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Towards Regional Environmental Accounts for Ireland

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Abstract: Existing environmental accounts for the Republic of Ireland are at the national level. This is fine for continental and global environmental problems, but information at a finer spatial scale is needed for local environmental problems. Furthermore, the impact of environmental policy may differ across space. We therefore construct regional estimates of the environmental pressures posed by Irish households and the environmental problems faced by them. The basic unit of analysis is the electoral district, and the prime data source is the CSO's Small Area Statistics, a product of the Census. We use the results of classifying regressions of the Household Budget Survey to impute domestic energy use. We use engineering relations to impute transport fuel use, and secondary data on household behaviour to impute waste arisings. We use EPA data on drinking water use and quality per county. The results show marked regional differences. Electricity use and waste arisings are higher in the East and in the cities and towns. Transport fuel use is highest in the commuter belts around the cities and towns. Other energy is relatively uniform. There is no clear pattern in estimated drinking water use, which may be due to data quality. Drinking water quality is poor across much of the country, but different counties suffer from different problems. The regional estimates are constructed using data in the public domain. However, various government agencies hold data that would allow for the construction of more detailed, more accurate, and more extensive regional environmental accounts.

Key words: Regional accounts; environmental accounts; energy use; transport; household waste; drinking water quality; drinking water quantity

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Towards Regional Environmental Accounts for Ireland

1. Introduction

Environmental accounts for the Republic of Ireland have been presented at the national scale. This makes sense for some emissions – e.g., it does not matter whether greenhouse gases are emitted in Wexford or in Donegal – but other environmental problems have a clear regional dimension – e.g., drinking water is typically sourced locally, and a clean Liffey does not help the people of Galway. Furthermore, environmental policy may have a different impact on different regions. Therefore, this paper presents estimates of energy use, waste, and water use for over 3,400 electoral districts in the Republic of Ireland.

Regional data on waste generation and water use are obviously important. These services are provided by local authorities. Average levels of provision contain little information. Overcapacity in Cork does not cancel out undercapacity in Limerick. Spatial data on energy use are important for planning the grid, and provide information on the distribution of the impact of policy measures to reduce greenhouse gas emissions. Data on local emissions and resource use may also be used to assess the sustainability of specific settlements or settlement patterns; see for example Moles *et al.*, 2008.

Most of the regional estimates presented in this paper are not directly observed. Rather, the "data" presented here are imputed from things that are observed (by the Census) at regional level and relationships derived from secondary data. Such imputation cannot be avoided. The alternative is to have no regional estimates at all.

Our imputation method uses household microdata to estimate statistical relationships between household characteristics and the variables of interest (i.e. emissions and resource use), and then apply these relationships to the average socioeconomic characteristics of small geographical areas to predict the values that the variables of interest should take in each area. We keep the regressions as simple as possible, often only averaging across multiple household characteristics. We avoid double imputation, that is, we only feed observations into the regression models. We do not use imputed data in the imputation.

Development of regional environmental accounting is in its infancy, but there are several international examples of its application: see e.g. New Zealand Centre for Ecological Economics, 1999 (Northern New Zealand); Turner, 2006 (Jersey); OECD, 2007 (Hyogo Prefecture, Japan); Wadeskog and Eriksson, 2004 (Stockholm); and RAMEA, 2008 (Italy, Netherlands, Poland and the UK).

The paper proceeds as follows. Section 2 discusses the population and income patterns that drive most of our results. Section 3 presents the methods and results for energy use, Section 4 for waste, and Section 5 for water use. Section 6 presents some further analysis that helps to support the conclusions and policy implications. The data can be found at:

http://www.esri.ie/irish_economy/environmental_accounts/index.xml

2. Population and income

Our small area income estimates are derived using two different CSO data sets. The Census yields the Small Area Population Statistics (SAPS), which contain demographic data on household structure, age, education, and employment per electoral district (ED) as well as data on housing conditions and facilities. The Household Budget Survey (HBS) has similar data on housing and demographics plus data on income and expenditures. To impute incomes for each area, we ran a regression of household income in the 2004/5 HBS anonymised data file on the characteristics found in the 2006 SAPS, and used the estimated equation to impute the income level for each electoral district. Because the SAPS hold fairly basic information only, the regression essentially computes the average income per group. It is a “classifying regression” rather than a continuous function – that is, the explanatory variables are dummies. Table A1 shows the estimated coefficients.

Table 1 shows selected characteristics of the population data per ED. EDs vary widely in the number of people and household that live there, as well as in population density. As revealed by the Gini coefficient, a small number of EDs account for most of the population. Moran’s I shows that large and densely populated EDs tend to cluster together. The variation in household size is much less, but here we also see spatial agglomeration of small and large households. Figure 1 shows this. Rural households in the West and Northwest of the country tend to be smaller than the average. Nonetheless, Table 3 shows a negative correlation between household size and population density.

Figure 2 shows the map of imputed household incomes. The high incomes are clearly concentrated around the cities. Table 1 confirms this with Moran's I. Table 3 also shows a negative correlation between population density and household income. Table 1 also has the characteristics of total income per ED. Both the Gini coefficient and Moran's I show that income is more spatially concentrated than population, which confirms that rural areas tend to be poorer than urban areas.

3. Energy, transport and carbon dioxide emissions

Regional data on electricity use and other fuel consumption are derived from the SAPS and the HBS, using the same type of classifying regression as described above for household income. Tables A2 and A3 shows the estimated coefficients for electricity use and other fuel consumption, respectively. Other fuels are primarily used for home heating, although there is also some fuel used for lawnmowers and barbeques. However, electricity is also used for heating: in 2005 about 7% of households used electricity as their principal means of winter space heating (Central Statistics Office, 2006, Table 9).

3.1. Energy use

Figure 3 depicts electricity use per household. The spatial pattern lies somewhere in between that of household size (Figure 1) and household income (Figure 2), but differences are less pronounced. This is also seen in Table 1. Table 3 shows that household size is slightly more important than income in explaining electricity use.

Figure 4 shows fuel consumption for home heating and other purposes per household.[1] This is roughly equal across the country – with the exception of a few urban electoral districts,

[1] Strictly, non-electric energy use for anything but transport.

where a combination of small dwellings and fuel poverty leads to heat use that is well below the national average. The positive value of Moran's I in Table 1 is explained by the urban concentration of low per household heat use. Table 1 also shows the characteristics of total heat. The concentration of heat use in a few EDs follows the distribution of the population. Income is less important (cf. Table 3).

Figure 5 shows transport fuel consumption, for commuting, per adult. The map reveals the commuter belts around the cities – but also shows that these belts are not continuous. Moran's I in Table 1 confirms the strong spatial concentration of transport fuel use. The Gini coefficient in Table 1 again reveals that a minority of electoral districts dominate total fuel use – following the distribution of population and work. Table 3 shows that the correlations of transport fuels use to household size and income are indeed low (but positive), while the correlation with population density is negative (and larger, in absolute terms, than any other correlation.) Unfortunately, there is no data available on total transport fuel use.

3.2. The impact of regulation

Figure 3 shows the spatial distribution of electricity use. To a first approximation, Figure 3 also shows the spatial distribution of changes in the price of electricity. These include the price effects of the priority dispatch of peat power and the feed-in tariffs for wind power. In the future, the price of electricity may reflect the price of carbon permits. Similarly, Figure 4 also shows the spatial pattern of the impact of excise duties on heating fuel, and Figure 5 shows the pattern for excises on transport fuel.

A carbon tax may well be introduced in the foreseeable future, applied to all carbon dioxide emissions that are not already regulated by the EU Emissions Trading Scheme (ETS). Figure 6 shows the average impact per household for each of the electoral districts. Figure 6 is the weighted sum of Figures 4 and 5, with the emission coefficients of heating and transport fuels as weights.[2] In the short run, the spatial pattern in Figure 6 is independent of the level of the tax.[3] We assumed a carbon tax of €20/tCO_2.

Although a carbon tax is occasionally portrayed as being an unfair burden on households at the countryside, Figure 6 shows a more nuanced pattern. A carbon tax would particularly hit the commuter belts around Cork, Dublin, Galway and Limerick, while the rest of the rural areas in fact see a below average impact. Table 3 confirms that transport fuel is more strongly correlated with the carbon tax than is other fuel use.

