

Population Growth, Energy Use and Environmental Impact: Comparing Canada with Sweden

Key words:

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Abstract:

There are many similarities between Canada and Sweden, as both are relatively affluent northern nations with diverse modern economies. Both have witnessed demographic growth and climbing affluence over recent decades with predominantly export-oriented economies. Yet in terms of their respective records on greenhouse gas emissions, there is a stark contrast between the two. Sweden is often considered a world leader in reducing emissions whereas Canada has been widely criticized for its failure to meet international commitments. The current paper attempts to delineate some of the factors responsible for the observed differences between the two countries, while also providing an international context. It examines trends in environmental impact (CO₂ levels) by applying a modified and updated version of Ehrlich's "IPAT equation". This method explicitly considers the relevance of population growth, climbing affluence and technological change in examining environmental impact. While Sweden's economy uses less energy than Canada's, somewhat surprisingly, its energy intensity is actually greater than most OECD countries. The crux of the matter in comparing the two countries is Canada's substantial population growth and heavy demand for energy (29th among 30 countries in the OECD on our measure of energy intensity) whereas Sweden has managed to move away from fossil fuels in driving its economic activity (ranking second best across the OECD on our measure of fossil fuel dependency).

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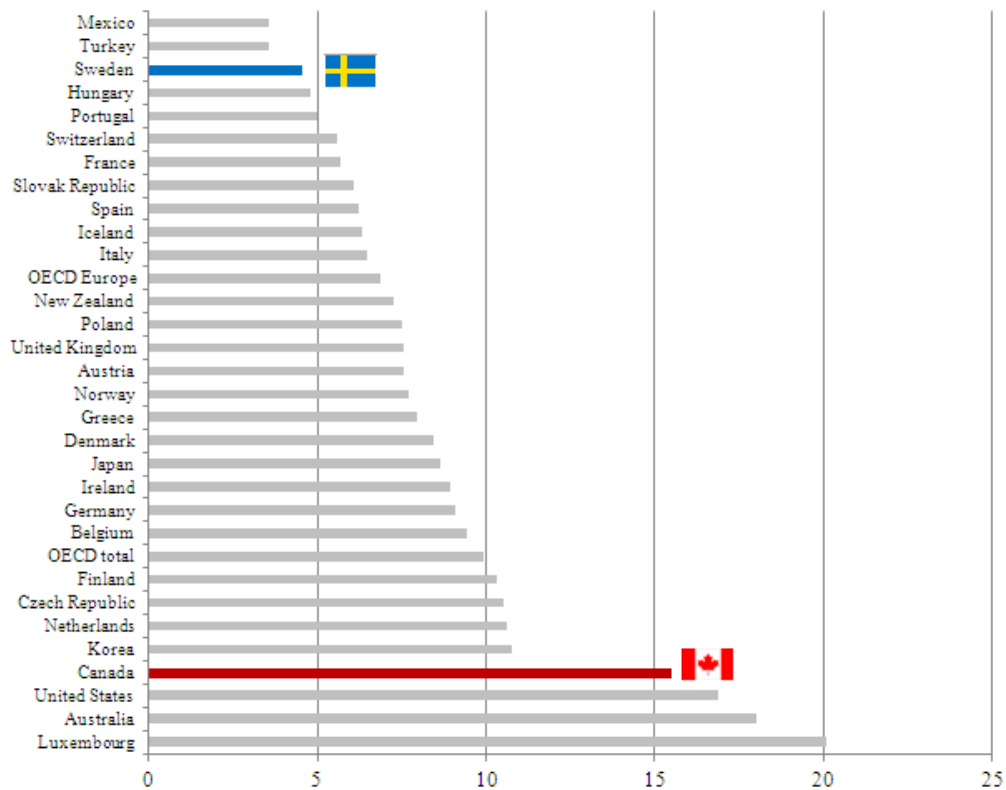
Introduction

According to the UN's Human Development Index that allows for international comparisons in terms of population health and social welfare, both Canada and Sweden are doing very well, ranking 8th and 9th respectively across over 170 countries (UN, 2011). Using data on life expectancy, literacy, education and standard of living, this index summarizes the relative success of countries in terms of promoting the social welfare of their populations. At the same time, the two countries differ dramatically in terms of their respective records on greenhouse gases (GHG's). On a per capita basis, Canada produces about 20 tons of greenhouse gases per person relative to less than 7 tons in Sweden - expressed as CO₂ equivalent (Environment Canada, 2011; Swedish Environmental Protection Agency, 2011). There are relatively few nations in the world that produce as much GHG relative to population size as Canada, whereas Sweden has been very successful in developing a modern economy without the same sort of carbon footprint.

There are many similarities between Canada and Sweden, as both are northern nations, with diverse modern economies, a relatively high standard of living and long democratic traditions. Both have witnessed substantial economic growth over recent decades, with export-oriented economies featuring a highly skilled labor force, excellent internal and external communications, a modern distribution system, and a similar industry/service breakdown in terms of employment (the service sector comprises 76% of the Canadian workplace relative to 71% of persons employed in Sweden). Yet in terms of their respective records on GHG emissions, there is a stark contrast between the two, as Sweden is often considered a world leader in reducing emissions whereas Canada has been widely criticized for its failure to meet international commitments (Simpson, Jaccard and Rivers, 2007).

