What Causes Waste Flows? An Interregional Analysis of Welsh Waste Shipments

Christa D. Jensen and Stuart McIntyre*

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Abstract

Much of the waste flow literature focuses on international waste trade and oftentimes solely on trade in hazardous wastes. However, data is often available for waste flows within national borders and these flows could yield just as much information on the relationships that exist between origins and destinations. In a world where waste creation, transport, and disposal is becoming a global problem, understanding and modelling these flows is becoming increasingly important.

This paper uses a gravity model approach and data on commercial waste shipments between local authorities within Wales to examine the characteristics that are responsible for origin-destination waste flow relationships. We focus on economic characteristics, as well as socioeconomic and demographic characteristics that may play a role in interregional Welsh waste trade.

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*Christa D. Jensen, Graduate Research Fellow, Regional Research Institute, Department of Economics, West Virginia University, PO Box 6825, Morgantown, WV 26506; Phone: (304) 293-8545; Fax: (304) 293-6699; Christa.Jensen@mail.wvu.edu. Stuart McIntyre, Doctoral Student, Department of Economics, University of Strathclyde, Sir William Duncan Building, 130 Rottenrow, Glasgow G4 0GE, Scotland, UK; Phone: +44 (0)141 548 3858 (Ext. 3858); s.mcintyre@strath.ac.uk.

1 Introduction

In the last few decades, humans have become increasingly aware of the environmental effects of their behaviour; for example, driving generates emissions and consumption generates waste. Although all humans create waste, a not in my backyard (NIMBY) attitude is often adopted when it comes to waste disposal. Over time, this behaviour has created a market for waste transportation and disposal that extends far beyond the proverbial backyard of the waste creator. The trade of both hazardous and non-hazardous wastes within and among nations is growing. However, it is becoming increasingly common for individuals and/or governments to want to take responsibility for the environmental externalities of their behaviour, including externalities from waste creation. As markets for waste generation, transportation, and disposal are increasing in scale, understanding and modelling these markets will become a crucial component of waste management and policy.

Certain types of waste flows are governed by sub-national, national, or even international regulations. One example of an international regulation is the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal* (UNEP, 1989), hereafter, the Basel Convention. In an effort to protect human health and the environment, the 172 parties to the Basel Convention are committed to reducing the volume and hazardousness of transboundary waste flows . Such regulations are often driven by a political or moral sentiment to limit the shipment of wastes from developed areas to developing areas (Baggs, 2009:2). In fact, 68 of the 172 parties to the Basel Convention have also ratified the Ban Amendment which implies an immediate ban on the exports of hazardous wastes for final disposal from Organisation for Economic Co-operation and Development (OECD) countries to non-OECD countries. As these types of regulations begin to take effect at all jurisdictional levels, it is important to understand the relationships and patterns that exist within regions, nations, and continents, which drive these waste flows. A better understanding of these waste flows will make it possible for researchers to better inform policymakers and their decisions on waste trade, disposal, and management.

Waste reduction and management strategies are also being implemented at the national level. In the United Kingdom, the country of Wales is taking major steps forward towards their waste reduction goals. The Welsh ecological footprint estimated in Ravetz et al. (2007) concludes that Wales consumes more than its fair share of global resources. In essence, if Welsh consumption levels were implemented globally, one planet (and all of its resources) would not be enough to sustain the population. The ultimate vision for One Planet Wales is for Welsh consumption to move towards one planet levels rather than continue at current unsustainable levels. Current and future Welsh waste strategies are an important component of the One Planet Wales vision as Welsh waste generation is responsible for 15% of the Welsh ecological footprint.

The Welsh Assembly Government recently released its latest waste reduction strategy, *Waste Strategy 2009-2050: Towards Zero Waste* (WAG, 2009). The primary objectives of this new waste strategy are to achieve a 27% reduction in waste generation (compared to 2007 levels) by 2025 and to achieve a zero waste economy by 2050. This stringent waste reduction strategy focuses on changing the behavior of industry, governmental bodies, and households so that waste creation is minimized and includes plans to improve waste infrastructure to make it more efficient, environmentally sensitive, and accessible.

