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Article

Rescuing Food from the Organics Waste Stream to Feed the Food Insecure: An Economic and Environmental Assessment of Australian Food Rescue Operations Using Environmentally Extended Waste Input-Output Analysis

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Abstract: In this paper we investigate the economic and environmental efficiency of charities and NGO's "rescuing" food waste, using a 2008 case study of food rescue organisations in Australia. We quantify the tonnages, costs, and environmental impact of food rescued, and then compare food rescue to other food waste disposal methods composting and landfill. To our knowledge this is the first manuscript to comprehend the psychical flows of charity within an Input-Output framework—treating the charity donations as a waste product. We found that 18,105 tonnes of food waste was rescued, and calculate that food rescue operations generate approximately six kilograms of food waste per tonne of food rescued, at a cost of US$222 per tonne of food rescued. This a lower cost than purchasing a tonne of comparable edible food at market value. We also found that per US dollar spent on food rescue, edible food to the value of US$5.71 (1863 calories) was rescued. Likewise, every US dollar spent on food rescue redirected food that represented 6.6 m^3 of embodied water, 40.13 MJ of embodied energy, and 7.5 kilograms of embodied greenhouse gasses (CO_2 equivalents) from being sent to landfill or composting, and into mouths of the food insecure. We find that food rescue—though more economically costly than landfill or composting—is a lower cost method of obtaining food for the food insecure than direct purchasing.

Keywords: food waste; food rescue; Australia; charity; input-output; life cycle analysis; food security; emergency food aid; food poverty; food bank

1. Introduction

Every year across the globe, millions of tons of consumable surplus food and grocery products are disposed of to landfill as organic waste, with up 45%–70% of the organic solid waste stream composed of food waste [1]. Much of what is grown, processed, and manufactured is never consumed due to failure to harvest, post-harvest loss, and product disposal due to expiration, over production, damage, and marketing or other business decisions [2–4]. What makes this sad fact even harder to digest is that up to 60% of the food tossed into landfills is wholesome, edible food [5–8]. This edible food could be diverted from landfill and "rescued" by philanthropic and community based organisations to be fed to those in need.

Food rescue, also called food recovery, is the practice of safely diverting edible food that would otherwise go into waste disposal systems, and distributing it to those in need—the food insecure. In 1999 food rescue operations diverted 3% of American food waste from landfill [9]. Over the last decade food rescue has gained further momentum, and now processes even greater volumes [10]—there are now food rescue operations in over 25 countries on six continents [11]. This rapid expansion of food rescue operations could be indicative symptoms of a society with (A) increasing income inequality and food insecurity—leading to certain demographics lacking the income to feed themselves; and (B) an inefficient food production system that is geared towards over production, with food rescue understood to be a "moral" form of disposal [12,13].

In waste management theory, food rescue sits above the organics waste management methods of landfill, anaerobic digestion, and composting in the typical waste disposal method hierarchy, as it is considered to be either promoting the avoidance, or the reuse of food waste from industry to feed the food insecure [14,15].

Food rescue has had little attention from waste management researchers, despite its emergence as a legitimate form of food waste/organics diversion. Salhofer *et al.* [16], Mohamad *et al.* [17], Reynolds *et al*. [18] and Beretta *et al.*[19] all reference food rescue as an emerging organic and food waste diversion method, but do not explore the area in further detail.

Other prominent papers in the broader food rescue literature are Youn *et al.* [20] who discuss the composition of food rescued by US operations; Cotugna and Beebe [21] who provide a historic background to the rise of food rescue in the US; Phillips *et al.* [22,23] who present an economic model of how food rescue operates within the economy; Wie and Giebler [24], who consider the functionality and limits of food rescue in California; Koshy and Phillimore [25] who provides an economic analysis of a single West Australian organization "Food Rescue"; Schneider [26] and Lorenz [27] who discuss Austrian and German food rescue operations; and Solak *et al.* [28] and Gunes *et al.* [29] who discuss food rescue vehicle pick up efficiency and location placement. Other academic literature investigates food rescue from social justice, food politics, or food security viewpoints [30,31]. In particular Cotugna *et al.* [32] calculate social and nutritional benefit of food rescue to the food insecure population of

Delaware. The majority of this prior food rescue literature deals with small case studies, on an individual basis there has been no quantification or analysis of food rescue operations and systems on a global scale.

In the literature, there is discussion of food rescue as method for food waste producing industries—such as hospitality and manufacturing—to increase their positive social impact and reduce their organic waste going to landfill [33,34]. Tarasuk and Eakin [35,36] dissected the motivations behind why food waste producing industries donate food to food rescue operations. Tarasuk and Eakin also highlighted that food rescue is volunteer driven, labour intensive, and a charity based operation, and so many not be able to be provide by the private sector without philanthropic (or government) support. This aspect of commercial viability is not often touched upon in food rescue literature.

In Australia there are four main organisations: Foodbank, Secondbite, Fareshare and OzHarvest, which operate predominantly throughout the Eastern states and South Australia [8]. These charities collect food "waste" that is still fit for consumption but is either close to becoming inedible (retail food that will soon reach its use by date, and thus cannot be sold) or is surplus to requirements (food left over at the end of a banquet or event that has yet to be served to the public).

Australian food rescue charities redistributed a total of 18 thousand tonnes of food in 2008–2009 that would have otherwise gone to landfill to disadvantaged recipients (Table 1). Though each charity operates in its own unique manner some operation, generalisations are possible. The main industry sectors to donate food waste are the service (hospitality and events) and the manufacturing sectors. Charities receive the donated foodstuffs, transform the food into meals or food parcels and then supply these directly or through a secondary charity/Non-Government /religious organisation. The recipients of this rescued food are people who are food insecure, and usually live in poverty [37].

Table 1. Tonnages produced by Australian Charities for the 2008 time period [38–44].

	Tonnes	**Food rescued/donated from the**
Ozharvest	289	Service Sectors
Secondbite	240	Service Sectors
Foodbank	17,573	Manufacturing Sectors
Fareshare	3	Manufacturing Sectors
Total	18,105	

Many of these charities also accept monetary donations, however, in this paper we only consider the physical food given to these charities. We understand that there is a large gap between the foodstuffs rescued and the demand for them, with the random/chaotic nature of food donations (as well as the perishability of donated food) leading to potential over and under supply scenarios on a daily basis [37]. Additionally, if consumed exclusively, the types of food rescued are not consistent with an overall healthy diet [45]. Thus, we recognise that donated money can be crucial in purchasing staple foodstuffs so that the charities can provide a secure and nutritious food supply. However, when considering charity as a waste disposal methodology this is—at present—additional information.

In grey literature in Europe, Asia and Australia, donating to charity is promoted as a method for diverting many types of waste (including clothing and textiles, furniture, white and electronic goods, and food waste) away from landfill [17,46–49]. Woolridge *et al*. [50] discussed the environmental benefits of recycling textiles via charity rather than using virgin materials in production. However, to our knowledge there is no discussion of charity within Input-Output economics literature, beyond the recognition of charity being part of the monetary goods and flows of the economy.