The current paper attempts to delineate some of the factors responsible for the observed differences between the two countries, while also providing an international context. More specifically, how has Canada and Sweden performed relative to the OECD, and what are some of the factors responsible for Sweden's relative success and Canada's comparative failure? As the bulk of GHGs are CO₂ emissions resulting from energy use and the burning of fossil fuels (i.e. about 80% in both countries), the current paper limits its focus primarily to CO₂ emissions. Quality information is available from the International Energy Association (IEA) on CO₂ emissions and energy use, supplemented by demographic and economic data as available from the UN and OECD. As a matter of introduction, on a per capita basis, Canada ranked 27th across the OECD in 2009 in terms of the carbon footprint, whereas Sweden has managed to produce less than any other wealthy nation, 3rd in the OECD behind only the developing economies of Mexico and Turkey (Figure 1). In addition, the disparity between the two countries has only been increasing over recent years, with CO₂ emissions up by roughly 20% in Canada over the 1990-2009 period, whereas Sweden experienced a reduction of fully -21%.

Figure 1 Per capita Carbon Emissions across OECD Countries, 2009



Source: IEA, 2011; UN, 2011; Author's calculations

In terms of methodology, this paper examines trends in environmental impact (CO₂ levels) by applying a modified and updated version of what is widely known among demographers as Ehrlich's "IPAT Equation" (Ehrlich and Holdren, 1971). Borrowing from demography and industrial ecology, IPAT is an acronym used to emphasize the utility of investigating environmental impact (I) as a direct function of population change (P), affluence (A) as well as technological change (T). As population (P) is often viewed as a fundamental driver of environmental impact (i.e. the larger the population, the greater the impact, all else held constant), it is useful to begin with differences across nations in terms of demographic growth. As climbing affluence (A) is associated with increased consumption and energy use, it is also useful to examine the variation that exists across countries in terms of level of affluence and how this has been evolving over recent years. Since technology (T) is often viewed as particularly fundamental in understanding environmental impact (I), this paper borrows from a growing literature of energy-related carbon emission studies that extends the technology component in IPAT in the decomposition of CO₂ emissions (Kayo, 1990; Hamilton and Turton, 2002; IPCC, 1996, Karakaya and Ozcag, 2005).

Technology potentially contributes to increased environmental impact (as an example, by shifting to more CO₂ intensive fossil fuels) while also holding the potential for decoupling CO₂ levels from economic growth (for example, by shifting away from such fuels to other non-conventional energy sources). The current study attempts to highlight this point, by systematically

comparing Canada with Sweden, placing their apparent successes and failures into a broader context within the OECD. Societies differ in terms of their reliance on fossil fuels, the types of fossil fuels used, not to mention differences in terms of the energy intensity of economic activity, efforts toward conservation and the efficiencies that exist in energy conversion technologies. While on the surface there appear to be many similarities between Canada and Sweden, the divergent trends as observed in the two countries are quite striking. As documented in the current paper, Sweden's record on reducing CO₂ emissions is among the strongest in the OECD while Canada's record continues to be among the poorest.

The IPAT Identity

In the early 1970s, Ehrlich and Holdren (1971, 1972) formulated the IPAT equation with the intent of refuting any argument that "population size", in and of itself, was a minor factor in explaining environmental change. Consistent with Ehrlich and Holdren's neo-Malthusian world view, rapid population growth was considered as one of "the most unyielding of all environmental pressures" (1971:150). The IPAT equation, in its simplicity, was proposed as a starting point for investigating the impact of human populations on the environment. As the global population was growing at an unprecedented pace, an understanding of the environmental impact would have to begin with current population size and pace of population growth.

These interrelationships have been summarized in terms of the "IPAT equation" or "impact equation", as:

$$\text{Impact (I)} = \text{Population (P)} \times \text{Affluence (A)} \times \text{Technology (T)} \quad [1]$$

Impact (I) refers to the amount of a particular kind of environmental degradation, population (P) the size of a population, affluence (A) typically measured in terms of income (or GDP) per capita, and technology (T) meant to capture the environmentally damaging properties of a particular technique. Working with this IPAT equation, the argument is that an increase in population (P) would lead to a proportional increase in environmental impact (I), if in fact there were no change in the other components (and likewise, this is also true of both affluence and technology). While this model has been criticized as being somewhat of an oversimplification, its primary utility was to highlight the centrality of demography to discussions of environmental problems. Although the rate of global population growth has slowed since the 1960s, there remains considerable variance across nation states, from the particularly low growth associated with many low fertility/low immigration nations in Europe to the more sustained growth characteristic of North America and other parts of the world.

Despite the potential for more complex models, IPAT has been used by researchers as a useful framework for investigating interactions of population, economic growth and technological change. While extensive debate continues as to the relative importance or "weight" of each term, there is a wide consensus that each of the terms definitely belongs in the equation. In treating this model as linear with the effects of the different terms being proportional, the Intergovernmental

Panel on Climate Change (IPCC, 2000) has used a revision of this identity to decompose change in anthropogenic GHG emissions by major world region. As a simple, robust model for descriptive work, the IPAT model has been applied as an identity, such that for a specific nation state, CO₂ emissions can be expressed as a direct function of (P) population size, (A) GDP/Population, and (T) CO₂ emissions/GDP:

$$\text{CO}_2 \text{ emissions} = \text{Population} \times \frac{\text{GDP}}{\text{Population}} \times \frac{\text{CO}_2 \text{ emissions}}{\text{GDP}} \quad [2]$$

While GDP/Population does not fully capture the social dimension of environmental impact, it does reflect the simple fact that there is substantial variation in affluence across societies – even within the OECD. While not all nations within the OECD are affluent (consider Mexico and Turkey, for example), most have witnessed substantial economic growth over recent years. While populations have grown steadily throughout the 20th century, affluence (or economic activity) has grown at an even more rapid pace. Affluence is often considered a critical determinant of environmental degradation because high rates of consumption tend to be associated with a larger ecological footprints and rapid rates of resource use and waste production (Rees, 1992). In general, increased affluence – with everything else held constant – implies a greater demand for energy and higher CO₂ emissions. In terms of relative affluence, both Canada and Sweden have witnessed substantial growth in terms of GDP per capita, although the manner in which this translates into increased impact appears to have differed in an important manner in comparing the two nations.

