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Extending the Waste Input Output Model to behavioural change: the case of municipal food waste in South Australia

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### Abstract:

Australian households are throwing out more than $5 billion worth of food each year, with over 40% of household food wasted. The creation, transport and disposal of this non consumed food constitutes a needless waste of resources and energy. Public education campaigns are run by government agencies in an attempt to reduce this wastage. These campaigns often lack the formal quantitative verification required to provide measures of economic and environmental impact.

This paper explores the extent to which the Waste Input-Output model (WIO) can be extended to provide the solution to this lack of quantification. This modification of WIO will enable an effective economic and environmental assessment of waste education and behaviour modification campaigns to take place. These modifications primarily include adapting the waste allocation matrix to include influences from psychological behavioural change models to gauge the reallocation of waste due to household behaviour change.

Informing the creation of this behavioural change based extension of the WI/O model is the 2010 South Australian local council program to provide a new food waste education and collection trial to further enhance municipal food waste collection.

Keywords: Municipal food waste, consumer behaviour change, Waste Input Output

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## Introduction

The announcement by The Australia Institute that Australian households throw out more than $5 billion worth of food each year, led to food waste becoming a high priority issue across Australia (Baker 2009). The various states of Australia have tackled the issue in a variety of ways. South Australia (SA) – indicating a high level of political and environmental commitment and a willingness to “‘stick its neck out” (2010 46-7) – established Zero Waste SA (ZWSA) via the Zero Waste SA Act in 2004, an organisation with the aim of reducing waste (of all forms) to landfill by 25% by 2014 (Moore 2009). At present, SA households output 1.5-3kgs of food waste per week on average into the residual waste bin rather than a specific ‘green’ garden organics bin (NA 2007; NA 2007). ZWSA has dertermind that the co-collection and extraction of domestic food waste from the waste stream could make a “significant contribution to improvement in landfill diversion rates” (NA 2007; NA 2007). The method chosen to implement this redirection was behavioural change via an education campaign rather than using economic tools such as monetary incentives.

However, the economic and environmental effects that result from public education or behavioural change campaigns are hard to quantify via standard input output modelling or indeed any other means (e.g. waste volume, CO2 emission levels etc). One model that has the potential to be modified to assess the impact of behavioural change is that of Nakamura and Kondo’s (2009; Suh, Nakamura et al. 2009) waste input-output (WIO) model.

Since its inception the WIO model of Nakamura et al (1999) has been utilised by scholars to model a variety of waste scenarios both in Japan and globally. As Kagawa (2007) asserts, the WIO model has become a recognised form of Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Environmental input–output analysis (EIOA) due to the WIO’s ability to account for multiple pollution types and expenses (air and water pollutants, energy and social costs) across the entire economy.

Kondo et al (Kondo 2007) furthered developed the WIO by integrating a consumer behaviour model, describing situations where technological change altered the maximum possible consumption levels. This model enabled time and consumption methodology to be investigated and the most efficient forms of consumption and waste disposal to be selected by the consumer.

Building upon the work of the aforementioned scholars, this paper reports a modification of the allocation matrix function of the WIO to enable it to describe and model the effects of psychological behavioural change of final demand waste producers (households) via the reallocation of waste into different waste streams. Due the brevity of this paper the estimation of the effects of behavioural change programs (advertising and public education) for waste reduction is understood to be an area for further research.

## Methodology

Before this modification can occur, notation must be standardised. Employing the same notation and framework as Nakamura and Kondo(2008), (Table 1 is also reproduced from Nakamura and Kondo (2008) to aid in visual depiction of the model). We define that bold faced capital letters refer to matrices and lowercase letters refer to vectors. We also define (as standard in IO) that there are goods and service producing sectors; waste treatment sectors; and waste types, with the other standard IO notation in place as detailed in Nakamura and Kondo (2008) (for example the output of Sector is defined as , whilethe input from Sector in Sector is ).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ***Goods producing sectors*** | ***Treatment Sectors*** | ***Final Demand*** | ***Total*** |
| ***Goods Input*** |  |  |  |  |
| ***Waste Generation*** |  |  |  |  |
| ***Waste input*** |  |  |  |  |
| ***Env. Load emission*** |  |  |  |  |
| ***Value Added*** |  |  |  |  |

Table 1: A visual representation of the WIO model, reproduced from Nakamura and Kondo(2008), note that the totals column is a vector

The generation and input of waste ( ) is represented by and respectively - generation referring to the creation of waste from that particular sector, while input refers to the processing or moving of waste from one sector to another. Extending this notation to the final demand sector variants we understand to be the final demand for , while – the generation of waste , and – the input of waste in to the final demand sector.

