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Analysis

Explaining the variation in household recycling rates across the UK☆

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ABSTRACT

Household waste recycling rates vary significantly both across and within regions of the UK. This paper attempts to explain the variation by using a new data set of waste recycling rates and policy determinants for all of the UK's 434 local authorities over the period 2006Q2 to 2008Q4. Our results suggest that the method of recycling collection chosen by policy makers is an important factor influencing the recycling rate. We also find an inverse relationship between the frequency of the residual waste collection and the recycling rate.

1. Introduction

In order to manage natural resources more sustainably a key environmental objective of the UK government is to reduce the amount of waste produced and to raise the proportion of waste that is recycled, rather than sent to landfill or incinerated. Recycling is deemed important since landfilled waste increases methane emissions, generates odour and noise pollution, and can result in groundwater contamination. It can also reduce the need to use virgin raw materials in the production of manufactured goods, thus limiting the environmental impact arising from extraction (Hershkowitz, 1997; WRAP, 2010a).

The UK recycled only 0.8% of its waste in 1983/4 (Defra, 2010).[1] Following a series of policy initiatives and greater public awareness, the recycling rate rose to 21.9% for 2004/05, climbing to 34.1% for 2007/08. This last figure compares well to the 2005 target of 25% set by central government, but the UK still lags behind many of its comparator economies. For example, the 2007/08 recycling rate places the UK 10th among the EU-27 nations (Eurostat, 2010) and the average recycling rate of the nine economies placed above it is 52%.[2]

While the UK's recycling rate is improving, it is noticeable that there are significant regional and intra-regional variations. Across the regions of the UK,[3] figures from our data set, covering the period 2006Q2 to 2008Q4, suggest that the region with the highest recycling rate is the East Midlands, with a mean rate of 38.1%, while the North East of England has the lowest mean recycling rate of just under 27.9%. These figures mask the considerable variability within regions e.g. within the East Midlands, North Kevesten District Council has a recycling rate of 56.1%, while Bassetlaw District council has a rate of just under 22.8%.[4] Also, within the North East of England, Middlesbrough Council has a recycling rate of 19.1%, while the top performer

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[1] The recycling rate is the volume of recycled materials divided by the amount of total waste, where total waste is the sum of recyclable volumes plus the volumes of residual waste. Recycling here refers to both dry recycling and composting.

[2] The 2007/8 figures also indicate that the UK generates municipal waste of 565 kg per person compared to an EU-27 average of 524 kg per person. Among the nine economies placed above the UK in terms of recycling rate, the average municipal waste is 623 kg per person.

[3] The UK has twelve regions, consisting of Northern Ireland, Scotland and Wales plus the nine regions of England comprising: the North East, North West, Yorkshire & the Humber, East Midlands, West Midlands, East of England, South West, South East and Greater London.

[4] In the UK, responsibility for recycling and waste collection rests with local authorities, which are defined as Unitary Authorities, District Councils or London Borough Councils.

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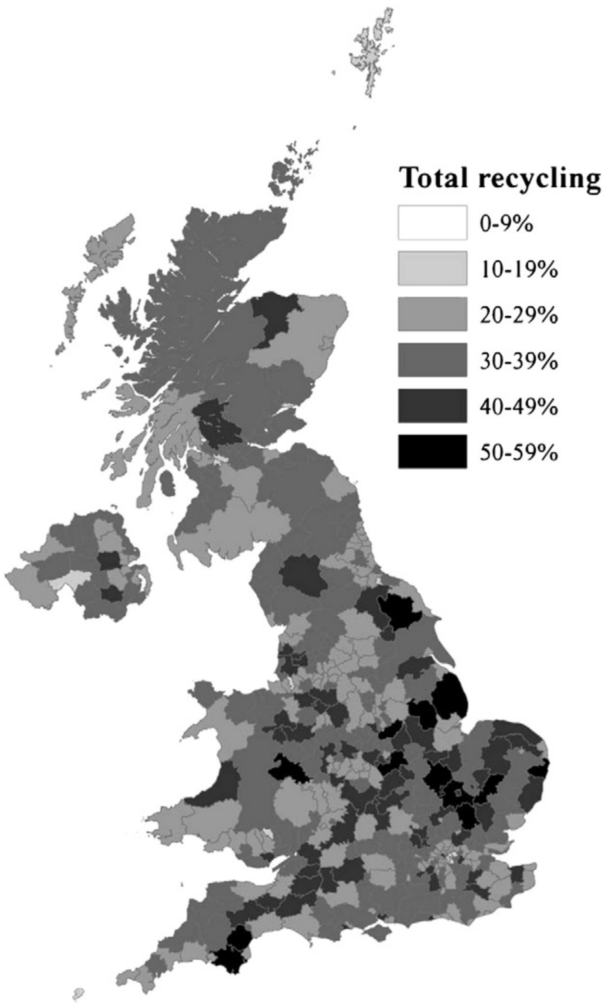

Fig. 1. Recycling Rates for UK local authorities, average 2006Q2 to 2008Q4 (All materials). Produced using Arcview GIS with data taken from http://www.wastedataflow.org.

is Castle Morpeth Borough Council at just under 40%. Fig. 1 provides an illustration of the distribution of high and low performing local authorities across the UK. It is noticeable that the high performers tend to be concentrated in the South of England, whereas the distribution of the relatively poorer performers is more mixed across the entire country.

The natural question that then arises is why do these differences exist? Conventional attempts to explain the demand for waste disposal and recycling services have focussed on the price charged to consumers for waste collection, through waste disposal fees or weight based charging. Evidence on whether charging for waste has a positive impact on recycling is mixed. In those countries where charging is permitted studies suggest that it has had a positive influence on the proportion of waste recycled (Ferrera and Missios, 2005; Kipperberg, 2007; Sterner and Bartelings, 1999). However, others find that although fees on waste production are predicted to reduce quantities, the effect is slight, as indicated by the inelastic demand for waste collection (Jenkins, 1993; Wertz, 1976). Based on a number of studies (Dijkgraaf and Gradus, 2004; Hong, 1999; Van Houtven and Morris, 1999 amongst others) Kinnaman (2006) asserts that only households that were initially recycling small amounts and faced low opportunity costs of recycling would respond significantly to unit-based pricing.[5]

However, local governments in the UK are not allowed to charge for waste collection. Funding for recycling and residual waste collections comes from the council tax, a tax on property, and a central government grant, which fund all local government services. The component of the council tax related to waste collection bears no relation to the quantity of waste produced, so households perceive the marginal cost of all units of waste disposed after the first as zero (Callan and Thomas, 2006). Thus, there is no monetary incentive for households to minimise waste production or to increase its recycling rate. Fiscal measures introduced to improve recycling performance have been directed towards local authorities rather than households. A two tier landfill tax was introduced in 1996, and in 2005, legislation was passed introducing a scheme of landfill allowances, which are tradable in England.

A key non-monetary initiative to encourage recycling is the provision of kerbside recycling services (De Young, 1990; Ferrera and Missios, 2005; Jones, 2006; Kipperberg, 2007; Vining and Ebreo, 1992). Kerbside schemes are expected to improve the recycling rate since they reduce the opportunity cost of time incurred by households that recycle (Sidique et al., 2010). Harder et al. (2006) acknowledge the importance of kerbside recycling in ensuring that the UK meets its recycling target but state that for a scheme to be effective it is important to understand how its various characteristics affect the overall performance. To our knowledge, research on how various aspects of recycling schemes, particularly related to the size and type of containers, affect household recycling is limited. Platt and Zachary (1992) provide case-studies of communities in the US that offer co-collection schemes (a single vehicle used to collect both waste and recyclables) which differ according to size and type of containers for recyclables. However, the focus of their study is on the cost-effectiveness of co-collection versus separate collection of recyclables and residual waste. In this study, we take the perspective of the household and examine how the effect of different containers influences the household recycling rate. In addition to the characteristics of the scheme itself, the context in which it operates, such as the nature of the residual waste collection and the number of civic amenity sites and bring sites in the locality, where households can drop-off recycled waste, may also impact on its effectiveness. For example, a fortnightly, rather than a weekly, collection of residual waste places more pressure on the household to recycle.