In comparing Canada with Sweden, we seek to apply and extend this equation, while also making further comparisons more broadly with other OECD countries. This involves borrowing from a growing literature of energy-related carbon emission studies that have been used to decompose differences in CO₂ emissions across nation states (Kayo, 1990; Hamilton and Turton, 2002; IPCC, 1996, Karakaya and Ozcag, 2005). This literature seeks to not only demonstrate the centrality of population growth (P) and affluence (A) to environmental impact but to decompose, in particular, the role of technology (T) in determining energy use patterns and environmental impact.

Technology and Environmental Impact

The technology term (T) incorporates some sort of combination of capital, labor, energy, materials and information, in the production and consumption of specific goods or services. The role of technology can be considered as particularly complex, as it is often at the heart of many environmental difficulties (as for example, the CO₂ emissions resulting from burning dirty coal) while also holding the promise for potential solutions (as for example, the development of “clean or renewable” energy). While Ehrlich and other environmentalists warned against a blind faith in technological fixes for serious environmental problems, many social scientists pragmatically view technological variables as potentially easier to manage than human behavior (Commoner, Corr and Stamler, 1971; Simon, 1981; Chertow, 2001). A comparison of Sweden with Canada on this front

does demonstrate the importance of this factor in particular, as two societies of comparable affluence have had dramatically differing impact on the environment in terms of level and growth in CO₂ emissions.

There are various ways in which technology (T) can lower environmental impact, including the switch away from high polluting fossil fuel to other energy resources. Fossil fuels (oil, natural gas and coal) continue to be fundamental in meeting the energy needs of most societies, such that their specific mix of these fuels can potentially have dramatic effect. Coal is obviously the dirtiest, most noxious fuel to burn, with the shift toward other sources holding considerable promise in reducing emissions. Natural gas is clearly preferable to coal or oil, when possible, as it generates fewer pollutants, particulates and CO₂: releasing 14 kg of CO₂ for every billion joules of energy produced, relative to 20 kg and 24 kg for oil and coal, respectively (Harper and Fletcher, 2011). The precise mix (or carbon intensity) of fossil fuels has an important place to play in explaining the progress (or lack thereof) of specific OECD countries. The environmental costs associated with the extraction, mining, refining, transportation, consumption, and substantial polluting by-products, vary in an important manner by fuel type and across OECD countries.

Electricity is often thought of as a less polluting alternative, although of course, this depends upon how the electricity is generated. Consumers of energy sometimes do not recognize the environmental impact at source, as for example, consumers use electricity in their homes without realizing that it is often generated through the combustion of fossil fuels. For example, many societies rely heavily upon coal in the generation of electricity, as is the situation in the United States where 45% of total electricity comes from the burning of coal. In Canada fully 16.5 % of electricity supply is generated from coal, with an additional 5.2 % generated by natural gas and 1.9% from petroleum (NRC, 2010). Consequently, the “total supply of energy” is greater than the “total energy directly consumed”, i.e. some energy is lost in conversion from fossil fuels into electricity. Typically across societies, CO₂ emissions are produced both directly in the burning of fossil fuels and sometimes, to a greater or lesser extent, indirectly in the conversion of fossil fuels into electricity, with the level of efficiency involved in this conversion inversely associated with overall emissions. Typically the lower the conversion efficiency, the greater the demand for fossil fuels in meeting the demand for electricity (by both households and industry) and subsequently, the greater the overall emissions associated with this process.

In meeting its energy needs, Canada has clearly invested in infrastructures to produce, process and use coal, oil and natural gas – which in turn has made it more difficult to shift to alternative (less polluting) energy technologies. For example, the use of oil in Canada has grown almost exponentially due to the simple fact that it remains relatively cheap and fundamental to the transportation sector, in the movement of persons and goods. While the North American economy is heavily reliant on fossil fuels, this situation is not true to the same extent in other OECD countries - and in parts of Western Europe and Scandinavia in particular (Boyd, 2001). As will be demonstrated in the current paper, Sweden, in particular, has been very successful in reducing its dependence on fossil fuels, with a much lower proportion of its current energy supply coming from this source. Just as the “carbon intensity” of fossil fuel usage varies across societies, so does the “fossil fuel intensity” of economic activity. As an example, France has managed to reduce its

dependency on fossil fuel imports through considerable investment in nuclear energy (with all its associated risks and hazards). In Sweden, a variety of energy sources have come to replace fossil fuels, with major development of alternative energy sources, such as hydro electricity, nuclear, and to a lesser extent, geothermal, wind and solar energy.