Figure 6 shows the incremental effect of a change in climate policy, viz. the introduction of a carbon tax on non-ETS CO_2 emissions. Figure 7 shows the impact of the total package of climate policies, including the effect of the ETS on electricity prices. That is, Figure 7 adds the carbon dioxide emissions from power generation, assuming that a permit price of €20/tCO_2 is fully passed on to final consumers.

Figure 7 reveals a spatial pattern which is less pronounced than that in Figure 6. While Figure 6 suggests that a carbon tax would be spatially inequitable, Figure 7 shows that a carbon tax in fact partially corrects for spatial inequities introduced by the EU ETS.

4. Biodegradable municipal waste generated by households

In this section we estimate the regional distribution of biodegradable municipal waste (BMW) generated by households and subsequently sent to landfill. This waste category is of policy interest because it poses particular problems for the environment if not managed properly and as a consequence is subject to EU regulatory limits.

Purcell and Magette (2009) estimate BMW quantities generated by the household and services sectors in the Dublin area. To estimate household waste, they apply fixed per-household waste generation factors taken from previous studies to SAPS data. Two factors

[2] Note that these emission coefficient are themselves weighted averages of the fuel-specific emission coefficients. This is particularly relevant for home heating, for which a range of different fuels (from peat to gas) are used.

[3] In the long run, the pattern would become less pronounced, as behaviour and technology would change faster for those affected most.

are tested: one based on social class of the household and one based on household size. While both methods provide estimates that are considerably higher than reported aggregate waste generation, the authors find that factors based on household size overstate total waste generation by a smaller margin.

Our approach has some similarities to Purcell and Magette's, but rather than building up estimates from per-household factors, we use the relationship between household size and waste generation to assign shares of total waste to individual EDs. Following Scott and Watson's (2006) results for mixed household waste, we assume that the weight of BMW generated by a household is proportional to the number of people in the household raised to the power 0.486. The number of households by size per ED is found in the SAPS (see Figure 1). According to the ESRI's environmental accounts (based on EPA National Waste Report data), total household BMW sent to landfill in 2006 was 0.95 million tonnes (Lyons *et al*., 2008).

Figure 8 shows estimated waste per household. Not surprisingly, the pattern is rather similar to the pattern of Figure 1, albeit less pronounced as differences are suppressed by a power that is less than one. Table 3 confirms this: The correlation between household waste and household size is very close to unity.

5. Water

5.1. Sewage

There is no spatially disaggregated information on the pressures that Irish households place on the sewage system.[4] However, there is a design standard for the volume: 225 litres per person per day, regardless of age, income, location, or anything. As a result, the spatial pattern of the demand for sewage facilities is equal to the pattern of population density.[5]

[4] Note that there are observations on sewage treatment facilities. We have not been able to connect these to the populations they serve.

[5] The gradient of population density between rural and urban areas is too sharp for a meaningful representation on a map, even in log scale.

The lack of readily available data on the quality of the water entering the sewage system is a potential concern because of the changing composition of detergents and the increased use of medication, be it prescribed or not. Sewage water treatment plants are designed to purify water of a certain quality. However, without frequent monitoring, one cannot be sure that the intake water quality has not changed since the plant was designed.

There is information available on the sewage provision, that is, whether houses are served by a public scheme, a group one, or a private one. Most electoral districts are served entirely by public schemes or by private ones. The division is by and large the same as the division between urban and rural areas.[6]

5.2. Drinking water

Data on water quality and supply was obtained from "The Provision and Quality of Drinking Water in Ireland" reports for the years 2001-2006 (with 2003 missing), published by the Environmental Protection Agency.

Monitoring of water quality is carried out by sanitary authorities in Ireland – the 34 City or County Councils - for a range of chemical, microbiological or additional indicator parameters. They must report exceedances for those supplies which are above the standard set by EU legislation for 48 parameters. The EPA is required to collect and verify monitoring results for all water supplies in Ireland covered by the Drinking Water Regulations. This involves the collection of results on an annual basis from local authorities and carrying out audits on selected local authorities to verify the information that has been submitted.

Data on the population served by each water supply is similarly collected and reported annually by each sanitary authority. These water supplies fall under four categories: public supplies (which provide water for the majority of households in Ireland), public group water schemes, private group water schemes (where the owners of the scheme source and distribute their own water) and small private supplies, which include a wide range of

[6] The bimodality is so sharp that this data cannot be meaningfully shown on a map.

supplies including industrial supplies to small private sources serving only one household. These small private supplies are largely exempt from the requirements of the regulations, except where the water is supplied as part of a public or commercial activity. This may explain why the population and water quality data for such supplies is limited or missing for many of the private supplies in the data we use.

We know the county in which each scheme is placed. We know the exact location only for a minority of drinking water schemes (see Figure A1) based on 2004 data from the Department of the Environment, Heritage and Local Government. This data nonetheless allows us to estimate the county average per capita water use. The variations over space and time are indicative of poor data quality. For example, Wexford reports an average water use of 18 litres per person per day in 2004, enough to flush the toilet twice. The data for Dublin are also suspect: There is no variation over time, in either population served or total water flow. The range of observed water use values is substantial. Averaging over the five years of available data, Wexford uses only 2,84 l/p/d (after removal of the 2004 outlier) while Sligo uses more than three times as much at 9,16 l/p/d

We therefore use smoothed data. First, we compute the average water use per county for the five years for which we have data. We also compute the average for the country. Then, we take the weighted average of the county and country, using the inverse of the variances as weights. If a county has a standard deviation that is less than half the country standard deviation, we use the latter.

The result is shown in Figure 9. There are substantial differences between counties, but there is no obvious pattern that can be used to downscale the estimates to the electoral district level. Figure 9 also shows imputed drinking water use based on the engineering estimates reported by WS Atkins Ireland, 2000. These estimates do not show much difference between countries – as indeed there are no reasons why people in Donegal would use the toilet more often than people in Dublin. The engineering estimates are also remarkably lower than the EPA estimates. This disparity probably reflects the use of water supplies by small businesses and farm enterprises in addition to households, but we cannot separate out these segments of demand.

Figure 10 shows the fraction of people, by county, whose drinking water did not meet the EU regulations in 2006. The numbers range from 40% in Cork North to 100% in the cities. Figure 11 shows the same data, but per water quality parameter. In 2006, Irish drinking water breached 36 of the 48 standards. In most cases, only a small number of people are affected. However, more than 10% of people had their drinking water polluted with manganese, iron, lead or aluminium. The share of people suffering from biological contamination (enterococci, colony, e-coli, clostridium, coliform) is even larger.

Figure 12 shows the odds ratio of experiencing a breach of water quality standards per type of water supply. The odds ratio is defined as the share of people per water supply type experiencing a problem over the share of people supplied by that type of water supply. Figure 12 reveals that by and large public water supplies have the worst water quality (or the best monitoring). Private group supplies are better overall, but much worse for a few water quality parameters (arsenic, boron, bromate, nitrate, polycyclic aromatic hydrocarbons). Private water supplies have consistently better water quality than average (or are badly monitored) except for turbidity at the tap. Overall, public group water supplies have the best water quality, except for nitrates.

Figure 13 compares breaches of water quality standards between 2004 and 2005, and between 2005 and 2006. Figure 13 reveals that many of the drinking water facilities with a problem identified in 2005 continued to report the same problem in 2006.[7] While some of the problems were adequately dealt with, more than 50% of cases of arsenic, coliform, aluminium, and nitrates were not solved within the calendar year.

6. Discussion and conclusions

In this paper, we construct a first set of regional environmental accounts for the Republic of Ireland. The data can be found at:

http://www.esri.ie/irish_economy/environmental_accounts/index.xml

[7] Note that water quality reporting was incomplete in 2004, so that fewer problems are seen to persist to 2005.

The regional accounts are limited to energy use by households, waste arisings from households, demand for drinking water and sewage services by households, and drinking water quality. The energy, waste and sewage accounts are available for 3401 electoral districts, and the water accounts for 34 counties.

The limited scope of the accounts notwithstanding, the results reveal that the spatial pattern of the impacts of energy and climate policy is different than we and others thought it is. There is a distinction between rural and urban areas, but there is a much sharper distinction between the commuter belt and other areas of the countryside. The water data reveal a shockingly low water quality, a significant degree of local persistence in water quality problems and a remarkably high level of water use.