This paper adds to the current literature in four respects. Firstly, to our knowledge it is the first study that attempts to explain the regional and intra-regional variation in household recycling rates across the UK. Previous studies have utilised either household-level data (e.g. Timlett and Williams, 2008; Wilson and Williams, 2007) or data specified at the community or county-level within a limited geographic region of a country (Callan and Thomas, 2006; Kinnaman and Fullerton, 2000; Podolsky and Spiegel, 1998). In this paper, we compare the recycling performance of every sub-region in one country, using a recently published dataset from www.wastedataflow.org, a UK government agency.[6]

Unlike previous contributions, we study the determinants of dry recycling rates and composting rates separately. We have already noted the considerable variation that exists across the UK when taking account of the total recycling rate. To explain the variation in total

[5] Linderhof et. al. (2001) is the notable exception.

[6] Under the UK's Landfill Allowances Trading Scheme (LATS) Regulation, a statutory instrument relating to each of the UK regions, all local authorities are obliged to report data on waste and recycling activity to the online reporting system http://www.wastedataflow.org. This includes submitting data, not only on waste and recycling volumes, but on the types of materials collected, the characteristics of the waste and recycling collections, and the frequency of collection. Data consistency is ensured since all local authorities respond to a pre-prepared questionnaire that details the exact specification of the data required and how it should be reported. Prior to release, from the local authority to the national level, the data is checked and authorised. Once this step has been completed the relevant national authority reconciles and validates the data.

recycling it is helpful to disaggregate it into dry recycling and composting, particularly in view of the strong seasonal patterns associated with composting. From analysis of Figs. 2 and 3 it is apparent that the top performers in overall recycling also exhibit strong performance in composting and that composting is by far the 'poor relation' in terms of waste diversion from landfill — 164 local authorities fall into the lowest category. It is also advantageous to separate out dry recycling and composting rates since the determinants are often different. For example, collection of materials is often separated, plus the characteristics of the collection will differ, for example the type of container used and the frequency of collection. A further innovation of our study is the use of quarterly data series, which is important, because annual time series, typically used hitherto fore, mask distinct seasonal patterns in the recycling rates. This is particularly the case for collection of compostable materials.

Thirdly, while the recent literature has been able to identify a positive effect arising from waste policy, such as the introduction of a kerbside scheme, our contribution differs, in that we examine how the 'quality' as well as the 'quantity' of the kerbside scheme encourages households to recycle. Our measure of 'quality' relates to the type of container offered and its size, as well as the frequency of collection. The new dataset that we use has the advantage of providing a classification of recycling schemes of varying characteristics. Woodward et al. (2005) note the importance of providing a dedicated container as part of the kerbside scheme but do not elaborate on how differences in the characteristics of containers may elicit different responses in terms of recycling rates. Research has shown that capacity for recycling materials is positively related to household recycling, with diminishing returns setting in after a certain stage (WRAP, 2010b). Thus, from the local authority's perspective there will be a trade-off between encouraging more recycling through larger containers and/or more frequent collections and the cost of servicing larger capacities for recycling.[7] The types of containers range from larger wheelie bins to sacks to small boxes.

Finally, we are able to investigate how the characteristics of the residual waste collection impacts on the household recycling rate. This can be measured again through the type of container used for residual waste, its size, and the frequency of collection. Mounting evidence which suggests that a lower frequency of residual waste collection increases recycling rates has encouraged many local authorities to move towards alternate weekly collections or fortnightly residual waste collections as a way to ensure they meet recycling targets and Biodegradable Municipal Waste diversion targets from landfills (Iredale 2011; LGA, 2006, 2007; Sanderson, 2007; WRAP, 2010b).[8] A hundred and sixty, which is almost half of English authorities, collect residual waste fortnightly (BBC, 2010). There has been concern over potential adverse health effects especially relating to food waste. However, no evidence has been found that fortnightly residual waste collections have adverse health impacts on either households or bin collectors (WRAP, 2009). Other opposition has centred on the accusation that the underlying motive of local authorities is not to increase recycling rates but rather to drive down costs (BBC, 2010). However despite the absence of adverse health impacts and the positive impact on recycling, government policy appears to be for local authorities to move back to weekly bin collections (BBC, 2010).

The remainder of the paper is organised as follows. The second section provides an overview of UK waste management policy and performance. The third section discusses the econometric model and data used for estimation, while the fourth section presents the estimation results and their policy implications. The final section concludes.

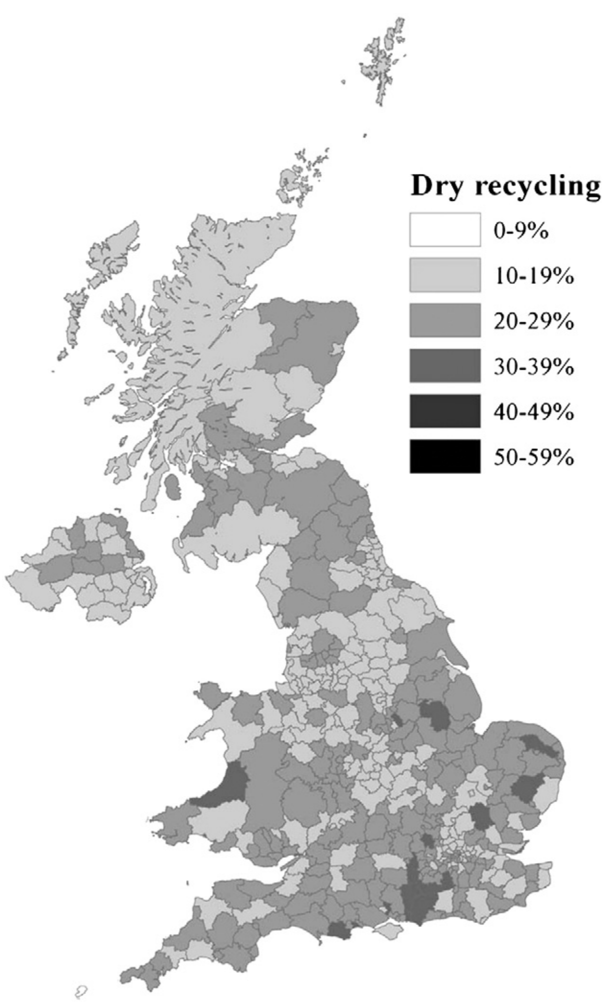

Fig. 2. Recycling Rates for UK local authorities, average 2006Q2 to 2008Q4 (Dry materials). Produced using Arcview GIS with data taken from http://www.wastedataflow.org.

2. UK Waste Management Policy and Performance

The UK household sector accounts for over 88% of the UK's municipal waste. The Department for Environment, Food and Rural Affairs (DEFRA) is responsible for meeting the UK's waste management obligations, as set down by the EU's Landfill and Waste Framework directives. DEFRA stipulates targets for the English regions, which are then devolved into individual targets for local authorities in England. In Northern Ireland and Wales, national targets are applied at local authority level, whereas Scotland has national composting and dry recycling targets.

England has 354 local authorities, which for the purposes of waste management are classified as either Waste Collection Authorities (WCAs), Waste Disposal Authorities (WDAs) or Unitary Authorities (UAs), the latter undertaking both collection and disposal activities. WCAs have a statutory duty to collect household waste, while WDAs are responsible for the safe disposal of household waste collected by WCAs. Typically, WCAs operate at a localised level and are usually borough councils or district councils, whereas WDAs are responsible for much larger areas and may be either district or county councils (Woodward et al., 2001). Scotland and Wales have 32 and 22 unitary authorities respectively, while Northern Ireland is divided into 26 districts of local government.

[7] Of course, the higher cost can be offset by higher revenues from the sale of recycled material but this is outside the scope of the present study.

[8] Alternate weekly collections are where residual waste gets collected 1 week and recycled waste is collected on the alternate week. Fortnightly residual waste collections tend to be accompanied by weekly recycled waste collections.