Overall there has been little investigation of the economic and environmental costs and benefits associated with food rescue from a waste management perspective, this is due to the complex modelling required to express the dynamics of food rescue in a first world country, and the lack of previously available data. In this paper we address this problem, using waste supply-use (WSU) analysis [51,52] (a recent extension of Nakamura and Kondo's Waste Input-Output (WIO) framework, first published in English as [53], and later [54,55]) to analyse the economic impacts of food rescue operations in 2008 (Foodbank, Secondbite, Fareshare and OzHarvest). We will then use the food waste environmental impact quantification methodology introduced by Reutter *et al.* [56] and Reynolds *et al*. [57] to discuss the environmental impacts of disposing of food waste via charity. Using these IO extensions together allows us to link charity to food waste treatment, while also gaining understanding of the environmental and economic impacts of food rescue in Australia—a novel approach to a complex problem.

Section 2 provides a background of Input-Output (IO) and waste economics theory. Section 3 lists our data sources and modelling assumptions. Section 4 presents and discusses our findings. Section 5 concludes.

2. Theory Review

In this section we propose how with-in IO economic theory, charity and philanthropy can be considered a waste treatment sector in the economy. From waste theory "first principals" [58], we specifically develop a theoretical framework that considers charity (reuse of goods by philanthropy) as a waste treatment route, as it is not traditionally considered a form of waste treatment. We have selected IO modelling as it allows the interactions between physical wastes flows and monetary spending to be linked in one model via treatment types. This is important when considering the impacts of food rescue, and also provides the ability to compare food rescue with other forms of food waste treatment.

From an industry production perspective, the creation of goods and services also creates "waste" products. This phenomenon is termed "joint production"; where the production of a good will also create negatively valued goods ("bads"—pollution, waste, *etc.*) that have to be dealt with [59–62]. However, if a market is found for the negatively valued goods, waste can then be understood to be a resource and have value; the act of disposal comparable to an act of production [63].

From a consumption perspective, goods are transformed into "waste" when the perceived value and durability of the good decreases to a point where it is no long wanted [58]. With rational individuals then selecting a disposal method with the cheapest disposal costs to the disposer [64]. However, not all these costs are purely monetary; others include time as well as environmental and social considerations.

The differing valuation of waste products and disposal costs by each disposer and processor leads to different waste disposal processes being selected. These disposal processes can be categorised as either "formal" waste disposal systems that have been set up by waste disposal businesses and government, or "informal" alternate routes. Reynolds *et al.* [18] provide a discussion of currently available informal food waste methods, and list disposing to charity as a form of informal disposal and waste treatment.

Charitable donation is a type of informal waste disposal as it involves a form of waste treatment that is not recognised by government waste accounts as a traditional method of waste disposal. This means that the waste rescued by charities is not accounted for in the formal waste stream, and is not accounted for in a country's official waste data set, diversion rate or recovery rate [65]. The decision to dispose of waste via charity can be attributed to more than just a lower disposal cost, with the perceived "good" effects of philanthropy—either for the recipients of the donated "waste" product or for the donor themselves—having an effect.

Nakamura and Kondo's [54,55] WIO methodology provides a methodological framework in which to represent the scenario of limited joint production, with waste products (usually thought of as "negative" externalities) transformed by treatment sectors and then sent or sold onward throughout the economy, turning the negative into a positive product. Through philanthropy, charities take unwanted, unvalued or surplus goods from households [66] and commercial enterprises [46] allowing them to be reused [67], and reallocated to another party who value this "waste".

To model charity as a waste treatment method we restrict the charities examined to those that deal with physical object donation, and not philanthropic donations of money. The donation of items or products allows us to focus on the material flow of the object, knowing that the donor of the object values it negatively, has found a party who has a higher value for the object and is willing to treat the object at a lesser disposal cost for the producers then other alternatives. It is also the case that a charity becomes a competing firm in the market, when donated money. This increases the competition for scarce resources, rather than designating charities being a destination for the negatively valued surplus goods.

3. Data Sources, Assumptions and Methods

Food waste tonnage data was sourced from Reynolds *et al.* [68] (see also Lenzen and Reynolds [51] and Reynolds *et al.* [52,69]). This data set provided Australian food waste tonnages for 2008, indicating which of the 61 categories of food waste were generated by the 344 intermediate industry sectors (industrial solid waste) and which by Australian households (municipal solid waste). Using an experimental estimation method called top down calculation, (this procedure is detailed in Reynolds *et al.* [68]), the food waste tonnages were extrapolated from government documents and industry reports [14,70–73], and account for food waste that has been disposed of via formal solid waste disposal routes (*i.e.*, no backyard composting, feeding to animals, food rescue or sewer disposal [18]).

The IO model provided in Reynolds *et al.* [52] had 343 intermediate sectors, 10 treatment sectors, and 15 waste types. We altered the existing model by moving the economically relevant portion of the intermediate sector 339 "Community services and religious organisations" from the intermediate transactions matrix to become a food rescue treatment sector alongside Landfill and Composting—the two formal methods of treating food waste that Reynolds *et al*. included in WSUT. The size of this economically relevant portion, for the 2008–2009 economic expenses associated with food rescue, was nearly $20 million US dollars (Table 2). This is 0.24% of the total expenses associate with the total "Community services and religious organisations" sector [25,37,39–43,74–77]. We then aggregated the number of intermediate industry sectors to seven (Agriculture, Mining, Forestry, Manufacturing, Utilities, Transport, and Services) for the purposes of clarifying this case study.

The 2008 Australian WSUT model estimated that 7.3 million tonnes of food waste were disposed of by formal methods with 4.1 million tonnes coming from municipal and household sources (final demand), and 3.2 million tonnes from industry (intermediate sectors). In 2008, 96% of food waste was sent to landfill (6.9 million tonnes) with only 4% sent to composting (0.3 million tonnes). We estimate that food rescue as treatment method generated 40 tonnes of food waste in 2008. The exact composition of the food waste generated was assumed to be identical to the aggregated composition of industrial food waste in Australia in 2008 as found in the 2008 Australian WSUT model.

18 thousand tonnes of informal food waste were treated by food rescue in 2008 (Tables 1 and 3). This is 0.22% of food waste in Australia. We allocated this additional waste to service and manufacturing sectors (Table 1). This increases the total food waste produced by Australia by 18 thousand tonnes. The composition of the food waste rescued was assumed to be identical to that disposed of in the Hotels, clubs, restaurants and cafes sector (for detail see the Appendix of Reynolds *et al.* [52]).

Taking into account the findings of Foodbank Australia report [37], we assume that without donated or rescued food, the food insecure party would lack the income to purchase food. For this reason, we did not edit the final demand sector—even though more food is being consumed in the economy. This is because our assumption is that the feeding of rescued food waste to insecure peoples does not detract or affect the composition of the final demand vector.

The resulting Australian WSUT model has intermediate sectors N_1 = 7, treatment sectors N_2 = 3, and waste types N_3 = 1.

Table 2. A list of food rescue expenses for the 2008 financial year in AU dollars converted into US dollars.

	Expenses
Ozharvest	AU$570,275
Secondbite	AU$534,194
Foodbank	AU$24,855,355
Fareshare	AU$402,792
Total in AU dollars	$26,362,616
Total in US dollars	$19,669,147.80
Total expenditure of "Community services and religious organisations"(US dollars)	$8,073,921,520
% of "Community services and religious organisations" that is food rescue	0.24%
AU dollar to US dollar 2008–2009 average exchange rate [78]	0.7461

To determine the monetary value, food security (calorific) benefit, and environmental impacts we followed the quantification methodology introduced by Reutter *et al.* [56] and Reynolds *et al.* [57].