Conclusions like these call for better data, and there is ample room for improvement. First, our “accounts” are imputed. Although household behaviour is not observed at the spatial detail used here, the CSO typically has more information on household location than is released in anonymised datasets. Related to this, the EPA has detailed information on the use and quality of drinking water and sewage, but the data is not organized for analysis or interpretation, and the quality of the data is not uniformly high. Third, we omit location-specific externalities of transport (noise, congestion, air pollution). There is little data on this, but values could be imputed from data on traffic flows. This is beyond the scope of the current paper, and the expertise of the current authors. Fourth, we omit emissions by companies. As all sizeable emitters of pollutants are licensed and monitored, a map of point sources of industrial emissions can be constructed. The main obstacle is the organization of the existing data by the EPA. The distribution of pollutants would require detailed modelling of the physical, chemical and biological environment. Fifth, we omit resource use and emissions by agriculture and forestry. Teagasc would be well-positioned to construct maps and regional accounts. Sixth, we limit our attention to the Republic of Ireland. North-South cooperation would be needed for building all-island accounts.

In sum, regional environmental accounts can be constructed for Ireland. This paper makes the first step, showing that the emerging insights are well worth the effort.

Acknowledgements

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Table 1. Characteristics of the data.

Variable	Unit	Mean	Standard deviation	Minimum	Maximum	Gini coefficient	Moran's I	Geary's C
Population	# p	1,247	2,018	76	32,288	0.58	0.169	0.978
Population density	#/km^2	6.71	17.99	0.01	194.67		0.861	1.093
Households	# hh	432	692	23	10,581	0.59	0.188	0.965
Household size	#/hh	2.87	0.28	1.58	3.89		0.240	1.011
Income	K€/yr	29,875	56,928	255	1,069,200	0.62	0.144	1.097
Income	€/hh/yr	65,757	13,142	9,813	119,920		0.099	0.969
Electricity	MWh	2,220	3,684	66	59,852	0.59	0.163	0.986
Electricity	KWh/hh	5,151	474	2,555	6,523		0.181	0.998
Heat	MWh	7,930	12,745	445	186,920	0.59	0.160	0.965
Heat	KWh/hh	18,666	1,536	5,900	23,543		0.275	1.530
Transport[a]	l/d	617	1,110	6	23,442	0.55	0.046	1.006
Transport[a]	l/d/p	1.43	0.53	0.06	3.21		0.482	0.839
Carbon tax	K€/yr	67.3	108.9	3.7	1,757.2	0.56	0.099	0.986
Carbon tax	€/hh/yr	173	35	37	274		0.455	0.913
Climate policy	K€/yr	97.6	158.4	5.4	2,453.4	0.57	0.117	0.985
Climate policy	€/hh/yr	243	39	86	347		0.436	0.926
Waste	Kt	0.598[b]	0.965	0.034	15.355	0.59	0.174	0.974
Waste	tonne/hh	1.398	0.071	1.052	1.643		0.235	1.018
Sewage	Ml/d	262	425	14	6,829	0.58	0.160	0.982
Sewage	l/ha	1,373	3,621	2	33,407		0.849	1.070
Public sewage	%	30.1	37.5	0.0	100.0		0.501	0.801

[a] Note that the units are litre per *working* day (per commuter).

[b] The average total waste of 598 tonnes per electoral district consists of 353 tonnes of biodegradable waste and 245 tonnes of other waste.

Table 2. Correlations between the variables: totals per electoral district.

	A	P	H	I	E	O	T	C	C+	W	S
Area	1										
Population	-0.16	1									
Household	-0.18	1.00	1								
Income	-0.13	0.97	0.97	1							
Electricity	-0.16	1.00	0.99	0.98	1						
Other fuels	-0.16	0.99	0.99	0.96	0.99	1					
Transport fuels	0.02	0.88	0.86	0.90	0.89	0.88	1				
Carbon tax	-0.06	0.96	0.95	0.97	0.97	0.97	0.97	1			
C tax + ETS	-0.09	0.98	0.97	0.98	0.99	0.98	0.95	1.00	1		
Waste	-0.17	1.00	1.00	0.97	1.00	0.99	0.87	0.96	0.98	1	
Sewage	-0.16	1.00	0.99	0.97	1.00	1.00	0.89	0.97	0.99	1.00	1

Table 3. Correlations between the variables: variables per household and per area (*).

	P	H	I	E	O	T	C	C+	W	S	P
Population density*	1										
Household size	-0.41	1									
Income	-0.23	0.42	1								
Electricity	-0.38	0.82	0.72	1							
Other fuels	-0.36	0.69	0.25	0.59	1						
Transport fuels	-0.52	0.39	0.26	0.34	0.39	1					
Carbon tax	-0.55	0.66	0.55	0.66	0.59	0.89	1				
C-tax + ETS	-0.55	0.71	0.60	0.74	0.61	0.85	0.99	1			
Waste	-0.40	1.00	0.45	0.84	0.70	0.39	0.66	0.71	1		
Sewage density*	0.77	-0.41	-0.15	-0.35	-0.44	-0.64	-0.66	-0.64	-0.40	1	
Public sewage**	0.51	-0.46	-0.08	-0.31	-0.39	-0.61	-0.65	-0.63	-0.43	0.66	1

** Fraction of sewage collected by public bodies.

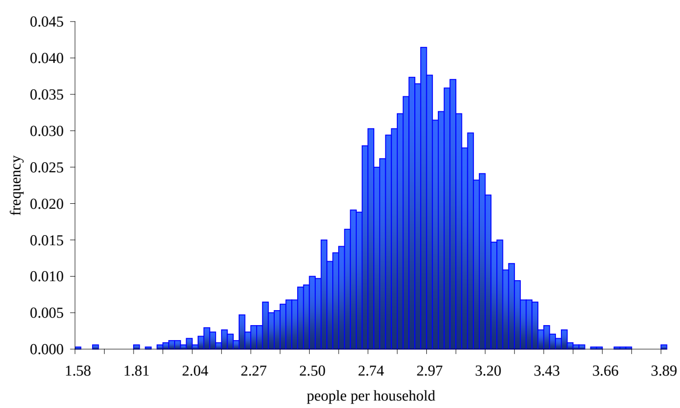

Figure 1. Average household size per electoral district.

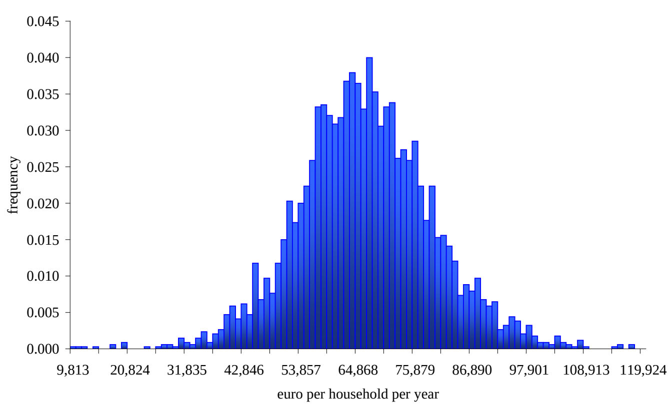

Figure 2. Average annual household income per electoral district.

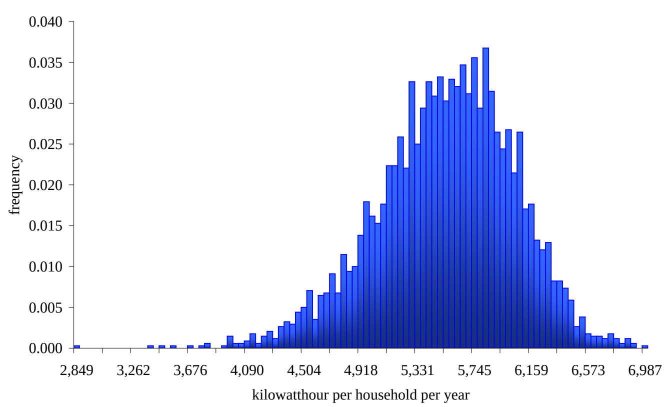

Figure 3. Average annual electricity use per household per electoral district.