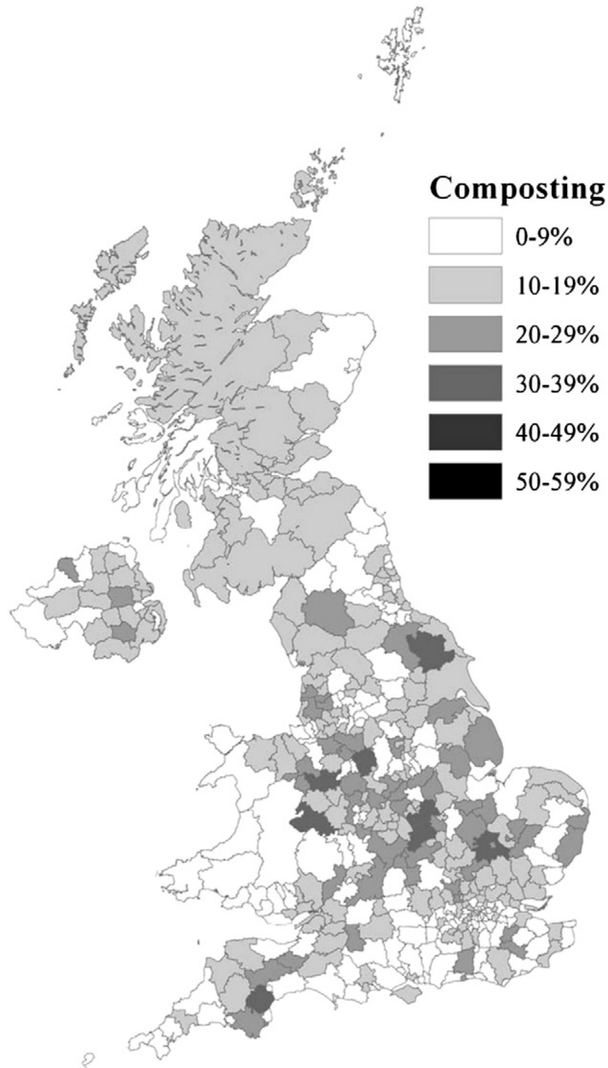

Fig. 3. Recycling Rates for UK local authorities, average 2006Q2 to 2008Q4 (Composting materials). Produced using Arcview GIS with data taken from http://www.wastedataflow.org.

There is considerable and persistent variation in recycling rates across the regions of the UK (Iparraguirre D'Elia, 2008; Ward, 2009).[9] Table 1 presents summary statistics of the dry recycling and composting rates. For the UK as a whole, over the sample period 2006Q2 to 2008Q4, the mean recycling rate is 32.9%, consisting of a mean dry recycling rate of 20.8% and a mean composting rate of 12.1%. The standard deviation of the dry recycling rate is 5.7% but the spread between the best and worst performing authorities is 44.8%. As well as being lower on average, composting rates appear to be more variable, with ten of the authorities in our sample offering no composting collection at all. Composting accounts for a smaller proportion of total waste retrieved than dry recyclables, which is to be expected, given that the amount of green waste produced, and then recycled, is to a large extent seasonal and because more materials are collected for dry recyclables.[10]

[9] Phillips et al. (2000) discusses the regional variations that exist in relation to waste minimisation (reduction at source) and the approach towards landfill as a future management option.

[10] For example, using the 2007 figures, the composting rate for the UK is at its lowest in the first quarter, with a rate of only 6.76%, rising to 14.55% and 14.78% for the second and third quarters, falling to 10.47% in the final quarter. By contrast, the figures for the dry recycling rate range from 19.78% to 22.07%.

Moving next to the four countries of the UK, the dry recycling performance of local authorities in England and Wales is superior to local government in Scotland or Northern Ireland. The mean dry recycling rates for England and Wales are 21% and 21.2% respectively, while Scotland's and Northern Ireland's are 18.9% and 19.4%. The maximum dry recycling rate for England (49.7%) is some 15.4% greater than the maximum rate for Northern Ireland. By contrast, Northern Ireland's local authorities have the highest composting rate on average (13.2%).

Based on Table 1 and Figs. 2 and 3, it is evident that among the nine regions of England, local authorities in the South East, the South West, East of England and East Midlands regions perform significantly better in dry recycling.[11] The composting rate is relatively high for the East Midlands, East of England, North West, and Yorkshire & the Humber. However, it is noticeable that the South East region has a significantly lower composting rate on average, particularly when compared to the performance of other regions and its ranking on the dry recycling rate. A similar conclusion can be drawn for the North East of England.

So how do the above trends compare to the performance targets set by central government? For England, Northern Ireland and Wales we can compare each local authority's rate of recycling relative to its target, whereas for Scotland we can only compare the average rate of recycling and composting across local authorities to the average target covering the period 2005/06 and 2007/08.

Our calculations suggest that the average overshooting of the target for England was almost 11%, around 13% for Wales, and for Northern Ireland almost 18%. All local authorities in Northern Ireland exceeded their target; 90% of English local authorities overshot their target, while only one local authority in Wales failed to reach its target. The average recycling rate for Scotland over the period being studied is 30%, compared to its average target of 27.5% for that period. It is difficult to decipher whether this excellent performance is due to impressive recycling performances *per se* or whether it is in fact due to targets being set too low.

3. Econometric Model and Data

We model the local authority recycling rate as a function of socio-economic and policy variables as follows:

$$RR_{it} = a_0 + \beta_1\, ln\,(Y)_{it} + \beta_2\, ln(HH)_i + \beta_3\, ln(PD)_{it} + \sum_{j=1}^{n}\delta_j DR_{jit} + \sum_{\ell=1}^{m}\lambda_\ell DRW_{\ell it} + \pi_1 FDR_{it} + \pi_2 FRW_{it} + \alpha_2 S_{2t} + \alpha_3 S_{3t} + \alpha_4 S_{4t} + a_i + u_{it}, \quad (1)$$

where RR_{it} is the recycling rate of authority i at time period t, ln(Y) is the log of average yearly income in the authority; ln(HH) is the log of average household size; and ln(PD) is the log of population density. The recycling rate is constructed separately for both green waste and dry recyclable materials. DR_j is an indicator variable that denotes the j^{th} method of recycling collection when equal to 1 and DRW_ℓ is the ℓ^{th} dummy variable for the method of residual waste collection.[12] The default method of dry/green recycling collection is 'other method/no method of collection', with the same default for the residual waste collection. FDR and FRW are dummy variables that equal to one

[11] Interestingly, the South East and South West of England significantly outperform the Greater London region. Closer examination indicated that Greater London produces significantly more residual waste per capita compared to other regions, though its recycling tonnages per capita are broadly similar.

[12] Kinnaman and Fullerton (2000) also control for the possible endogeneity of recycling policy, where the probability of a kerbside scheme existing depends upon the socio-economic characteristics of a community. However, in our study, this choice does not typically exist for most of the UK's local authorities since, over our sample period, they typically have a scheme in place. The decision they have to make if the type of scheme to offer.

Table 1
Recycling rates.

	Dry recycling rate (percentage)				Composting rate (percentage)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
UK	20.8	5.7	4.9	49.7	12.1	8.8	0	52.6
England	21.0	5.8	6.9	49.7	12.2	9.2	0	52.6
Wales	21.2	5.9	9.6	49.5	10.1	5.3	1.1	25.6
Scotland	18.9	5.3	4.9	37.1	11.3	6.6	0	25.8
Northern Ireland	19.4	4.4	9.5	34.3	13.2	7.6	0	37.2
Greater London	20.0	5.0	9.7	36.1	6.6	5.5	0	27.8
South East	23.8	5.7	8.9	49.7	8.1	6.8	0	31.7
South West	22.3	4.9	8.2	36.5	12.3	8.9	0	52.6
East of England	22.1	5.8	10.8	42.2	15.5	9.5	0	39.6
East Midlands	21.9	5.8	8.2	45.4	16.2	10.9	0	41.4
West Midlands	18.6	6.0	7.6	40.7	15.0	10.6	0	45.5
North East	19.6	5.3	8.7	35.8	8.3	6.5	0	44.5
North West	18.6	5.4	6.9	40.1	14.3	7.5	2.0	32.7
Yorkshire & the Humber	17.7	4.2	7.1	30.6	14.1	8.5	1.8	40.9
The 'North' of England	19.0	5.5	6.9	43.8	13.4	9.4	0	45.5
The 'South' of England	22.4	5.6	8.2	49.7	11.4	9.1	0	52.6
Urban authorities	20.3	5.7	6.9	49.7	11.1	7.6	0	36.5
Rural authorities	21.6	5.9	4.9	49.5	13.5	9.8	0	45.5

Note: All figures are derived using data taken from http://www.wastedataflow.org over the period 2006Q2 to 2008Q4.

whenever the frequency of collection of recycling materials and residual waste is less than once a week. S_2 to S_4 are dummy variables, included to model the seasonality in the recycling rate. The individual effects are represented by a_i and u_{it} is a white noise error term.