To estimate the dollar value of food waste by category i (K_i) the tonnages of food waste categories (W_i), were multiplied by the price per tonne of the associated food category (F_i).

$$K_i = W_i \times F_i \quad (1)$$

To calculate the basic price per tonne value of the associated food products Fi we sourced Gross Production Values in US dollars (constant price 2004–2006) and production quantities from the FAOSTAT database [79]. Additional data on seafood, manufactured and baked goods, fruits, and vegetables from Australian government and industry reports [80–82]. The Gross Production Value was divided by the tonnage produced to find a price per tonne. Australian prices were converted to US dollars using the calendar year average exchange rate for 2008–2009 of $0.7461 [78]. Our valuation assumes that the food waste is still valued at market value (basic price), and has the same amount of "use value" (durability) that it had when first bought [58,83].

To estimate the calories embodied in Australian food waste by category i (J_i), the tonnages of food waste categories (W_i) were multiplied by the calorific values of each food category per tonne (C_i).

$$J_i = W_i \times C_i \tag{2}$$

We sourced the calorific values of associated food product per tonne from the Wolfram Alpha database [84]. The calorific values were based on globally averaged nutrient values for generic food products (*i.e.*, lamb, beef, flour, *etc.*). Vegetables, fruits, and processed goods were provided as an average calorific value per tonne from a basket of associated products selected by Wolfram Alpha.

To calculate the water, energy, and greenhouse gasses CO_2 equivalents (GHG-CO_2e) embodied in Australian food waste, we performed an environmentally extended Input-Output Analysis—an operation explained in the Appendix of [85].

The resource embedded in food waste by category i ($P_{\text{water } i}$, $P_{\text{GHG } i}$, $P_{\text{energy } i}$) were calculated by multiplying the value of food waste (K_i) by the total environmental impacts of production per dollar spent in sector s, ($E_{\text{water s}}$, $E_{\text{GHG s}}$, $P_{\text{energy s}}$) to find P_i, the total environmental impacts of food waste.

$$P_{\text{water } i} = K_i \times E_{\text{water i}} \tag{3}$$

This environmental impacts data was sourced from the Eora database (versions 600.61 and 199.74) in US thousands of dollars [86–88] and featured GHG CO_2e, Energy (MJ), and Water (m^3) [89]. The greenhouse gas and energy accounts were from the year 2008, with the water account from the year 2000. This difference in base years is due to data availability.

4. Results and Discussion

In Table 3 we present a transaction WSUT of the 2008 Australian economy in which charity is understood to be waste treatment type. It presents the food waste flows of Australia (with seven aggregated intermediate industry sectors, three treatment sectors, and the single waste type of food waste). Waste volumes are reported in physical units of 1,000,000 tonnes and monetary units of US$1,000,000,000. All monetary values discussed below are in US dollars.

Tables 4 and 5 show the waste generation coefficients and multipliers. Table 5 presents the total waste generation multipliers determined through the Leontief inverse. The values of Table 5 are higher than those in Table 4 due to the multipliers accounting for the waste produced in an individual sector (reflected in the coefficient) and additionally, the waste produced throughout the supply chain to enable this sectors' production. Caution should be used when reading Tables 4 and 5, as there are multiple scales in one table, with millions of dollars per millions of dollars; dollars per tonne, tonnes per tonne, and tonnes per millions of dollars being used in both tables.

Direct waste generation is the waste generated by an industry's own on-site production processes, and indirect waste generation is the volume of waste generated as a result of the production processes of all industries in the supply chain of a particular industry. Total waste generation is the sum of the direct and indirect waste generation. Further information on how to interpret Tables 3, 4, and 5 can be found in Reynolds *et al.* [52].

From Table 3, it can be observed that the four food rescue charities treated 18,065 tonnes of food waste more than it generated. This positive volume of waste treated to waste generated is an indication that charity disposal is an efficient treatment option.

Shown in Tables 4 and 5, the direct and total food waste generation coefficients of 2.23 and 5.87 kilograms of food waste generated per tonne of waste treated. The relatively small economic size of the charity sector also leads to a greater economic impact per tonne processed, with every tonne of food waste donated to charity directly effecting US$108.64 of economic activity within the charity sector, while in total every tonne of food waste donated effects US$221.94 worth of economic activity economy wide.

Compared to landfill or composting, food rescue has a high waste generation rate, and high economic activity cost. Discussed in Reynolds *et al.* [52] landfill and composting have total waste generation coefficients of 0.06 and 1.08 kilograms of food waste generated per tonne of waste treated, while every tonne processed stimulates economic activity by US$2.53 (landfill) or US$47.37 (compost).

This finding that food rescue is high cost is unsurprising as the food rescue has a comparatively low volume of waste treated (in terms of total waste generation composting treats 19 times more tonnes than food rescue) and an economic structure that has a much higher inputs of service, transport, manufacturing industries, *etc.* per tonne of waste treated than both composting and landfill.

In defence of this "high" price of food rescue, it is worth noting that these per tonne processing costs are lower than purchasing a tonne of edible food at market value (refer to the FAOSTAT database [79] for food price time series). Furthermore, using EIIOA we calculate that in 2008 food rescue operations in Australia rescued US$112.3 million US dollars of food, with each tonne of edible food worth on average ~US$6000. Thus, for every dollar spent on food rescue, edible food to the value of US$5.71 was rescued.

We calculate that Australian charities rescued 36.6 billion calories worth of food in 2008. A person is understood to be "food secure" when they have access to an average 3000 calories a day [90]—with the average Australian consuming 3220 calories daily in 2006–2008 [79]. Thus, we calculate that the volume of food rescued is enough to feed half of Australia's population (~12 million people) for a day [91]. For every dollar spent on food rescue, 1863 calories worth of food was rescued—*i.e.*, over half a day's calorific food supply per person.

Furthermore, we calculate that the food waste rescued by Australian food rescue charities represented over 131 million M^3 of embodied water, 789 TJ of embodied energy, and 148 Gg of embodied GHG-CO_2e. Meaning that in 2008 every dollar spent on food rescue saved food that represented 6.6 m^3 of embodied water, 40.13 MJ of embodied energy, and 7.5 kilograms of embodied GHG-CO_2e. Note that these environmental impact values do not include the resources used, or GHG- CO_2e generated as part of the food rescue operation.

With these economic and environmental considerations taken into account, food rescue becomes a more attractive waste disposal option—although with a higher economic cost (US$221.94) and waste generation rate (50 kilograms per tonne of waste rescued) than landfill or composting.

It should be noted that the waste generation rates of producing a tonne of food "from scratch" are much larger than that of saving a tonne of food via food rescue—one tonne of waste generated for every tonne ($6000) of food produced, implying that it is more effective to rescue food where possible. Furthermore, the waste generated by food rescue is channelled into other treatment methods, though the volumes of waste generated currently are very small and so there is little additional environmental or economic impact.

If we were to consider the hypothetical situation of food rescue treating all the "avoidable" food waste disposed of in Australia (this is assumed by Reynolds *et al.* [57] to be 1/3 of total food waste—2.5 million tonnes), food rescue would generate an additional 31 thousand tonnes of waste (specifically 5 thousand tonnes of food waste (0.007% of Australia's current food waste generation)), cost US$541 million, and recover food to the value of US$190 billion or 1.8 trillion calories—enough to feed 921 thousand people for a year. This extreme (and unlikely) example indicates that the additional waste generated by food rescue would be a very small part of the total Australian waste footprint.