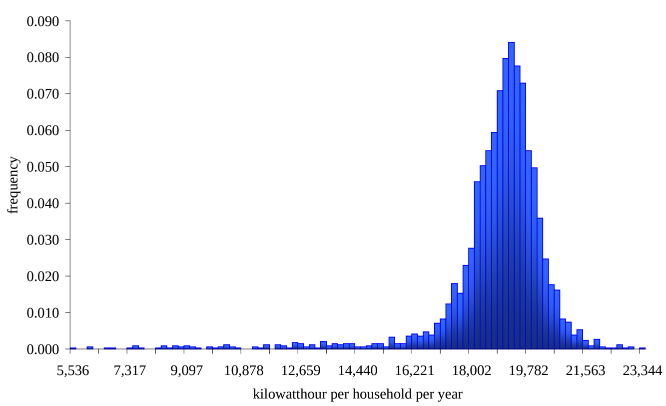

Figure 4. Average annual consumption of other fuels per household by electoral district.

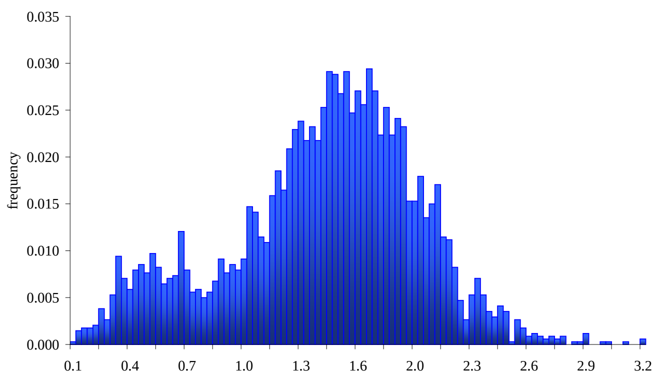

Figure 5. Average daily consumption of transport fuels per person by electoral district.

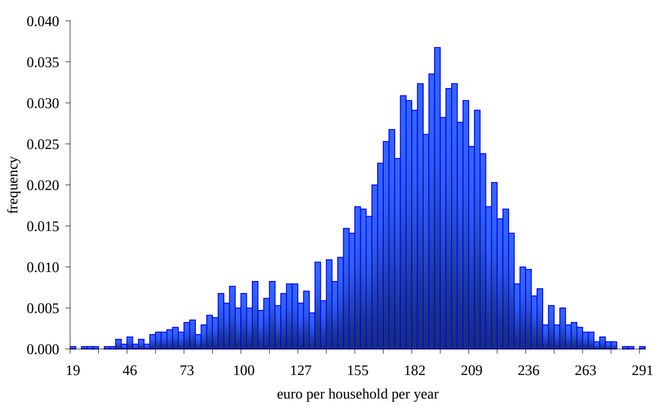

Figure 6. Average annual carbon tax per household by electoral district.

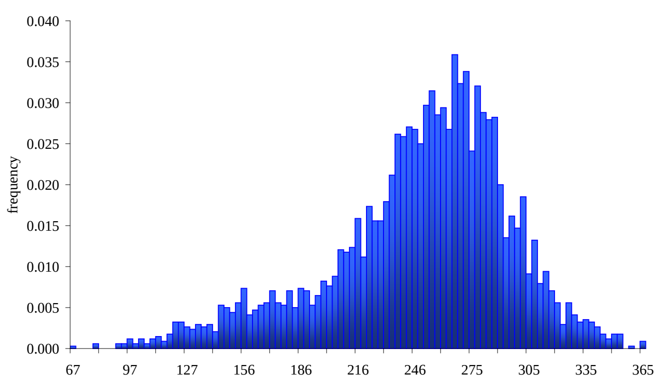

Figure 7. Average annual carbon tax plus pass-through of carbon permit price per household by electoral district.

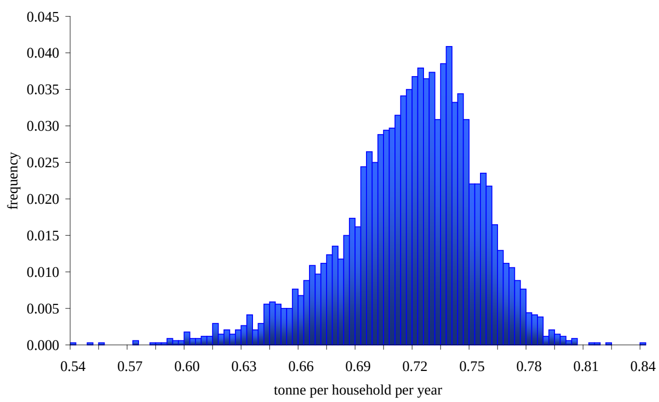

Figure 8. Average annual biodegradable waste generation per household by electoral district.

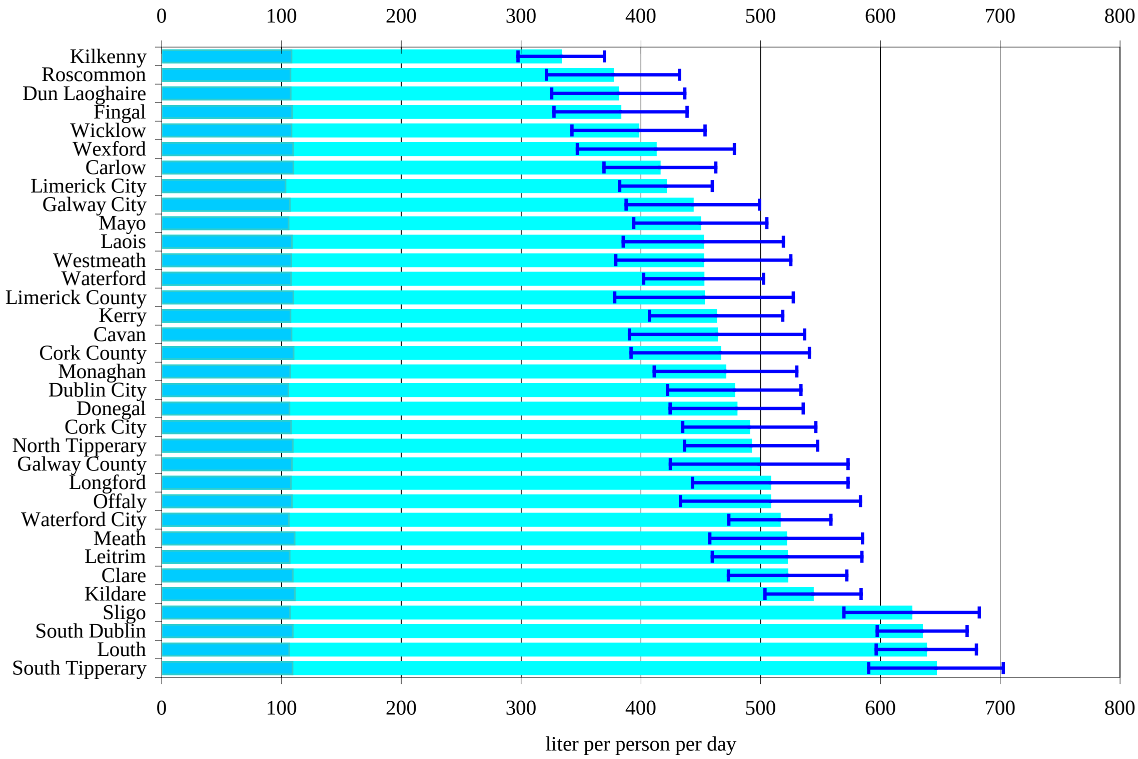

Figure 9. Reported drinking water production (light blue) and estimated drinking water use (dark blue) in litres per person per day for each of the 34 sanitary authorities; the graph also shows the 67% confidence interval around the reported water production.

