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Socioeconomic Distribution of Emissions and Resource Use in Ireland

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Abstract: This paper uses the ESRI's ISus model to explore the distributional differences in emissions by household type. Most greenhouse gas and metal emissions are emitted via indirect means, although direct sources of emissions play a role for CO_2, SO_2 and CO. The results suggest that the richest decile is the biggest emitter and poorer and larger households are seen to emit the least per person.

Key words: pollution, household emissions, distributional analysis

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1. Introduction

Households differ, both in idiosyncratic ways and in the form of systematic differences between household types. One effect of these variations is that different household types exert different pressures on the environment through their varying behaviour. For example, people in rural areas tend to use their cars more often and people who are out of work have a reason to heat their home in the day time. It is important to be able to quantify these distributional differences as they may have implications for environmental policy making. For example, energy is a necessary good and thus policies that increase the cost of energy tend to be regressive; that is, poorer households are adversely affected disproportionally relative to richer households. Additional policies may therefore be needed to offset the equity impact of regressive environmental policies.

This paper is part of a broader literature on distributional analysis at the household level. Most distributional analysis undertaken in the literature estimates the effects of a carbon tax on different types of households and studies have been done for several countries including Ireland (Verde and Tol, 2009), Spain (Labandeira and Labeaga, 1999), the USA (Hassett *et al.*, 2007) and the UK (Symons *et al.* 1994). All papers find that a carbon tax is regressive, indeed Hassett *et al.*, (2007) find that the lowest income burden can be up to four times that of the richest decile. When Hassett *et al.*, (2007) use consumption as a proxy for income however, the authors find that a carbon tax is less regressive. The introduction of a carbon tax in the UK and Ireland is also found to be highly regressive, however less so for Spain.

This paper also informs the environmental justice literature. That literature is typically concerned with analysing which household types are more affected by environmental pollution (Krieg & Faber, 2004; Levy et al., 2007). Instead, we focus on which household types are more responsible for environmental pollution. Combining the two types of analyses would yield insight into who imposes what pollution on whom.

The studies use an input-output methodology which not only allows the study of the whole economy rather than just one specific sector but also it highlights the significance of indirect emissions from final consumption (Labandeira and Labeaga, 1999) and thus a decomposition of the importance of direct and indirect emission sources for each household type.

This paper aims to determine direct and indirect emissions for an average person by household type, across a wide range of emissions. The household type categories we use are location (urban and rural), income decile, household composition and number of disabled residents. To do this Ireland's Sustainable Development Model (ISus) is used which allows the analysis of direct and indirect sources of pollution per household. Four sets of results are presented: first for greenhouse gas emissions, second for air pollutants, third for persistent organic pollutants and lastly for metals. An analysis section shows how the picture changes when one controls for the size and income of households. All results analysed are for the year 2006.

The main conclusions are that indirect emission sources are the main contributor of pollution for most emissions; direct emissions play different roles for each emission, and income is a more important factor than household size for the quantities of pollution emitted. The paper is set up as follows; Section 2 presents the methodology, Section 3 describes the data, Section 4 analyses the results[1], Section 5 offers some analysis and Section 6 concludes.

2. Methodology

The first step is to run an input-output model to determine emissions from production attributed to final demand sectors. The ISus model uses the input-output table for 2000 (CSO, 2006) updated to 2006 using the RAS method (Parikh, 1979). The standard input-output model is set-up as (1) where X is a vector of production, Y is a vector of final demand, A is a matrix of production coefficients, I is the identity matrix and L is the Leontief inverse.

$$X = AX + Y \Leftrightarrow (I - A)X = Y \Leftrightarrow X = (I - A)^{-1}Y = LY \qquad (1)$$

There are 20 sectors in total (NACE19 plus the residential sector), the most disaggregated level possible given the emissions data, which are shown in Table 1.

Table 1: Sectors

Agriculture, fishery and forestry	Rubber and plastic production
Coal, peat, petroleum, metal ores and quarrying	Residential
Food, beverage and tobacco	Transport
Textiles, clothing, leather and footwear	Services excluding transport
Wood and wood products	Construction
Pulp, paper and print production	Fuel, power and water
Chemical production	Other manufacturing
Non-metallic mineral production	Transport equipment
Metal production excluding machinery and transport equipment	Electrical goods
Agriculture and industry machinery	Office and data processing machines

Let M denote emissions and B the matrix of emission intensities of production. Then

[1] Results for HFC's, ammonia and nitrogen oxide can be found in the Appendix due to the large number of emissions in the model.

$$R = BX = BLY \tag{2}$$

As a next step, we split final demand *Y* into its components, those being households, charities, government, investment, inventories and exports:

$$R = BLY = BL(E + C + G + K + I + X) \tag{3}$$

Finally, household expenditure *E* is split into the expenditure by household type:

$$R = BL(\sum_t E_t + C + G + K + I + X) \tag{4}$$

The indirect emissions from household type *t* are thus defined as

$$R_t = BLE_t \tag{5}$$

The distribution of direct emissions by type of household[2] are estimated for pollutants produced by combustion only. They are calculated by using the household fuel consumption quantity data from the CSO anonymised Household Budget Survey data file (CSO, 2007). For each household type, the emission shares add to unity. For example, for CO_2 from fossil fuels the share emitted per person in an urban household is 0.585 and the share for a rural household is 0.415. These figures are calculated by using the emissions factor database (EFDB) which converts the fuel consumption data into common units. Fuel consumption is then multiplied by the appropriate emission factor from the EFDB to find each individual household's (of the 6,884 in the survey) contribution to total emissions. These households are then aggregated by household type and total emissions for each type is then multiplied by a population grossing factor which yields the national share of each emission produced by each household category for each emission. Direct emissions are found by multiplying the residential total emissions for each pollutant by the household-type share for each pollutant.

3. Data Employed

The ISus model is based on both environmental and economic data. For this study emissions are broken down into direct and indirect emissions, the latter being those emitted as a consequence of production. One of the main sources for information on direct emissions is anonymised data file for the Irish Household Budget Survey (HBS) which is a random sample of representative households in Ireland. The main aim of this survey is to quantify how much the average household (by household type) spends on each basket of goods (milk and boys

[2] Household type categories being: location (urban or rural), income decile (1, poorest to richest, 10), household size (1 person to 7+ people), household composition (single adults working and retired, a couple, a couple with 1, 2 3 or 4+ children and a single parent) and number of disabled residents (none to 3 or more).

clothes, for example) for the weighting of the CPI index and is carried out by the Central Statistics Office (CSO, 2007). In the most recent 2004/2005 survey 6,884 private households in Ireland participated (a 47% response rate). In this cross-sectional micro dataset detailed information is also provided on income and household facilities, for example it is possible to examine which household characteristics, which appliances and which heating and cooking methods significantly influence the amount of energy used in the home. The survey asks if certain appliances are owned or continuously available for use (i.e. rented accommodation) in the accommodation. In addition, households are asked to report expenditure on, as well as quantity used, of different fuel types in the past year.

The emissions data are taken from a range of sources found in Table 2 along with variable descriptions.

Table 2: Variable Descriptions

Variable	**Description** (years available, source, measurement unit)
CO_2 from fossil fuel	Carbon dioxide emissions from fossil fuels 1990-2009, (UNFCCC reports, 2011) thousand tonnes
CO_2 other	Carbon dioxide emissions from non fossil fuels 1990-2009 (UNFCCC reports, 2011) thousand tonnes
CH_4	Methane emissions 1990-2009 (UNFCCC reports, 2011) thousand tonnes
N_2O	Nitrous oxide emissions 1990-2009 (UNFCCC reports, 2011) thousand tonnes
HFC23	Halofluorocarbon emissions 1990-2095 (UNFCCC reports, 2011) tonnes of CO_2 equivalent
HFC32	
HFC134a	
HFC125	
HFC143a	
HFC152a	
HFC227ea	
CF_4	Perfluorocarbon emissions 1990-2009 (UNFCCC reports, 2011) tonnes of CO_2 equivalent
C_2F_6	
cC_4F_8	
SF_6	Sulphurhexafluoride emissions 1990-2009 (UNFCCC reports, 2011) tonnes CO_2 equivalent
SO_2	Sulphur dioxide emissions 1990-2009 (UNFCCC reports, 2011) thousand tonnes
NOx	Oxides of nitrogen 1990-2009 (UNFCCC reports, 2011) thousand tonnes
CO	Carbon monoxide 1990-2009 (UNFCCC reports, 2011) thousand tonnes
NMVOC	Non-methane volatile organic compounds 1990-2005 (UNFCCC reports, 2011) thousand tonnes
NH_3	Ammonia 1990-2009 (CSO environmental accounts, 2010) thousand tonnes
BOD	Organic water pollution emissions 1990-2009 (Scott, 1999) thousand tonnes
Dioxin (water)	Dioxin emissions to water 1990-2009 (Hayes & Murnane, 2002) g TEC
Dioxin (air)	Dioxin emissions to air 1990-2009 (Hayes & Murnane, 2002) g TEC
Dioxin(land)	Dioxin emissions to land 1990-2009 (Hayes & Murnane, 2002) g TEC
PCB (air)	Polychlorinated biphenyl emissions to air 1990-2009 (Creedon et. al, 2010) kg
PCB (land)	Polychlorinated biphenyl emissions to land 1990-2009 (Creedon et. al, 2010) kg
HCB (air)	Hexachlorobenzene emissions to air 1990-2009 (Creedon et. al, 2010) kg
HCB (land)	Hexachlorobenzene emissions to land 1990-2009 (Creedon et.al, 2010) kg
HCB (water)	Hexachlorobenzene emissions to water 1990-2009 (Creedon et. al, 2010) kg
Benzo(a)pyrene	Emissions 1990-2009 (Creedon et. al, 2010) kg
Benzo(b)fluoranthene	Emissions 1990-2009 (Creedon et. al, 2010) kg
Benzo(k)fluoranthene	Emissions 1990-2009 (Creedon et. al, 2010) kg
Indeno(1,2,3)pyrene	Emissions 1990-2009 (Creedon et. al, 2010) kg
Mercury	Emissions 2001-2009 (IPPC) kg
Cadmium	Emissions 1996-2009 (IPPC) kg
Lead	Emissions 1996-2009 (IPPC) kg
Chromium	Emissions 1996-2009 (IPPC) kg
Arsenic	Emissions 1996-2009 (IPPC) kg
Zinc	Emissions 1996-2009 (IPPC) kg
Copper	Emissions 1996-2009 (IPPC) kg
Nickel	Emissions 1996-2009 (IPPC) kg
Population	1990-2009 (ESRI's databank) thousands of people
Output	1990-2009 (ESRI's databank) million euro constant 2004 gross output

Figure 1 shows the breakdown of the three biggest emitting sectors of final demand and the percentages of pollutants each sector emits. A full table of percentages including all six final demand sectors can be found in Table A1 in the Appendix. CO_2 from fossil fuels is emitted mainly on behalf of households (just less than 50%) whereas CO_2 other (non-greenhouse gas emissions) can be attributed more to exports (33%) and investment (17%) as well as households (30%). Households cause 95% of benzo(a)pyrene emissions, whereas PCB emissions to land are mainly due to exports (97%). The biggest emission for the government sector is pollution of dioxins into water followed closely by copper; the government contributes roughly 20% of these pollutants. Households emit the majority of sulphur dioxide (SO_2), contributing 50% of emissions. Greenhouse gas emissions of nitrous oxide (N_2O) and methane (CH_4) are emitted mainly from exports; however households emit a large share of roughly 35% with households emitting slightly more nitrous oxide than methane.