A limitation of our IO methodology, is that we have been unable to measure the social benefit of feeding the food insecure via food rescue. However, considering no other food waste treatment option contributes to the social "wellbeing", food rescue must have some degree of social impact superiority over methods such as landfill or composting. This quantification of social impacts is a topic for future research.

5. Conclusions

In this paper we have adapted the WSUT and WIO methodologies to formalise philanthropy as a waste treatment sector. To our knowledge this is the first manuscript to comprehend the psychical flows of charity within an IO framework—treating the charity donations as a waste product. This is important as it allows many new charity waste types to be considered—*i.e.*, the waste treatment of clothing or furniture.

Furthermore, this is the first manuscript to quantify the environmental and economic impacts of food rescue operations in Australia. We have found that food rescue— though more economically costly than landfill or composting—is a cheaper method of obtaining food for the food insecure than direct purchasing with every dollar spent on food rescue enabling US$5.71 of edible food to be rescued.

We believe that future research into food rescue should first examine this relatively new treatment method as time series, as since 2008 Australian food rescue operations have grown dramatically. Second, the effects of food rescue upon the demand of households should be reassessed if rescued food is fed to more than just food insecure peoples. Third, it must be recalled that feeding the rescued food to humans is not the end of the material flow—further upstream human (sewage) waste will result from this increase in food consumption. In this paper, this treatment of human waste has not been traced, if a future comprehensive material flow analysis is to take place, this must be addressed. However, prior to further application of this methodology, additional research is required around the food rescue sector, as higher quality data of both physical and economic flows will give more comprehensive results.

Table 3. An aggregated waste supply-use transactions table (WSUT) for Australia for 2008. With seven intermediate sectors, three treatment sectors, one waste type. Monetary values in units of 10^9 of US dollars, waste flows in units of 10^6 tonnes. Values < 0.005 are not displayed for the sake of readability. Food rescue treatment sector is highlighted by the dashed line.

	Ag	Mi	Fo	Ma	Ut	Tr	Se	Fr	Lf	GlR	PprR	PlaR	Me	OrC	CnR	EWR	LeR	RuR	Food	Gdn	Tim	Txt	Ppr	Pla	Ru	Gl	Pb	Cn	MF	MNF	EW	Oth	Fd	Total
Ag	47.14	0.10	0.04	9.51	0.04	0.24	11.10		0.01			0.01	0.01	0.01	0.01																		45.02	113.25
Mi	1.71	30.92	0.09	20.16	5.86	6.41	3.96		0.10	0.02	0.03	0.06	0.04	0.08	0.06	0.01	0.01	0.01															7.59	77.13
Fo	0.12	0.02	0.10	1.89	0.01	0.02	0.03																										0.01	2.21
Ma	14.72	7.18	0.37	114.99	2.13	12.92	79.20		0.07	0.01	0.02	0.04	0.03	0.06	0.05	0.01	0.01	0.01															116.24	348.04
Ut	2.54	2.91		7.22	2.44	1.92	7.72																										11.01	35.78
Tr	8.03	6.17	0.04	32.76	0.93	16.77	35.26		0.05	0.01	0.02	0.03	0.02	0.04	0.04	0.01		0.01															22.21	122.42
Se	15.85	13.03	0.28	79.89	6.69	37.00	263.15	0.01	0.08	0.01	0.03	0.05	0.04	0.07	0.06	0.01	0.01	0.01															235.16	651.42
Fr																			0.02															0.02
Lf																			6.99	1.27	1.26	1.70	1.72	2.46	0.05	0.09	0.19	6.37	0.21	0.07	0.31	4.78		27.46
GlR																										0.17								0.17
PprR																							2.69											2.69
PlaR																								0.73										0.73
Me																													1.71	0.58				2.29
OrC																			0.31	0.65	0.25													1.22
CnR																					1.01						0.06	9.55				1.43		12.04
EWR																															0.03			0.03
LeR																						0.23												0.23
RuR																									0.01									0.01
Food	0.56	0.12		0.76	0.05	0.19	1.52																										4.11	7.32
Gdn	0.13	0.04		0.19	0.01	0.06	0.71																										0.79	1.92
Tim	0.05	0.06	0.01	0.40	0.02	0.09	0.66																										1.23	2.51
Txt	0.01	0.02		0.12		0.01	1.43																										0.35	1.94
Ppr	0.10	0.09		0.60	0.04	0.16	1.33																										2.08	4.40

Table 3. *Cont.*

	Ag	Mi	Fo	Ma	Ut	Tr	Se	Fr	Lf	GlR	PprR	PlaR	Me	OrC	CnR	EWR	LeR	RuR	Food	Gdn	Tim	Txt	Ppr	Pla	Ru	Gl	Pb	Cn	MF	MNF	EW	Oth	Fd	Total
Pla	0.12	0.11	0.01	0.49	0.03	0.17	0.89																										1.38	3.19
Ru				0.01			0.03																										0.01	0.06
Gl	0.01	0.01		0.04		0.01	0.08																										0.11	0.26
Pb							0.24																											0.25
Cn	0.02	0.15		0.27	0.03	0.05	15.40																										0.01	15.92
MF	0.03	0.04		0.46	0.01	0.07	0.71																										0.60	1.92
MNF		0.06		0.25		0.02	0.16																										0.16	0.65
EW	0.01			0.05		0.04	0.24																											0.34
Oth	0.12	0.15		0.71	0.06	0.23	1.71																										3.22	6.20

Table 4. The coefficients matrix of the WSUT in Table 3, for Australia for the year 2008. Values < 0.005 are not displayed for the sake of readability. Food rescue treatment sector is highlighted by the dashed line.

	Ag	Mi	Fo	Ma	Ut	Tr	Se	Fr	Lf	GlR	PprR	PlaR	Me	OrC	CnR	EWR	LeR	RuR	Food	Gdn	Tim	Txt	Ppr	Pla	Ru	Gl	Pb	Cn	MF	MNF	EW	Oth
Ag	322.08	1.02	18.42	19.92	0.93	2.28	11.18	2.00	0.05	1.39	0.17	1.24	0.30	1.00	0.08	4.87	0.46	14.17														
Mi	11.70	307.09	45.73	42.21	141.58	60.80	3.99	1.13	0.35	9.03	1.07	8.05	1.93	6.52	0.53	31.72	3.02	92.28														
Fo	0.85	0.20	50.76	3.97	0.15	0.22	0.03											0.01														
Ma	100.59	71.33	178.51	240.75	51.36	122.43	79.80	22.95	0.25	6.45	0.77	5.75	1.38	4.65	0.38	22.65	2.16	65.90														
Ut	17.34	28.88	1.62	15.13	59.00	18.15	7.78	4.47	0.02	0.39	0.05	0.35	0.08	0.28	0.02	1.37	0.13	3.99														
Tr	54.87	61.33	20.44	68.59	22.43	158.97	35.53	24.43	0.20	5.08	0.60	4.53	1.08	3.67	0.30	17.84	1.70	51.92														
Se	108.33	129.43	134.83	167.26	161.49	350.74	265.15	53.67	0.31	7.94	0.94	7.07	1.69	5.73	0.46	27.89	2.66	81.14														