To successfully implement such a strategy, Welsh researchers and policymakers may find it useful to understand not only how and why waste is generated but also where the waste originates, where it is disposed of, and why the origin of the waste creation and destination of its disposal may not be the same. This paper aims to contribute to the discussion on Welsh waste strategy by examining the patterns of waste shipments within Wales. The factors that explain the flow of waste within a region or nation would surely be important in informing any discussion on waste reduction or infrastructure policies.

To date there have been very few analyses done purely on the flow of waste and those that do exist have focused on international hazardous waste flows. This paper outlines the first step in our investigation of the factors influencing waste flows between Welsh local authority areas. We use a simple gravity model and survey data on commercial and industrial waste shipments within Wales. Although the methodology applied in this paper is not new or unique, we attempt to fill a gap in the literature, which to our knowledge, contains no attempts to analyse the pattern of sub-national waste flows in such a manner.

We test whether, in a sub-national case, the waste that is generated flows from more developed areas to less developed areas as is suggested in the international waste trade literature (e.g. Baggs, 2009). Based on an analysis at the local (or unitary) authority level, this paper explores what characteristics, if any, explain the flows of commercial and industrial waste within Wales. The analysis focuses on economic, socioeconomic, and demographic characteristics that may play a role in Welsh waste trade. The remainder of this paper is structured as follows: Section 2 provides a concise overview of the related literature, Section 3 describes the analytical model, and Section 4 contains a description of the Welsh data used within this analysis. Results are presented and discussed in Section 5 and Section 6 concludes and offers directions for future research.

2 Literature Review

Hazardous waste trade has been an important topic in many fields of academic research since the late 1980's including the international trade and law literature

(Allen, 1995; O'Neill, 1998; Frey, 1998). Many articles focus on waste dumping that occurs in developing countries, examining equity and social justice (Williams, 1991; Marbury, 1995; Cusack, 1989-90). However, there also exists an extensive hazardous waste trade network between developed countries. O'Neill (2000) examines hazardous waste trade among OECD countries in an effort to contrast it with waste trade between developed and developing countries. She points out that although the trade of hazardous wastes produced in rich countries is often associated with cases of waste dumping on poorer countries in Africa, Latin America, and the Caribbean, the majority (80%) of this trade consists of legal trade between industrialised countries (O'Neill, 2000: 1).

Another recent contribution to the waste trade literature, Baggs (2009), looks at the pattern of international hazardous waste trade using data collected through the implementation of the Basel Convention. To our knowledge, Baggs (2009) is the first explicit treatment of origin-destination hazardous waste flows in the literature. Using a gravity model approach and two-stage regression analysis, her paper tests a version of the pollution haven hypothesis and concludes that while there is some evidence to suggest that there is a pollution haven effect in the international hazardous waste market, this effect is perhaps explained better by differences in capital per worker than by differences in income per capita (Baggs, 2009:12).

While the main focus within the literature has been on international hazardous waste trade, data are often available for waste generation, disposal, and trade within national and/or regional borders and may yield just as much information as their international counterparts. Many articles in the limited literature on subnational hazardous waste trade model only one side of the trade relationship. These articles attempt to model relationships between management/disposal choice and various location characteristics without modelling the actual flows. Levinson (1998, 1999) examines interstate hazardous waste shipments within the United States and the extent to which state taxes on imports have altered these shipments. Levinson ran multiple empirical specifications on data from both Resource Conservation and Recovery Act reports and the Toxics Release Inventory and found that state taxes matter. Sigman (1996) examines how waste management prices affect generation and disposal decisions for a specific type of hazardous waste. Alberini and Bartholomew (1999) take a slightly different approach to identify the determinants of hazardous waste disposal choice and find that this choice is dependent upon not only the cost of disposal but also existing contamination and the track record of the disposal facility.