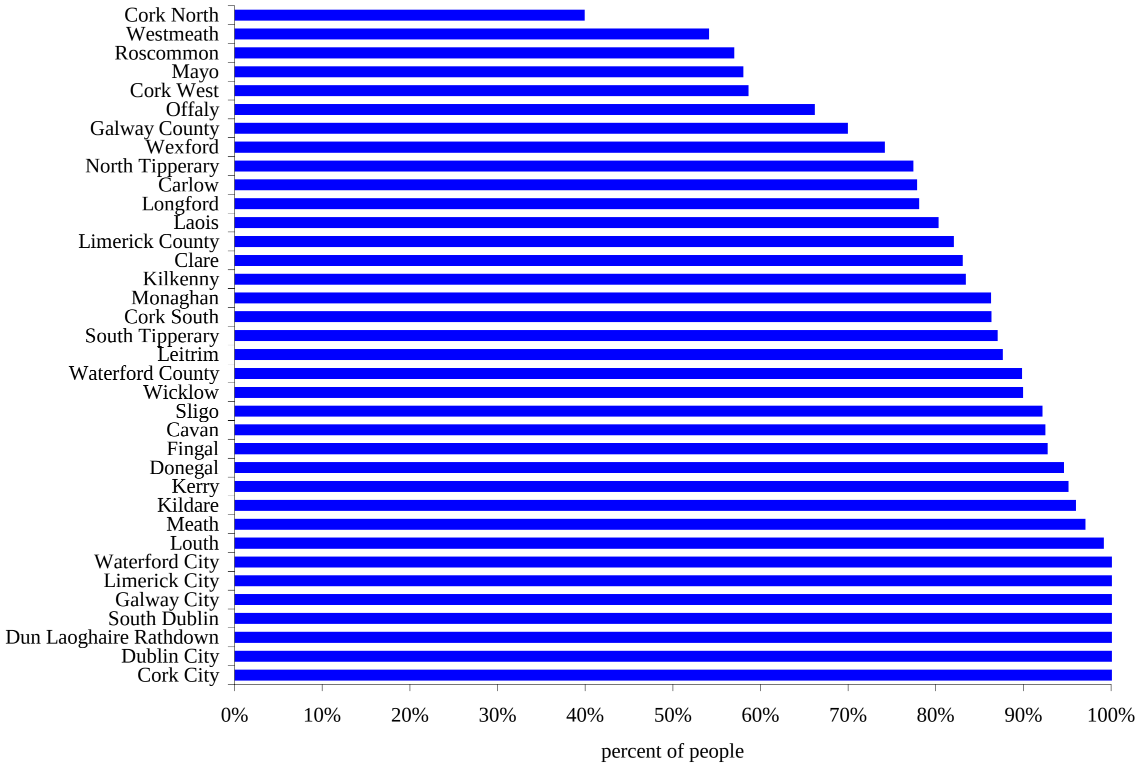

Figure 10. The percentage of people who are supplied with drinking water that exceeds at least one of 48 water quality standards, per sanitary authority, for 2006.

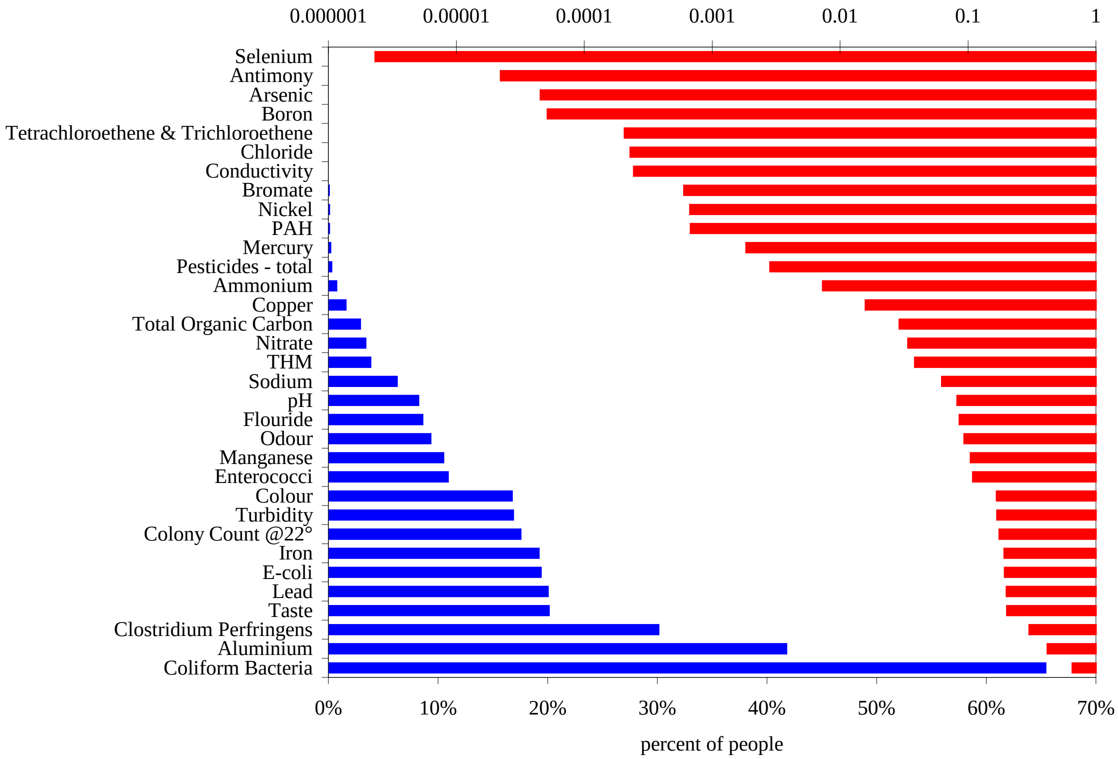

Figure 11. The percentage of people who are supplied with drinking water that does not meet the EU quality standard, per water quality parameter, for 2006. The bottom axis is in levels, and the data are shown to the left in blue. The top axis is in logarithms, and the same data are shown to the right in red. Note that there are 12 additional water quality parameters for which no problems were reported.

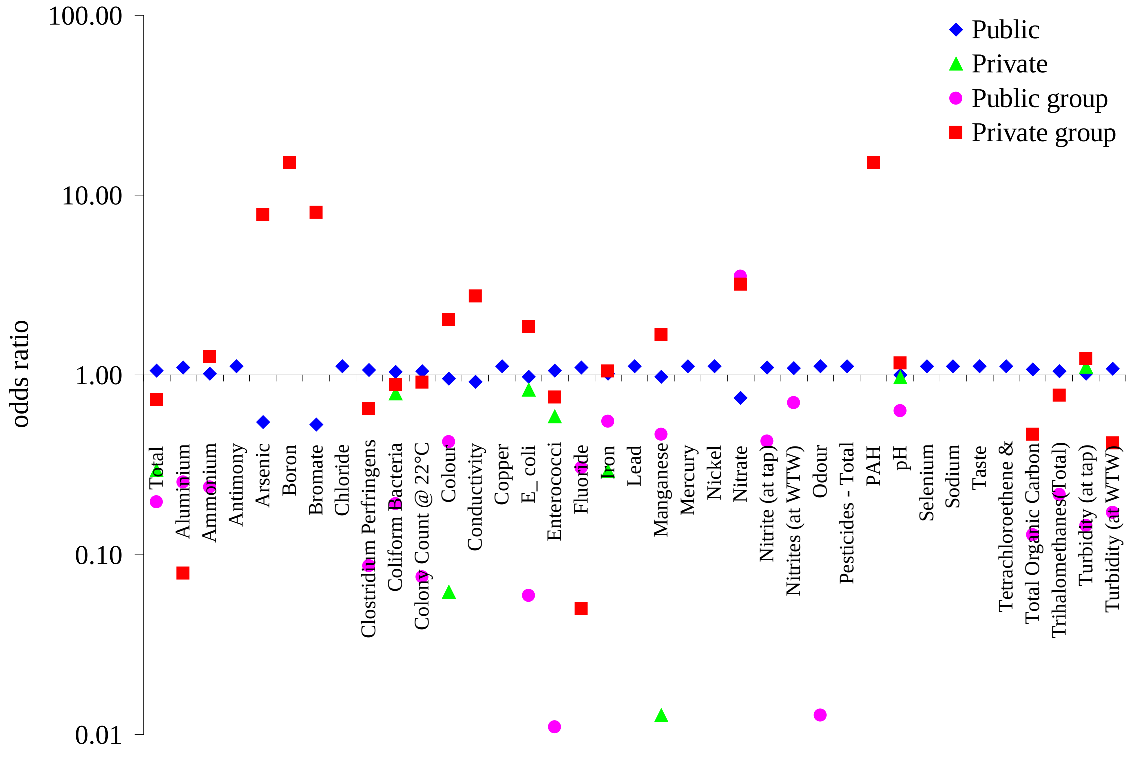

Figure 12. The odds ratio of experiencing a breach of standard per water quality parameter and per water supply type in 2006. Zeros are not displayed.