Next we describe the net generation of waste k from sector or . We understand that when > sector generates greater amount of waste than it uses as input, it creates a positive demand for waste treatment. Alternatively, when < , sector j reduces the amount of waste that has to be treated as waste (Nakamura and Kondo 2008). Furthermore, the total amount of waste that undergoes waste treatment is given by the sum of ‘s for all j e.g. .

## The S matrix: A developmental history

The environmental IO (EIO) model of Leontief (Leontief 1970) and Duchin (Duchin 1990) corresponds to the early development of the WIO model. Implicit in the EIO model is the assumption that there exists for each pollutant (waste) one and only one abatement (treatment) method that treats no other pollutant but that pollutant. This condition is hardly applicable to the reality of waste management because, in general, there is no one-to-one correspondence between a waste and its treatment method. It is usually the case that a multiplicity of treatment methods can be applied to a given solid waste, either separately or jointly. For instance, food waste can be composted, gasified, incinerated, or landfilled. Any of these methods can be applied separately or in combination.

Prior to the introduction of the WIO model, the one to one correspondence () of waste type and treatment methods was a limiting factor, that although enabling the analysis of waste in the economy, it did so at the expense of detailed analysis (Leontief 1970; Duchin 1990). Nakamura and Kondo (2002) overcame this barrier to detailed investigation via the elegant utilisation of an matrix. Termed the “allocation matrix”, its () component refers to the share of waste that is treated by treatment method (Nakamura 2002), with  due to the percentage like nature of the components of *.*

By the relaxation of restrictions found in previous EIOA/WIO style models, Nakamura and Kondo (2002) found that multiple pollutants can be treated by a single abatement process and the condition does not hold, rather .This in turn means that several treatment methods can be utilised in conjunction with a single type of waste as each column can contain more than one non-zero element.

Multiplication from the left by converts the net waste generation (as seen in the above table) into the net input of waste treatment services and and the net amount of waste treated into the - vector of output of waste treatment sectors (Nakamura and Kondo 2008)

Thus, as given by (Nakamura and Kondo 2008) the quantity WIO is given as:

This can be solved for the net input to waste treatment services, as well giving the waste multipliers (if the inverse matrix exists):

Model Modification  
The modification we propose is that the content of the allocation matrix – usually determined via economic factors, technological factors, and institutional factors (Nakamura and Kondo 2009 192) – can now also be modified via psychological behavioural change factors e.g. an increase in consumer education (rather than through tax or financial incentives or government mandate which would be economic and institutional factors). We posit this shift in behaviour – ceteris paribus – can be modelled by representing the change in the matrix rather than in ,as the amount of rubbish produced in final demand is not changing. Instead the change occurs in the consumers selection of disposal methodology.[[1]](#footnote-1)

However, behaviour change is hard to quantify and apply directly into as it is normally reported as the number of the population who reallocated in waste or via alterations weight and volume of waste flows (the latter of these already a reporting method for ). The easiest method to report change to the former however is to adapt psychological behavioural change models - which give a quantifiable percent based score that can be harmonised with the rest of **.**

There are a variety of psychological behavioural change models and metrics worth investigation. Due to the brevity of this exploratory paper, we will only cite two examples of behaviour change metrics and models: the WRAP (Waste & Resources Action Programme) standard survey metrics (WRAP 2010), and the Transtheoretical Model (TTM) of behaviour change (Prochaska and DiClemente 1983). These metrics have the ability to express a statistical measure of how waste streams are affected by behavioural change, this can then be expressed as change in over the course of the educational program.

