag	13420.64	200.87	24772.39	34.25	571.12	175.60	6784.67	1.00	19917.47	65878.00
Mi	64.29	18979.43	29647.24	3426.72	1399.34	99.48	2826.65	1.42	106070.44	162515.01
Ma	5099.91	7253.39	72764.32	1899.70	44135.63	4383.00	64633.10	102.90	173394.06	373666.01
EGW	1057.32	2499.78	6213.25	17311.37	1304.40	633.32	11422.44	13.85	23770.28	64226.00
Co	1104.48	7569.35	3049.72	4266.23	81429.02	6760.20	29083.91	138.92	180232.18	313634.01
Pa	62.82	520.55	1275.65	150.54	1100.35	3184.70	8717.94	2.26	100736.19	115750.99
AOI	12648.48	23691.54	69747.18	7742.55	71020.60	31563.06	404647.88	389.92	748848.79	1370300.00
WMS	1.81	49.55	128.87	52.96	2039.10	30.50	319.70	0.01	1108.51	3731.00
Primary input	32418.24	101750.56	166067.39	29341.70	110634.43	68921.14	841863.71	3080.73	197135.10	1551213.00
Total input	65878.00	162515.00	373666.00	64226.00	313634.00	115751.00	1370300.00	3731.00	1551213.00	4020914.00

Table A.4 The Australian aggregated IO table, 2010–2011

	Ag	Mi	Ma	EGW	Co	Pa	AOI	WMS	Final demand	Total output
(Million $AUD)										
Ag	13881.67	277.23	24956.53	28.22	543.46	174.54	6054.83	0.52	24024.81	69942.13
Mi	114.39	17264.46	33299.39	3115.48	2077.38	130.89	3459.11	7.87	119579.73	179044.12
Ma	5059.59	8497.98	69093.36	1714.33	48124.90	3993.37	61747.67	74.44	170778.89	369103.56
EGW	1074.62	2813.77	6904.18	19755.70	1413.32	1526.03	12204.49	27.53	25982.09	71691.63
Co	1348.29	8509.97	2799.20	3882.16	90890.39	6384.47	29401.81	17.52	197650.57	340965.34
Pa	63.04	820.31	1327.41	153.58	1366.49	3471.88	9116.67	1.99	125294.43	141615.99
AOI	12805.48	30393.45	68546.79	9371.92	72741.79	33503.98	434305.70	808.07	795521.30	1457730.70
WMS	93.68	44.21	282.00	104.02	604.79	108.02	2635.58	41.08	1167.61	5081.00
Primary input	39878.85	130671.73	158201.11	42168.56	147817.09	84701.42	998605.67	4101.97	235915.60	1842062.00
Total input	74455.00	214268.00	347884.00	86836.00	389164.00	137045.00	1605361.00	5081.00	1842062.00	4702155.99

Table A.5 The Australian aggregated IO table, 2011–2012

	Ag	Mi	Ma	EGW	Co	Pa	AOI	WMS	Final demand	Total output
(Million $AUD)										
Ag	12894.99	285.06	25998.88	17.29	409.76	150.38	4915.96	0.00	24217.658	68889.9784
Mi	33.38	15703.03	56214.41	2963.22	1516.89	49.85	4974.00	3.90	126859.9	208318.578
Ma	9178.41	16751.96	95710.64	3343.76	68707.16	6012.65	93574.69	178.87	156454	449912.136
EGW	1129.67	3445.43	7312.70	22622.28	1564.74	2633.50	12696.43	21.86	25222.164	76648.7741
Co	1151.65	7646.73	1201.86	3250.73	97351.21	5550.60	19361.35	44.70	192538.88	328097.706
Pa	62.03	1130.70	1327.97	161.11	1689.38	1960.09	9035.71	2.10	111125.97	126495.057
AOI	15209.55	41161.58	68397.33	11212.07	78560.28	37824.65	490171.80	692.31	776187.22	1519416.79
WMS	74.10	47.11	241.07	92.88	1243.73	72.85	1803.75	36.34	1094.0586	4705.88865
Primary input	33079.07	111980.45	105953.34	35015.01	110612.95	82732.73	884066.31	3464.11	376858.05	1743762.02
Total input	72812.85	198152.05	362358.20	78678.35	361656.10	136987.30	1520600.00	4444.19	1790557.9	4526246.93

Table A.6 The Australian aggregated IO table, 2012–2013

	Ag	Mi	Ma	EGW	Co	Pa	AOI	WMS	Final demand	Total output
(Million $AUD)										
Ag	13053.21	453.97	25324.81	16.17	488.13	130.00	4595.14	0.52	30393.05	74455.00
Mi	264.06	13834.54	40603.70	2493.00	4144.78	384.93	5936.66	7.87	146598.46	214268.00
Ma	4978.94	10987.15	52571.40	1412.30	53120.13	3214.13	55976.82	74.44	165548.70	347884.02
EGW	1167.35	4016.16	7898.00	24725.01	1707.48	4004.35	13768.60	27.53	29521.51	86836.00
Co	1835.92	10341.71	2298.16	3114.02	108036.80	5633.00	30037.63	17.52	227849.24	389164.00
Pa	63.49	1546.29	1430.91	172.25	2105.45	3585.54	10044.54	1.99	118094.54	137045.00
AOI	13119.49	42372.23	59273.91	12630.67	71139.34	35283.62	483760.36	808.07	886973.31	1605360.99
WMS	93.68	44.21	282.00	104.02	604.79	108.02	2635.58	41.08	1167.61	5081.00
Primary input	39878.85	130671.73	158201.11	42168.56	147817.09	84701.42	998605.67	4101.97	235915.60	1842062.00
Total input	74455.00	214268.00	347884.00	86836.00	389164.00	137045.00	1605361.00	5081.00	1842062.00	4702155.99

Table A.7 The Australian aggregated IO table, 2013–2014

	Ag	Mi	Ma	EGW	Co	Pa	AOI	WMS	Final demand	Total output
(Million $AUD)										
Ag	14187.29	633.39	29123.65	24.63	522.09	138.18	4871.85	0.31	30334.62	79836.00
Mi	274.66	15667.00	32944.21	2388.86	4242.29	431.03	6054.95	5.16	166138.84	228147.00
Ma	5645.67	10923.42	50112.03	1851.35	52611.01	2784.09	57530.06	84.55	165527.84	347070.02
EGW	1725.01	4480.51	9344.93	24637.17	2043.18	3388.38	15590.42	16.21	30028.19	91254.00
Co	2040.18	9996.01	2139.42	4034.81	114766.74	6449.99	33292.21	12.72	233559.95	406292.01
Pa	56.87	1269.56	1402.35	224.61	1948.13	2834.40	9648.14	2.00	119423.94	136810.00
AOI	14596.52	39823.03	59880.43	15076.13	72498.15	33203.17	502933.75	756.22	934540.59	1673307.97
WMS	96.03	37.76	314.12	131.98	571.48	97.86	2659.19	28.67	1205.93	5143.00
Primary input	41213.77	145316.32	161808.86	42884.46	157088.95	87482.91	1040727.44	4115.18	242880.13	1923518.02
Total input	79836.00	228147.00	347070.00	91254.00	406292.00	136810.00	1673308.00	5021.02	1923640.00	4891378.02