The theoretical literature does not suggest a particular functional form for the relationship between recycling and independent variables (Hage and Söderholm, 2008). Recycling performance can enter the model in a variety of ways: volume; participation rate in kerbside scheme; or recycling rate. We choose the latter since most policy-makers evaluate the effectiveness of recycling and waste management programmes by considering the recycling rate (usually against a target), which captures movements in the amount of waste generated and recycled simultaneously.

As our primary focus is to examine the effect of policy variables on the recycling rate we limit socio-economic variables to income, household size, and population density. This choice reflects the literature (see Sidique et al., 2010 for a recent review), our interest in the spatial dimension of recycling (both household size and population density are characteristics of local authority jurisdictions) and the availability of data in a form consistent with the policy variables.[13] Following Callan and Thomas (1997) the role of the socio-economic variables is to empirically isolate the policy influence.

Income may have both positive and negative effects on the recycling rate.[14] Sidique et al. (2010) speculate that higher incomes result in higher consumption, therefore generating greater waste and thus leading to a lower recycling rate. Their econometric results substantiate this claim. Yang and Innes (2007) find that when a mandatory recycling policy is in place, recycling goes up but the rate of increase diminishes with income. Both of these contributions, in line with much of the literature (e.g. Saltzman et al., 1993) that looks at the effect of income on recycling, explain that because higher earners have a higher opportunity cost of time, the volume of recycled material will fall relative to the total waste generated. Another possible explanation distinct from the time element of sorting out waste is the link between income and purchasing patterns. Basing their analysis on the opportunity cost of time argument, Saltzman et al. (1993) find that purchasing patterns shift away from goods with a higher recyclable content. However, it could be that higher earners have greater financial flexibility and so can use their discretion to purchase goods with a higher recyclable content (alluded to in Callan and Thomas (2006)). However, this explanation has yet to be tested in the literature given the difficulty of obtaining data on household budgetary allocations (Yang and Innes, 2007). Furthermore, higher incomes may lead to higher rates of recycling because high earning households can afford to pay for a better environment (Berglund and Söderholm, 2003; Owens et al., 2000; Terry, 2002). Irrespective of income, individuals desire a better environment. However, whether they have the capacity to fulfil this desire through their budget will differ across incomes.

Hong et al. (1993) find that larger households participate more in kerbside recycling, while Terry (2002) finds the opposite result. The explanation he offers is that higher per capita waste production in smaller households provides more scope for recycling and recycling may be easier to organise in smaller households (see also Mazzanti and Zoboli, 2009).

Both Callan and Thomas (1997) and Kinnaman and Fullerton (2000) found population density to have a negative and statistically significant effect on the recycling rate. A possible explanation could be that in densely populated areas the space to store recyclables separately from residual waste is limited (Ando and Gosselin, 2005; Barr et al., 2003).

All of our policy determinants, such as the type of container used for recycling and residual waste collections, come from http://www.wastedataflow.org. that contains quarterly data on dry recycling and composting rates, together with the methods and frequencies of collection for all 434 local authorities of the UK. Data on the socioeconomic variables come from Official National Statistics (available on ONS website).

There are nine different methods of collection classified for dry recycling and seven methods of collection for composting. Our sample period is 2006Q2 to 2008Q4, giving us a total of $434 \times 11 = 4774$ observations. 2006Q2 is the first quarter when recycling rates are published by wastedataflow.org, while 2008Q4 was chosen to end our sample period, because from April 2009 a number of structural changes took place within UK local government, leading to the creation of new unitary authorities.

4. Estimation Results

Estimation results for all of the local authorities are presented in Tables 2 (dry recycling) and 3 (composting). We use both fixed effects and random effects estimators. The estimated standard errors are adjusted to allow for the potential effects of clustered errors across the 434 local authorities. A Hausman misspecification test was found to be statistically significant in all but two instances, in which case the hypothesis that the individual effects are randomly distributed and uncorrelated with the regressors can be rejected. While these tests would lead us to favour the results of the fixed effects model, we will also make reference to the random effects results when referring to the estimates of the log of the average household size variable, since it is a time invariant variable and therefore not estimated separately in the fixed effects specification.

Four broad themes emerge from the econometric results. Firstly, we find that for both dry recycling and composting, the frequency of the residual waste collection is inversely related to the recycling rate i.e. the lower the frequency of collection of residual waste the higher the recycling rate. The evidence for this is found in Tables 2 and 3. As the dummy variable is one for a frequency of collection less than once a week, a positive coefficient implies a gain to the recycling rate whenever local authorities choose a frequency of residual waste

[13] It would be interesting to widen the scope of the analysis further to consider the effects of socio-economic variables, such as cultural factors, but obtaining a consistently reported data set, disaggregated to the level of the borders of individual local authorities would prove challenging.

[14] The impact of income has also been found to have differential impacts on different streams of recycling. For example, income may increase the recycling rate of paper but not glass (Jakus et al., 1996; Saltzman et al., 1993).

Table 2
Panel estimates for determinants of the dry recycling rate.

	Fixed effects	Random effects
Constant	−0.340	0.427*
	(−1.32)	(2.85)
ln(income)	−0.038	−0.012
	(−1.88)	(−0.81)
ln(population density)	0.591*	−0.006*
	(6.56)	(−3.35)
ln(household size)	–	−0.079
		(−1.62)
Dry recycling method		
Kerbside box < 35 l	0.001	−0.006
	(0.19)	(−1.13)
Kerbside box 35–50 l	−0.008	−0.010
	(−1.17)	(−1.85)
Kerbside box > 50 l	−0.025*	−0.023*
	(−3.55)	(−4.29)
Reusable sacks	0.006	0.006
	(1.42)	(1.85)
Non-reusable sacks	0.015*	0.015*
	(3.39)	(3.77)
Wheeled bin < 120 l	0.034*	0.027*
	(3.86)	(3.07)
Wheeled bin 120–180 l	0.004	0.004
	(0.84)	(0.78)
Wheeled bin 181–240 l	0.021*	0.018*
	(3.76)	(3.93)
Wheeled bin 241 + l	0.009*	0.011*
	(2.18)	(3.19)
Frequency of recycling collection less than once a week	0.006	−0.001
	(0.91)	(−0.22)
Residual waste method		
Wheeled bin 100–150 l	−0.001	−0.002
	(−0.18)	(−0.46)
Wheeled bin 151–200 l	0.010	0.002
	(1.87)	(0.46)
Wheeled bin 251–300 l	−0.002	−0.008
	(−0.36)	(−1.64)
Wheeled bin > 350 l	0.002	−0.002
	(0.41)	(−0.60)
Plastic sacks	−0.010	−0.007
	(−1.70)	(−1.60)
Refuse bins	−0.001	−0.004
	(−0.11)	(−0.50)
Communal bins	0.004	0.003
	(0.90)	(0.93)
Frequency of residual waste collection less than once a week	0.038*	0.040*
	(8.11)	(10.17)
R^2-overall	0.019	0.364
R^2-between	0.022	0.364
R^2-within	0.368	0.342
$N \times T^{\dagger}$	4644	4644
Hausman test: $\chi^2(23)$	307.93*	

Note: t-ratios are reported in parentheses, calculated from robust standard errors, adjusted for clustering effects across the local authorities. * denotes significance at the 5% level. Seasonal dummies and individual dummy variables for each of the UK regions are also included, the estimates from which are not reported to conserve space. † $N \times T$ refers to the total number of observations available for estimation. N is the number of local authorities in the UK and T is the number of time periods. With 434 authorities and 11 periods there is a potential data set of 4774 observations. However, with some missing observations the figures reported are slightly smaller. l refers to litres.

collection that is fortnightly (or longer) rather than weekly (or more frequent). The gain from adopting a fortnightly collection for residual waste is an increase in the dry recycling rate of 3.8%, while the gain for composting is 4.6%. This finding is supported by the literature. For example, although Callan and Thomas (2006) do not separate between dry recycling and composting, they find that a 10% decrease in the frequency of residual waste collection gives rise to almost a 2% increase in recycling. Woodward et al. (2005) note that the two local authorities with the highest rates of recycling have a fortnightly residual waste collection. The intuition behind this result is that when faced with fewer residual waste collections, households have an incentive to exert more effort in separating recyclable from non-recyclable waste. The effect is more pronounced for compostable waste because, by its nature, it is bulky and organic (leads to rotting and odours), both of which reduce the desirability of storage indoors. Thus, this research further reiterates that a move back to weekly residual waste collections, as currently advocated by certain policy makers (Iredale, 2011), could be detrimental for UK recycling rates.