In the North American context, a wide set of historical factors, including an early abundance of conventional energy resources, has left for a powerful set of tax biases and subsidies that have encouraged the use of fossil fuels while discouraging longer term investment in alternative energy technology. In addition, for a wide variety of reasons, including the economic structure of Canada's economy, the "energy intensity" of economic activity is higher here than elsewhere. With all of these considerations, Hamilton and Turton (2002) have set out to extend the aforementioned IPAT decomposition, to move beyond the "carbon intensity" of different economies (CO₂ emissions/GDP) as an indicator of the impact of technology. Using detailed information on levels and type of energy use from the International Energy Association (IEA), it is possible to further extend the IPAT model, such that the carbon intensity in economic activity (the T component in Equation 2) can be broken down into four further terms (see Equation 3 below).

In the following equation, the acronym FOSS represents "total fossil fuel consumption", TPES represents "total primary energy supply" (prior to any conversion of energy resources, if applicable), and TFC represents "total final energy consumption". In addition to the impact of population (P) and affluence (GDP/Population), we can move on to identify for each OECD country, 4 distinct technology effects:

$$\text{CO}_2 \text{ emissions} = \text{Population} \times \frac{\text{GDP}}{\text{Population}} \times \left[\frac{\text{CO}_2}{\text{FOSS}} \right] \times \left[\frac{\text{FOSS}}{\text{TPES}} \right] \times \left[\frac{\text{TPES}}{\text{TFC}} \right] \times \left[\frac{\text{TFC}}{\text{GDP}} \right] \quad [3]$$

As portrayed by Equation 3, it is possible to delineate a (i) carbon intensity effect $\left[\frac{\text{CO}_2}{\text{FOSS}} \right]$ (ii) fossil fuel intensity effect $\left[\frac{\text{FOSS}}{\text{TPES}} \right]$ (iii) conversion efficiency effect $\left[\frac{\text{TPES}}{\text{TFC}} \right]$ and (iv) energy intensity effect $\left[\frac{\text{TFC}}{\text{GDP}} \right]$. With regard to the first term, the "carbon intensity effect" is merely the ratio of CO₂ emissions relative to total fossil fuel combustion [FOSS]. This term would be at its highest in societies that burn the dirtiest of fossil fuels, including low grade, high carbon content, sulfur rich coal. The second technology term, or the "fossil fuel intensity effect" indicates the proportion of total primary energy supply [TPES] that obtained from fossil fuels [FOSS]. This term is obviously highest in societies that have failed to develop alternative sources of energy, whether that be nuclear, hydro, geothermal, wind or solar. The third technology term, the "conversion efficiency effect", represents the extent to which energy resources are used to create energy in another form (as for example, coal is used in the generation of electricity). As the ratio of total primary energy supply [TPES] relative to total final consumption of energy [TFC], it varies according to conversion efficiency and the fuel mix or type of primary energy supply used. The fourth technology term, or the "energy intensity effect of economic activity" is merely total final energy consumption [TFC] relative to the total size of a given economy [GDP]. This reflects both investments in energy efficiency (where Canada's record is not particularly strong) as well as the

nature of economic activity and economic structure (industrial, commercial/ service, resource based, agricultural, etc).

Hamilton and Turton (2002) have applied this model to the 1980-1997 data from the International Energy Association (IEA), comparing a limited number of European and North American countries. Karakaya and Ozcay (2003) have enacted a similar exercise across several nation states in Central Asia. Kerr and Mellon (2012) have more recently updated this work, in drawing systematic comparisons for Europe and North America for the 1990-2007 period. We shall again use this IPAT decomposition to further update this research through to 2009, yet this time with a specific emphasis on Canada and Sweden. We shall begin with a brief discussion of Canada and Sweden's respective circumstances in terms of population and economic growth over recent years, prior to considering the technology components in Equation 3, all relative to what is happening elsewhere in the OECD.