Figure 1: Emissions by final demand sectors (%)

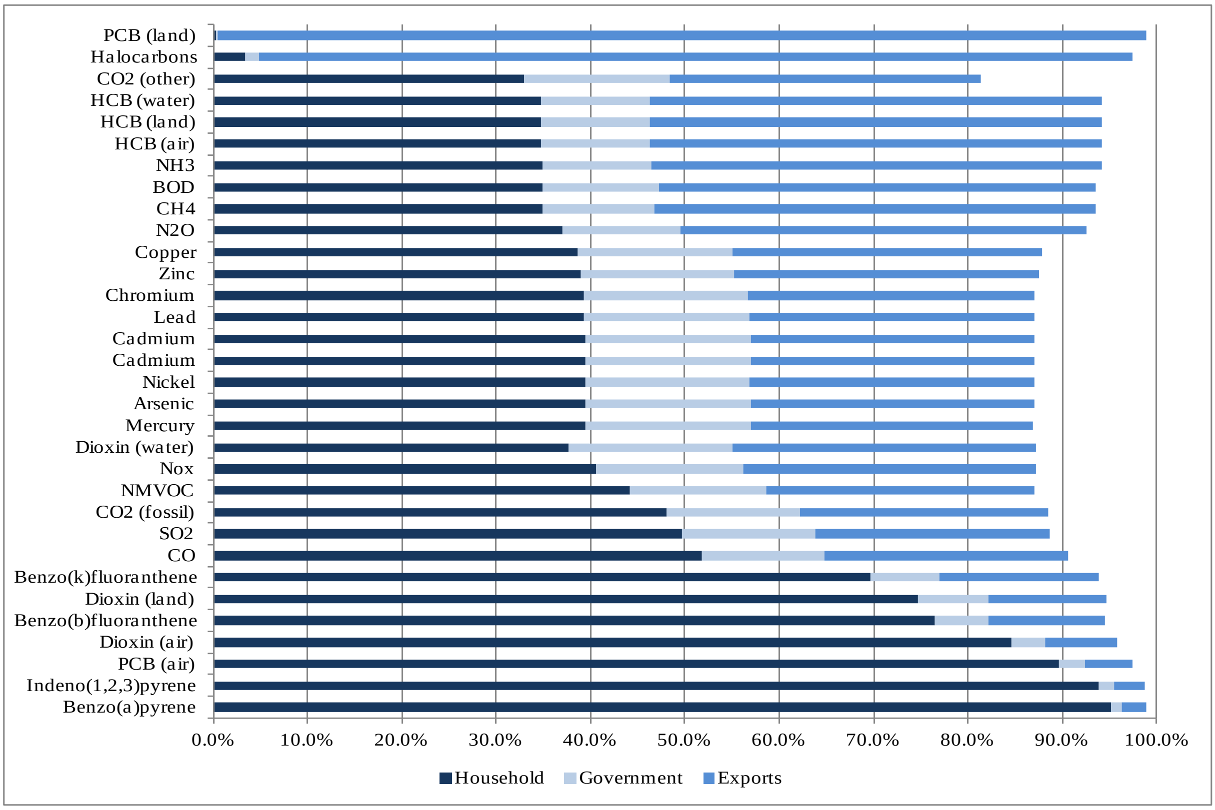
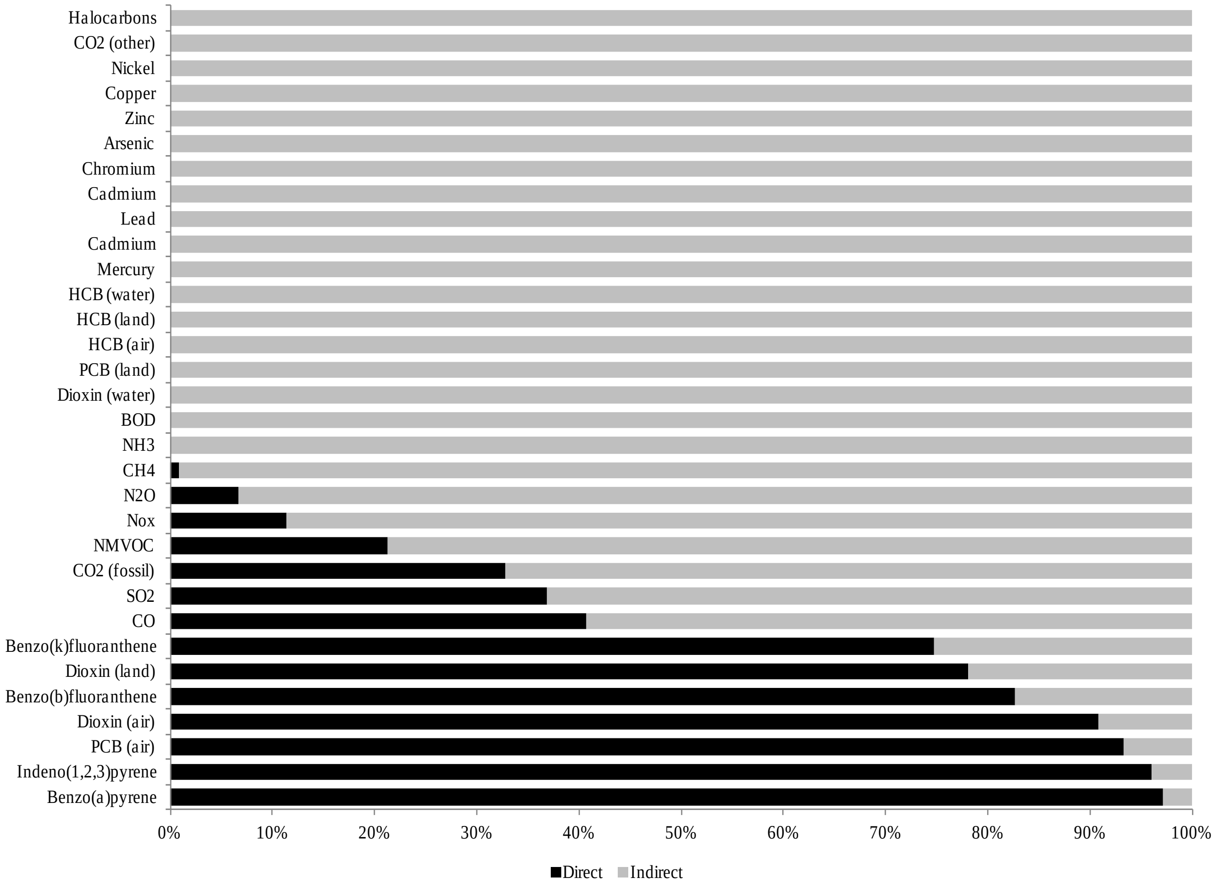


Figure 2 shows the split of direct and indirect emission sources for households. The majority of emissions are emitted indirectly; however, the most important greenhouse gasses are also emitted directly. For example roughly 1% of methane comes from direct sources; 8% of nitrous oxide is contributed by direct sources, 38% for sulphur dioxide and roughly 33% for carbon dioxide from fossil fuel. Emissions of dioxins to air, PCB pollution to air, indeno(1,2,3)pyrene and benzo(a)pyrene are mainly emitted directly with direct emissions contributing to over 90% of these pollutants. CO_2 (other), HCB's and halocarbons are all emitted 100% indirectly, as a consequence of production.

Figure 2: Emissions from households by direct and indirect channels (%)

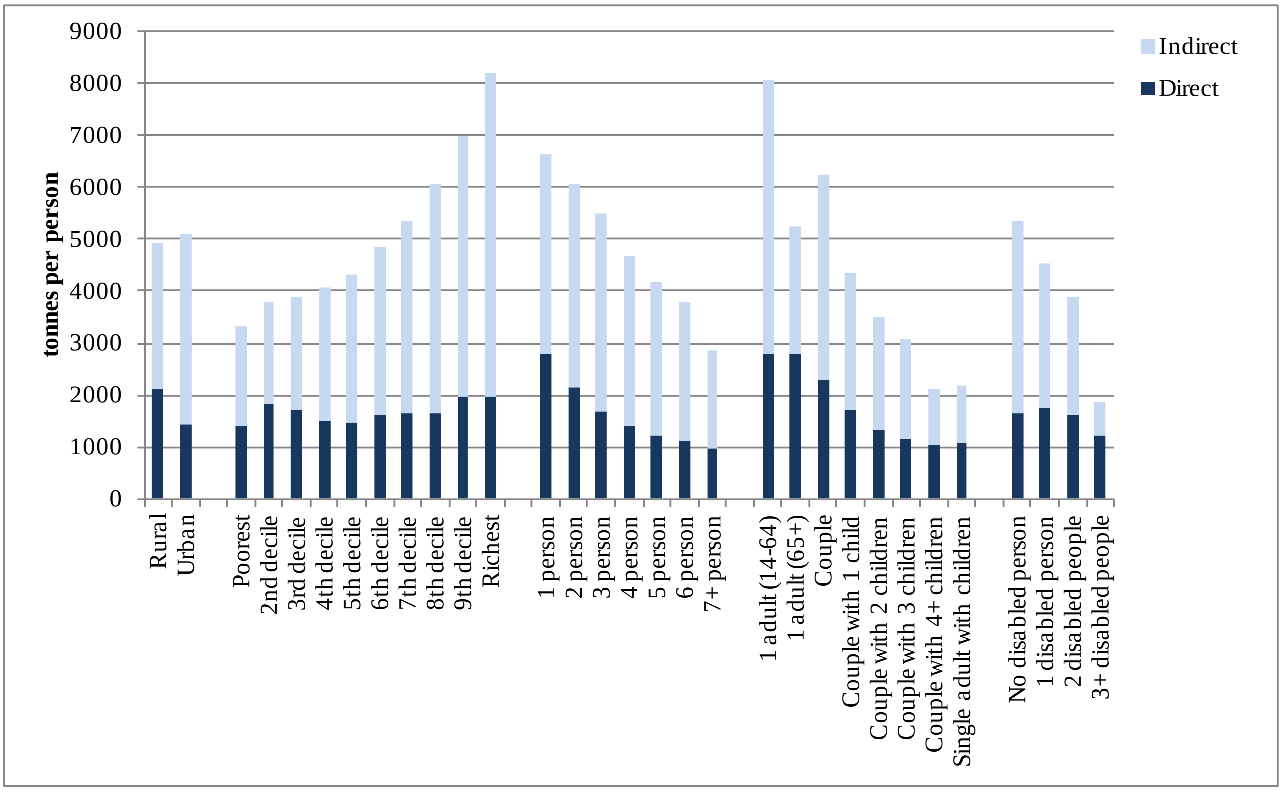


4. Results

4.1 Greenhouse gas emissions per person by household type

The first set of results presented here are for the year 2006 and show greenhouse gas emissions per average person for a range of household types. Figure 3 depicts the per person emissions by household type for carbon dioxide.