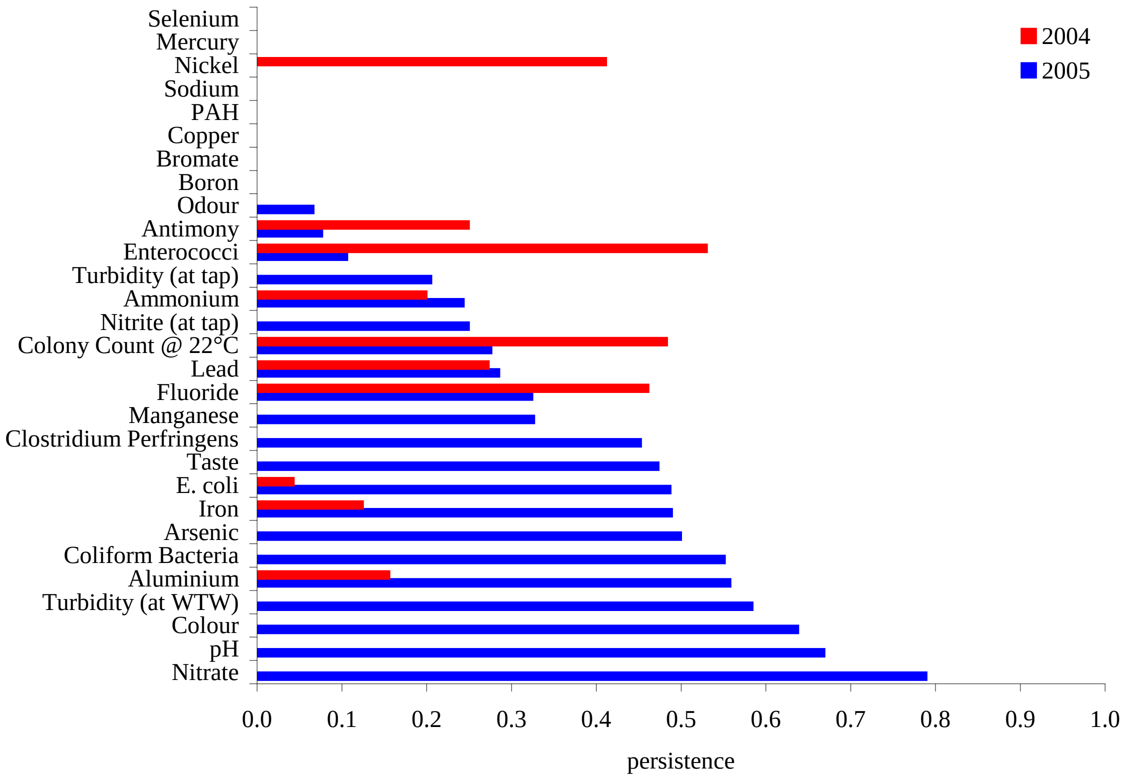

Figure 13. The persistence of breaches of water quality standards between 2004 and 2005 and between 2005 and 2006, per water quality parameter. Note that persistence is based on facility counts.

Table A1: Household disposable income, OLS cross-section regression results		
Variables and statistics	**All variables**	
Dep. variable	*ln(Weekly disposable income of household, €)*	
	Coef.	Robust S.E.
d_social_1	0.318	0.0223***
d_social_2	0.366	0.0257***
d_social_3	0.219	0.0199***
d_social_5	-0.074	0.018***
d_social_6	-0.144	0.0204***
d_social_7	-0.185	0.0202***
d_social_8	-0.081	0.0309***
d_social_9	-0.148	0.0264***
d_social_10	-0.167	0.0485***
d_social_11	-0.112	0.0255***
d_empstatu~2	-1.2	0.0417***
d_empstatu~3	-1.17	0.0357***
d_empstatu~4	-0.754	0.0248***
d_empstatu~5	-1	0.0255***
d_persons_1	-0.605	0.019***
d_persons_3	0.377	0.0172***
d_persons_4	0.656	0.0198***
d_persons_5	0.815	0.0235***
d_persons_6	0.968	0.0288***
d_persons_7	1.01	0.0456***
d_persons_8	1.27	0.0644***
Constant	6.87	0.0179***
Observations	6,884	
R^2	0.654	

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively. Numbers in brackets are p-values.*

Table A2: Total energy use from household fuels, OLS cross-section regression results

Variables and statistics	All variables		Preferred model	
Dep. variable	*Total energy use in household (kWh)*		*Total energy use in household (kWh)*	
	Coef.	Robust S.E.	Coef.	Robust S.E.
d_rooms_1	-113	50.3**	-78.9	37**
d_rooms_2	-210	38.9***	-183	27.7***
d_rooms_3	-112	26.4***	-110	23.9***
d_rooms_4	-13.7	19.2		
d_rooms_6	0.351	12.3		
d_rooms_7	25.4	14.2*	25.6	12.4**
d_rooms_8	72.3	17.9***	74.4	16.5***
d_built_1	-9.29	17.3		
d_built_3	-25.7	20.3		
d_built_4	-25	17.3		
d_built_5	-57.7	16.3***	-40.3	12.7***
d_built_6	-70.8	16.4***	-52.6	12.8***
d_built_7	-55.4	21.6***	-41.7	18.5**
d_social_1	3.51	16.8		
d_social_2	18.9	25.5		
d_social_3	-1.91	16.8		
d_social_5	-34.4	16.8**	-40.7	13.9***
d_social_6	-15.8	18.3		
d_social_7	27.5	31.7		
d_social_8	34	26.1		
d_social_9	-63.4	19.1***	-76.9	14.3***
d_social_10	-86.3	38.4**	-91.6	37**
d_social_11	-38.6	23*	-37.9	17.9**
d_centheat	70.7	34.3**	70.4	34.2**
d_persons_1	-84.5	13.5***	-94.8	12.3***
d_persons_3	37.1	15.4**	28.6	13.1**
d_persons_4	21.3	15.9		
d_persons_5	68.4	22.5***	65.7	21***
d_persons_6	86.1	35.1**	84.3	29.6***
d_persons_7	83.5	45.6*	86.5	42.5**
d_persons_8	40.1	61		
d_urban	13.1	11.3		
d_housetyp_2	-122	28.2***	-132	27.3***
d_housetyp_3	-154	58.8***	-188	47.2***
d_housetyp_4	101	91.9		
d_empstatu~2	0.932	36.5		
d_empstatu~3	29	32.7		
d_empstatu~4	46.5	16.4***	37	15.8**
d_empstatu~5	74.9	22.9***	65.4	18.4***
Constant	359	36.7***	374	37.2***
Observations	6,884		6,884	
R^2	0.0473		0.0449	

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively. Numbers in brackets are p-values.*

Table A3: Household electricity use, OLS cross-section regression results				
Variables and statistics	**All variables**		**Preferred model**	
Dep. variable	*Electricity use (kWh)*		*Electricity use (kWh)*	
	Coef.	Robust S.E.	Coef.	Robust S.E.
d_rooms_1	-21.8	10.6**	-11.3	5.23**
d_rooms_2	-13	7.02*	-10.9	6.27*
d_rooms_3	0.429	4.27		
d_rooms_4	-0.158	2.40		
d_rooms_6	9.16	1.84***	9.06	1.71***
d_rooms_7	15.2	2.01***	15.2	1.91***
d_rooms_8	24.6	2.42***	24.7	2.33***
d_built_1	6.5	2.59**	6.68	2.36***
d_built_3	-1.47	2.28		
d_built_4	7.84	2.12***	7.75	1.85***
d_built_5	3.46	2.11*	3.21	1.81*
d_built_6	1.54	2.39		
d_built_7	-2.15	2.91		
d_social_1	3.67	2.30	4.31	1.87**
d_social_2	7.78	3.57**	8.49	3.31***
d_social_3	2.83	2.40		
d_social_5	-2.01	2.19		
d_social_6	-1.87	2.42		
d_social_7	0.613	3.60		
d_social_8	16.3	5.57***	16.9	5.30***
d_social_9	-10.8	3.03***	-10.5	2.48***
d_social_10	-4.65	6.47		
d_social_11	-3.05	3.46		
d_centheat	-9.38	3.14***	-9.18	3.12***
d_persons_1	-22.2	1.78***	-22.2	1.63***
d_persons_3	16	2.07***	15.4	1.99***
d_persons_4	26	2.62***	25.1	2.41***
d_persons_5	40.4	3.44***	39.0	2.88***
d_persons_6	43.4	4.09***	42.0	3.64***
d_persons_7	51.6	6.22***	49.9	5.95***
d_persons_8	63.7	12.6***	61.5	12.3***
d_urban	0.318	1.72		
d_housetyp_2	6.3	4.21		
d_housetyp_3	12	12.4		
d_housetyp_4	4.84	9.56		
d_empstatu~2	-1.91	4.62		
d_empstatu~3	-3.9	4.13		
d_empstatu~4	-23.8	2.28***	-23.6	2.11***
d_empstatu~5	-13.6	3.34***	-15.2	2.23***
Constant	81.2	4.62***	81.0	3.54***
Observations	6,884		6,884	
Adjusted R^2	0.222		0.220	