A second important result is that the method of recycling collection appears to be more important for dry recycling than for green waste collection. Only one method of green recycling collection is statistically significant in explaining the composting rate, while five of the dummies are statistically significant in the dry recycling equation. Within dry recycling, the rate is on average lower for the 'Kerbside box > 50 l' but is on average greater for the 'Non-reusable sacks' and three of the 'Wheeled bin' methods. Of these, the 'Wheeled bin < 120 l' method provides the greatest increase with a rise of 3.4%, whereas the gains for 'Wheeled bin 181–240 l' and 'Wheeled bin 241 + l' are 2.1% and 0.9% respectively. Non-reusable sacks increase the dry recycling rate by 1.5%. The intuition for the relatively better performance of the 'Wheeled bin' category is that these are more likely to be kept outside, so there could be less of a storage issue associated with them. Thus, households are more predisposed to

Table 3
Panel estimates for determinants of the composting recycling rate.

	Fixed effects	Random effects
Constant	−0.089	−0.119
	(−0.32)	(−0.70)
ln(income)	−0.035	0.0005
	(−1.68)	(0.03)
ln(population density)	0.302*	−0.009*
	(3.13)	(−3.57)
ln(household size)	–	0.167*
		(2.93)
Composting method		
Reusable sacks	−0.006	−0.0005
	(−0.96)	(−0.01)
Non-reusable sacks	−0.005	−0.001
	(−0.80)	(−0.18)
Wheeled bin < 120 l	0.003	0.002
	(0.21)	(0.19)
Wheeled bin 120–180 l	0.018	0.024*
	(1.59)	(3.03)
Wheeled bin 181–240 l	0.027*	0.034*
	(4.57)	(7.06)
Wheeled bin 241 + l	0.014	0.014
	(0.88)	(1.02)
Frequency of composting collection less than once a week	0.010*	0.009
	(2.00)	(1.86)
Residual Waste method		
Wheeled bin 100–150 l	−0.002	0.0001
	(−0.26)	(0.02)
Wheeled bin 151–200 l	−0.009	−0.008*
	(−1.77)	(−2.06)
Wheeled bin 251–300 l	−0.005	−0.004
	(−0.81)	(−0.63)
Wheeled bin > 350 l	−0.002	−0.004
	(−0.33)	(−0.88)
Plastic sacks	−0.006	−0.006
	(−0.92)	(−1.14)
Refuse bins	−0.002	−0.003
	(−0.35)	(−0.55)
Communal bins	0.014*	0.014*
	(2.33)	(2.70)
Frequency of residual waste collection less than once a week	0.046*	0.043*
	(7.16)	(7.98)
R^2-overall	0.030	0.409
R^2-between	0.056	0.395
R^2-within	0.472	0.468
Total number of observations: $N \times T$	4644	4644
Hausman test: $\chi^2(23)$	80.20*	

Note: see notes to Table 2.

Table 4
Estimation results for the dry recycling rate for Super Regions.

	Region 1		Region 2		Region 3		Region 4	
	GL, SE, SW		EM, WM, EE		NW, NE, YH		NI, SC, WL	
	FE	RE	FE	RE	FE	RE	FE	RE
Constant	−0.392	0.555*	−0.123	0.537*	−0.785	0.177	0.337	0.727
	(−0.83)	(2.24)	(−0.26)	(2.09)	(−1.35)	(0.56)	(0.77)	(1.78)
ln(income)	−0.044	−0.006	−0.052	−0.030	0.022	0.007	−0.070	−0.069
	(−1.42)	(−0.25)	(−1.42)	(−1.25)	(0.51)	(0.22)	(−1.66)	(−1.71)
ln(population density)	0.524*	−0.006	0.573*	−0.006*	0.476*	−0.011*	0.944*	−0.0005
	(3.73)	(−1.75)	(3.66)	(−2.07)	(2.05)	(−3.17)	(5.53)	(−0.10)
ln(household size)	–	−0.292*		0.008		−0.039		0.168
		(−4.57)		(0.07)		(−0.32)		(1.78)
Dry recycling method								
Kerbside box<35 l	−0.013	−0.020*	−0.003	−0.003	−0.002	0.005	0.070*	0.018
	(−1.10)	(−2.02)	(−0.31)	(−0.39)	(−0.16)	(0.66)	(2.57)	(0.90)
Kerbside box 35–50 l	−0.035*	−0.033*	0.002	−0.002	−0.017	−0.005	0.030	0.009
	(−3.79)	(−4.20)	(0.18)	(−0.33)	(−1.55)	(−0.65)	(1.13)	(0.50)
Kerbside box>50 l	−0.044*	−0.041*	−0.018*	−0.019*	−0.040*	−0.019*	0.019	0.007
	(−3.18)	(−3.68)	(−2.02)	(−2.46)	(−3.73)	(−2.62)	(0.86)	(0.52)
Reusable sacks	−0.002	−0.001	0.010	0.008	0.010	0.012	0.0007	−0.001
	(−0.22)	(−0.12)	(1.80)	(1.46)	(1.02)	(1.87)	(0.04)	(−0.10)
Non-reusable sacks	0.00007	−0.002	0.020*	0.025*	0.025*	0.025*	0.005	0.006
	(0.01)	(−0.30)	(2.45)	(3.47)	(3.00)	(3.17)	(0.40)	(0.73)
Wheeled bin<120 l	0.006	0.010	–	–	0.020	0.002	0.041*	0.045*
	(0.85)	(1.66)			(1.40)	(0.08)	(3.54)	(5.48)
Wheeled bin 120–180 l	0.012	0.011	−0.005	−0.004	−0.0008	−0.0002	0.015	0.003
	(1.71)	(1.71)	(−0.62)	(−0.56)	(−0.06)	(−0.02)	(1.18)	(0.27)
Wheeled bin 181–240 l	0.038	0.005	0.026*	0.026*	0.027*	0.021*	0.034*	0.015
	(0.35)	(0.50)	(3.47)	(4.07)	(3.26)	(3.43)	(2.71)	(1.26)
Wheeled bin 241+l	0.0008	0.003	0.014*	0.021*	0.025*	0.020*	-	−0.003
	(0.15)	(0.58)	(2.50)	(3.92)	(2.90)	(3.64)		(−0.12)
Frequency of recycling collection less than once a week	0.010	0.005	0.002	−0.007	−0.007	−0.004	0.002	−0.005
	(1.36)	(0.82)	(0.14)	(−0.59)	(−0.56)	(−0.44)	(0.12)	(−0.39)
Residual waste method								
Wheeled bin 100–150 l	0.009	0.007	−0.009	−0.006	0.002	0.005	−0.043*	−0.027
	(1.85)	(1.35)	(−0.97)	(−0.78)	(0.26)	(0.95)	(−2.04)	(−1.87)
Wheeled bin 151–200 l	0.0003	−0.001	0.010	−0.002	0.011	0.010	−0.001	−0.015
	(0.04)	(−0.21)	(1.15)	(−0.28)	(0.95)	(1.11)	(−0.06)	(−1.47)
Wheeled bin 251–300 l	0.006	0.001	0.0006	−0.008	−0.010	−0.006	−0.040	−0.030
	(0.87)	(0.16)	(0.07)	(−1.03)	(−0.88)	(−0.64)	(−1.69)	(−1.79)
Wheeled bin>350 l	0.008	0.004	0.002	−0.005	−0.007	−0.007	−0.007	0.010
	(1.37)	(0.82)	(0.20)	(−0.75)	(−0.98)	(−1.09)	(−0.33)	(0.59)
Plastic sacks	0.005	0.002	−0.032*	−0.019*	−0.021*	−0.018*	−0.088*	0.010
	(0.79)	(0.42)	(−3.04)	(−2.07)	(−2.37)	(−2.74)	(−7.52)	(0.38)
Refuse bins	0.006	0.005	0.017*	0.010	−0.052	−0.025*	0.031	−0.004
	(0.43)	(0.41)	(2.48)	(1.20)	(−1.93)	(−2.18)	(0.99)	(−0.31)
Communal bins	0.003	0.005	0.010	0.006	0.016*	0.015*	−0.053*	−0.020
	(0.55)	(0.90)	(1.41)	(1.00)	(2.54)	(2.61)	(−6.85)	(−1.19)
Frequency of residual waste collection less than once a week	0.047*	0.047*	0.035*	0.004*	0.027*	0.036*	0.023*	0.028*
	(6.71)	(7.37)	(4.58)	(5.71)	(2.55)	(4.07)	(3.13)	(4.02)
R^2-overall	0.035	0.311	0.032	0.466	0.082	0.408	0.024	0.199
R^2-between	0.035	0.298	0.051	0.458	0.148	0.421	0.043	0.212
R^2-within	0.403	0.372	0.516	0.489	0.421	0.401	0.283	0.204
Total number of observations: $N \times T^{\dagger}$	1536	1536	1337	1337	957	957	814	814
Hausman test: $\chi^2(23)$	161.86*		109.03*		67.27*		96.79*	