Population Growth and Environmental Impact

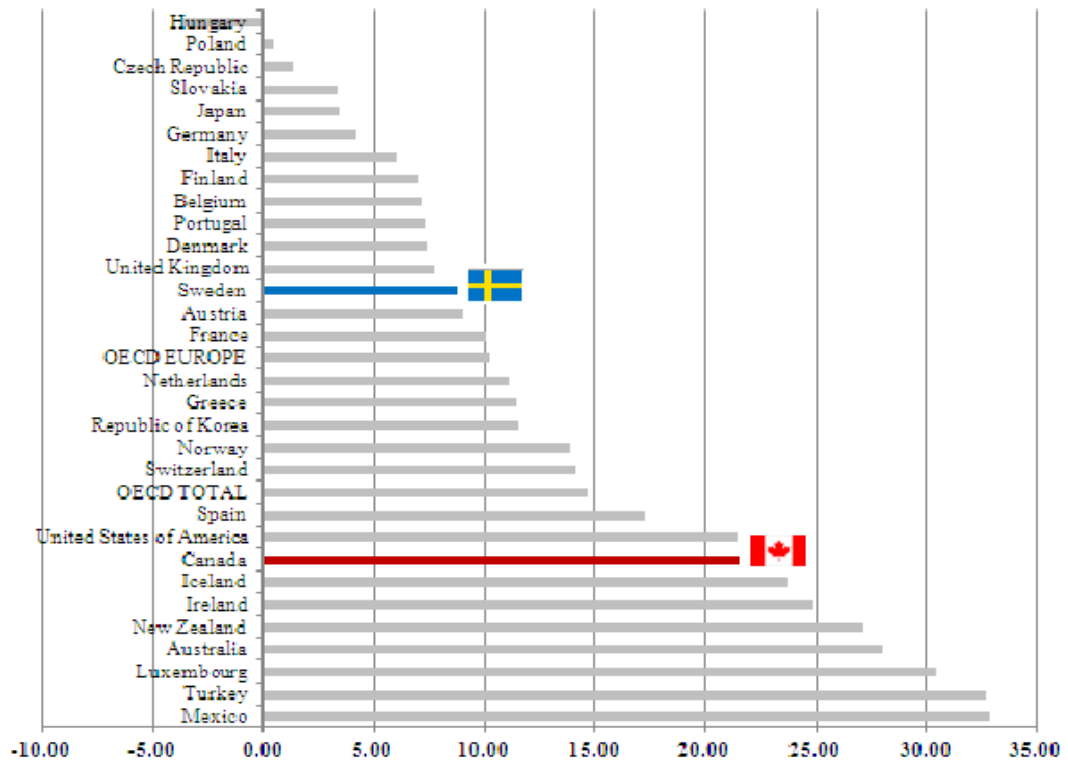
Canada's population growth has been relatively robust over recent decades, +21.6% over the 1990-2009 period (Figure 2). This leaves Canada as among the most rapidly growing OECD countries, with only a few countries experiencing faster growth, including the high fertility countries of Turkey and Mexico, as well as other countries also noted as being particularly open to immigration, including Australia, New Zealand, the United States, and most recently, Iceland and Ireland. On the other hand, Sweden has not experienced nearly as much demographic pressure, with its population up by 8.8% over this same period (i.e. by well under half the % increase documented for Canada). In this regard, Sweden's demographic situation is similar to elsewhere in Europe whereas Canada fits closer the broader North American pattern. Europe has had a much longer history of low fertility, which has resulted in substantial population aging, lower rates of natural increase, and more modest demographic growth relative to elsewhere in the OECD.

While both Sweden and Canada have had comparable fertility rates (TFR's) during the 1990s and 2000s (between 1.5 and 1.8 births per woman), Sweden's history of below replacement fertility goes back much further than Canada. For example, Sweden never experienced the substantial upturn in fertility that characterized the baby boom era in North America. As a result, Sweden has an older age structure than Canada, with currently almost 19% of its population over the age of 65 - relative to only about 13% in Canada. In North America, the baby boom cohorts as born during the 1950s and early 1960s are currently middle aged, and for this simple reason, Canada continue to have a substantially lower proportion of its population over the age of 65. Older populations tend to grow more slowly, as is the case with Sweden, which has an age distribution that produces more deaths and fewer births relative to populations with younger age structures.

Canada has more in common with the broader North American pattern, with continued growth through positive natural increase (more births than deaths) supplemented with relatively high immigration targets. Sweden's rate of natural increase has already dropped on a couple of occasions into negative territory (more deaths than births), something that is not anticipated for

Canada for at least an additional 15-20 years (Statistics Canada, 2010). While Sweden admits on a per capita basis more immigrants than most European countries, it does not welcome nearly as many immigrants as Canada, either overall or relative to the total size of its population. While most of Sweden's growth is currently through net international migration, its lower immigration targets (relative to North America) are supplemented by modest growth through natural increase.

Figure 2. Population Growth across OECD Countries, 1990-2009



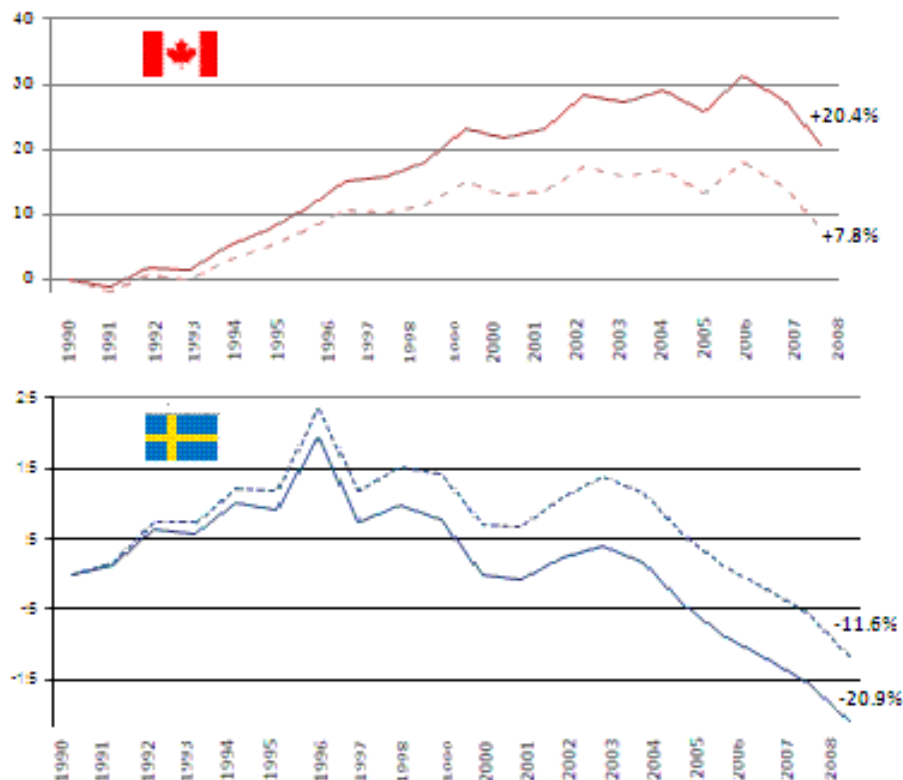
Source: UN Department of Economic and Social Affairs, Population Division, 2011

As Canada has experienced considerable demographic growth without shifting away from its heavy reliance on fossil fuels, overall CO₂ emissions have climbed rapidly. As aforementioned, Canadian CO₂ emissions are up by +20% over the 1990-2009 period, whereas Sweden actually succeeded in reducing emissions by -21%. The question that could be asked in this context is “to what extent the Canadian and Swedish records differ as a result of their very different rates of population growth”? Consistent with the logic of the IPAT model, we might assume that Canada’s growth in CO₂ emissions is at least partially the by-product of relatively rapid population growth, just as Sweden’s preferred outcome on CO₂ emissions occurred in a context of much more modest demographic growth.

