Regional Science and Urban Economics 60 (2016) 96–111

Contents lists available at ScienceDirect

Regional Science and Urban Economics

journal homepage: www.elsevier.com/locate/regec

Comparing household greenhouse gas emissions across Canadian cities

Juan Fercovic[a], Sumeet Gulati[b,*]

[a]Food and Resource Economics, University of British Columbia, Vancouver, BC V6T 1Z4, Canada
[b]Food and Resource Economics, The Faculty of Land and Food Systems, Vancouver, BC V6T 1Z4, Canada

ARTICLE INFO

Article history:
Received 10 August 2015
Received in revised form 2 June 2016
Accepted 27 June 2016
Available online 8 July 2016

JEL classification:
Q4
R2
R3

Keywords:
Greenhouse gases
Carbon dioxide
Cities
Urban development
Electricity
Natural gas
Transportation

ABSTRACT

We provide an estimate of the expected direct greenhouse gas emissions for an average Canadian household in 17 Census Metropolitan Areas. We include emissions from the consumption of gasoline, natural gas, and electricity. Higher density is associated with lower gasoline consumption in personal vehicles, cold weather is associated with higher energy consumption for heating, and higher income and family size are associated with overall greater energy use. The average Canadian household produces the lowest greenhouse gas emissions in Montréal, Québec, followed by Vancouver, British Columbia. Highest emissions are in Edmonton, followed by Calgary. The source of energy used matters more than we expected. Despite its inclement weather, Montréal has the lowest emissions because hydropower supplies much of its household energy use (including home heating). Edmonton and Calgary have the highest associated emissions, due to their extreme weather, low density, and coal based electricity supply. The average household across all cities (weighted by population share) experienced a decline in its predicted CO_2 emissions from 11.49 tonnes per year in 1997 to 9.7 tonnes in 2009 (16% over 12 years). One of the reasons for this decline is that population growth was higher in cities where emissions fell faster.

1. Introduction

In 2004, households contributed 46% of the overall CO_2 emissions in Canada (Clark and Gagnon, 2008). A third of these were direct emissions generated at the household—comprising emissions from motor and residential fuel use (Clark and Gagnon, 2008). The rest are indirect emissions, those from the production of the goods and services consumed.

Studies find that household emissions are influenced by household and urban characteristics. For instance, a larger, richer family is likely to consume more fuel, and increasing neighborhood density induces lower levels of driving (see Glaeser and Kahn, 2008).

We ask two questions. First, how do Canadian Census Metropolitan Areas differ in the CO_2 emissions produced by a standardized household?[1] Or alternatively, if an average Canadian household (with mean income, household size, and age of the head of the household) were to locate to a randomly chosen Census Metropolitan Area, what would be their expected direct CO_2 emissions?

Second: how are the average household emissions in Canada changing over time? This involves two sub questions: first, are the rankings of Canadian cities with respect to household emissions, changing over our sample period? Second, are population changes systematically related to emissions across Canadian cities? In other words, are there more people choosing to live in high emission or low emission cities?

To estimate household emissions, we employ data for fuel consumption, household and city level characteristics for 17 Census Metropolitan Areas (CMA) across Canada over 12 years (1997–2009). We use our data to estimate the effects of household and CMA level

* Corresponding author at: Food and Resource Economics, 341-2357 Main Mall, MacMillan Building, University of British Columbia, Vancouver, V6T 1Z4, Canada, Phone: +1 (604) 822-2144, Fax: +1 (604) 822-2184.
E-mail addresses: jmfercov@gmail.com (J. Fercovic), sumeet.gulati@ubc.ca (S. Gulati).

[1] Glaeser and Kahn (2008) conduct a similar exercise for cities in the United States of America.

http://dx.doi.org/10.1016/j.regsciurbeco.2016.06.010
0166-0462/

Table 1
Descriptive statistics.

Variable	Mean	SD	N
Gasoline Q (L)	2162.40	327.15	187
Natural gas Q (m^3)	1972.72	1074.89	112
Electric Q (kW h)	11982.40	4133.25	187
Gasoline price (*cents*/L)	79.12	19.19	187
Natural gas price (*cents*/m^3)	33.07	16.85	119
Electricity price (*cents*/kW h)	9.25	2.95	187
Density (person/km^2)	267.06	287.38	187
Income ($)	65550.60	14394.56	187
Avg. household size	2.52	0.18	186
Age of the reference person (years)	48.23	2.18	187
Heating degree days	4696.12	1167.74	187
Pct. of HH with more than 2 vehicles	0.35	0.09	186
Avg. number of rooms per dwelling	6.14	0.43	186
Pct. of HH with natural gas in ppal heating system	0.75	0.27	106
Pct. of houses built between 1961 and 1970	0.16	0.04	155
Pct. of houses built between 1981 and 1990	0.18	0.04	165

Source: See source in Table 9 in Annex.

characteristics on fuel consumption for three main fuels: gasoline, natural gas and electricity. Holding constant household characteristics (income, household size, and age of the head of household at the level of an average Canadian household), we predict fuel use across different CMAs. We then convert this predicted fuel use to CO_2 emissions using available local CO_2 emission factors for each fuel and compare emissions across CMAs. Once this is done, the emission for the average household in Canada can be calculated by simply weighting each CMA emission by its population share.[2]