Table 4. *Cont.*

	Ag	Mi	Fo	Ma	Ut	Tr	Se	Fr	Lf	GlR	PprR	PlaR	Me	OrC	CnR	EWR	LeR	RuR	Food	Gdn	Tim	Txt	Ppr	Pla	Ru	Gl	Pb	Cn	MF	MNF	EW	Oth
Fr																			0.002													
Lf																			0.955	0.66	0.50	0.88	0.39	0.77	0.83	0.33	0.77	0.40	0.11	0.11	0.90	0.77
GlR																										0.67						
PprR																							0.61									
PlaR																								0.23								
Me																													0.89	0.89		
OrC																			0.043	0.34	0.10											
CnR																					0.40						0.23	0.60				0.23
EWR																															0.10	
LeR																						0.12										
RuR																									0.17							
Food	3.82	1.20	1.66	1.60	1.22	1.83	1.53	2.23	0.02	0.45	0.05	0.40	0.10	0.32	0.03	1.57	0.15	4.57														
Gdn	0.88	0.37	0.73	0.39	0.36	0.53	0.72	5.27	0.01	0.21	0.03	0.19	0.05	0.15	0.01	0.75	0.07	2.19														
Tim	0.34	0.57	2.55	0.84	0.56	0.89	0.66	0.83	0.01	0.18	0.02	0.16	0.04	0.13	0.01	0.64	0.06	1.86														
Txt	0.05	0.16	0.23	0.25	0.06	0.13	1.44	0.13		0.06	0.01	0.05	0.01	0.04		0.20	0.02	0.59														
Ppr	0.70	0.88	1.04	1.26	0.90	1.52	1.34	1.20	0.01	0.36	0.04	0.32	0.08	0.26	0.02	1.26	0.12	3.67														
Pla	0.80	1.04	2.51	1.03	0.75	1.61	0.89	0.72	0.05	1.42	0.17	1.26	0.30	1.02	0.08	4.97	0.47	14.46														
Ru		0.02	0.01	0.03	0.04	0.02	0.03	0.04		0.04		0.03	0.01	0.03		0.13	0.01	0.37														
Gl	0.07	0.05	0.06	0.08	0.05	0.08	0.08	0.08		0.02		0.01		0.01		0.06	0.01	0.17														
Pb		0.02		0.01			0.25																									
Cn	0.11	1.46	0.59	0.56	0.65	0.48	15.52	0.03	0.01	0.16	0.02	0.15	0.03	0.12	0.01	0.57	0.05	1.67														
MF	0.19	0.41	1.89	0.97	0.17	0.66	0.72	0.35	0.01	0.22	0.03	0.19	0.05	0.16	0.01	0.77	0.07	2.23														
MNF	0.03	0.63	0.57	0.52	0.06	0.15	0.17	0.11		0.06	0.01	0.05	0.01	0.04		0.20	0.02	0.59														
EW	0.04	0.02		0.11		0.34	0.25			0.10	0.01	0.09	0.02	0.07	0.01	0.36	0.03	1.06														
Oth	0.80	1.46	1.71	1.49	1.46	2.18	1.72	2.04	0.02	0.46	0.05	0.41	0.10	0.33	0.03	1.61	0.15	4.68														

Million $ per Million $ | Dollar $ per Tonne | Tonnes per Tonne | Tonnes per Million dollar $ | Kilograms per Tonne.

Table 5. Total waste generation multipliers of the WSUT in Table 3, for Australia for the year 2008

	Ag	Mi	Fo	Ma	Ut	Tr	Se	Fr	Lf	GlR	PprR	PlaR	Me	OrC	CnR	EWR	LeR	RuR	Food	Gdn	Tim	Txt	Ppr	Pla	Ru	Gl	Pb	Cn	MF	MNF	EW	Oth
Ag	1489.83	15.55	43.73	49.23	12.19	24.96	29.52	6.38	0.11	2.89	0.34	2.58	0.62	2.09	0.17	10.16	0.97	29.56	0.21	0.78	0.33	0.21	0.25	0.68	5.12	1.98	0.12	0.15	0.56	0.56	1.12	0.12
Mi	64.58	1482.95	101.35	109.19	237.93	141.48	30.68	10.51	0.59	15.26	1.81	13.59	3.25	11.00	0.89	53.57	5.10	155.85	1.06	4.13	1.75	1.13	1.34	3.58	26.98	10.42	0.66	0.77	2.96	2.96	5.89	0.66
Fo	2.51	1.26	1054.86	5.99	0.87	1.61	0.82	0.24		0.07	0.01	0.06	0.01	0.05		0.24	0.02	0.71	0.01	0.02	0.01	0.01	0.01	0.02	0.12	0.05			0.01	0.01	0.03	
Ma	268.38	210.29	311.37	1405.76	145.77	296.66	174.18	50.31	0.55	14.30	1.70	12.74	3.05	10.31	0.83	50.21	4.78	146.07	1.09	3.87	1.64	1.06	1.25	3.35	25.29	9.76	0.62	0.72	2.77	2.77	5.52	0.62
Ut	39.52	55.23	14.93	33.18	1076.89	39.65	17.86	7.65	0.06	1.53	0.18	1.37	0.33	1.11	0.09	5.38	0.51	15.66	0.12	0.41	0.18	0.11	0.13	0.36	2.71	1.05	0.07	0.08	0.30	0.30	0.59	0.07
Tr	140.65	144.58	75.75	144.96	73.65	1256.27	80.45	39.13	0.37	9.50	1.13	8.46	2.02	6.85	0.55	33.34	3.17	97.00	0.74	2.57	1.09	0.70	0.83	2.23	16.79	6.48	0.41	0.48	1.84	1.84	3.66	0.41
Se	368.68	393.04	328.52	424.36	349.07	705.15	1453.07	107.74	0.85	22.08	2.63	19.66	4.71	15.92	1.28	77.51	7.38	225.53	1.76	5.98	2.53	1.63	1.93	5.18	39.05	15.07	0.95	1.11	4.28	4.28	8.52	0.95
Fr	0.02	0.01	0.01	0.01	0.01	0.01	0.01	1000.01								0.01		0.04														
Lf	16.70	14.70	15.39	15.03	11.45	20.20	20.55	29.30	1000.30	7.76	0.92	6.91	1.65	5.59	0.45	27.24	2.59	79.25	0.96	0.66	0.50	0.88	0.39	0.77	0.84	0.34	0.77	0.40	0.11	0.11	0.90	0.77
GlR	0.12	0.09	0.09	0.12	0.08	0.13	0.10	0.17		1000.04	0.01	0.04	0.01	0.03		0.15	0.01	0.44								0.67						
PprR	1.34	1.45	1.33	1.67	1.19	2.08	1.44	2.49	0.03	0.70	1000.08	0.62	0.15	0.51	0.04	2.46	0.23	7.16					0.61									
PlaR	0.49	0.55	0.81	0.52	0.38	0.73	0.39	0.70	0.02	0.49	0.06	1000.43	0.10	0.35	0.03	1.70	0.16	4.96						0.23								
Me	1.11	2.07	3.13	2.42	0.96	1.99	1.47	2.33	0.03	0.83	0.10	0.74	1000.18	0.60	0.05	2.90	0.28	8.43											0.89	0.89		
OrC	1.03	0.63	0.89	0.67	0.51	0.84	0.65	2.73	0.01	0.32	0.04	0.29	0.07	1000.23	0.02	1.13	0.11	3.28	0.04	0.34	0.10											
CnR	4.84	6.52	5.74	6.07	5.11	9.07	14.92	12.84	0.12	2.99	0.36	2.67	0.64	2.16	1000.17	10.51	1.00	30.57			0.40				0.01		0.23	0.60				0.23
EWR	0.02	0.02	0.01	0.03	0.01	0.06	0.04	0.05		0.02		0.02		0.02		1000.07	0.01	0.21													0.10	
LeR	0.09	0.11	0.10	0.12	0.08	0.15	0.26	0.23		0.05	0.01	0.05	0.01	0.04		0.19	1000.02	0.55				0.12										
RuR		0.01	0.01	0.01	0.01	0.01	0.01	0.02		0.01		0.01		0.01		0.03		1000.09							0.17							