Assuming no departure from observed trends in terms of all the components in IPAT with the “exception of population”, how might Canada’s record on CO₂ emissions have differed with a population increase similar to that of Europe or Scandinavia? Similarly, how might Sweden’s record have differed had it experienced demographic growth of the order of countries like Canada or the United States? Figure 3 briefly addresses this issue with a relatively simple exercise: (i) it

contrasts the observed % climb in emissions for Canada with what this country might had hypothetically experienced with demographic growth comparable to Sweden's (i.e. a population growth of 8.8% rather than the observed population growth of 21.6%), and (ii) we do the converse, we contrast the observed % decline in emissions for Sweden with what this country might had witnessed with demographic growth of the order of Canada.

Figure 3. Growth in CO₂ Emissions in Canada and Sweden, 1990-2009, with Observed and Hypothetical Rates of Population Growth



Source: Author's calculations

By assuming no departure from the observed trends in terms of affluence (A) or technology (T), our simulation implicitly assumes that these components have roughly proportional effects that are largely independent of population growth. This directly implies that the time series on GDP per capita and the CO₂ emissions per unit of GDP would have remained unchanged, with the only difference relating to the rate of population growth. To the extent that this is a reasonable assumption, what is clear is that Sweden's success in terms of reducing emissions would have been cut in half, a -11.6% decline rather than the observed -20.9%. Similarly, the estimated climb in emissions for Canada under this slower growth scenario is more than cut in half, from the observed +20.4% to about +7.8%.

CO₂ Emissions and Affluence

While Canada's population growth has clearly outpaced Sweden's, the same is not true of our second IPAT component, i.e. "affluence" (A). While much of the OECD has recently experienced economic stagnation and contraction – starting with the financial crisis of 2008 - the longer term time series (1990-2009) suggests a period of substantial growth, with all OECD economies larger in 2009 than they were a few decades earlier.¹ While climbing affluence (and associated consumption) is logically relevant in explaining why emissions have increased in most countries, there are obviously confounding factors that obscure the nature of the relationship. After adjusting all figures to constant US dollars, our indicator of affluence, i.e. GDP per capita, was up by +27.9% in Canada over the 1990-2009 (notwithstanding the fiscal crisis of 2008), +29.8% for the OECD average - and even further, +31.1% for the Swedes. In other words, our indicator of "affluence" for Sweden has climbed at a slightly more rapid pace than has Canada's, without this being translated into the same sort of proportional increase in CO₂ emissions. Both the Canadian and Swedish economies grew at about the middle of the pack among OECD countries, yet in this context, the two economies differed quite a bit in terms of environmental impact.

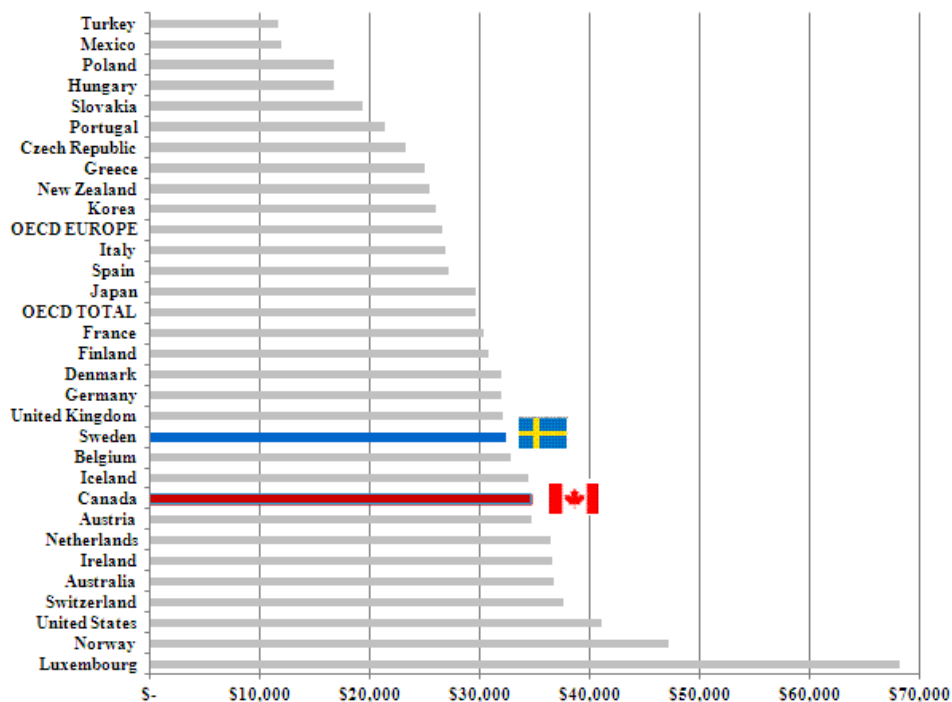
Affluence (A) is considered a critical determinant of environmental degradation because high rates of consumption tend to be associated with larger ecological footprints, a greater demand for energy, and rapid rates of resource use and waste production. Although the IPAT indicator "GDP/population" is an imperfect measure of affluence (A), it is used here to highlight the possible economic pressures that contribute to increased CO₂ emissions. As a general rule, in following the logic of the IPAT equation, the greater the level of affluence (or GDP per capita) in a given society, the greater the environmental impact - everything held constant. Across the OECD, there is considerable variation in GDP per capita, from a high of almost \$70,000 in Luxembourg to a low of just over \$10,000 in Turkey (Figure 4). In comparing Sweden with Canada, clearly both countries rank relatively high with Canada ranking slightly higher than Sweden (9th and 12th overall) Yet as aforementioned, the situation of Sweden is particularly unique, i.e. it has managed to achieve this relatively high level of affluence, by all international standards, while also maintaining a surprisingly low carbon footprint. Even further, without considering in detail how