Others take steps towards identifying relationships on both sides of the hazardous waste transaction. McGlinn (2000) describes the spatial agglomeration of both hazardous waste generation and management within the United States. Using data for 1995, he concludes that the petroleum and petrochemical industries of the Gulf Coast are responsible for a large portion of United States hazardous waste generation and management but that smaller generators are likely to ship their waste an average of 200 miles to be managed and disposed of. He also concludes that the destination of these shipments is in part attributed to state-specific disposal fees.

Sub-national studies on waste in general, as opposed to hazardous wastes, are even more limited. Engel (1994-95) provides some treatment of the solid waste situation within the United States. She characterises the uneven distribution of solid waste and examines the characteristics of states that are net waste importers vs. net waste exporters. Solid waste in Wales has also been studied in Jensen et al. (2009), which provides an attribution analysis for waste arisings. This type of analysis derives what type of final demand drives waste generation, but does not examine the pattern of observed waste flows within a country's borders.

We can also seek to draw parallels to our study from a sizeable segment of the environment and trade literature. This literature has taken many different forms from tests of the pollution haven hypothesis (e.g. Akbostanci et al., 2007; Cave and Blomquist, 2008; Grether and de Melo, 2003), to tests on trade liberalisation and energy-use (see Cole, 2006), even an examination of the link between environmental quality and trade levels for a given level of GDP (see Frankel and Rose, 2005). A frequent narrative in this literature is determining whether international trade is good or bad for the environment.

In seeking to determine the answer to this question, researchers often attempt to test the pollution haven hypothesis. In what is now a vast literature, there are conflicting conclusions about the presence of international pollution havens, making the current subnational analysis even more important. Theoretically, the pollution haven hypothesis states that increases in trade and the liberalisation of investment opportunities will cause pollution-intensive industries to concentrate in regions with relatively weak environmental policies and regulations. According to this hypothesis, pollution-intensive industries move to "pollution havens" to reduce their environmental liabilities in much the same manner that businesses move to "tax havens" to reduce their tax liabilities.

Jug and Mirza (2005) note that it was van Beers and van den Bergh (1997) who first used a gravity-based approach to examine the relationship between increased international trade and the level of environmental regulation in place in the trading countries as a measure of "environmental stringency". Van Beers and van den Bergh found "partial support" for the presence of pollution havens. Harris et al. (2002) built on this foundation, but were critical of the model specification chosen by van Beers and van den Bergh (1997). Using a different specification, Harris et al. (2002) reached the opposite conclusion, finding no support for the pollution haven hypothesis. Jug and Mirza (2005) find that in examining European trade, environmental legislation is indeed important in explaining these trade flows.

Within the environment and trade literature, there also exist sub-national studies. For example, adopting a similar methodology to the international analysis of Frankel and Rose (2005), Chintrakarn and Millimet (2006) examine the environmental impact of trade flows within the United States. The sub-national focus of this paper was in part motivated by the argument that Chintrakarn and Millimet (2006) used to justify their sub-national analysis. In short, they argue that there are two primary reasons why sub-national analyses are important: 1) there is a lack of empirical evidence at the sub-national level, which we discovered ourselves in our research, and 2) the theoretical framework guiding the international analyses is possibly incomplete (Chintrakarn and Millimet, 2006: 431). These two arguments provide the basis for the sub-national analysis in the paper at hand, as well as the opportunity to measure the transferability of the conclusions reached in international analyses, such as Baggs (2009), to sub-national cases.