Table 5. *Cont.*

	Ag	Mi	Fo	Ma	Ut	Tr	Se	Fr	Lf	GlR	PprR	PlaR	Me	OrC	CnR	EWR	LeR	RuR	Food	Gdn	Tim	Txt	Ppr	Pla	Ru	Gl	Pb	Cn	MF	MNF	EW	Oth
Food	7.07	3.12	3.20	3.53	2.55	4.17	2.83	5.87	0.06	1.50	0.18	1.34	0.32	1.08	0.09	5.28	0.50	15.35	1.00													
Gdn	1.80	1.03	1.25	1.03	0.83	1.37	1.19	6.57	0.02	0.57	0.07	0.50	0.12	0.41	0.03	1.99	0.19	5.78		1.00												
Tim	1.16	1.45	3.31	1.71	1.17	1.96	1.22	2.45	0.02	0.64	0.08	0.57	0.14	0.46	0.04	2.25	0.21	6.55			1.00											
Txt	0.71	0.88	0.82	1.00	0.66	1.27	2.16	1.88	0.02	0.45	0.05	0.40	0.10	0.33	0.03	1.58	0.15	4.61				1.00										
Ppr	2.19	2.38	2.18	2.73	1.95	3.41	2.36	4.09	0.04	1.15	0.14	1.02	0.24	0.83	0.07	4.04	0.38	11.74					1.00									
Pla	2.13	2.41	3.54	2.26	1.65	3.17	1.68	3.06	0.08	2.11	0.25	1.88	0.45	1.52	0.12	7.41	0.71	21.57						1.00								
Ru	0.03	0.06	0.03	0.06	0.06	0.06	0.05	0.09		0.05	0.01	0.05	0.01	0.04		0.19	0.02	0.54							1.00							
Gl	0.17	0.14	0.14	0.17	0.11	0.19	0.14	0.25		0.06	0.01	0.06	0.01	0.05		0.23	0.02	0.66								1.00						
Pb	0.09	0.12	0.09	0.12	0.09	0.18	0.36	0.27		0.06	0.01	0.05	0.01	0.04		0.20	0.02	0.60									1.00					
Cn	6.23	8.49	6.09	7.64	6.58	11.95	22.75	17.43	0.15	3.95	0.47	3.52	0.84	2.85	0.23	13.87	1.32	40.37							0.01			1.00				
MF	0.94	1.20	2.63	1.83	0.72	1.69	1.28	1.94	0.02	0.65	0.08	0.58	0.14	0.47	0.04	2.28	0.22	6.62											1.00			
MNF	0.30	1.13	0.89	0.89	0.36	0.54	0.36	0.68	0.01	0.28	0.03	0.25	0.06	0.20	0.02	0.98	0.09	2.86												1.00		
EW	0.23	0.20	0.15	0.31	0.13	0.63	0.41	0.46	0.01	0.21	0.02	0.19	0.04	0.15	0.01	0.73	0.07	2.14													1.00	
Oth	2.69	3.57	3.21	3.40	2.91	4.68	3.04	5.82	0.06	1.53	0.18	1.36	0.33	1.10	0.09	5.37	0.51	15.62														1.00

Million $ per Million $ | Dollar $ per Tonne | Tonnes per Tonne | Tonnes per Million dollar $ | Kilograms per Tonne.

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Author Contributions

All authors contributed equally to this paper.

Conflicts of Interest

The authors declare no conflict of interest.

References and Notes

1. Goldstein, N. State of Organics Recycling in the United States. U.S. Environmental Protect Agency, Web Academy, 2007.
2. Parry, A.; James, K.; LeRoux, S. *Strategies to Achieve Economic and Environmental Gains by Reducing Food Waste*; The Waste & Resources Action Programme (WRAP): Banbury, UK, 2015.
3. Institution of Mechanical Engineers. *Global Food—Waste Not, Want Not*; Institution of Mechanical Engineers: London, UK, 2013. Available online: http://www.imeche.org/knowledge/themes/environment/global-food (accessed on 16 April 2015).
4. FAO E-Forum on Full Cost Accounting of Food Wastage, 21 October–24 November 2013. Available online: http://www.fao.org/nr/sustainability/food-loss-and-waste/food-wastage-forum/en/ (accessed on 16 April 2015).
5. The Waste & Resources Action Programme (WRAP). *The Composition of Waste Disposed of by the UK Hospitality Industry*; WRAP: Banbury, UK, 2011.
6. WRAP Synthesis of Food Waste Compositional Data 2010. Available online: http://www.wrap.org.uk/sites/files/wrap/Synthesis%20of%20Food%20Waste%20Compositional%20Data%202010%20FINAL.pdf (accessed on 16 April 2015).
7. WRAP New estimates for household food and drink waste in the UK 2011. Available online: http://www.wrap.org.uk/content/estimates-household-food-and-drink-waste-uk-2011 (accessed on 16 April 2015).