Figure 3: Direct and Indirect Emissions of Carbon Dioxide per person by household type

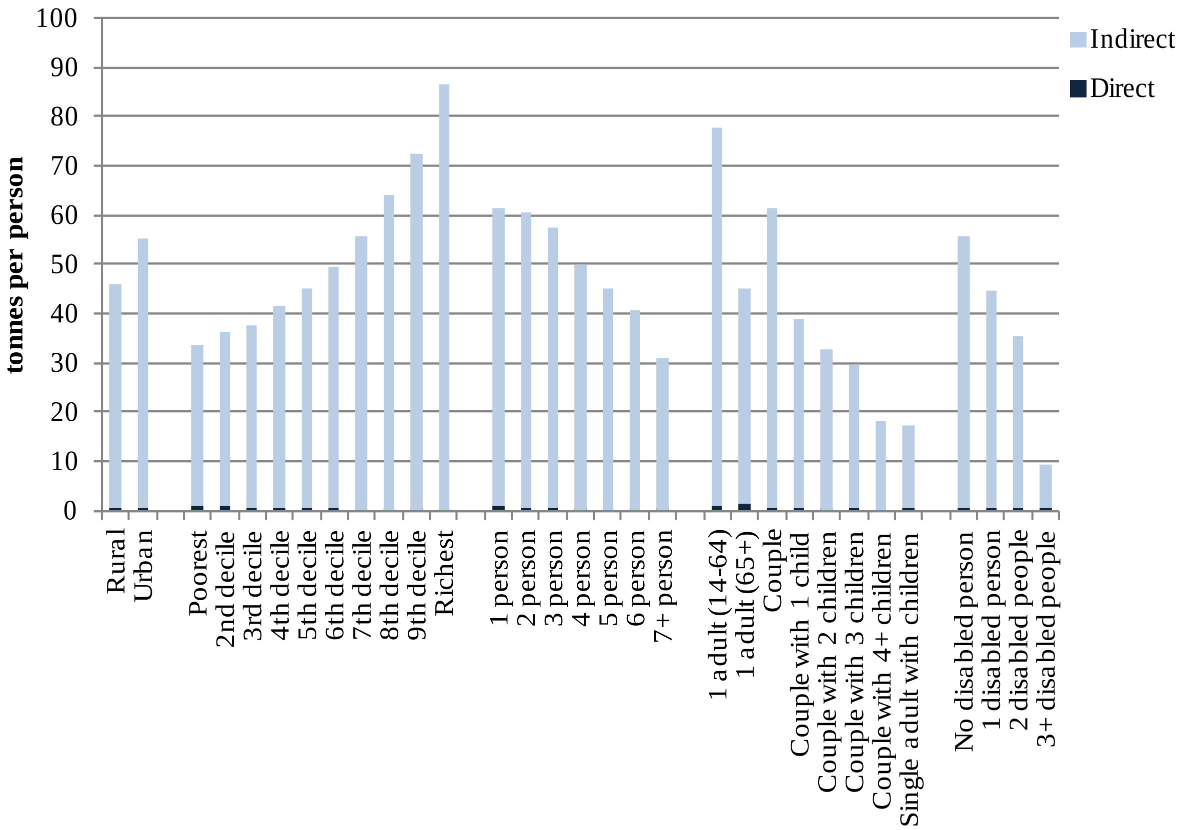


The average person in a rural household emits more CO_2 directly than an average person in an urban household; however an average urban household emits more CO_2 indirectly and also more in total than an average person in a rural household. Direct emissions in rural areas could be due to transport for example as cars are used more in rural areas whereas public transport is used more in urban areas. The definition of 'rural' used here includes much of the commuter belt.

The poorest households emit the least CO_2 both directly and indirectly with nearly 1400 tonnes and 1900 tonnes per person respectively, and the richest households emit the most CO_2 both directly (1985 tonnes) and indirectly (6224 tonnes) per person and thus the richest decile emits 4900 tonnes more in total than the poorest decile. The increase in each decile for indirect emissions seems to be more an exponential growth than a linear one. The larger the household the less CO_2 is produced per person, with decreases in indirect, direct and thus total emissions as households get bigger. This is consistent with the presence of economies of scale in consumption; where household activities, for example cooking, are undertaken for the whole household rather than by each individual and thus emissions per person are less for households with more people. The only anomaly is for a retired aged single adult; for a single adult it is expected that total emissions would higher than a for a couple, however this is not the case and results suggest a couple emits 999 tonnes more than an average retired adult. This could be due to an average couple having a higher income than an average single retired person.

Figure 4 shows per average person emissions for methane (CH_4) where almost all household emissions of this gas are indirect. It is clear that, indirectly, urban households emit more per person than rural households by 10 tonnes but rural households emit more per person than urban households by 0.2 tonnes from direct sources. The richer the average person becomes the higher the indirect emissions (and the lower the direct emissions), and this increase seems to be more exponential rather than linear. The difference between indirect and direct emissions for the richest decile is 85 tonnes.

Figure 4: Direct and Indirect Emissions of Methane per person by household type

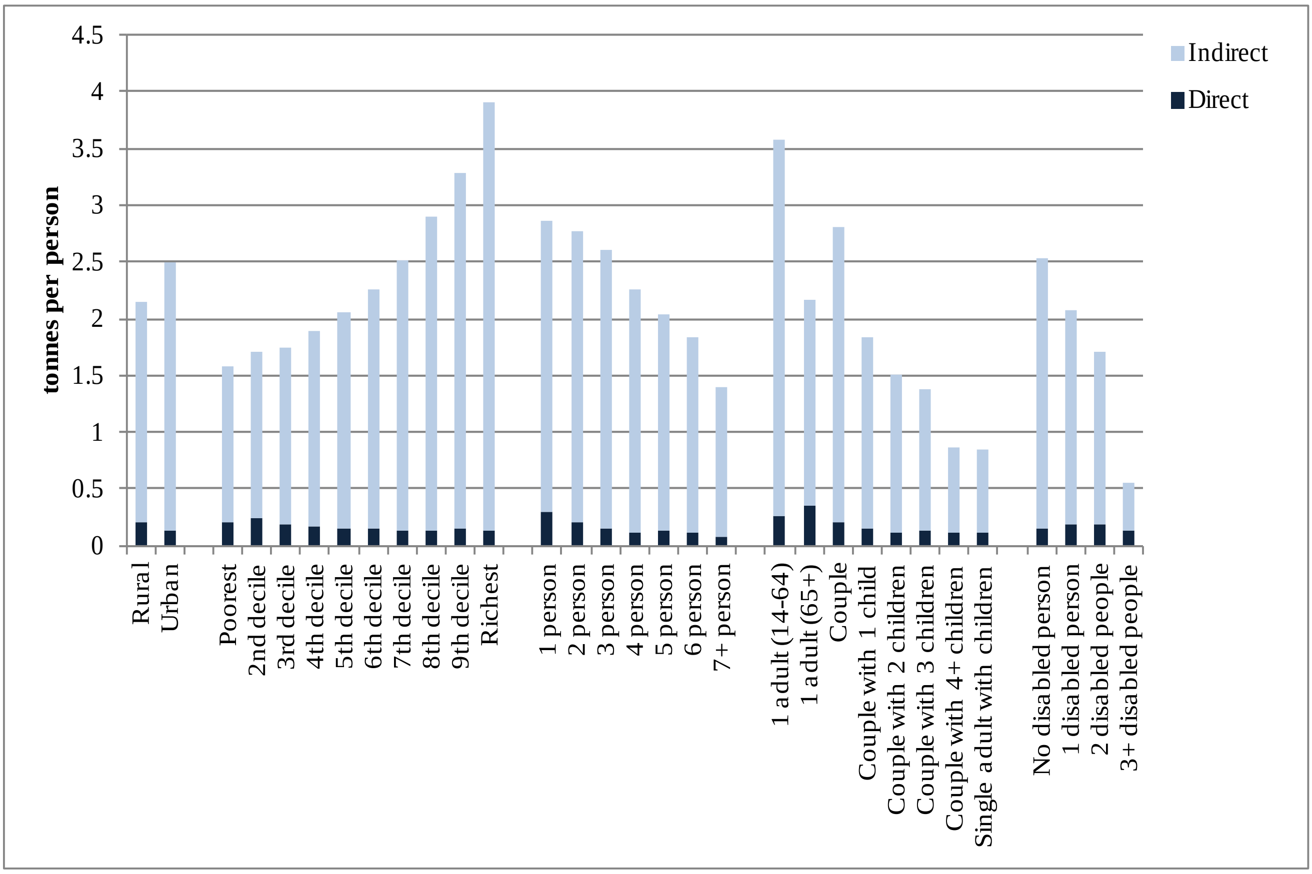


One and two person households emit roughly the same quantity of methane per person indirectly, however a one person household emits more than any other household size by direct sources (a one person household emits 1 tonne directly whereas a two person household emits 0.6 tonnes and a seven or more person household emits 0.2 tonnes from direct sources). The larger the household the less is emitted per person both from indirect and direct sources, making smaller households bigger emitters. A similar pattern holds for household composition for both direct and indirect emissions; single adults and couples are the largest emitters per person and emissions fall the more children are in the household. A working aged adult emits the most indirectly with 76 tonnes and a retired adult emits the most directly at 1.3 tonnes. Again the pattern is similar for the number of disabled people in a household; the more disabled people the less emissions per person from indirect sources. This, however, is not the same for direct emissions; emissions from direct sources increase with the number of disabled people, amounting to 0.6 tonnes for two disabled people whereas with no disabled person in a household the average per person emission of methane is 0.4 tonnes. Emissions do fall, however, when there are at least three disabled people in a household to just over 0.4 tonnes. A detailed graph of direct emissions of methane (and other emissions) can be found in the Appendix (Figure A1), although roughly 99% of methane emissions come from indirect sources as shown by Figure 2.

Figure 5 depicts emissions of nitrous oxide per person by household type. Nitrous oxide emissions are mostly emitted indirectly, with the richest income decile emitting the most (the difference between direct and indirect emissions is roughly 3.5 tonnes for the richest decile). The more people in the household, the less emissions per person both indirectly and directly; for one and two person households the average person emits similar amounts indirectly (2.37 and 2.35 tonnes respectively), however a two person household emits less directly than a one person household.

Urban households emit more nitrous oxide indirectly by 0.3 tonnes. Rural households emit more directly, although this difference is a lot smaller. For a household with three or more disabled people, the average person per household emits less nitrous oxide than other other household type (the difference between direct and indirect emissions is also the smallest). A more detailed graph of direct emissions of N_2O can be found in the Appendix (Figure A2).

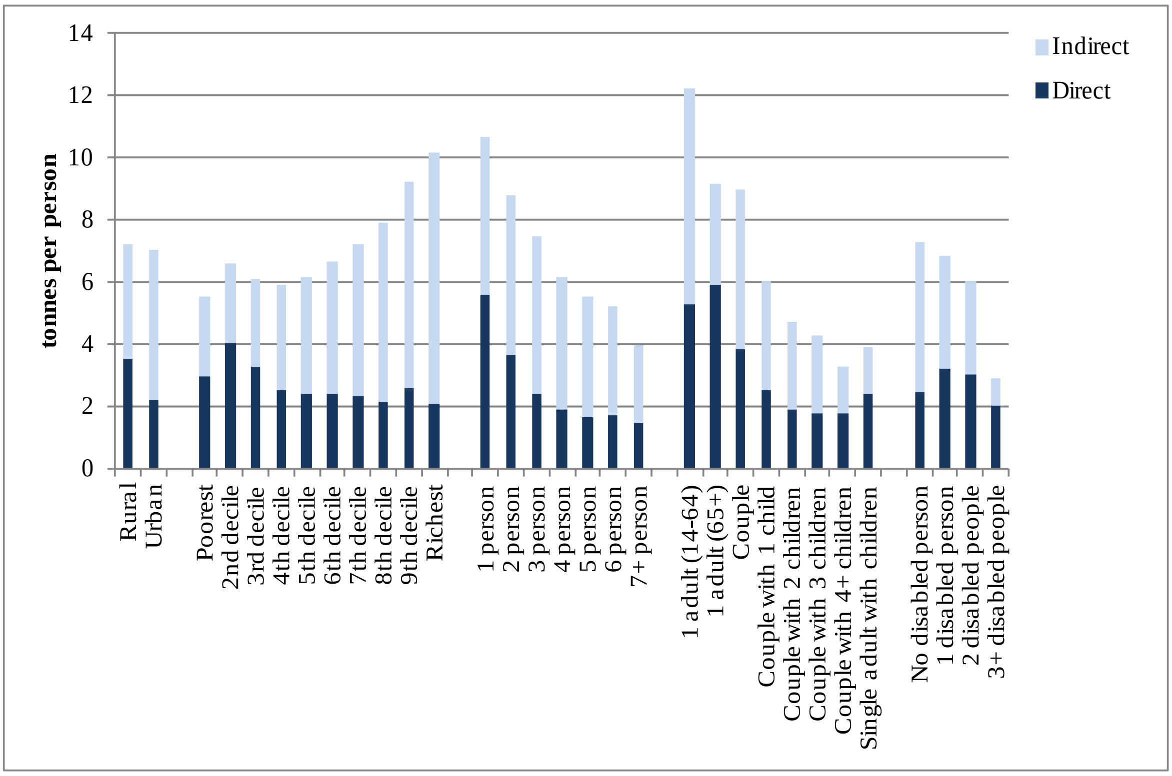
Figure 5: Direct and Indirect Emissions of Nitrous Oxide per person by household type



4.2 Air pollutants per person by household type

Figure 6 shows emissions from both direct and indirect sources of sulphur dioxide (SO_2) for an average person in each household type. Direct emissions per person fall gradually as household income increases, whereas indirect emissions increase sharply with income. The average person in an urban household emits more by indirect means than an average rural residing person; however this pattern is reversed with direct emissions. In contrast, indirect emissions are roughly constant across household sizes, while direct emissions per person are lower for larger households. Similar total emissions for urban and rural households mask differing composition, with rural households having relatively more direct emissions.