WRAP is a not for profit, quasi non governmental organisation created in 2000 as part of the UK Government's waste reduction strategies and has been at the forefront of waste reduction in England, Scotland, Wales and Northern Ireland. One of roles of WRAP has been to measure the UK population’s participation and commitment in relation to waste reduction methods such as recycling, composting or food waste reduction (WRAP 2009; WRAP 2010 4-53). WRAP’s survey metric is an easy to administer set of three questions per waste reduction behaviour; with responses to these questions determining what percentage of the population are “committed waste reducers”.

The Transtheoretical Model (TTM) of Change introduced in the 1980s has now risen to be “arguably the dominant model of health behaviour change” (Armitage 2009 195), and has been suggested to evaluate change in pro environmental behaviours (Davison, Thompson et al. 2011 Forthcoming ). The ability of the TTM to adapt to a variety of investigations is due to the ease of use. Via a few questions the TTM is able to indicate both participants’ readiness for change and personal barriers to change (in relation to the issue). The TTM proposes taxonomy of five change stages that citizens move through (‘pre-contemplation’, ‘contemplation’, ‘planning’, ‘action’ and ‘maintenance’). These in turn can be broken down into population numbers with probabilities representing movement between stages, giving the TTM the ability to represent (and give reasons for) behavioural shift.

The two aforementioned psychological behavioural change metrics provide a foundation to illustrate how waste streams are affected by behavioural change. Simply put, each type of waste treatment option from the household perspective will result in a direct action that may or may not be adopted as behaviour. Education campaigns (and the psychological change they create) play a role in altering how waste is disposed of, resulting in the shifting of waste allocation. This can be observed as changes over the course of the educational program’s duration.

## Case study: South Australian food waste pilot

In 2009-10 ZWSA undertook a food waste diversion campaign (known as “the South Australian food waste pilot”) to educate 17,426 households from 10 participating council areas about the little known capacity for food waste to be disposed of in the ‘green’ garden organics bin rather than into the ‘red or blue’ residual waste (landfill) bin (Zero Waste SA 2010). Table 2 displays the waste disposal/treatment methods available to the household in SA - this in turn reflects the standard matrix (Table 3 and 4) that is used when discussing food waste in SA.

## Education Campaign methodology

The education and communication campaign commenced via distributed materials to households including an information brochure, kitchen food waste container sticker and street bin lid sticker, and a collection calendar, along with written materials (websites, newsletters and media releases). Depending on council area, participating households were also given of one of two food waste recycling systems (see Figure 1) – the kitchen caddy or the bio basket (with one year’s supply of compostable bags) – as well as weekly or fortnightly pickup of the garden organics bin, in order to motivate new waste disposal practices.



Figure 1: The two food waste recycling systems piloted – the kitchen caddy (left) and bio basket (right) with roll of compostable bag. (Zero Waste SA 2010)

To test the change in waste disposal practices two kerbside audits of domestic waste, recycled and garden organics were conducted, one prior to the commencement of the pilot in Spring 2008 and another ‘post’ audit commenced in Autumn 2009. The sample for these audits consisted of 1130 households from the 10 participating council areas (6 metropolitan, 4 rural). Sampling was based on the same households for each suburb in each kerbside audit for each waste stream and was undertaken over an appropriate period to ensure all of the collection services (residual waste, recycling and garden organics) in each area were sampled.

The significant costs associated with the pilots development, deployment and data collection included the supply of containers and compostable cornstarch liner bags; the kerbside auditing; market research and the design of communication material. These elements cost in the vicinity of $615,000AUD (Lang 2011).

|  |  |
| --- | --- |
| **Waste disposal option** | **Waste treatment type** |
| **Municipally provided options:** |  |
| Residual waste/rubbish bin | Landfill |
| Garden Organics Bin | Centralised Composting |
| **Household provided options:** |  |
| Composting | Local Composting |
| Animal disposal | Local Composting/Landfill |

Table 2: Food Waste disposal options for households in SA,

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Waste type** |  |  |
| **Treatment methods** | **Food waste** | **Residual waste** | **Green waste** |
| **Landfill** | 1 | 1 | 0 |
| **Centralised Composting** | 0 | 0 | 1 |

Table 3: Pre education campaign, SA S matrix for municipal food waste.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Waste type** |  |  |
| **Treatment methods** | **Food waste** | **Residual waste** | **Green waste** |
| **Landfill** | 40.3 | 1 | 0 |
| **Centralised Composting** | 59.7 | 0 | 1 |

Table 4: Modified post education campaign “best case” SA S matrix for municipal food waste.