8. Mason, L.; Boyle, T.; Fyfe, J.; Smith, T.; Cordell, D. National Food Waste Assessment: Final Report. Available online: http://www.environment.gov.au/system/files/resources/128a21f0-5f82-4a7d-b49c-ed0d2f6630c7/files/food-waste.pdf (accessed on 16 April 2015).
9. Griffin, M.; Sobal, J.; Lyson, T.A. An analysis of a community food waste stream. *Agric. Human Values* **2009**, *26*, 67–81.
10. Lipinski, B.; Hanson, C.; Loma, J.; Kitinoja, L.; Waite, R.; Searchinger, T. Reducing Food Loss and Waste, World Resources Institute, 2013. Available online: http://www.wri.org/publication/reducing-food-loss-and-waste (accessed on 16 April 2015).
11. Making a World of Difference. The Global FoodBanking Network Annual Report 2013. Availabe online: http://foodbanking.wpengine.com/wp-content/uploads/2014/04/GFN-2013AR-FINAL-Spreads-HiRes.pdf (accessed on 16 April 2015).
12. Riches, G. The politics of food waste and poverty, Guard 2014. Available online: http://www.theguardian.com/society/2014/dec/01/politics-of-food-waste-and-poverty (accessed on 16 April 2015).
13. Poppendieck, J. *Sweet Charity?: Emergency Food and the End of Entitlement*; Penguin Books: London, UK, 1998.
14. Environment Protection and Heritage Council and the Department of Environment, Water, Heritage and the Arts. National Waste Report 2010. Available online: http://www.environment.gov.au/protection/national-waste-policy/publications/national-waste-report-2010 (accessed on 16 April 2015).
15. Reynolds, C.J.; Thompson, K.; Boland, J.; Dawson, D. Climate Change on the Menu? A Retrospective Look at the Development of South Australian Municipal Food Waste Policy. *Int. J. Clim. Chang. Impacts Responses* **2011**, *3*, 101–112.
16. Salhofer, S.; Obersteiner, G.; Schneider, F.; Lebersorger, S. Potentials for the prevention of municipal solid waste. *Waste Manag.* **2008**, *28*, 245–259.
17. Mohamad, Z.F.; Idris, N.; Baharuddin, A.; Muhammad, A.; Nik Sulaiman, N.M. The role of religious community in recycling: Empirical insights from Malaysia. *Resour. Conserv. Recycl.* **2012**, *58*, 143–151.
18. Reynolds, C.J.; Mavrakis, V.; Davison, S.; Høj, S.B.; Vlaholias, E.; Sharp, A.; Thompson, K.; Ward, P.; Coveney, J.; Piantadosi, J.; *et al.* Estimating informal household food waste in developed countries: The case of Australia. *Waste Manag. Res.* **2014**, *32*, 1254–1258.
19. Beretta, C.; Stoessel, F.; Baier, U.; Hellweg, S. Quantifying food losses and the potential for reduction in Switzerland. *Waste Manag.* **2013**, *33*, 764–773.
20. Youn, A.; Ollinger, M.; Kantor, L.S. Characteristics of mid-Atlantic food banks and food rescue organizations. *Food Rev.* **1999**, *22*, 45–51.
21. Cotugna, N.; Beebe, P. Food banking in the 21st century: Much more than a canned handout. *J. Am. Diet. Assoc.* **2002**, *102*, 1386–1388.
22. Phillips, C.; Hoenigman, R.; Higbee, B.; Reed, T. Understanding the Sustainability of Retail Food Recovery. *PLoS ONE* **2013**, doi:10.1371/journal.pone.0075530.
23. Phillips, C.; Hoenigman, R.; Higbee, B.; Reed, T. *Food Redistribution as Optimization*; Computer Science Technical Report, CU-CS-1085-11; University of Colorado: Boulder, CO, USA, 2011.
24. Wie, S.; Giebler, K. Nonfood-Related Challenges and Resources Affect Functioning of Food Banks. *J. Foodserv. Bus. Res.* **2013**, *16*, doi:10.1080/15378020.2013.761044.

25. Koshy, P.; Phillimore, J. Bridge of Support: The Economic Impact of Foodbank WA. *J. Contemp. Issues Bus. Gov.* **2008**, *14*, 21–33.
26. Schneider, F. The evolution of food donation with respect to waste prevention. *Waste Manag.* **2013**, *33*, 755–763.
27. Lorenz, S. Socio-ecological consequences of charitable food assistance in the affluent society: The German *Tafel*. *Int. J. Sociol. Soc. Policy* **2012**, *32*, 386–400.
28. Solak, S.; Scherrer, C.; Ghoniem, A. The stop-and-drop problem in nonprofit food distribution networks. *Ann. Oper. Res.* **2014**, *221*, 407–426.
29. Gunes, C.; van Hoeve, W.-J.; Tayur, S. Vehicle routing for food rescue programs: A comparison of different approaches. In *Integration of AI and OR Techniques in Constraint Programming for Combinatorial Optimization Problems*; Springer: New York, NY, USA, 2010; pp. 176–180.
30. Riches, G. *Food Banks and the Welfare Crisis*; James Lorimer & Company: Ottawa, ON, Canada, 1986.
31. McPherson, K.L. Food insecurity and the food bank industry: A geographical analysis of food bank use in Christchurch. Master's Thesis, University of Canterbury, Christchurch, New Zealand, 2006.
32. Cotugna, N.; Vickery, C.; Glick, M. An outcome evaluation of a food bank program. *J. Am. Diet. Assoc.* **1994**, *94*, 888–890.
33. Adams, C.; Tabacchi, M. Perishable-food-rescue programs: Status and prospects. *Cornell Hotel Restaur. Adm. Q.* **1997**, *38*, 62–67.
34. Binns, S. Food rescue: How restaurants serve the hungry. *Top. Clin. Nutr.* **1998**, *13*, 46–50.
35. Tarasuk, V.; Eakin, J. Food assistance through "surplus" food: Insights from an ethnographic study of food bank work. *Agric. Human Values* **2005**, *22*, 177–186
36. Tarasuk, V.; Eakin, J. Charitable food assistance as symbolic gesture: an ethnographic study of food banks in Ontario. *Soc. Sci. Med.* **2003**, *56*, 1505–1515.
37. Foodbank Australia. End Hunger In Australia. Available online: https://www.foodbank.org.au/hunger-in-australia/the-endhunger-report/ (accessed on 16 April 2015).
38. Godinho, M. Re: FareShare information 2013, Personal Communication.
39. Fareshare. Annual Report 2008–2009. Available online: http://www.fareshare.net.au/wp-content/uploads/2014/08/FareShare-2009-annual-report.pdf (accessed on 16 April 2015).
40. Fareshare. Annual Report 2007–2008. Available online: http://www.fareshare.net.au/wp-content/uploads/2014/08/FareShare-2008-annual-report.pdf (accessed on 16 April 2015).
41. OzHarvest. Annual Report 2009. Available online: http://www.ozharvest.org/news-and-media/annual-reports/ (accessed on 16 April 2015).
42. OzHarvest. Annual Report 2008. Available online: http://www.ozharvest.org/news-and-media/annual-reports/ (accessed on 16 April 2015).
43. SecondBite. Annual Report 2009. Available online: http://secondbite.org/annual-reports (accessed on 16 April 2015).
44. Pereira, L. RE: Request for food waste Data 2012, Personal Communication.
45. Food Bank. How We Work. Available online: http://www.foodbank.org.au/about-us/how-we-work/ (accessed on 16 April 2015).
46. Seik, F.T. Recycling of domestic waste: Early experiences in Singapore. *Habitat Int.* **1997**, *21*, 277–289.