3 Model

Before outlining the application of the gravity model that we use in this paper, it is perhaps worth briefly outlining the history of this type of model. Gravity models are based on the Newtonian observation that gravity is a function of the size of the masses and the distance between them. Isard (1956) first tried to take this approach and apply it to international trade, by essentially modelling the trade flow between two "masses", i.e. countries, as a function of their size (usually modelled as GDP in trade applications) and the distance between them. This approach was further developed by Tinbergen (1962), to move it closer to the form that is now used. The gravity model approach yielded important and interesting conclusions and generated results that fit the data well (Anderson, 1979:106), but was criticised for its lack of theoretical justification (see Baldwin, 1994).

It was only with the work of Linnemann (1966) and Bergstrand (1985, 1989), as well as Anderson (1979) who introduced product differentiation, that these concerns were placated. Linnemann (1966) developed a partial equilibrium basis for the gravity model. Bergstrand (1985) also developed a general equilibrium microeconomic foundation for the gravity model and continued to develop the model with his later paper, Bergstrand (1989), that introduced multiple industries and factors, as well as monopolistic competition. This allowed him to demonstrate the compatibility of the gravity model approach with later trade theories such the Heckscher-Ohlin-Samuelson model. The flexibility of the gravity model was further demonstrated by the work of Feenstra, Markusen, and Rose (2001), who showed that the gravity model was able to differentiate between a series of trade models (Feenstra, Markusen and Rose, 2001:446). Moving away from modelling pecuniary trade flows, there have been several applications of the gravity model approach that model flows as diverse as: money laundering (Walker and Unger, 2009), financial flows (Herrmann and Mihaljek, 2010; Wong, 2008), hazardous waste (Baggs, 2009), and in some cases flows of people, i.e. migration (Lewer and van den Berg, 2008 and Berthelemy et al., 2009). The reader is referred to Deardorff (1998) and Evenett and Wolfgang (2002), who chart the history and evolution of these models in much greater detail.

Given this model's proven track record of estimating pecuniary and non-pecuniary trade flows, we believe it to be a good candidate to model the flows of waste in our analysis of commercial and industrial waste flows in Wales, UK. The basic gravity model that we estimate in this first stage of analysis takes the following form (all variables are in logs):

$$f_{ij} = \beta_1 + \beta_O X_O + \beta_D X_D + \delta d_{ij} + \epsilon$$

where f_{ij} is the flow of waste from local authority i to local authority j and X_O is a matrix of variables (waste, socioeconomic, and demographic) relating to the origin local authority; that is, the local authority where the flow of waste originated. Similarly, X_D is a matrix of the same set of explanatory variables relating to the destination local authority, i.e. the local authority that receives the waste. β_1, β_2, and β_3 are vectors of constants, coefficients on origin characteristics, and coefficients on destination characteristics, respectively. d_{ij} represents distance between the origin and destination local authority, encompassing our only measure of a transaction cost of trade. Depending on the application, modelers can include additional measures of transaction costs including, but not limited to, currency exchange, tariffs, non-tariff barriers, language barriers, and any other quantifiable barriers to trade that may exist. ϵ represents the vector of error terms. It is also important to note that zero flows do exist within our model. In order to make the log-linear form of the gravity equation tractable, we chose to set zero flows to a trivially small number (.00001) rather than exclude them from the analysis. Additional options for handling this situation are discussed in Section 6.

4 Data

There were three primary sources for data used within this paper, two sources for waste-related variables and one for socioeconomic and demographic variables, all of which are discussed in more detail below. The primary source for waste data was a survey conducted by the Economic and Social Research Council's Centre for Business Relationships, Accountability, Sustainability, and Society (BRASS) research unit based at Cardiff University, through which data was gathered on commercial and industrial waste shipments within Wales. The local authority administrations provided the remainder of the waste-related data through their responses to Freedom of Information (FOI) requests submitted by the authors. It should be noted that this analysis does not include all 22 Welsh local authorities. Three local authority areas were excluded (Isle of Anglesey, Newport, and the Vale of Glamorgan) due to a lack of data on waste-related variables. All of the socioeconomic data were accessed through statistics provided by the Welsh Assembly Government on the StatsWales website, `http://statswales.wales.gov.uk`. Short variable descriptions are displayed in Table 1 and descriptive statistics for each variable are shown in Table 2.