Note: t-ratios are reported in parentheses, calculated from robust standard errors, adjusted for clustering effects across the local authorities. * denotes significance at the 5% level. Seasonal dummies and individual dummy variables for the UK regions are also included, the estimates from which are not reported to conserve space. † N×T refers to the total number of observations available for estimation. N is the number of local authorities in the Super Region and T is the number of time periods.

having them, compared to Kerbside boxes, which tend to be stored indoors.[15] However, if the size of the wheeled bin is too large, this can discourage householders from recycling as they perceive the amount recycled appears to be insignificant and not worth setting out for collection. The variation in performance of containers dedicated to recycling suggests that local authorities should focus their efforts on finding the optimal size of recycling capacity for dry recyclables.

Thirdly, unlike in the case of dry recycling, the frequency of recycling collection is statistically significant in the case of composting. The dummy variable equals one whenever the frequency of collection is fortnightly or longer or zero for a weekly collection or more frequent. The gain for the composting collection of having a frequency of collection less than weekly is a rise in the composting rate of 1.0%. Intuitively we would expect a positive relationship between the frequency of collection and the recycling rate. However, because the nature of the composting activity is such that it takes place on a much more infrequent basis than dry recycling, more closely matching collection to the activity increases the amount set out by the household.[16]

Fourthly, common to both dry recycling and composting, we find that the method of residual waste collection has poor explanatory

[15] Barr et al. (2003) find a positive relationship between property size (which acts as a proxy for available space to store recyclables) and the recycling rate for participants in a survey of households in Exeter, a UK city.

[16] Compostable waste for the period of time considered in the study is essentially garden waste.

Table 5
Estimation results for the composting rate for Super Regions.

	Region 1		Region 2		Region 3		Region 4	
	GL, SE, SW		EM, WM, EE		NW, NE, YH		NI, SC, WL	
	FE	RE	FE	RE	FE	RE	FE	RE
Constant	−0.182	0.103	−0.528	−0.491	−0.182	−0.378	0.490	0.372
	(−0.34)	(0.45)	(−0.92)	(−1.34)	(−0.24)	(−1.06)	(1.52)	(1.27)
ln(income)	−0.041	−0.024	−0.035	0.007	0.016	0.031	−0.052	−0.027
	(−1.10)	(−1.12)	(−0.75)	(0.19)	(0.34)	(0.92)	(−1.73)	(−0.99)
ln(population density)	0.303*	−0.006	0.614*	−0.014*	0.043	−0.015*	0.218	−0.003
	(2.54)	(−1.28)	(3.64)	(−2.66)	(0.13)	(−2.71)	(1.32)	(−0.69)
ln(household size)	–	0.237*	–	0.562*	–	0.148	–	−0.044
		(3.04)		(2.65)		(0.89)		(−0.45)
Composting method								
Reusable sacks	0.004	0.007	−0.014	−0.007	−0.030	−0.028*	0.003	0.004
	(0.47)	(1.32)	(−1.54)	(−0.69)	(−1.49)	(−2.48)	(0.22)	(0.50)
Non-reusable sacks	0.009	0.009	−0.041*	−0.023*	−0.002	0.001	−0.007	−0.006
	(1.61)	(1.83)	(−2.21)	(−2.37)	(−0.13)	(0.15)	(−0.72)	(−1.12)
Wheeled bin < 120 l	−0.007	−0.010	0.031	0.036*	0.017	0.013	-	-
	(−0.71)	(−1.33)	(1.71)	(2.94)	(1.36)	(0.86)		
Wheeled bin 120–180 l	0.035*	0.033*	0.032	0.043*	−0.029	0.003	−0.013	0.004
	(4.89)	(5.58)	(1.20)	(3.62)	(−1.19)	(0.21)	(−1.23)	(0.44)
Wheeled bin 181–240 l	0.029*	0.032*	0.004	0.022*	0.002	0.009	0.036*	0.042*
	(3.40)	(7.29)	(0.31)	(2.53)	(0.14)	(0.79)	(3.80)	(4.80)
Wheeled bin 241 + l	0.024	0.021*	−0.003	0.021	−0.0004	0.007	−0.046	−0.010
	(1.25)	(2.21)	(−0.11)	(0.15)	(−0.05)	(0.42)	(−1.34)	(−0.31)
Frequency of recycling collection less than once a week	0.009	0.008	0.026*	0.014	−0.008	−0.008	0.009	0.010
	(1.64)	(1.94)	(2.36)	(0.94)	(−0.62)	(−0.80)	(0.96)	(1.32)
Residual waste method								
Wheeled bin 100–150 l	0.021*	0.018*	−0.005	0.0004	−0.006	−0.001	−0.027*	−0.012
	(3.09)	(3.79)	(−0.34)	(0.05)	(−1.25)	(−0.15)	(−2.34)	(−1.49)
Wheeled bin 151–200 l	−0.016*	−0.013*	−0.004	−0.012	−0.003	0.0008	−0.029*	−0.018*
	(−3.29)	(−3.32)	(−0.35)	(−1.54)	(−0.28)	(0.11)	(−2.31)	(−2.22)
Wheeled bin 251–300 l	0.005	0.005	−0.002	−0.006	−0.002	0.001	−0.030*	−0.016
	(0.53)	(0.70)	(−0.15)	(−0.84)	(−0.10)	(0.11)	(−2.18)	(−1.57)
Wheeled bin > 350 l	−0.001	−0.002	−0.003	−0.012	0.007	0.002	−0.008	0.006
	(−0.18)	(−0.37)	(−0.37)	(−1.62)	(0.66)	(0.21)	(−0.64)	(0.61)
Plastic sacks	−0.0008	−0.001	−0.010	−0.020	−0.002	0.006	−0.077*	−0.026
	(−0.13)	(−0.26)	(−0.53)	(−1.65)	(−0.25)	(0.67)	(−3.58)	(−1.94)
Refuse bins	−0.001	−0.005	0.003	0.004	−0.025	−0.009	−0.013	−0.016
	(−0.15)	(−0.81)	(0.39)	(0.28)	(−1.59)	(−0.67)	(−0.05)	(−1.79)
Communal bins	−0.003	−0.003	0.023*	0.023*	0.021*	0.022*	0.008	0.019
	(−0.33)	(−0.68)	(2.79)	(3.55)	(4.05)	(3.85)	(0.05)	(1.70)
Frequency of residual waste collection less than once a week	0.039*	0.038*	0.066*	0.066*	0.029*	0.031*	0.016*	0.015*
	(4.93)	(8.39)	(5.64)	(10.82)	(2.49)	(5.17)	(2.31)	(3.13)
R^2-overall	0.059	0.342	0.038	0.361	0.007	0.469	0.003	0.394
R^2-between	0.095	0.361	0.069	0.249	0.056	0.424	0.001	0.273
R^2-within	0.328	0.323	0.627	0.616	0.537	0.534	0.601	0.590
Total number of observations: $N \times T$	1536	1536	1337	1337	957	957	814	814
Hausman test: $\chi^2(23)$	21.06		99.74*		17.98		37.07*	

Note: see notes to Table 4.

power. We find only one method, communal bins, to stand out in raising the composting rate. We speculate that householders might wish to limit the number of visits to communal bins by diverting more of their compostable waste.