The simplified results of this campaign (Zero Waste SA 2010) indicate that the mean best case scenario across the councils was food waste captured and diverted from the residual waste or rubbish bin at a rate of 59.7% ( or 1.86 kg per bin load), with the highest diversion rate being 74.08% in the suburb of Kensington. These results were accomplished via the use of the Bio Bin and fortnightly rubbish collection. Other variants were less successful and resulted in diversion rates of 28.0% (1.30 kg per bin, Bio basket (weekly rubbish collection)), and 9.31% (0.38 kg per bin, Kitchen caddy).

It must also be noted that we are focusing on measuring the impact of the study upon members of the population who prior to the pilot were disposing of their food waste in the residual waste bin, rather than those who were disposing of their food waste via household provided options (such as composting or animal disposal). This is due to the pilot focusing its efforts on modifying the behaviour of those who utilised the municipally provided system, rather than those who worked outside the municipally provided disposal options.

Utilising the pilot’s data we have estimated the effectiveness of this waste education strategy and disposal system, projecting the impacts of the educational campaign if implemented across the Adelaide metropolitan area (19 council areas, or 503,034 households). This would include fortnightly collection of green organics bins (26 collections per year) across the metropolitan area with an average fortnightly collection of residual waste of 5.54kg, and an average fortnightly food waste diversion to the organics bin of 1.86 kg.

## Results

Once the WIO model was prepared the immediate results indicated that 24,327 tonnes per year of food waste are diverted to composting while 16,422 tonnes still become landfill (see Chart 1). The environmental impact of this shift can be observed via CO2 emission reduction. In Australia, it is estimated that for every tonne of municipal waste stored in a landfill 0.74 tonnes of CO2 gases are released (Barton and Atwater 2002; Productivity Commission 2006 428). Thus, computed via the WIO, 18,063 tonnes of CO2 gases are diverted from landfill, with 12,152 tonnes still being released annually from the non diverted waste (see Chart 1) . This is a reduction from 60 kilograms of CO2 produced per household (urban SA) per year to 24 kilograms via the change in waste allocation – a reduction of 36kgs. Finally, considering the cost of the trial was $615,000 - or $35.30 per household - this gives the figure of $1.02 per kg or $1020 per tonne of C02 offset. Further research is needed to validate if this amount of spending is reasonable for the amount of C02 offset.

Chart 1: Reduction in Tonnage via Behavioural Change for a full SA roll out.

## Conclusion

This paper constructed a waste input output model that had a modified S allocation matrix to allow for psychological change of waste producers (households changing their waste disposal habits) to be modelled. This modified WIO model was then utilised to hypothesise results of expanding the 2009/10 food waste education pilot (trialled in 10 participating councils), to all of urban South Australia. The WIO indicated that rolling out the education campaign across SA would decrease household CO2 emissions by 36 kg per year at the cost of $35 per house.

The main modification is that the allocation matrix (already a percentage measure that is determined via economic factors, technological factors, and institutional factors (Nakamura and Kondo 2009 192)) can also now be modified via psychological behavioural change factors, which in the case above was an educational campaign. This modification allows for change to waste allocation via education to occur and be analysed in a I/O framework.

Limitations are present however, as this papers modification cannot cope with behavioural change that reduces overall waste rather than just re-allocation of waste. Further work must be carried out in order to investigate expanding the modification to deal with this type of behavioural change.

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1. Education campaigns can also be utilised to reduce waste, rather than change disposal habits of its target audience. However, the SA food waste pilot focused on the changing disposal methodology and thus the topic of waste reduction via education campaigns shall be left for further research in future research. [↑](#footnote-ref-1)