The BRASS research unit kindly provided data from the Commercial and Industrial Waste Survey Wales. This data included the Standard Industry Classification (SIC) code for the sector that generated the waste, annual tonnage shipped, the origin local authority, and the local authority associated with the final destination of the waste for shipments taking place in 2002-2003. It should be noted that since this data is survey-based and was not further inflated to estimate national totals, it provides only a sample of the waste shipments that actually took place. As many waste related variables were only available from 2006 onward, the data on waste shipments was adjusted using SIC employment growth rates to estimate shipment levels for 2006. The first major assumption necessary to perform this adjustment is that commercial and industrial waste levels per employee are constant between 2003 and 2006. As there were no major innovations in waste creation or reduction during this time period, this assumption is not all that restrictive. Since data is not available for actual commercial and industrial waste shipments in 2006, we also have to assume that each business that ships waste did not move between 2003 and 2006 (i.e. the origin local authority is the same) and that the waste that is shipped in 2006 goes to the same final destination as it would have in 2003. This data was subsequently aggregated into a matrix of estimated commercial and industrial waste flows between Welsh local authorities for 2006. Although intraregional shipments are included in this initial analysis, any shipments that were exported outside of Wales were excluded as our interest lies in the characterisation and analysis of shipments within Wales, not outside its jurisdictional boundaries.

Table 1: Variable Descriptions

Variable	Variable Tag	Description
Waste Flows	flows	Estimated total waste flows between Welsh local authorities in tonnes for 2006
Active Businesses	actvbusiness	Total number of active businesses (in hundreds), where active is defined as a business that had either turnover or employment at some point in 2006. This covers those businesses that are PAYE/VAT registered.
Collected Income	collincome	Total income (in thousands of pounds) to each local authority from commercial waste collection in 2006
Commercial Waste Customers	cwcustomers	Total number of commercial waste customers (in hundreds) in 2006
Inert Capacity	inertcap	Amount of inert landfill capacity in thousands of cubic metres in 2006
Income	income	Average gross weekly earnings (in pounds) in 2006
Landfills	landfills	Number of active environmental permits for landfills in 2006
Low Education	lowed	Percentage of the population that report having no formal educational qualifications as of year end in 2006
Metal Recycling	metrecycling	Number of active environmental permits for metal recycling facilities in 2006
Noninert Capacity	noninertcap	Amount of non-inert landfill capacity in thousands of cubic metres in 2006
Nonwhite Pop	nonwhite	Percentage of the 2006 population that is nonwhite
Percent Allowance	percallow	Percentage of landfill allowance that was used up in 2006
Pop Density	popdens	Number of persons per square kilometre in 2006
Production Employment	prodemp	Total number of employees (in hundreds) in production industries in 2006
Restricted Capacity	restrictcap	Amount of restricted landfill capacity in thousands of cubic metres in 2006
Transfer Facilities	transferfacs	Number of active environmental permits for waste transfer facilities in 2006
Treatments Facilities	trtmentfacs	Number of active environmental permits for waste treatment facilities in 2006

Table 2: Descriptive Statistics

Variable	Min	Max	Mean	Std Deviation
Waste Flows	0.00	1,417,199.73	6,302.66	75,454.54
Active Businesses	11.45	101.65	41.67	20.44
Collected Income	112.32	2,956.98	673.86	651.66
Commercial Waste Customers	3.19	33.35	13.49	8.49
Inert Capacity	0.00	1,500.00	91.58	342.43
Income	404.20	494.3	452.66	29.05
Landfills	0.00	4.00	1.42	1.26
Low Education	0.09	0.26	0.16	0.04
Metal Recycling	1.00	12.00	4.74	2.73
Noninert Capacity	0.00	8,088.00	1,691.05	2,300.23
Nonwhite Pop	0.01	0.10	0.02	0.02
Percent Allowance	0.70	0.94	0.83	0.07
Pop Density	25.00	2,293.00	417.32	514.81
Production Employment	23.00	200.00	78.57	46.17
Restricted Capacity	0.00	3,200.00	173.76	733.21
Transfer Facilities	3.00	19.00	9.47	3.42
Treatments Facilities	0.00	5.00	2.05	1.68