¹ In providing some sense as to the impact of this economic downturn, our indicator of affluence (GDP per capita, in constant dollars) declined by roughly -4% in Canada over the 2007-2009 period and -7% in Sweden. This decline in GDP per capita actually occurred across 27 of the 30 OECD countries listed here, with a reduction of about -5% in GDP per capita for the OECD overall. At the same time, overall CO₂ emissions, after rising +17.4% over the 1990-2007 period, fell by roughly -8.5% across the OECD over the 2007-2009 period. In this context, it is far from certain as to how much of this decline was due to economic recession and a subsequent reduction in the demand for energy and how much was the result of successful initiatives to reduce GHG emissions more generally.

this wealth is shared or distributed within these OECD countries, on a general level, Sweden has experienced economic growth in a context of lower income inequality (true relative to both Canada as well as a majority of OECD countries).

As previously demonstrated (in Figure 1), the OECD’s wealthiest nation Luxembourg actually has the highest level of carbon emissions on a per capita basis, while the OECD’s poorest countries (Turkey and Mexico) actually have the lowest carbon footprints. Yet while affluence is typically associated with greater emissions, there are clearly some rather interesting exceptions to this general rule. For example, Norway, second only to Luxembourg in terms of GDP per capita, reports only about one third of its CO₂ emissions per capita (7.71 metric tons of CO₂ emissions per capita relative to 20.07 metric tons). As aforementioned, Sweden produced in 2009 less than one third of Canada’s CO₂ emissions per capita (4.48 metric tons per capita relative to 15.46 metric tons). Across the OECD, only two countries produce lower emissions on a per capita basis than Sweden, yet both are particularly poor by OECD standards (Mexico and Turkey).

Figure 4. GDP per capita across OECD countries, 2009



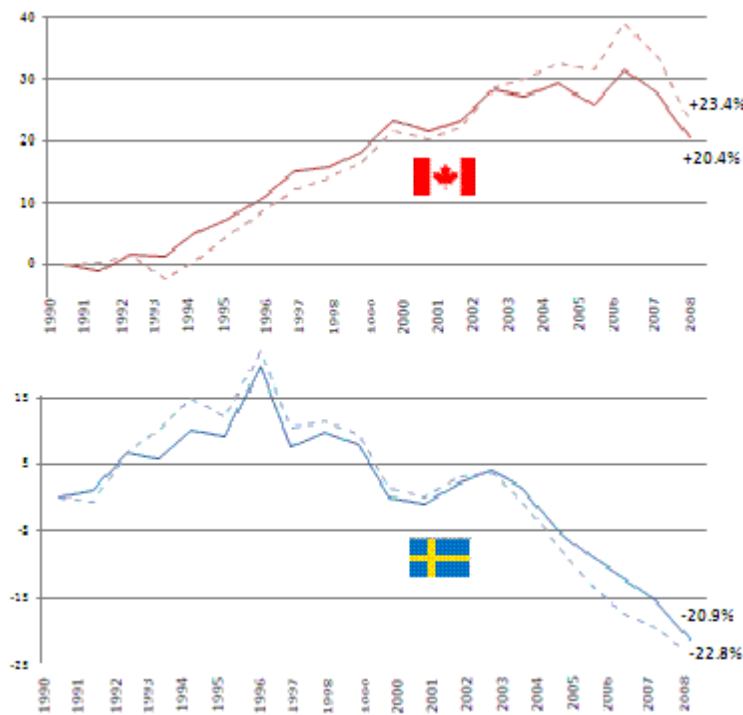
Source: UN Department of Economic and Social Affairs, Population Division, 2011; OECD, 2011

The OECD (2002) has used the term “decoupling” to refer to the breaking of the link between “environmental bads” and “economic goods”. In other words, while most affluent nations have relatively high carbon footprints, a few have managed to “decouple” somewhat their prosperity from this form of environmental impact. Typically, while population, economic growth and environmental impact tend to increase together, Sweden and a few other OECD countries have managed to remain relatively prosperous while at least partially “decoupling” economic growth

from CO₂ emissions. On the other hand, Canada's economy remains particularly carbon intensive, with both GDP per capita and total emissions up substantially over the last two decades.