Figure 6: Direct and Indirect Emissions of Sulphur Dioxide per person by hosuehold type



In Figure 7 we show the distribution of carbon monoxide emissions per average person for different household types. A working aged single person generates the most carbon monoxide and a couple with at least four children emits the least carbon monoxide. Again direct emissions play a significant role although for most households per person emissions are mainly from indirect sources. The patterns are similar to those analysed before; the richest decile is the biggest emitter quantified as 30 tonnes and the more people per household, the lower emissions per person become. For rural households, the poorest three income deciles, a one person household, a retired single adult, a couple with 4 children, a single parent and households with at least two disabled people, per person emissions are greater from direct sources than indirect sources. The highest emission per person from direct sources is for a retired adult (23 tonnes) and the smallest for a seven person household at just under 5 tonnes. This is similar to the results for sulphur dioxide and carbon dioxide but substantially different from the other gas emissions.

Figure 7: Direct and Indirect Emissions of Carbon Monoxide by household type

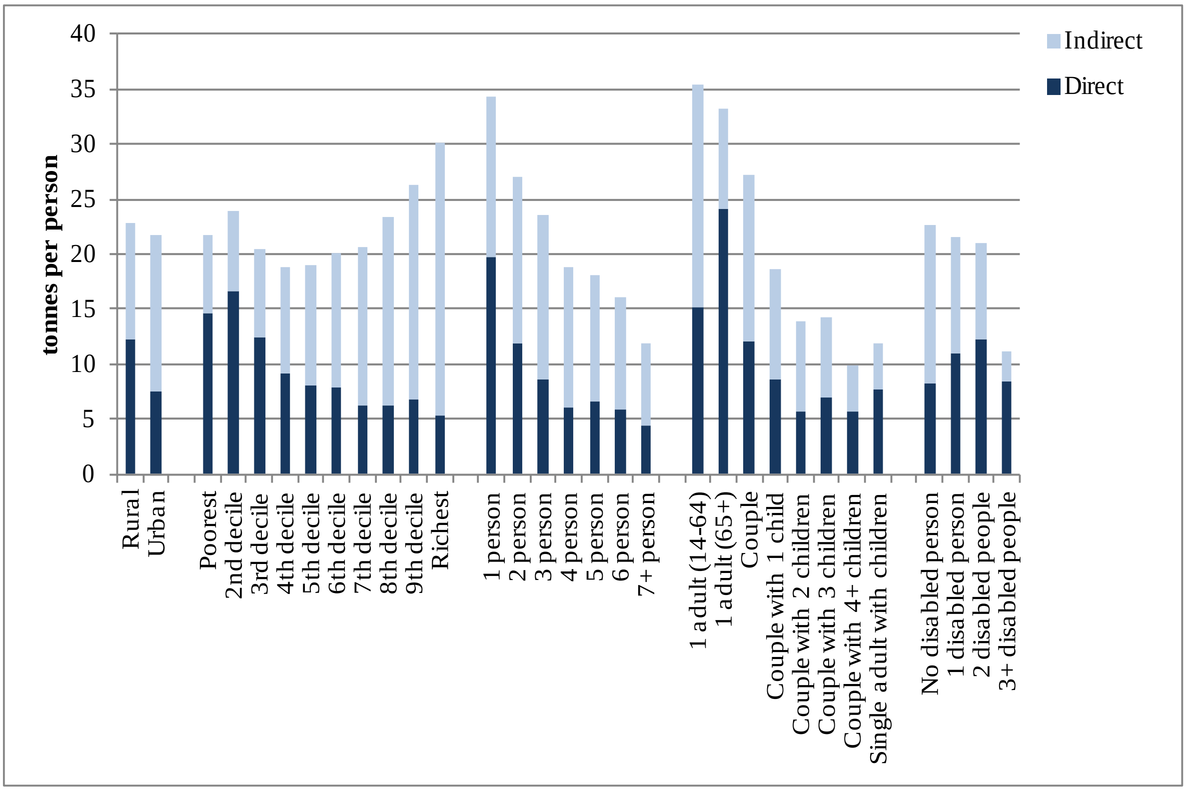
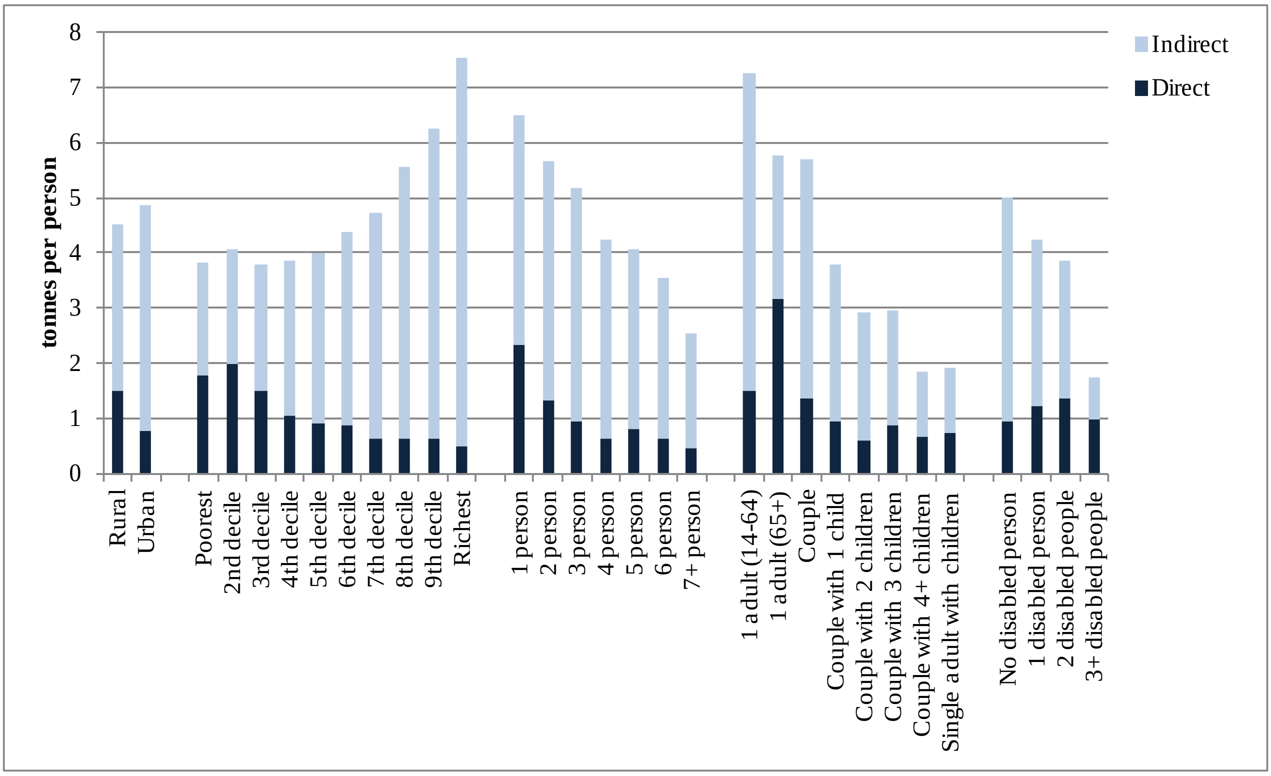


Figure 8 shows direct and indirect sources of emissions for NMVOC. A retired adult and an average household with at least three disabled residents in emit more NMVOC directly than indirectly. The rich emit more indirectly and in total than the poor, however, the poor emit more directly than the rich. For both indirect and direct channels of emissions, the larger the household the lower emissions per person. This is consistent with household composition where the more children there are in a household, the lower emissions per person.

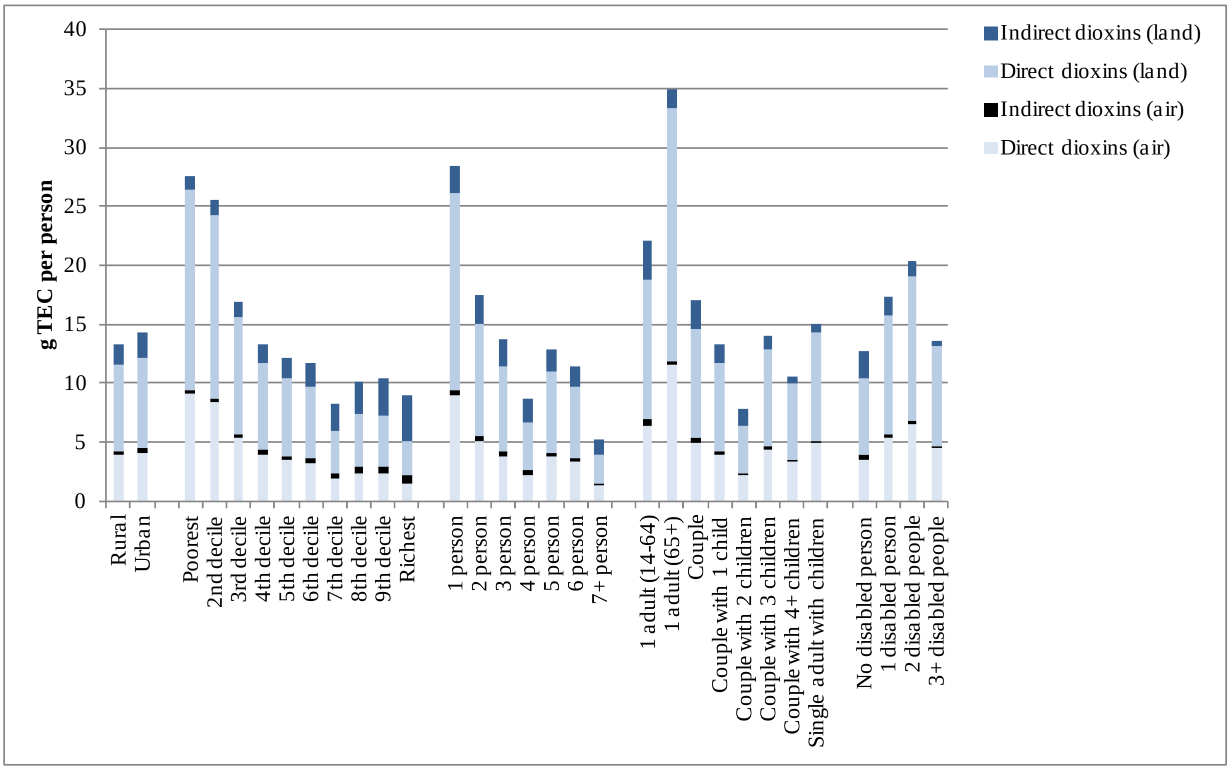
Figure 8: Direct and Indirect Emissions of Non-methane VOC by household type



4.3 Persistent organic pollutant emissions per person by household type

Figure 9 shows direct and indirect emissions of dioxins which go into land and air. Emissions of dioxins into water, which are negligible in quantity, can be found in the Appendix (A7). Urban and rural households emit roughly the same of each type of dioxins. The richer deciles emit less than poorer deciles in total, which stands in contrast to every other emission we studied. Poorer households emit larger quantities directly, perhaps due to greater use of open fireplaces, wood stoves and coal fired utility boilers. The richest deciles do, however, emit more indirectly into land than the poorer deciles. Bigger households pollute less than smaller households per person, as found for other emissions. If up to two disabled people reside in the household, emissions are higher than for three or more disabled people which is also different from the gas emissions previously analysed where emissions fall for each additional disabled resident.