Additional information on local authority level waste characteristics was provided through FOI requests that were submitted to all 22 local authorities in Wales. Variables collected through FOI requests and used in the analysis include: total income from commercial waste collection and total commercial waste customers. The FOI requests and responses were supplemented by personal communications with the Environment Agency of Wales who provided local authority level detail for a few publicly available waste variables. These data include: inert landfill capacity, non-inert landfill capacity, restricted landfill capacity, number of landfill sites, number of metal recycling facilities, number of transfer facilities, number of treatment facilities, and percentage of landfill allowance used.

Socioeconomic and demographic variables including: number of active businesses, number of employees in the production sector, percentage of population with only a low level of education, average gross weekly earnings, percentage of the population that is non-white, and population density were obtained from the StatsWales website. The final variable necessary for the gravity model is distance, which was obtained using data provided by the Ordnance Survey - Great Britain's

National Mapping Agency. Using files provided through their OS OpenData program, we mapped the Welsh local authority areas and calculated a matrix of origin-destination distances between the local authority centroids.

5 Results Analysis

The results from the OLS gravity model are presented in Table 3. One immediately noticeable result is that none of the coefficients relating to the origin local authority characteristics are significant at the 5% level. This implies that the characteristics of the local authority from which commercial and industrial waste flows originate do not affect the volume of the waste that is shipped. Of more interest is the fact that five coefficients related to the destination local authority are significant at the 5% level. These variables include the number of active businesses, the non-inert landfill capacity, the total income from commercial waste collection, the number of commercial waste customers, the number of landfills, and the number of transfer facilities.

The fact that the coefficient for non-inert landfill capacity is significant is not surprising. The capacity variables were expected to be significant as it was safe to assume that a local authority with more landfill capacity (of any type) would be able to handle more waste. However, the negative sign on this coefficient is surprising. This result implies that the more non-inert landfill capacity within a destination local authority, the less waste they receive. The relationship driving this result may be that local authority areas with higher non-inert landfill capacity generate a large amount of commercial and industrial waste within their own borders so that they are unable to receive large amounts from outside. If this is the case, it would also explain the significant negative coefficient on the number of commercial waste customers within the destination local authority. The more commerical waste customers a

Table 3: Results from OLS Gravity Equation

Variable Tag	Coefficient	T-statistic	T-probability
Constant	22.1021	0.0858	0.9317
o-actvbusiness	8.4490	1.4004	0.1623
o-percallow	8.8708	0.6478	0.5176
o-inertcap	0.0687	0.4017	0.6882
o-noninertcap	0.2598	0.8827	0.3781
o-restrictcap	-0.0420	-0.2234	0.8234
o-collincome	-2.1252	-0.3740	0.7086
o-cwcustomers	-3.1270	-0.4613	0.6449
o-landfills	-0.3916	-1.1293	0.2596
o-metrecycling	9.5152	1.0813	0.2804
o-transferfacs	-3.2997	-0.9638	0.3359
o-trtmntfacs	-0.1718	-0.3714	0.7106
o-lowed	6.3537	1.0017	0.3172
o-income	15.5789	0.4670	0.6408
o-nonwhite	-0.5208	-0.1159	0.9078
o-popdens	0.1158	0.0747	0.9405
o-prodemp	-8.3023	-1.2131	0.2259
d-actvbusiness	.12.8280*	-2.1262	0.0342
d-percallow	26.6441	1.9458	0.0525
d-inertcap	0.1924	1.1243	0.2617
d-noninertcap	-0.9974**	-3.3884	0.0008
d-restrictcap	-0.1096	-0.5827	0.5605
d-collincome	24.2247**	4.2633	0.0000
d-cwcustomers	-14.0797*	-2.0771	0.0386
d-landfills	1.1048**	3.1862	0.0016
d-metrecycling	8.1282	0.9236	0.3564
d-transferfacs	-13.0182**	-3.8024	0.0002
d-trtmntfacs	-0.3313	-0.7163	0.4743
d-lowed	-1.3614	-0.2146	0.8302
d-income	-32.8819	-0.9857	0.3250
d-nonwhite	-5.5202	-1.2288	0.2200
d-popdens	0.3364	0.2170	0.8283
d-prodemp	9.2374	1.3498	0.1780
distance	-0.9666**	-9.0885	0.0000