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively. Numbers in brackets are p-values.*

Table A4: Household direct CO_2 emissions, OLS cross-section regression results				
Variables and statistics	**All variables**		**Preferred model**	
Dep. variable	*CO_2 emissions (T CO_2/ week)*		*CO_2 emissions (T CO_2/ week)*	
	Coef.	Robust S.E.	Coef.	Robust S.E.
d_rooms_1	-0.0301	0.0266		
d_rooms_2	-0.0583	0.013***	-0.0552	0.0118***
d_rooms_3	-0.0308	0.00896***	-0.0277	0.00857***
d_rooms_4	-0.00477	0.00699		
d_rooms_6	0.0201	0.00471***	0.0223	0.0046***
d_rooms_7	0.0462	0.00585***	0.0494	0.00581***
d_rooms_8	0.0949	0.0127***	0.0987	0.0123***
d_built_1	0.00752	0.00653		
d_built_3	0.0227	0.0124*		
d_built_4	0.0173	0.00606***	0.0111	0.00518**
d_built_5	0.00828	0.00811		
d_built_6	0.00135	0.00653		
d_built_7	0.0053	0.00797		
d_social_1	0.0233	0.0124*	0.0236	0.0105**
d_social_2	-0.000489	0.0103		
d_social_3	0.0142	0.00943		
d_social_5	-0.00267	0.00858		
d_social_6	-0.00867	0.0089		
d_social_7	-0.0118	0.00912		
d_social_8	0.0227	0.0121*	0.024	0.01**
d_social_9	-0.0213	0.0101**	-0.0193	0.00743***
d_social_10	-0.0102	0.0178		
d_social_11	-0.00932	0.0114		
d_centheat	0.0275	0.00751***	0.0297	0.00742***
d_persons_1	-0.0514	0.00581***	-0.0535	0.00583***
d_persons_3	0.045	0.00694***	0.0451	0.00668***
d_persons_4	0.0706	0.0082***	0.0707	0.00747***
d_persons_5	0.118	0.0112***	0.119	0.0105***
d_persons_6	0.155	0.0273***	0.155	0.0263***
d_persons_7	0.145	0.019***	0.145	0.0184***
d_persons_8	0.159	0.0269***	0.159	0.0266***
d_urban	-0.0341	0.00565***	-0.0329	0.00561***
d_housetyp_2	-0.0353	0.0116***	-0.036	0.0113***
d_housetyp_3	-0.0513	0.0276*	-0.072	0.0085***
d_housetyp_4	0.00394	0.0253		
d_empstatu~2	-0.0373	0.013***	-0.0422	0.0129***
d_empstatu~3	-0.0858	0.0191***	-0.0914	0.0158***
d_empstatu~4	-0.0251	0.00797***	-0.0263	0.0076***
d_empstatu~5	-0.0375	0.00984***	-0.045	0.0066***
Constant	0.206	0.0121***	0.209	0.00968***
Observations	6,884		6,884	
Adjusted R^2	0.165		0.185	
*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively. Numbers in brackets are p-values.*				

Table A5: Household disposable income after housing expenditures, OLS cross-section regression results

Variables and statistics	**All variables**	
Dep. variable	*ln(Weekly disposable income of household after housing expenditures, €)*	
	Coef.	Robust S.E.
d_social_1	0.339	0.0232***
d_social_2	0.344	0.0293***
d_social_3	0.217	0.0233***
d_social_5	-0.0499	0.0203**
d_social_6	-0.13	0.0248***
d_social_7	-0.173	0.0265***
d_social_8	-0.0644	0.0338*
d_social_9	-0.0661	0.0269**
d_social_10	-0.118	0.0526**
d_social_11	-0.142	0.0324***
d_empstatu~2	-1.28	0.0495***
d_empstatu~3	-1.23	0.0428***
d_empstatu~4	-0.68	0.0279***
d_empstatu~5	-0.97	0.0288***
d_persons_1	-0.605	0.0212***
d_persons_3	0.376	0.0199***
d_persons_4	0.673	0.0235***
d_persons_5	0.86	0.0265***
d_persons_6	1.02	0.0325***
d_persons_7	1.07	0.0478***
d_persons_8	1.32	0.0696***
Constant	6.75	0.02***
Observations	6,884	
R^2	0.654	

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively. Numbers in brackets are p-values.*

Table A6: Household expenditures on heating and lighting, OLS cross-section regression results

Variables and statistics	All variables		Preferred model	
Dep. variable	*Total heating & lighting expenditures (€/week)*		*Total heating & lighting expenditures (€/week)*	
	Coef.	Robust S.E.	Coef.	Robust S.E.
d_rooms_1	-5.54	2.5**	-4.55	2.47*
d_rooms_2	-10.1	2.02***	-8.74	1.68***
d_rooms_3	-3.92	1.43***	-3.39	1.35**
d_rooms_4	-1.08	0.824		
d_rooms_6	1.77	0.55***	1.98	0.546***
d_rooms_7	4.39	0.657***	4.58	0.667***
d_rooms_8	7.35	0.839***	7.66	0.849***
d_built_1	1.09	0.808		
d_built_3	-1.03	0.844		
d_built_4	1.39	0.75*	1.65	0.614***
d_built_5	-0.675	0.716		
d_built_6	-1.42	0.73*	-1.12	0.57**
d_built_7	-1.18	1.01		
d_social_1	0.339	0.755		
d_social_2	1.52	1.14		
d_social_3	0.543	0.783		
d_social_5	-1.7	0.738**	-1.96	0.601***
d_social_6	-0.862	0.786		
d_social_7	1.39	1.37		
d_social_8	4.72	1.33***	4.4	1.26***
d_social_9	-2.55	0.958***	-2.54	0.816***
d_social_10	-4.41	1.96**	-4.75	1.88**
d_social_11	-1.99	1.05*	-1.6	0.696**
d_centheat	0.777	1.54		
d_persons_1	-6.59	0.593***	-6.67	0.562***
d_persons_3	3.7	0.693***	3.54	0.655***
d_persons_4	4.73	0.757***	4.54	0.653***
d_persons_5	8.37	1.04***	8.15	1.02***
d_persons_6	9.87	1.49***	9.68	1.31***
d_persons_7	11.4	2.09***	11.2	2***
d_persons_8	11.3	3.35***	10.8	3.27***
d_urban	-3.55	0.547***	-3.57	0.526***
d_housetyp_2	-4.12	1.16***	-4.77	1.12***
d_housetyp_3	-6.33	3.04**	-6.69	2.77**
d_housetyp_4	2.92	3.91		
d_empstatu~2	0.211	1.79		
d_empstatu~3	-0.167	1.43		
d_empstatu~4	-1.44	0.72**	-1.57	0.682**
d_empstatu~5	1.4	1.04		
Constant	29.2	1.7***	30.2	0.68***
Observations	6,884		6,884	
R^2	0.160		0.157	

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively. Numbers in brackets are p-values.*