Figure 9: Direct and Indirect Emissions of Dioxins per person by household type



4.4 Metal emissions per person by household type

We have data only for metal emissions via indirect channels by households and thus we do not show any direct pollution from households for the metal pollutants examined.

Figure 10 depicts the indirect emissions per person by household type for three metals, namely lead, mercury and cadmium. The patterns are essentially the same for these emissions, so we analyse them together.

Urban households emit more than rural households, the richest deciles emit more than the poorer deciles and the larger the household the lower emissions are per person. Households with up to three residents emits roughly the same quantities per person of lead, mercury and cadmium, which is slightly different from the pattern observed for gas emissions where two and three person households emitted visibly less than one person households. Of the three metals, the least cadmium and the most mercury is emitted by households. Cadmium is emitted is the manufacturing of electrical equipment, and it is also found in cigarettes. Most mercury pollution form households is from production (of non-ferrous metal and cement for example), but it is also from waste disposal.

Figure 10: Indirect Emissions of Lead, Mercury and Cadmium by household type

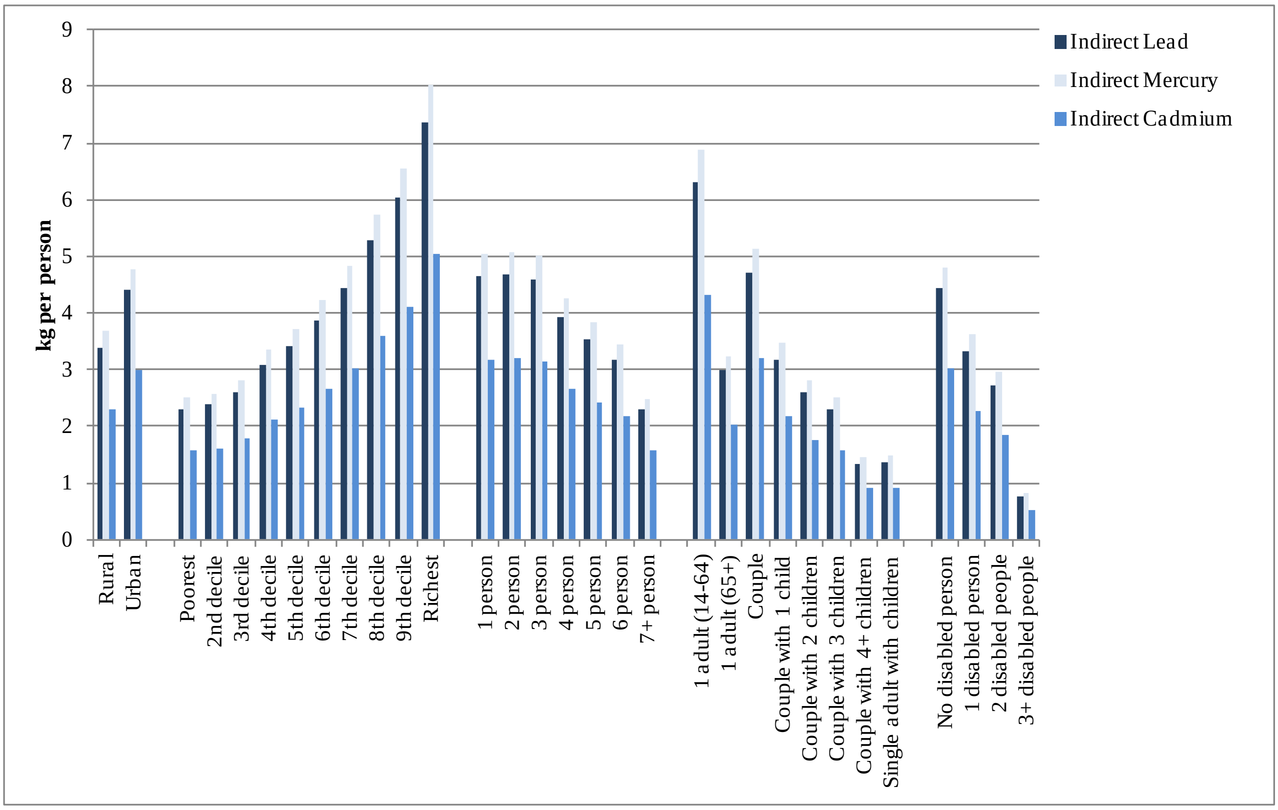
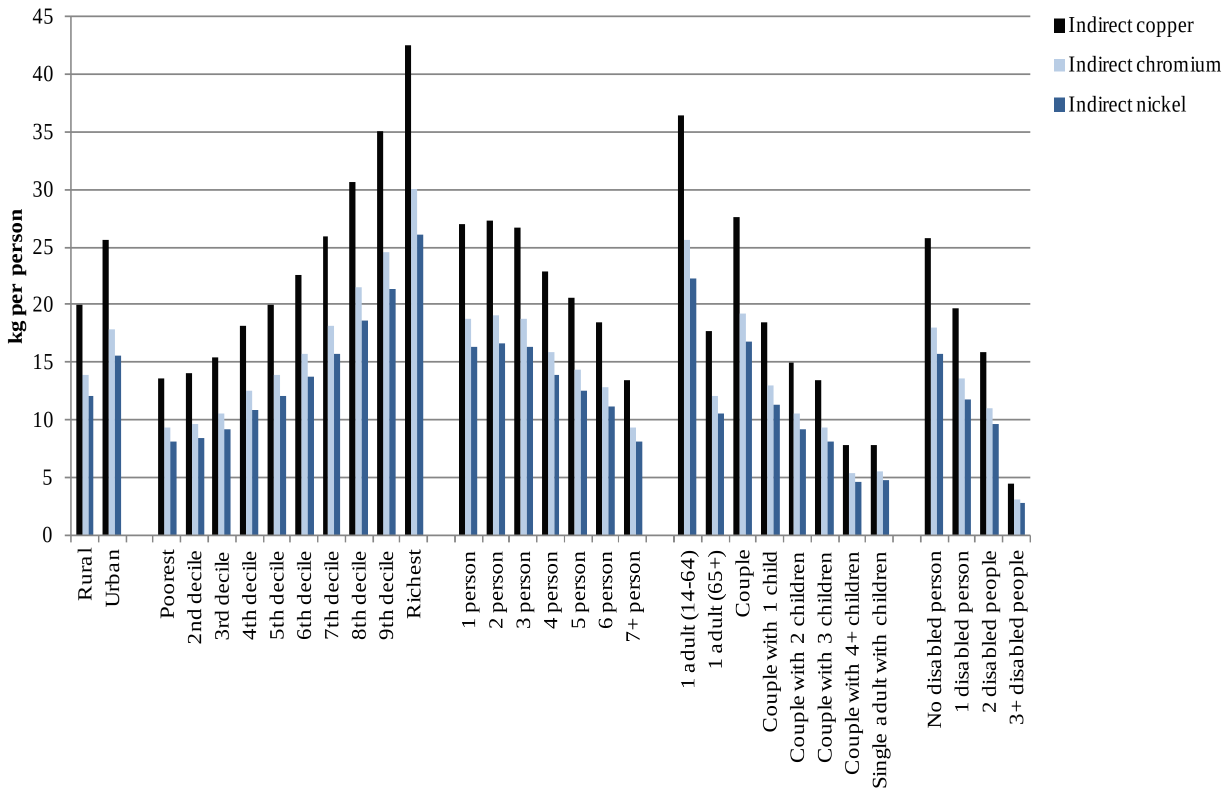


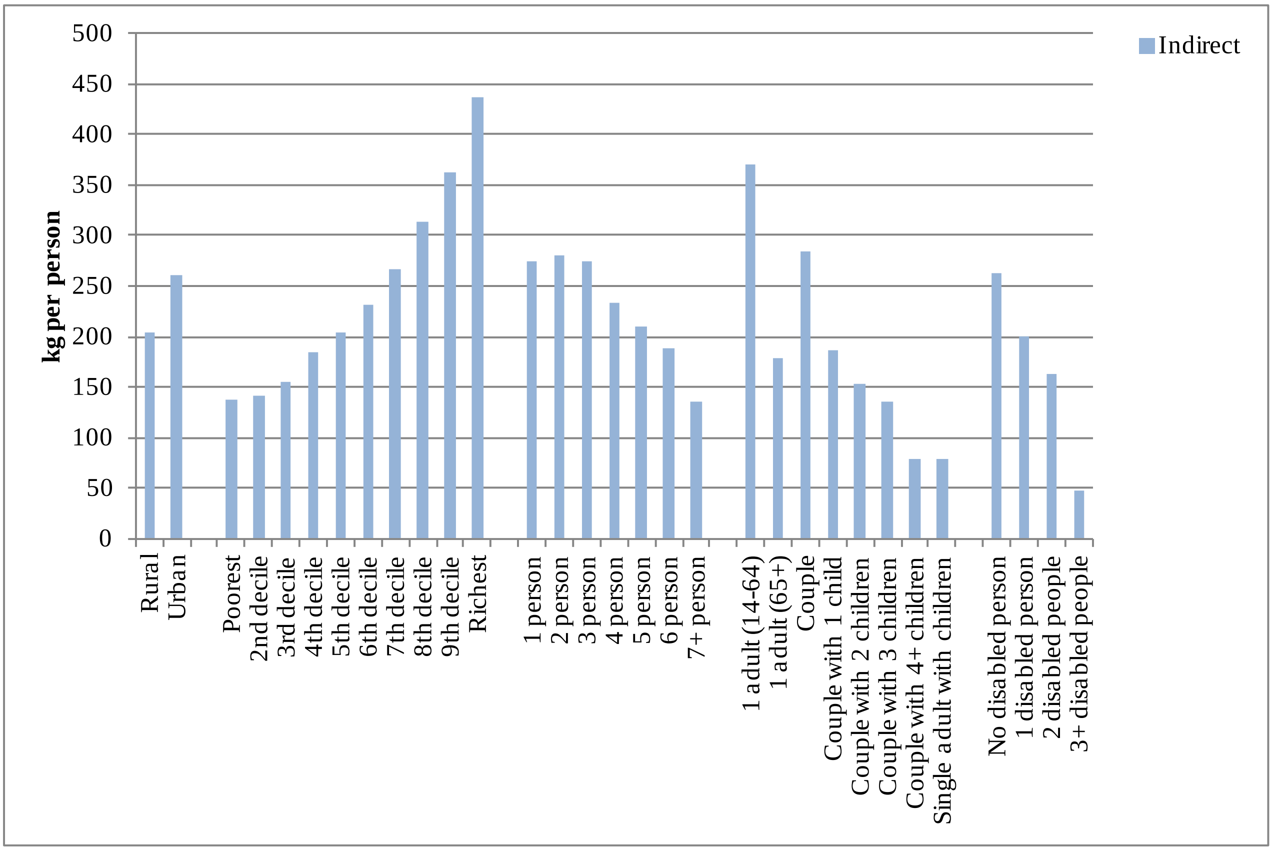
Figure 11 shows the indirect emissions by household type for copper, chromium and nickel. Once again, we group these metals together because their patterns are similar. Urban households emit more than rural households, the richer income deciles emit more than the poorer deciles and the larger the household size the fewer emissions per person. For all emissions the richest decile is the biggest emitter and a household with at least three disabled residents are the smallest emitters with the difference being 38kg, 26kg and 24kg for copper, chromium and nickel respectively.

Figure 11: Indirect Emissions of Copper Chromium and Nickel per person by household type



In Figure 12 we show the indirect emissions by household type for zinc. Urban households emit more than rural households, the richer deciles emit more than the poorer deciles and the larger the household the less are emissions per person. The richest decile emits the most (436kg) and a household with at least three disabled residents emits the least (46kg). The difference between the richest and the poorest is 300kg. The difference between per person emissions of a single adult with children and a single adult of working age without children is on a similar scale: 292kg.