As noted at the outset there appears to be significant variation in recycling rates across the UK. To assess the degree to which there is a regional dimension to our four main findings discussed above, we organise the dataset into four 'Super Regions'. While ideally we would like to derive separate estimates for all twelve regions of the UK, this was not possible, since it would have resulted in the dropping of too many policy dummies, when no authority in the region offers a particular method of collection. Super Region 1 includes Greater London, the South East, and South West; Super Region 2 includes the East Midlands, West Midlands, and East of England; Super Region 3 is the North West; the North East, and Yorkshire & the Humber; and Super Region 4 is Northern Ireland, Scotland and Wales.

Focussing firstly on the re-estimation of the dry recycling equation for the Super Regions (Tables 4 and 5), we find that there is a significant and negative relationship between the frequency of residual waste collection and both categories of recycling. In terms of dry recycling, hypothesis testing suggested that the estimated coefficients were not significantly different from one another for Super Region 1 and Super Region 2 but for Super Regions 3 and 4, the estimated coefficients were found to be significantly different from the estimate for Super Region 1, which has the largest marginal effect. One possible explanation for the differences in the estimated coefficients could be the differences in the population density across the Super Regions. The South of England is the most densely populated Super Region of the UK,[17] thus switching from a weekly to a fortnightly residual waste collection is likely to put greatest pressure on storage capacity for residual waste and thus acts as an even bigger incentive to recycle than in the less densely populated regions, particularly the non-English regions.

Compared to our previous results based on the disaggregated dataset, the relative strength of the relationship for composting is not consistently higher than the dry recycling rate across Super Regions,

[17] From our data set, the mean population density for Super Region 1 is 19.61 persons per hectare; 9.32 persons per hectare for Super Region 2; 9.84 persons per hectare for Super Region 3; and 4.18 persons per hectare for Super Region 4.

although it is notably high for Super Region 2 which covers the central and eastern parts of England. We might speculate that the combination of relatively high population density and availability of green space, which provides the opportunity to compost, could be responsible for this.

The relative importance of the method of recycling for the dry recycling category as compared to composting is repeated when we consider Super Regions — more of the coefficients for the different methods of dry recycling are statistically significant. To a large degree the direction of effect is also carried over — the 'Kerbside box>50 l' reduces the dry recycling rate, whereas the 'Wheeled bins' and 'Non-reusable sacks' increase it. As regards the regional effect, Super Regions 2 and 3 appear to be more sensitive to the method of dry recycling — more of the methods are statistically significant in explaining the dry recycling rate for these two regions.

Similarly, our previous result that frequency of recycling collection was not important for dry recycling is also reflected in our results for the Super Regions. Interestingly, the relationship between the frequency of collection and the composting rate is only significant for Super Region 2. This result together with our earlier result that Super Region 2 responded strongly in terms of its composting rate when residual waste is collected less frequently suggests that composting is an important issue for households in central and eastern England.

Finally, as regards the method of residual waste collection, the results are more mixed for Super Regions — only eleven of the fifty six coefficients are significant in explaining the recycling rate. The provision of communal bins increases the composting rates for Super Regions 2 and 3. Of the four Super Regions, Super Region 4 appears to be most sensitive to the method of residual waste collection in terms of the impact on its composting rate (it has a greater number of significant coefficients).

In terms of the control variables we find that income has poor explanatory power, which appears to be picking up the opposing effects income that can have on the recycling rate i.e. higher earners have a higher propensity to recycle because the environment is a luxury good but also have a higher opportunity cost of time which acts to reduce their recycling rates. Although positive, Terry (2002) also finds that the relationship between income and recycling is insignificant.

The estimated coefficient for population density is positive and significant, with Super Region 4 having the largest estimated coefficient: this could in part be explained by the fact that Super Region 4 has the lowest population density among the four Super Regions, some four times smaller than that of Super Region 1. Thus coming from a lower base, a unit increase in population density has a larger impact on the recycling rate for the non-English regions of the UK than the more densely populated South of England. This result runs contrary to Callan and Thomas (1997) and Kinnaman and Fullerton (2000), who both found a significant and negative relationship between population density and recycling. One possible explanation for our results could be that with greater access to recycling facilities, households living in more densely populated areas find it easier to recycle thus improving the recycling rate.

Using the random effects estimator, average household size is found to be insignificant for the dry recycling equation, a conclusion supported for three out of the four Super Regions. In the composting equation, household size is significant and positively signed: this finding is supported for two of them, with the largest estimate for Super Region 2. One reason for this result could be that larger households tend to live in larger properties e.g. detached housing with bigger garden space and hence more opportunity for composting.

5. Conclusions

In this paper, we have set out to answer the question of why, although all local authorities in the UK have broadly improved in terms of their household recycling rates, there are still significant and persistent differences between them. It would appear that a key factor in the UK's improved recycling performance has been the expansion of kerbside recycling. Several contributions in the literature allude to the importance of identifying which characteristics of kerbside recycling contribute most to increased recycling without actually quantifying their effects. Since local authorities predominantly have autonomy in the way they spend their budgets, differences arise in recycling policy, specifically kerbside recycling provision. To capture these differences, we classified kerbside schemes according to the size and type of container provided, as well as the frequency of collection. Attempting to draw broad conclusions from our results, we find that: the frequency of residual waste collection is important for increasing the recycling rate, with the lower the frequency the higher the recycling rate; the method of recycling or container used is more important for dry recycling than it is for composting; the frequency of recycling collection is only important in the case of composting; and the method of residual waste collection is unimportant for the recycling rate.

Based on these results, the question arises as to their policy implications. We have briefly discussed the current debate of whether to reverse the trend, emerging amongst local authorities, of reducing the frequency of residual waste collection. Our findings suggest that the answer to this is a resounding no. Reducing the frequency of residual waste collection appears to be important in incentivising households to sort their waste between recyclables and non-recyclables. Thus, this is an important driver in increasing the recycling rate and helping local authorities to meet their targets, both in terms of recycling rates and reducing the amount of household waste going to landfill. The role of central government should be to show clear policy direction on this and support local authorities who wish to retain or adopt alternate weekly or fortnightly waste collections but face accusations that they are doing so for cost considerations only. Any savings that are made from reducing the frequency of residual waste collection should be directed towards enhancing recycling provision.

Given limited resources, local authorities have to get 'more bang for their buck'. Never is this more true than now in the post financial crisis period with local authorities facing dramatic cuts to their budgets. The findings of this research suggest that they should focus their attention on type of container used in relation to dry recycling only. Given the type of containers currently provided, there is an optimal size of recycling container which according to this study is the 'Wheeled bin<120 l' method. Other container types not currently provided could perform even better and this is a possible avenue to explore for local authorities interested in fine-tuning their kerbside collection scheme to have the maximum impact in encouraging recycling. Also, linked to the design of recycling provision, the frequency aspect appears to be only important in relation to composting. Hence, in local authorities where composting is a sizeable component of the overall recycling activity, a lower frequency of recycling collection should increase overall recycling. Our results suggest that in terms of its effect on the recycling rate, local authorities can be indifferent between types of container used for residual waste collection.

In terms of our regional analysis a few additional points can be made. The importance of the impact of frequency of residual waste collection on the recycling rate appears to be greatest for households in the south of England. Thus, local authorities located here should benefit most from reducing the frequency of their residual waste collections. Composting emerged as relatively important for central and eastern England. Super Regions 2 and 3 appear to be more sensitive to the method of dry recycling.

However, it is possible to extend the results of this paper in a number of ways. Firstly, it would be interesting to discover whether recycling policy has the same effect on the recycling rate of different materials. So, for example, does the same method of collection and frequency of collection have a differential effect for glass compared to paper? Secondly, it is possible to compare recycling rates according to whether the collection is kerbside or non-kerbside. It may be the case that efforts to raise the recycling rate through greater kerbside provision have been at the expense of lower recyclable volumes delivered to drop-off or civic amenity sites, so that overall recycling volumes have not risen (Beatty et al., 2007). Finally, wastedataflow.org publishes data on the type of organisation that undertakes the collection. Systematic differences in the recycling rates may arise between local authorities that have in-house provision of environmental services compared to those that contract-out to not-for-profit community organisations, use private providers or have a joint venture. Addressing these questions is left for future research.

References

Ando, A., Gosselin, A., 2005. Recycling in multifamily dwellings: does convenience matter? Economic Inquiry 43 (2), 426–438.