47. Read, M.; Gregory, M.K.; Phillips, P.S. An evaluation of four key methods for monitoring household waste prevention campaigns in the UK. *Resour. Conserv. Recycl.* **2009**, *54*, 9–20.
48. Refsgaard, K.; Magnussen, K. Household behaviour and attitudes with respect to recycling food waste—experiences from focus groups. *J. Environ. Manag.* **2009**, *90*, 760–771.
49. Mena, C.; Adenso-Diaz, B.; Yurt, O. The causes of food waste in the supplier-retailer interface: Evidences from the UK and Spain. *Resour. Conserv. Recycl.* **2011**, *55*, 648–658.
50. Woolridge, A.C.; Ward, G.D.; Phillips, P.S.; Collins, M.; Gandy, S. Life cycle assessment for reuse/recycling of donated waste textiles compared to use of virgin material: An UK energy saving perspective. *Resour. Conserv. Recycl.* **2006**, *46*, 94–103.
51. Lenzen, M.; Reynolds, C. A Supply-Use approach to Waste Input-Output Analysis. *J. Ind. Ecol.* **2014**, *18*, 212–226.
52. Reynolds, C.J.; Piantadosi, J.; Boland, J. A Waste Supply-Use Analysis of Australian Waste Flows. *J. Econ. Struct.* **2014**, *3*, 1–16.
53. Nakamura, S. Input-output analysis of waste cycles. In Proceedings of the First International Symposium On Environmentally Conscious Design and Inverse Manufacturing, Tokyo, Japan, 1–3 February 1999; pp. 475–480.
54. Nakamura, S.; Kondo, Y. Input-Output Analysis of Waste Management. *J. Ind. Ecol.* **2002**, *6*, 39–63.
55. Nakamura, S.; Kondo, Y. Waste Input-Output Analysis, LCA and LCC. In *Handbook on Input-Output Economics in Industrial Ecology*; Suh, S., Ed.; Springer: New York, NY, USA, 2008; pp. 561–572.
56. Reutter, B.; Reynolds, C.; Kenway, S.; Lane, J.; Piantadosi, J.; Boland, J. The environmental impact and economic value of food waste in Australia; a state by state examination: An Input-Output approach. In *Industrial Ecology In The Asia-Pacific Century: Interdisciplinary Science For Building Sustainable Industrial Systems And Human Settlements*, Proceedings of the Joint 11th International Society For Industrial Ecology (ISIE) Socio-Economic Metabolism Section Conference, Melbourne, Australia, 17–19 November 2014.
57. Reynolds, C.J.; Reutter, B.; Boland, J.; Piantadosi, J.; Kenway, S. The economic value and environmental impacts of food waste in Australia. In Proceedings of the 22nd International Input-Output Conference, Lisbon, Portugal, 14–18 July 2014.
58. Thompson, M. *Rubbish Theory:The Creation and Destruction of Value*; Oxford University Press: Oxford, UK; New York, NY, USA, 1979.
59. Kurz, H.D. Goods and bads: Sundry observations on joint production, waste disposal, and renewable and exhaustible resources. *Prog. Ind. Ecol. An Int. J.* **2006**, *3*, 280–301.
60. Kurz, H.D. Classical And Early Neoclassical Economists On Joint Production(*). *Metroeconomica* **1986**, *38*, 1–37.
61. Lager, C. Joint Production with “Restricted Free Disposal”. *Metroeconomica* **2001**, *52*, 49–78.
62. Lager, C. Prices of Goods’ and “Bads”: An Application of the Ricardian Theory of Differential Rent. *Econ. Syst. Res.* **1998**, *10*, 203–223.
63. O’Brien, M. Rubbish values: Reflections on the political economy of waste. *Sci. Cult. (Lond.)* **1999**, *8*, 269–295.

64. Östblom, G.; Söderman, M.L.; Sjöström, M. *Analysing Future Solid Waste Generation- Soft Linking a Model of Waste Management with a CGE-Model for Sweden*; The National Institute Of Economic Research (Nier): Stockholm, Sweden, 2010.
65. The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Recovering resources, creating opportunities Integrating the informal sector into solid waste management, 2011.
66. Burnley, S.J.; Ellis, J.C.; Flowerdew, R.; Poll, A.J.; Prosser, H. Assessing the composition of municipal solid waste in Wales. *Resour. Conserv. Recycl.* **2007**, *49*, 264–283.
67. Bulkeley, H.; Gregson, N. Crossing the threshold: Municipal waste policy and household waste generation. *Environ. Plan. A* **2009**, *41*, 929–945.
68. Reynolds, C.; Geschke, A.; Piantadosi, J.; Boland, J. Estimating Industry and Municipal solid waste data at high resolution using economic accounts: An Input-Output approach with Australian case study. *J. Mater. Cycles Waste Manag.* **2015**, doi:10.1007/s10163-015-0363-1.
69. Reynolds, C.J. Quantification of Australian Food Wastage with Input Output Analysis. Ph.D Thesis, University of South Australia, Adelaide, Australia, 2013.
70. Allan, P. *Waste and Recycling in Australia*; Department of Environment and Heritage: Canberra, Australia, 2006.
71. WCS Market Intelligence. *The Blue Book : Australian Waste Industry : 2007/08 Industry and Market Report*; WCS Market Intelligence: North Sydney, Australia, 2008.
72. Waste Management & Environment Media Pty Ltd. Inside Waste Industry Report 2011–2012.
73. Hyder Consulting. *Waste and Recycling in Australia 2011: Incorporating a Revised Method for Compiling Waste and Recycling Data*; Department of Sustainability, Environment, Water, Population and Communities: Canberra, Australia, 2012.
74. Foodbank. NSW 2009–2010 Annual Review. Available online: http://www.foodbanknsw.org.au/files/2014/06/00-Foodbank-NSW-Financials-2010-FINAL.pdf (accessed on 16 April 2015).
75. Foodbank. 2009/10 Annual Report Victoria. Available online: http://www.foodbankvictoria.org.au/files/2011/08/Foodbank-Victoria-Annual-Report_2009-2010.pdf (accessed on 16 April 2015).
76. Foodbank. WA Annual Report 2009.
77. Foodbank. South Australia Annual Report 2009/2010.
78. Westpac, E.R.S. Financial year average exchange rates Australian dollar 1999/00–2012/13.
79. Food and Agriculture Organization of the United Nations FAOSTAT database 2014.
80. Department of Agricultrue, Fisheries and Forestries (DAFF). *Australian Food Statistics 2009*; DAFF: Canberra, Australia, 2010.
81. Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). *Australian Fisheries Statistics 2011*; ABARES: Canberra, Australia, 2012.
82. Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). *Agricultural Commodities: September Quarter 2011*; ABARES: Canberra, Australia, 2011.
83. Marx, K. Aveling, translated from the third G. In *A Critical Analysis of Capitalist Production*; Engels, F., Ed.; Swan Sonnenschein & Co: London, UK, 1889.
84. Wolfram Alpha LLC. Available online: http://www.wolframalpha.com (accessed on 16 April 2015).

85. Reynolds, C.J.; Piantadosi, J.; Buckley, J.D.; Weinstein, P.; Boland, J. Evaluation of the environmental impact of weekly food consumption in different socio-economic households in Australia using environmentally extended input–output analysis. *Ecol. Econ.* **2015**, *111*, 58–64.
86. Lenzen, M.; Geschke, A.; Kanemoto, K.; Moran, D. Eora: A Global Multi-Region Input Output database. Available online: http://www.globalcarbonfootprint.com (accessed on 16 April 2015).
87. Lenzen, M.; Moran, D.; Kanemoto, K.; Geschke, A. Building Eora: A global multi-region input-output database at high country and sector resolution. *Econ. Syst. Res.* **2013**, *25*, 20–49.
88. Lenzen, M.; Kanemoto, K.; Moran, D.; Geschke, A. Mapping the Structure of the World Economy. *Environ. Sci. Technol.* **2012**, *46*, 8374–8381.
89. Lenzen, M.; Bhaduri, A.; Moran, D.; Kanemoto, K.; Bekchanov, M.; Geschke, A.; Foran, B. *The Role of Scarcity in Global Virtual Water Flows*; Discussion Papers on Development Policy No. 169; Social Science Research Network: Bonn, Germany, 2012.
90. Hanjra, M.A.; Qureshi, M.E. Global water crisis and future food security in an era of climate change. *Food Policy* **2010**, *35*, 365–377.
91. Australian Bureau of Statistics. *3101.0—Australian Demographic Statistics*; Australian Bureau of Statistics: Canberra, Australia, 2014.