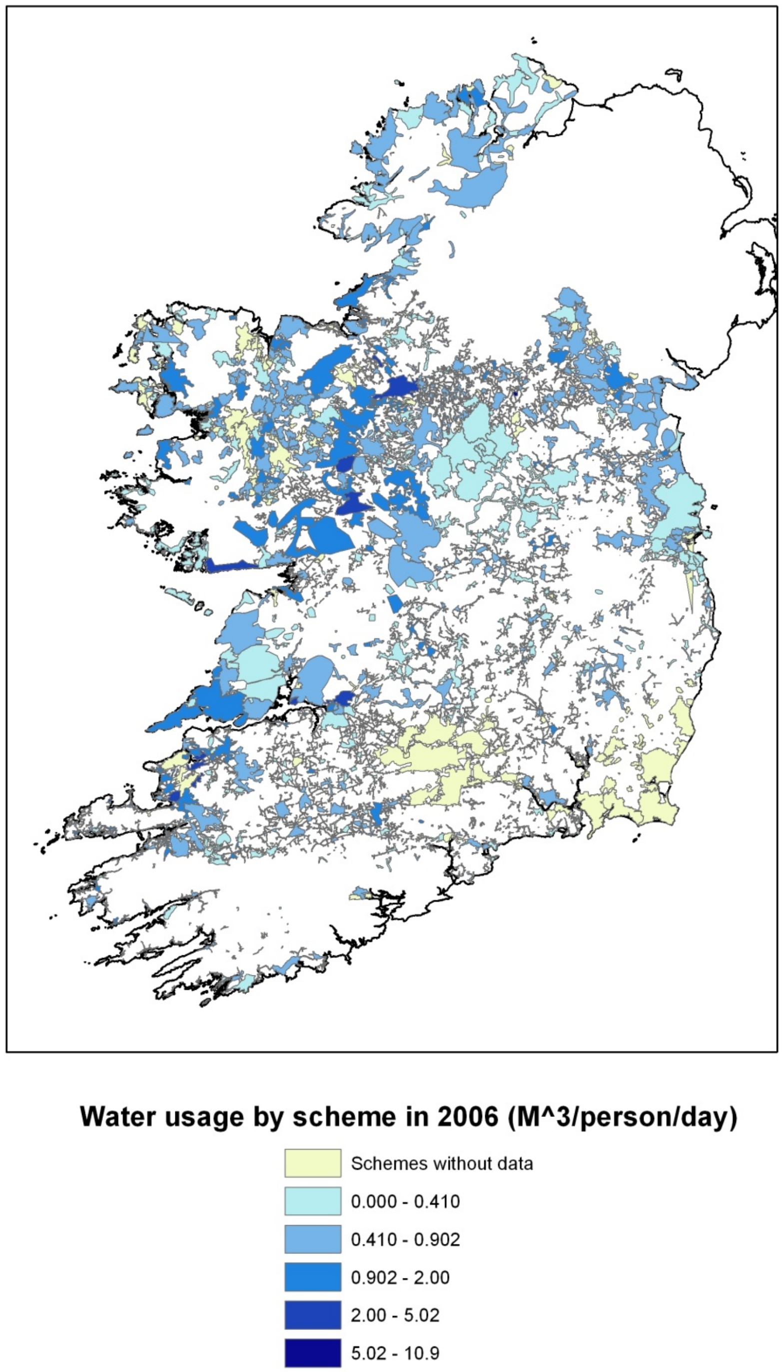

Figure A1. Water use by water scheme, known locations only.

Table A4. The percentage of people who are supplied with drinking water that does not meet the EU quality standard, per water quality parameter and sanitary authority, for 2006.

	Any cause	Coliform	Colour	Ecoli	Clostridium Perf.	pH	Iron	Manganese	Nitrate	Aluminium	Lead	Total Organic Carbon	Colony Count @22°	Turbidity	Enterococci	Ammonium	Flouride	Bromate	THM	3ClM, 4ClM	Conductivity	Taste	Odour	Sodium	PAH	Copper	Chloride	Antimony	Mercury	Selenium	Arsenic	Pesticides	Nickel	Boron
Carlow	78%	3%	2%	2%	0%	2%	2%	0%	0%	58%	15%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cavan	92%	33%	66%	21%	11%	26%	8%	40%	6%	27%	7%	7%	23%	19%	13%	2%	23%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Clare	83%	53%	11%	1%	2%	20%	42%	4%	1%	18%	1%	0%	2%	0%	5%	0%	4%	1%	45%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cork City	100%	99%	99%	0%	0%	1%	99%	99%	0%	99%	0%	0%	0%	99%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cork North	40%	19%	6%	11%	6%	3%	0%	0%	0%	14%	3%	0%	11%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cork South	86%	77%	6%	1%	3%	5%	0%	0%	0%	10%	0%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cork West	59%	23%	16%	9%	30%	1%	0%	0%	0%	39%	0%	0%	7%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Donegal	95%	60%	35%	8%	42%	15%	48%	51%	16%	43%	0%	0%	19%	63%	0%	0%	2%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dublin City	100%	100%	0%	22%	93%	0%	0%	0%	0%	53%	61%	0%	27%	0%	63%	0%	22%	0%	0%	0%	0%	89%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dun Laoghaire Rathdown	100%	100%	25%	20%	24%	0%	19%	0%	0%	39%	21%	0%	24%	1%	0%	0%	0%	0%	0%	0%	0%	42%	41%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fingal	93%	92%	0%	81%	0%	0%	0%	0%	0%	82%	81%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	93%	93%	81%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
South Dublin	100%	100%	0%	0%	92%	0%	0%	0%	0%	92%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Galway City	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Galway County	70%	45%	30%	30%	13%	4%	23%	14%	5%	9%	0%	0%	5%	33%	1%	0%	1%	0%	20%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kerry	95%	58%	60%	9%	6%	75%	14%	6%	0%	2%	12%	11%	1%	21%	0%	0%	2%	0%	3%	0%	0%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kildare	96%	95%	0%	60%	90%	0%	63%	0%	0%	31%	31%	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	31%	0%	0%	0%	0%	0%	0%	0%	0%
Kilkenny	83%	57%	44%	1%	18%	7%	25%	15%	4%	54%	0%	39%	0%	37%	0%	0%	63%	0%	7%	0%	0%	0%	0%	0%	0%	0%	0%	0%	14%	0%	0%	0%	0%	0%
Laois	80%	11%	8%	1%	4%	0%	10%	11%	6%	2%	0%	8%	44%	4%	1%	0%	8%	0%	8%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Leitrim	88%	81%	16%	16%	12%	15%	77%	5%	41%	63%	0%	1%	27%	71%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Limerick City	100%	100%	0%	0%	100%	0%	0%	0%	0%	100%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Limerick County	82%	15%	2%	6%	10%	0%	0%	0%	0%	62%	0%	5%	0%	45%	0%	10%	36%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Longford	78%	8%	9%	1%	1%	2%	62%	37%	0%	66%	0%	0%	2%	41%	0%	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Louth	99%	81%	45%	2%	0%	0%	49%	0%	0%	54%	0%	68%	33%	31%	60%	0%	48%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mayo	58%	22%	22%	15%	24%	4%	27%	9%	5%	9%	0%	0%	10%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Meath	97%	69%	1%	29%	1%	27%	51%	34%	0%	38%	0%	0%	5%	16%	30%	0%	0%	0%	29%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%
Monaghan	86%	45%	42%	6%	21%	0%	42%	32%	0%	46%	1%	0%	29%	41%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
North Tipperary	77%	47%	4%	5%	0%	0%	20%	0%	3%	0%	0%	4%	46%	15%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	0%	3%	0%
South Tipperary	87%	75%	45%	0%	7%	17%	21%	3%	0%	41%	0%	2%	40%	5%	0%	17%	51%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Offaly	66%	55%	0%	3%	7%	0%	0%	0%	3%	37%	0%	0%	7%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	9%	0%	0%
Roscommon	57%	22%	16%	8%	12%	13%	0%	0%	0%	0%	20%	1%	13%	16%	3%	0%	8%	0%	7%	0%	0%	11%	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sligo	92%	55%	19%	25%	14%	27%	43%	11%	1%	14%	0%	0%	36%	15%	9%	0%	0%	0%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Waterford City	100%	100%	0%	100%	0%	0%	0%	100%	100%	100%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Waterford County	90%	28%	17%	1%	2%	30%	29%	11%	11%	16%	0%	0%	40%	1%	18%	0%	19%	0%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Westmeath	54%	50%	3%	29%	9%	0%	0%	0%	0%	29%	0%	0%	0%	0%	3%	0%	2%	0%	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Wexford	74%	22%	45%	8%	0%	45%	1%	12%	1%	8%	0%	0%	50%	45%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
Wicklow	90%	12%	5%	3%	19%	16%	28%	0%	20%	16%	0%	0%	20%	0%	3%	0%	23%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
State	**88%**	**65%**	**17%**	**19%**	**30%**	**8%**	**19%**	**10%**	**3%**	**42%**	**20%**	**3%**	**18%**	**17%**	**11%**	**1%**	**9%**	**0%**	**4%**	**0%**	**0%**	**20%**	**9%**	**6%**	**0%**	**2%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

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