We find that household size, and income increase fuel consumption. Higher population density reduces emissions, due to reduced driving and likely smaller dwellings. Moderate temperatures lower energy needs for dwelling level temperature control. Differences in emission factors have a large impact on CO_2 emissions: thus the source of a province's electricity is important, so is the composition of natural gas used (see Table 2). These three factors suggest that cities on the coast in British Columbia are likely to have the lowest emissions. Vancouver and Victoria are relatively dense, have moderate temperatures, and use electricity generated from hydroelectric dams. Instead we find that despite its famously harsh winters, Montréal has the lowest predicted carbon emissions (at only 5 tonnes for the standardized household, Vancouver is second at 7.2 tonnes).[3] Evidence suggests that Montréal has the lowest emissions as its residents use electricity for heating. The choice of natural gas versus electricity for heating having a significant impact on household level CO_2 emissions. The highest predicted CO_2 emissions are in Edmonton (with over 20 tonnes per family, Calgary is second highest at a little under 18 tonnes).

This relative ranking holds true through most of our sample. An average Canadian household in Montréal has always had the lowest greenhouse gas emissions, and the same household situated in Edmonton has always had the highest emissions. We also find that all CMAs experienced a decline in average emissions through our sample. The average household across Canada (across eight CMAs to be precise) saw its predicted CO_2 emissions decline from 11.49 tonnes per year in 1997 to 9.7 tonnes in 2009. A decline of approximately 16% over 12 years. We also find suggestive correlations that population growth has been higher in cities where emissions are declining faster. We do not know the reason underlying this correlation, but this population trend reduces overall household emissions in Canada.

We also find suggestive evidence explaining Montréal's use of natural gas for electricity in heating. While electricity prices in Québec are amongst the lowest in the country, they aren't very different from CMAs in other hydropowered Provinces (Manitoba and British Columbia). On the other hand, average natural gas prices in Québec are the highest in the country. The average price in Montréal (at 49.08 ¢/m^3) is almost double (approximately 78% higher) in gas rich Alberta (at 27.63 ¢/m^3 in Edmonton and Calgary), and approximately 25% higher than that in British Columbia (at 39.08 ¢/m^3 in Victoria). Historically high gas prices might have spurred infrastructure and cultural changes (residential building norms) which lead to an overwhelming use of electricity for heating.

The implications from our analysis are fairly straightforward. If we encourage high density development or encourage development of low carbon energy, households lower their greenhouse gas emissions. If we encourage residents to move to high dense locations, the average emissions per household in Canada also fall. This implies that one way to lower the average emissions by household in Canada is to encourage city level policies encouraging densification. As a city densifies, it reduces average household emissions. As it densifies, it also reduces barriers to entry for residents, thus increasing population. So densification mimics the correlation we find in our data. Finally, our analysis also reaffirms the importance of prices. Prices can influence fuel use which has a large impact on greenhouse gas emissions.

2. Methodology

Our analysis follows and builds on Glaeser and Kahn (2008), who estimate carbon dioxide emissions associated with major metropolitan cities in the United States of America for the year 2000. They use household level data. Instead, we estimate carbon dioxide emissions associated with cities in Canada for a panel of years from 1997–2009. We use city (Census Metropolitan Area–CMA) level data. Because the structure of data used across our two studies is so different, our questions and methods diverge significantly.

Similar to Glaeser and Kahn (2008), we quantify GHG household emissions from three typical sources of energy used by a Canadian household: gasoline, electricity and natural gas. Gasoline is used mostly in personal vehicles. Electricity and natural gas are used for multiple purposes (for example, lighting, temperature control, cooking) in a household dwelling. According to Clark and Gagnon (2008), these three sources account for almost all of an average household's direct emissions. Gasoline is responsible for a third (33%), natural gas and heating oil for 39%, and electricity consumption the remaining approximately 28%.

Unlike Glaeser and Kahn (2008) we use a panel data regression. This allows us to control for unobserved heterogeneity across

Table 2
Provincial fuel emission factors.

Province	Electricity (CO_2 g/kW h)	Natural gas (CO_2 g/m^3)	Gasoline (CO_2 g/L)
Alberta	850	1918	2289
British Columbia	31	1916	2289
Manitoba	6	1877	2289
New Brunswick	569	1891	2289
Newfoundland and Labrador	20	1891	2289
Northwest Territories	367	2454	2289
Nova Scotia	770	1891	2289
Ontario	100	1879	2289
Prince Edward Island	17	.	2289
Québec	3	1878	2289
Saskatchewan	760	1820	2289
Yukon	40	.	2289

Source: Greenhouse Gas Division, Environment Canada, National Inventory Report, 1990–2010.

[2] We only use eight CMA's for this exercise. These are the CMAs for which we have data on all three fuels used, gasoline, electricity, and natural gas. We use population shares amongst the eight used, this ensures that our weights sum to 1.

[3] See Tables 4 and 5.