Barr, S., Ford, N., Gilg, A., 2003. Attitudes towards recycling household waste in Exeter, Devon: quantitative and qualitative approaches. Local Environment 8 (4), 407–421.

BBC, 2010. Minister wants return to weekly bin collectionsavailable at http://news.bbc.co.uk/1/hi/politics/10346895.stm.

Beatty, T., Berck, P., Shimshack, J., 2007. Curbside recycling in the presence of alternatives. Economic Inquiry 45 (4), 739–753.

Berglund, C., Söderholm, P., 2003. An econometric analysis of global waste paper recovery and utilization. Environmental and Resource Economics 26 (3), 426–456.

Callan, S., Thomas, J., 1997. The impact of state and local policies on the recycling effort. Eastern Economic Journal 23 (4), 411–423.

Callan, S., Thomas, J., 2006. Analyzing demand for disposal and recycling services: a systems approach. Eastern Economic Journal 32 (2), 221–240.

De Young, R., 1990. Recycling as appropriate behaviour: a review of survey data from selected education programs in Michigan. Resources, Conservation and Recycling 3 (4), 253–266.

Defra, 2010. Key Facts About: Waste and Recycling. Department for Environment, Food and Rural Affairs. Available at http://www.defra.gov.uk/evidence/statistics/environment/waste/kf/wrkf04.htm.

Dijkgraaf, E., Gradus, R.H.J.M., 2004. Cost savings in unit-based pricing of household waste: the case of The Netherlands. Resource and Energy Economics 26 (4), 353–371.

Eurostat, 2010. Environment in the EU 27: 40% of municipal waste recycled or composted in 2008, Eurostat news release 43/2010Available at http://europa.eu/rapid/pressReleasesAction.do?reference=STAT/10/43&format=HTML&aged=0&language=EN&guiLanguage=fr.

Ferrera, I., Missios, P., 2005. Recycling and waste diversion effectiveness: evidence from Canada. Environmental and Resource Economics 30 (2), 221–238.

Hage, O., Söderholm, P., 2008. An econometric analysis of regional differences in household waste collection: the case of plastic packaging waste in Sweden. Waste Management 28 (10), 1720–1731.

Harder, M., Woodward, R., Bench, M., 2006. Two measured parameters correlated to participation rates in curbside recycling schemes in the UK. Environmental Management 37 (4), 487–495.

Hershkowitz, A., 1997. Too Good to Throw Away: Recycling's Proven Record. National Resources Defense Council. available at http://www.nrdc.org/cities/recycling/recyc/recyinx.asp.

Hong, S., 1999. The effects of unit pricing system upon household solid waste management: the Korean experience. Journal of Environmental Management 57 (1), 1–10.

Hong, S., Adams, R., Love, H., 1993. An economic analysis of household recycling of solid wastes: the case of Portland Oregon. Journal of Environmental Economics and Management 25 (2), 136–146.

Iparraguirre D'Elia, J.L., 2008. Determinants of Household Waste Recycling in Northern Ireland. Economic Research Institute of Northern Ireland.

Iredale, T., 2011. Eric Pickles is talking rubbish says Tory Councilavailable at http://www.bbc.co.uk/blogs/timiredale/2011/01/.

Jakus, P., Tiller, K., Park, W., 1996. Generation of recyclables by rural households. Journal of Agricultural and Resource Economics 21 (2), 96–108.

Jenkins, R., 1993. The Economics of Solid Waste Reduction: the Impact of User Fees. Edward Elgar.

Jones, A., 2006. Trends in Waste Recycling. Fact Sheet No. 6. The Open University Household Waste Study.

Kinnaman, T., 2006. Policy watch: examining the justification for residential recycling. Journal of Economic Perspectives 20 (4), 219–232.

Kinnaman, T., Fullerton, D., 2000. Garbage and recycling with endogenous local policy. Journal of Urban Economics 48 (3), 419–442.

Kipperberg, G., 2007. A comparison of household recycling behaviours in Norway and the United States. Environmental and Resource Economics 36 (2), 215–235.

LGA, 2006. LGA backs fortnightly residual waste collections. Local Government Association Press release 13 February 2006. available at http://www.letsrecycle.com/news/latest-news/councils/lga-backs-fortnightly-residual-waste-collections.

LGA, 2007. Recycling rates rocket by 30% when councils switch to alternate weekly collection. Local Government Association Press release 25 April 2007. available at http://www.lga.gov.uk/lga/core/page.do?pageId=41797.

Linderhof, V., Kooreman, P., Allers, M., Wiersma, D., 2001. Weight-based pricing in the collection of household waste: the Oostzaan case. Resource and Energy Economics 23 (4), 359–371.

Mazzanti, M., Zoboli, R., 2009. Municipal waste Kuznets curves: evidence on socio-economic drivers and policy effectiveness from the EU. Environmental and Resource Economics 44 (2), 203–230.

Owens, J., Dickerson, S., Macintosh, D., 2000. Demographic covariates of residential recycling efficiency. Environment and Behaviour 32 (5), 637–650.

Phillips, P., Adams, K., Read, A., Green, A., 2000. Regional variations in waste minimisation in England: challenges and issues for policy development. Regional Studies 34 (3), 297–302.

Platt, B., Zachary, J., 1992. Co-collection of Recyclable and Mixed Waste: Problems and Opportunities. Institute for Local Self-Reliance.

Podolsky, M., Spiegel, M., 1998. Municipal waste disposal: unit pricing and recycling opportunities. Public Works Management and Policy 3 (1), 27–39.

Saltzman, C., Duggal, V.G., Williams, M.L., 1993. Income and recycling effort: a maximisation problem. Energy Economics 33–38.

Sanderson, P. 2007. The weekly recycling debate. R&WM magazine, Lyonsdown publishing.

Sidique, S., Joshi, S., Lupi, F., 2010. Factors influencing the rate of recycling: an analysis of Minnesota counties. Resources, Conservation and Recycling 54 (4), 242–249.

Sterner, T., Bartelings, H., 1999. Household waste management in a Swedish municipality: determinants of waste disposal, recycling and composting. Environmental and Resource Economics 13 (4), 473–491.

Terry, N., 2002. The determinants of municipal recycling: a time series approach. Southwestern Economic Review 29 (1), 53–62.

Timlett, R., Williams, I., 2008. Public participation and recycling performance in England: a comparison of tools for behaviour change. Resources, Conservation and Recycling 52 (4), 622–634.

Van Houtven, G.L., Morris, G.E., 1999. Household behaviour under alternative pay-as-you-throw systems for solid waste disposal. Land Economics 75 (4), 515–537.

Vining, J., Ebreo, A., 1992. Predicting recycling behaviour from global and specific environmental attitudes and changes in recycling opportunities. Journal of Applied Social Psychology 22 (20), 1580–1607.

Ward, P., 2009. Cited in Hickman L. The truth about recycling, Guardian G2, 26/2/09available at http://www.guardian.co.uk/environment/2009/feb/26/recycling-waste-environment.

Wertz, K., 1976. Economic factors influencing households' production function of refuse. Journal of Environmental Economics and Management 2 (4), 263–272.

Wilson, C., Williams, I., 2007. Kerbside collection: a case study from the north-west of England. Resources, Conservation and Recycling 52 (2), 381–394.

Woodward, R., Harder, M., Bench, M., Philip, M., 2001. Evaluating the performance of a fortnightly collection of household waste separated into compostables, recyclates and refuse in the south of England. Resources, Conservation and Recycling 31 (3), 265–284.

Woodward, R., Bench, M., Harder, M., 2005. The development of a UK kerbside scheme using known practice. Journal of Environmental Management 75 (2), 115–127.

WRAP, 2009. Commentary — scoping study of potential health effects of fortnightly residual waste collections and related changes to domestic waste systems. Report Prepared by WRAP & CIWM.

WRAP, 2010a. Environmental benefits of recycling — 2010 update. Waste and Resources Action Programme, Final Report. available at http://www.wrap.org.uk/wrap_corporate/publications/benefitsrecycling.html.

WRAP, 2010b. Analysis of Kerbside Dry Recycling Performance in the UK 2008/09.

Yang, H., Innes, R., 2007. Economic incentives and residential waste management in Taiwan: an empirical investigation. Environmental and Resource Economics 37 (3), 489–519.