Figure 12: Indirect Emissions of Zinc per person by household type



5. Analysis

In this section we consider how household income and size are associated with emissions of the substances covered in the paper. Figure 13 depicts the relationships that direct and indirect emissions have with income: the emissions ratio of the richest decile to the poorest decile. For each emission, this is per person pollution emitted directly (indirectly) for the richest household income decile divided by per person pollution emitted directly (indirectly) for the poorest income decile. Thus an emission with a high ratio is one where emissions are strongly related to income, whereas low ratios indicate emissions with little association with income.

HCB (emitted to water) is shown to have the lowest ratio both indirectly and directly. Top earning households cause only 2.6 times the per capita indirect emissions that low earning households do. Non-methane volatile organic compounds (NMVOC) have the highest ratio for indirect emissions (almost 3.5) and oxides of nitrogen (NOx) have the highest for direct emissions. Only NOx and CO_2 from fossil fuels have a ratio of more than 1 for direct emissions. *Ceteris paribus*, policies that affect the cost of direct emissions are likely to be much more regressive than those affecting indirect emissions.

Figure 13: Income intensity of emissions: ratio of household emissions per person for those in the highest income decile to those in the lowest decile by substance

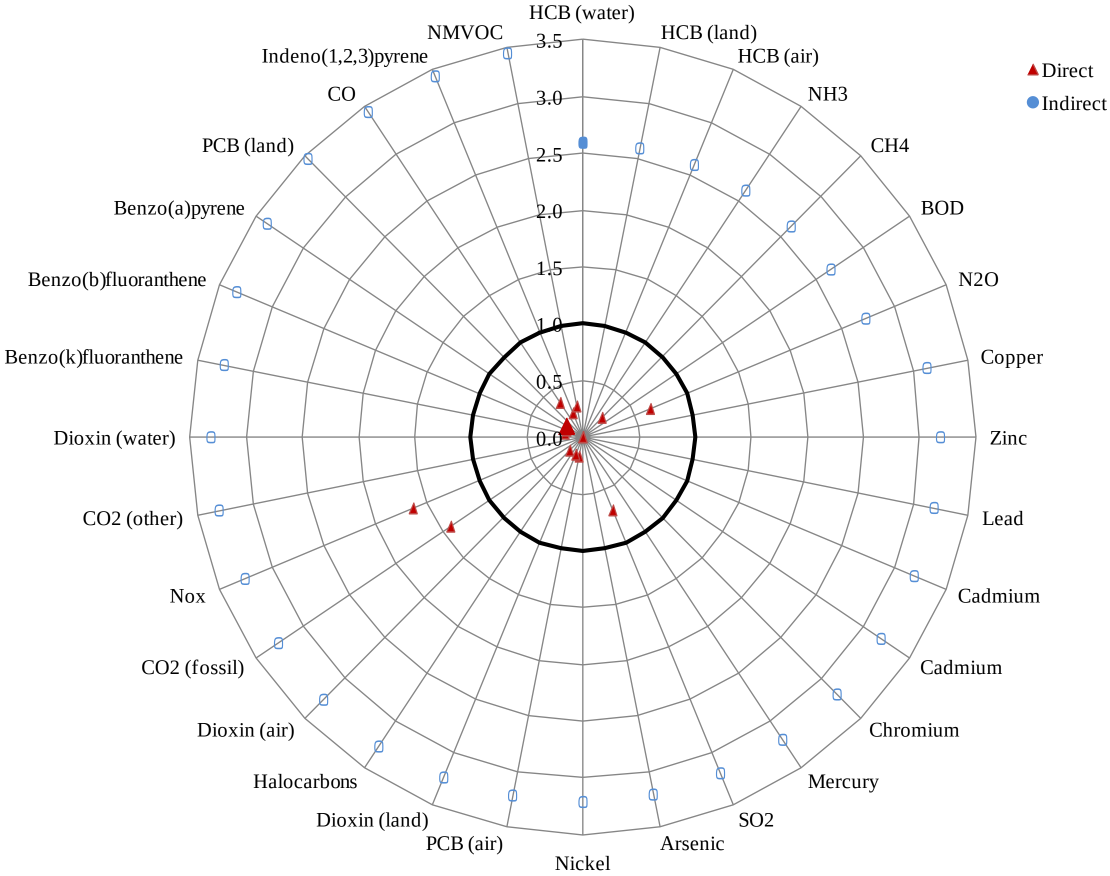
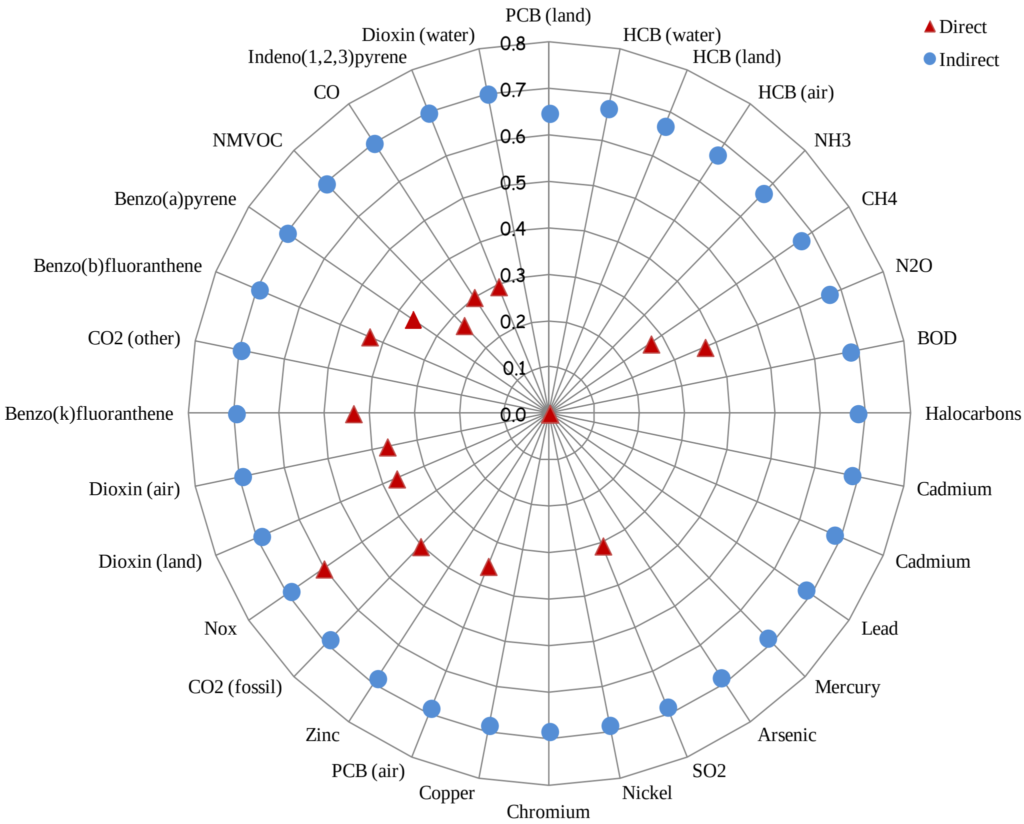


Figure 14 illustrates the association between household size and emissions: the emissions ratio of the largest household size to the smallest household size. This is calculated as the per person pollution of direct (indirect) emissions for a six person household divided by the per person pollution of direct (indirect) emissions for a one person household, for each emission. Pollutants show a very similar pattern, with an average ratio of 0.68. Again oxides of nitrogen (NOx) have the highest direct emissions ratio and PCB (pollution to land) has the lowest. Size ratios are generally lower than the income ratios discussed above; in Figure 14 no emission has a ratio over 0.7; however in Figure 13 all indirect emissions ratios and two of the direct emissions ratios are over 1. Income has a must stronger association with household emissions per person than household size does.

Figure 14: Household size intensity of emissions: ratio of household emissions per person the largest households (6 persons) to those in the smallest (one person) by substance



6. Conclusion

This paper has reported estimates of Ireland's direct and indirect emissions per capita by household type for a range of pollutants. Households are split in five ways, by location, income decile, composition, size and the number of disabled residents. This was done for indirect emissions using input-output modelling and for direct emissions (where relevant) by applying emission factors to microdata from an expenditure survey.

The results show that most pollution comes from indirect sources; in fact for the greenhouse gases, direct sources never make up more than 35% of household emissions per person. In general, richer deciles tend to pollute more than poorer deciles; however dioxins seem to be an exception to this pattern. Another common feature is that the larger the household the less pollution per person. Urban households tend to pollute more than rural households except for emissions of carbon monoxide and sulphur dioxide, which probably has to do with differences in the average household fuel mix. For emissions of CO_2, N_2O and CH_4, indirect sources play a more important role than direct sources of emissions, whereas for emissions CO and SO_2, direct emission sources are relatively more important.

For metals we have estimated emissions only for the indirect channel. Zinc is emitted the most by households of all the metals followed by copper. Cadmium is emitted the least. The patterns by household type are similar across the various metals, and they are not dissimilar to those found for the gases. There are some subtle differences; for example, for the metal emissions a household of up to three residents emit a fairly equal share, however, for the gas emissions a two person household emits visibly less than a one person household and a three person household again visibly emits less than a two person household.

We also noted that household size has a weaker association with both direct and indirect emissions than household income does. Variations in indirect emissions are much more strongly associated with income than direct emissions, implying that a similar proportional change in the cost of emissions would be more regressive if applied to direct emissions than to indirect emissions.

The impact of environmental policy will tend to have differing incidence across households, to the extent that household types have differing emission patterns. This non-homogeneity has implications for environmental policy, because measures that raise the cost of emitting a pollutant (e.g. a tax or regulatory restriction) will fall more heavily on some households than others. If this significantly affects vulnerable households or changes the distribution of taxation in a material way, it may be necessary to offset the impact through appropriate tax or benefit measures.

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Appendix

Table A1: Percentage shares of emissions by final demand sector

	Household	Charities	Government	Investment	Inventories	Exports
Benzo(a)pyrene	95.1%	0.2%	1.2%	0.9%	0.0%	2.5%
Indeno(1,2,3)pyrene	93.9%	0.3%	1.6%	1.0%	0.0%	3.2%
PCB (air)	89.7%	0.4%	2.7%	2.1%	0.0%	5.1%
Dioxin (air)	84.6%	0.6%	3.5%	3.6%	0.0%	7.6%
Benzo(b)fluoranthene	76.6%	0.9%	5.6%	4.5%	0.0%	12.4%
Dioxin (land)	74.7%	1.2%	7.5%	4.0%	0.0%	12.5%
Benzo(k)fluoranthene	69.7%	1.2%	7.3%	4.9%	0.0%	16.9%
CO	51.9%	2.1%	12.9%	7.2%	0.0%	25.9%
SO_2	49.8%	2.3%	14.1%	9.0%	0.0%	24.8%
CO_2 (fossil)	48.0%	2.4%	14.2%	9.1%	0.0%	26.2%
NMVOC	44.2%	2.4%	14.4%	10.5%	0.0%	28.4%
NOx	40.6%	2.6%	15.6%	10.2%	0.0%	31.0%
Dioxin (water)	37.6%	2.8%	17.4%	10.0%	0.0%	32.1%
Mercury	39.5%	2.9%	17.6%	10.1%	0.1%	29.9%
Arsenic	39.5%	2.9%	17.5%	10.0%	0.1%	30.0%
Nickel	39.5%	2.9%	17.3%	10.0%	0.2%	30.2%
Cadmium	39.4%	2.9%	17.6%	10.0%	0.0%	30.0%
Cadmium	39.4%	2.9%	17.6%	10.0%	0.0%	30.0%
Lead	39.3%	2.9%	17.5%	9.9%	0.1%	30.3%
Chromium	39.4%	2.9%	17.2%	9.9%	0.2%	30.5%
Zinc	39.0%	2.7%	16.2%	9.4%	0.5%	32.2%
Copper	38.6%	2.8%	16.4%	9.1%	0.2%	32.9%
N_2O	37.0%	2.3%	12.4%	5.2%	-0.1%	43.1%
CH_4	35.0%	2.2%	11.8%	4.4%	-0.1%	46.8%
BOD	34.9%	2.3%	12.4%	4.1%	0.1%	46.3%
NH_3	34.9%	2.2%	11.7%	3.8%	-0.1%	47.6%
HCB (air)	34.7%	2.2%	11.6%	3.7%	-0.1%	47.9%
HCB (land)	34.7%	2.2%	11.6%	3.7%	-0.1%	48.0%
HCB (water)	34.7%	2.2%	11.6%	3.7%	-0.1%	48.0%
CO_2 (other)	33.0%	2.5%	15.3%	16.1%	0.1%	33.0%
Halocarbons	3.5%	0.2%	1.4%	2.3%	0.0%	92.6%
PCB (land)	0.3%	0.0%	0.1%	1.2%	-0.1%	98.4%

Figure A1 shows direct emissions of methane per person. Direct emissions for methane are very small however patterns are the same as for those explained above in Section 4.1. An average rural household emits more than an urban household, the poor emit more than the rich, the larger the household the smaller emissions per person and a single person emits more than a household with children.