* significant at the 5% level

** significant at the 1% level

R-squared: 0.3692

Adjusted R-squared: 0.3055

No. of Observations: 361

destination local authority has, the more waste they produce themselves, which explains why the receive less waste from outside their own borders.

The total income received for commercial waste collection by a destination local authority has a significant positive coefficient. This result suggests that the more income from commercial waste collection that a destination local authority collects, the more commercial and industrial waste received. If the destination local authority is receiving money for commercial and industrial waste that is collected from other local authorities but transported for disposal within their own local authority area, then this result would obviously be positive. However, if this is not the case and the waste is transported and disposed of within the destination local authority without compensation for collection, then this result is a bit harder to motivate. This variable only captures income to the local authority from collection, not necessarily additional income from taxes or charges on management or disposal. Also, we do not control for the presence of private sector alternatives in this analysis. Total income from collection of commercial waste may be a proxy for the development of waste infrastructure within the local authority boundaries. If this is the case, then as this measure of income increases, we can assume that the waste infrastructure within the local authority is more developed, which may explain this positive coefficient.

Two of the three variables indicating the number of waste management facilities within a destination local authority are significant with opposite signs, the number of landfills and transfer facilities. To understand the sign of each of these coefficients, it is important to remember that within the origin-destination matrix in this model, we include the origin and *final* destination of the waste. It is much more likely that the final destination of a commercial and industrial waste shipment is a landfill than any other type of facility. Therefore, it is not surprising that a destination local authority with more landfills, receives more commercial and industrial waste. As the transfer facility would most likely be an intermediate stop and not the final destination of a waste shipment, it is also not surprising that the more transfer facilities a destination local authority has, the less waste they receive. Moreover, giving more validity to this result, it is also unlikely that waste would be placed in a transfer facility that is located within the same local authority as the final destination.

The final destination characteristic that has a significant effect on commercial and industrial waste flows is the only significant variable that is not directly related to waste, the number of active businesses. This variable has a negative and significant effect on the waste that flows into a local authority and represents our only indication that Welsh waste flows exhibit a pollution haven type result. The more active businesses that a destination has, the less waste they receive, perhaps indicating that more developed areas receive less waste for final disposal. This result is weak evidence as none of our other variables that proxy for development (measures of income, education, population density, and ethnicity) are significant.

It is also worth emphasising that the coefficient on our distance variable is highly significant and negative. This is not only what we expected but justifies our choice of model for this analysis. This coefficient suggests that the larger the distance between local authorities, the less waste flows between them. This result is intuitive if we assume that shipping waste a greater distance costs more. This explanation also begs for the inclusion of variables that attempt to capture other transactions costs which are currently not included.

6 Conclusions and Future Research

The aim of this paper was to test whether the general observations made within international waste analyses are transferrable to a sub-national analysis. While we have not exhausted the analysis of this data, there is already some evidence that waste-related and economic variables in destination local authorities are important in explaining the pattern of commercial waste shipments in Wales. While a number of the arguments made by Baggs (2009) regarding hazardous waste in an international context are not clearly transferrable, and while we were unable to test some of her other findings, we detected only weak evidence of waste moving to less developed areas. We believe that the initial results presented here provide interesting insights into the factors that help explain the pattern of Welsh commercial and industrial waste shipments.