Figure A1: Direct emissions of methane per person

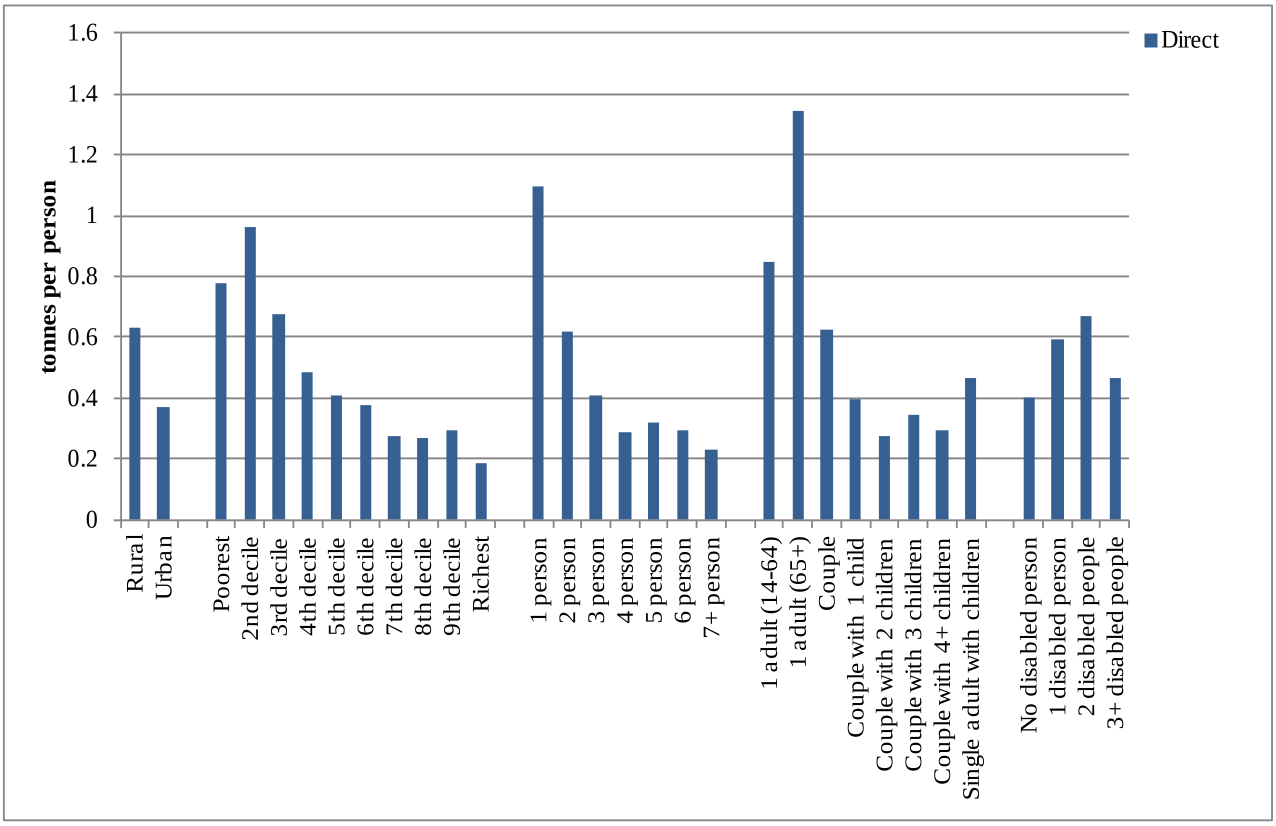


Figure A2 shows direct emissions of nitrous oxide per person. Direct emissions are extremely small; Figure 2 suggests only 1-2% of nitrous oxide emissions are emitted directly. Rural households emit more directly than urban households, the poorer deciles emit more than the richer deciles and the larger the household the fewer emissions per person. A retired adult emits the most directly followed by a one-person household and a 7+ person household emits the least directly.

Figure A2: Direct emissions of nitrous oxide per person

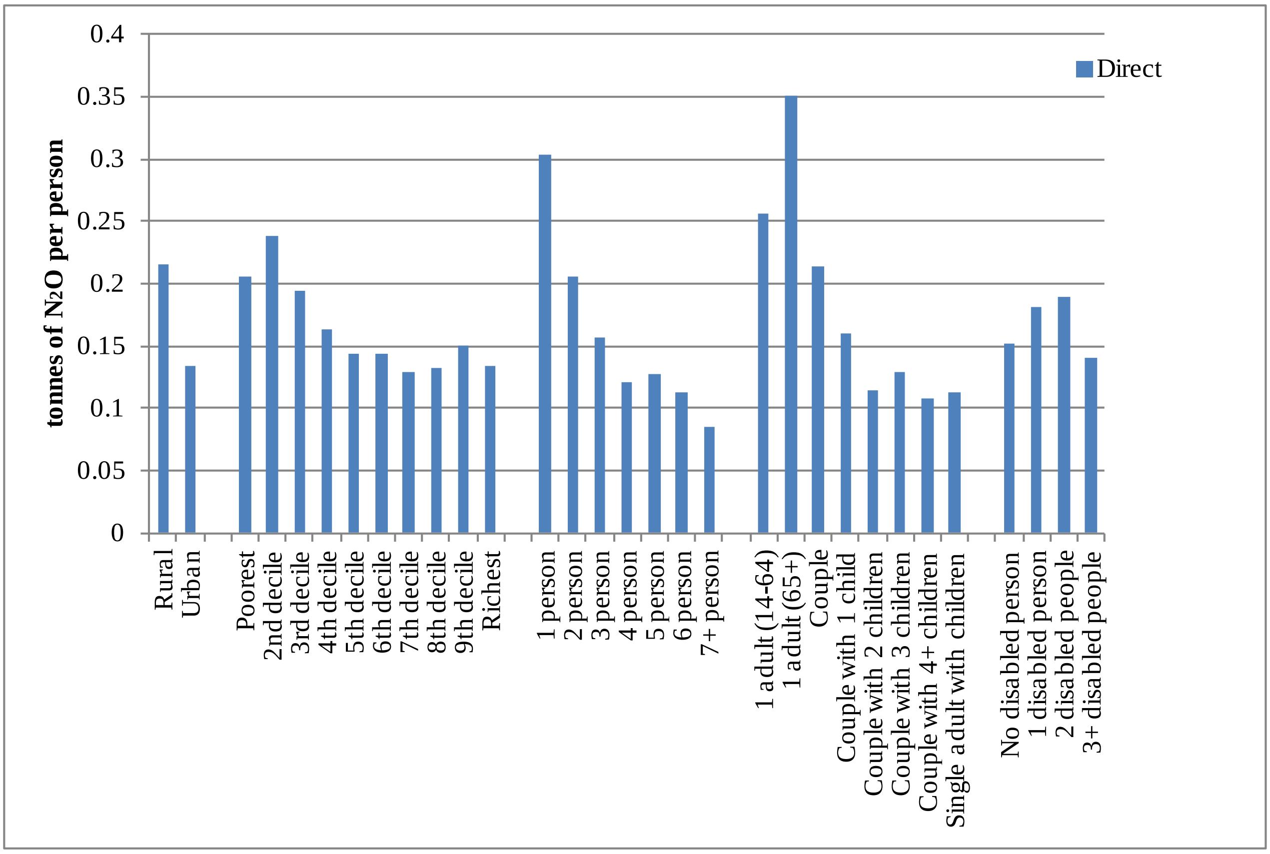


Figure A3 shows indirect emissions for HFC's; emissions from direct sources are zero. The patterns are the same as analysed before where the average urban resident emits more than a rural resident. The richer the average person the higher emissions are. A one to three person household emit roughly the same (with a two person household emitting slightly more) but as the household gets bigger emissions per person fall. Working aged adults and couples emit more than other household compositions and emissions strictly decrease with an increase in the number of disabled residents.

Figure A3: Indirect emissions of HFC's per person

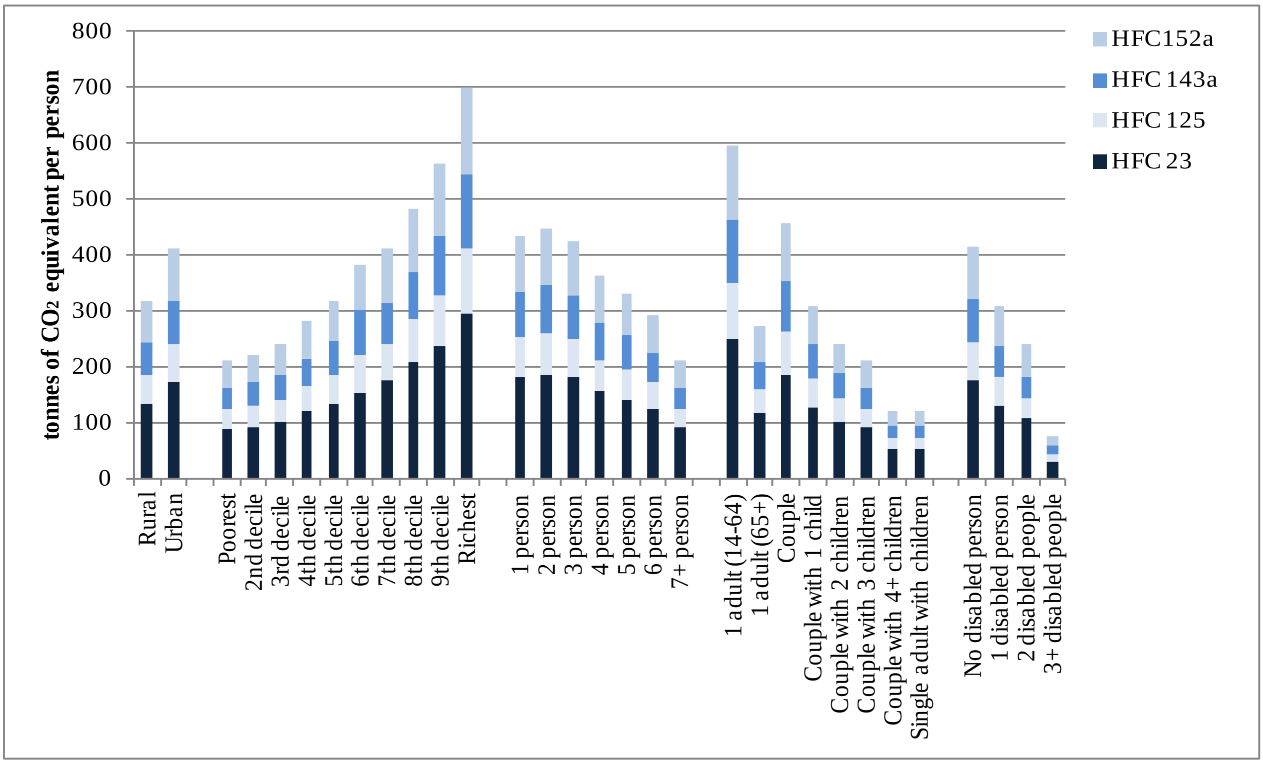


Figure A4 shows the indirect emissions ammonia per person by household type; direct emissions of ammonia are zero. Urban households emit more than rural households which may be surprising given how widely ammonia is used in agriculture for fertilizers. A high concentration of ammonia is also found in household cleaners as it leaves a none-streaky shine on surfaces such as glass and stainless steel which is a cause of household indirect ammonia emissions. The richer deciles pollute more than the poorer deciles and the larger the household the fewer emissions per person. The richest decile emits the most of all household types and a household with at least three disabled residents emits the least ammonia per person and the difference is just over 13 tonnes.