As an aside, it is worth noting that in examining sub-national flows, the gap between local authority areas in Wales for a number of the variables used, is likely to be far smaller than it would be if we compared country level data and included a range of rich and poor countries in the analysis. Jug and Mirza (2005) point out, in relation to the pollution haven hypothesis, that in analyzing groups of countries where the economic and development fundamentals are similar, you are less likely to find evidence of a pollution haven. This may be one reason for the lack of evidence of a pollution have type result in our results at this stage but these conclusions may change as we apply different and more robust techniques to this data set.

The results that are presented here do not represent our final work, but represent the first step in our research agenda. The next step is to run a two-stage Heckman selection model to generate unbiased results. Both truncating the data set, and setting zero flows to small positive numbers, are common approaches in the gravity model literature but both introduce a bias. The next stage recognises the contribution of Helpman et al. (2008) who show that excluding zero trade flows from the analysis leads to a bias in the results and Martin and Pham (2008) who show that setting zero flows to a trivially small positive number leads to a bias as well. Setting zero flows to be a trivially small positive number is done so that the model can be estimated in logs, as we outlined above. Since the log of zero is undefined, estimation in logs without some form of amendment is not possible. While it is necessary in carrying out the simple gravity model approach to set zero flows to be very small values (as we do in this paper), this amendment is unnecessary in the Heckman selection model.

The method of truncating the zero flows from the dataset causes a downward bias on the coefficient of the distance function (Helpman, 2008:454) through a correlation of the residuals with the distance function, which in gravity models is often taken to be a measure of combined trade barriers. By excluding the zero flows, we estimate a coefficient for the distance function on the basis that there are no flows in which the distance function is such that no trade occurs and imply that the data in the model suggests that all possible trade flows exist. Thus, it precludes the costs being so high that trade doesn't occur between i and j, which means that the coefficient on the distance function is biased downward. The solution to this type of bias, as identified by Helpman et al. (2008) and implemented by Baggs (2009), is to use a two step Heckman selection model (Heckman, 1979).

The first step of the Heckman approach consists of calculating the inverse Mills ratio which corrects for the effect of the omitted variable resulting from the sample selection bias (following Heckman (1979) and Johnston and DiNardo (2007:448)). The second step involves estimating the gravity equation with the inverse Mills ratio included as an explanatory variable (Heckman, 1979:157; Baggs, 2009:5; Johnston and DiNardo, 2007:448). Heckman shows that this process results in a consistent estimator of the coefficients on the explanatory variables (Heckman, 1979:15; Johnston and DiNardo, 2007:449).

Once completed, we will be able to compare the simpler OLS estimation results with the results observed from the more robust Heckman selection model. We also plan to extend our analysis to examine other features of the data, for example considering different waste streams and whether, for example, the factors that explain commercial and industrial waste flows also explain hazardous waste flows. These next steps will provide an interesting extension of to our initial research question as they examine whether our results vary across waste types, and thus, whether there is evidence for regional pollution haven effects developing for some waste streams but not others. It is conceivable that a local authority area with lower land values may have a comparative advantage in disposing of municipal solid waste in a landfill. This result may be reversed for other waste flows. It may be the case that for certain hazardous waste flows, due to the specialized equipment and/or personnel required to treat these waste streams, there is a reverse pollution haven effect. If handling this waste requires the skills, capital, and infrastructure not found in poorer areas, we may observe that these waste types flow to more developed areas.

By performing the extensions described here, we will complete an exhaustive analysis of Welsh waste shipments. As Wales implements its stringent waste strategies and moves to become a zero waste society, this and future analyses may be just what policymakers need to encourage drastic change. Knowledge on why Welsh waste moves from one local authority to another can provide additional information for policies on waste disposal, management, and reduction.

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