Figure A4: Indirect Emissions of Ammonia per person by household type

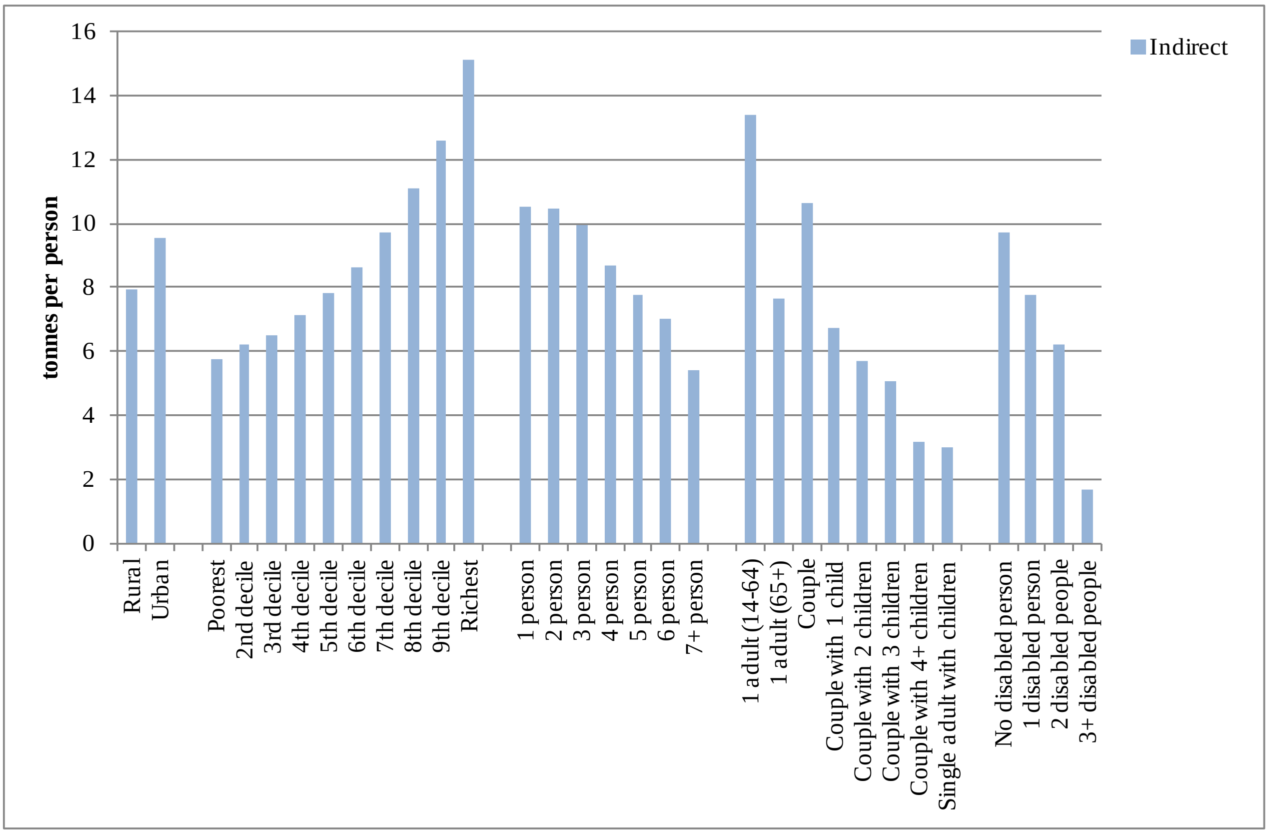


Figure A5 shows indirect and direct sources of emissions for NOx. Most emissions are from indirect sources with again the average person in a richer decile emitting more than the poorer deciles. Urban households emit more per person than rural households. The biggest emitters indirectly are the richest decile (19 tonnes) and a working aged adult (16 tonnes). The smallest indirect emitter of nitrogen oxide per person is a household with three or more disabled people (2 tonnes). Direct emissions are fairly small per person with the highest being for a working aged adult (2 tonnes) and the smallest being a seven or more sized household (0.9 tonnes).

Figure A5: Direct and Indirect Emissions of Nitrogen Oxide per person

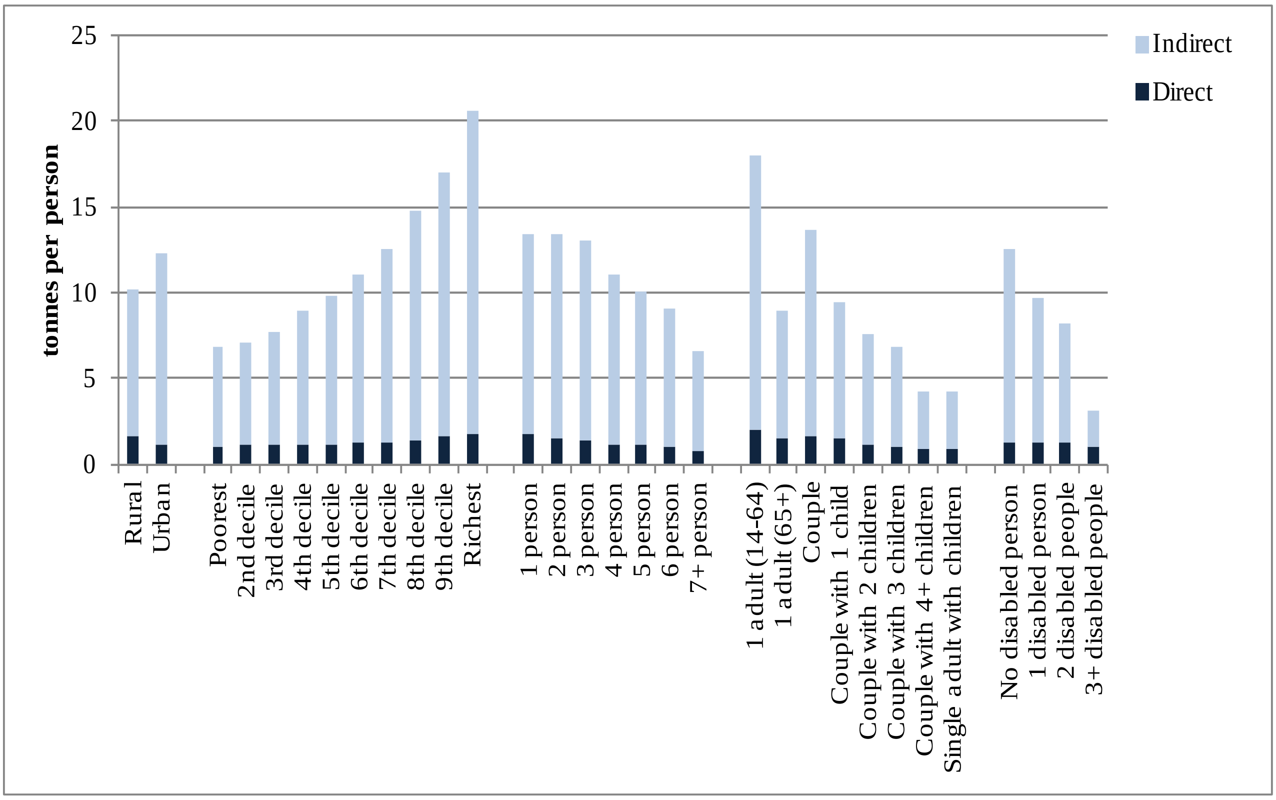
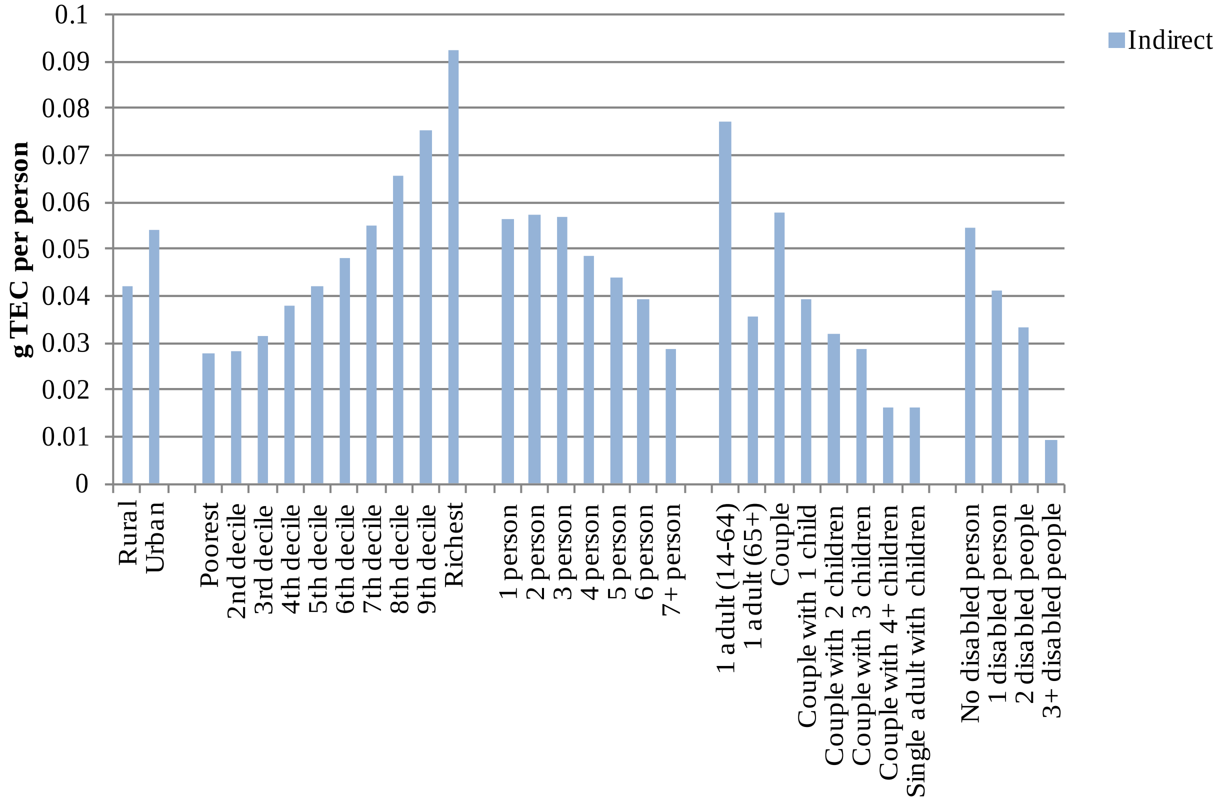


Figure A6 shows indirect emission sources per person of dioxins to water; direct emissions are zero. Emissions are very small is size, however, urban households pollute more than rural households and the richer the decile the more pollution. The first and second income deciles emit roughly the same amount. A household with at least three disabled people residing is shown to be the smallest emitter of dioxin to water and the richest decile is the biggest emitter of dioxins to water. The larger the household size the smaller the pollution levels per person.

Figure A6: Indirect emissions of dioxins to water per person



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