With this in mind, we again repeat the same exercise as reported earlier with population growth, shifting our attention to differences in terms of affluence (A). More specifically, how might Canada's record on CO₂ emissions had differed with an increase in GDP per capita comparable to Sweden's (which was slightly greater than Canada's, at 31.1% relative to 27.9%), and vice versa, how might Sweden's decline in CO₂ be modified by a rate of economic growth comparable to Canada's. We again simplify things by making the implicit assumption that the other IPAT components have independent and proportional effects, and that over time, observed trends in population (P) and technology (T) remain unchanged from what was observed. As demonstrated in Figure 5, since our indicator of affluence (A) increased more rapidly in Sweden than Canada, then Canadian emissions would have been even higher under this scenario (up +23.4% rather than the observed increase of +20.4%) - whereas Sweden's success would have been even greater (down by -22.8% rather than the -20.9% as observed). To a certain extent, it would appear that the impact of demographic growth in comparing the two countries has at least been partially offset by differences in economic growth. Yet in terms of the substantial differences that remain, it is necessary to turn to other factors beyond affluence and demography, that is to the third component of IPAT, the technology component (T).

Figure 5. Growth in CO₂ Emissions in Canada and Sweden, 1990-2009, with Observed and Hypothetical Rates in GDP per capita



Source: Author's calculations

CO₂ Emissions and Technology

The technology component in IPAT is fundamental in better understanding current CO₂ emissions in both Canada and Sweden. As aforementioned, the technology component can be further delineated into four separate terms, including: (i) a fossil fuel intensity effect, (ii) a carbon intensity effect, (iii) a conversion efficiency effect, and (iv) an energy intensity effect. Prior to considering how these terms have changed over time, for Canada and Sweden separately, Table 1 summarizes how the two countries are currently performing on these four separate terms, again relative to all other countries within the OECD. Table 1 also provides the rank order of Canada and Sweden on each of these terms across the OECD, which theoretically at least, ranks countries from having the lowest environmental impact (rank 1) through to highest (rank 30). All figures are presented for 2009 while acknowledging that CO₂ emissions are down somewhat since 2007, due at least partially to the most recent global recession and economic downturn.

Fossil fuel dependency FOSS/TPES (2009)		Carbon Intensity CO ₂ /FOSS (2009)		Conversion effect TPES/TFC (2009)		Energy intensity TFC/GDP (2009)					
Rank		Rank		Rank		Rank					
1	Iceland	0.157	1	Norway	22.46	1	Luxembourg	1.09	1	United Kingdom	66.80
*	Sweden	0.327	2	Belgium	23.92	2	Austria	1.20	2	Ireland	70.02
3	France	0.510	3	Netherlands	24.21	3	Ireland	1.27	3	Switzerland	70.09
4	Switzerland	0.533	4	Iceland	24.31	4	Portugal	1.28	4	Greece	72.52
5	Finland	0.540	5	Mexico	25.74	5	Netherlands	1.30	5	Spain	74.25
6	Norway	0.588	6	Hungary	26.11	6	Denmark	1.31	6	Italy	77.69
7	New Zealand	0.637	7	Italy	27.03	*	Canada	1.31	7	Denmark	80.58
8	Slovak Republic	0.695	8	United Kingdom	27.11	8	Italy	1.31	8	Mexico	82.61
9	Austria	0.702	9	France	27.11	9	Turkey	1.33	9	Portugal	83.00
10	Belgium	0.736	*	1: Canada	27.35	10	Switzerland	1.34	10	Japan	83.70
11	Hungary	0.742	11	Korea	27.54	11	Finland	1.36		OECD EUROPE	84.24
*	1 Canada	0.749	12	Spain	28.04	12	Spain	1.37	11	France	84.55
	OECD EUROPE	0.760	*	1: Sweden	28.05	13	New Zealand	1.39	12	Germany	84.97
13	Portugal	0.780	14	New Zealand	28.23	14	Hungary	1.39	13	Norway	87.16
14	Germany	0.795	15	Portugal	28.26	*	1: Sweden	1.42	14	Turkey	87.37
15	Czech Republic	0.796		OECD EUROPE	28.32		OECD EUROPE	1.42	15	Austria	90.60
16	Spain	0.799		OECD	28.37	16	Germany	1.42	16	Australia	96.56
17	Denmark	0.804	16	Luxembourg	28.48	17	Norway	1.42	17	Netherlands	99.42
	OECD	0.809	17	Austria	28.52	18	Greece	1.43		OECD	99.62
18	Japan	0.810	18	Slovak Republic	28.54	19	Belgium	1.46	18	Poland	100.79
19	Korea	0.817	19	United States	28.55	20	Poland	1.46	19	Slovak Republic	103.15
20	United States	0.841	20	Japan	28.58		OECD	1.46	20	Czech Republic	106.41
21	United Kingdom	0.873	21	Ireland	28.97	21	United States	1.48	21	Hungary	106.51
22	Italy	0.875	22	Turkey	29.20	22	United Kingdom	1.49	*	2 Sweden	#####
23	Luxembourg	0.888	23	Switzerland	29.54	23	Japan	1.51	23	Luxembourg	106.84
24	Mexico	0.889	24	Germany	29.63	24	Slovak Republic	1.54	24	Belgium	112.20
25	Turkey	0.899	25	Finland	30.72	25	Korea	1.55	25	New Zealand	113.91
26	Greece	0.924	26	Denmark	31.29	26	Mexico	1.59	26	United States	115.75
27	Poland	0.928	27	Australia	31.93	27	France	1.60	27	Korea	118.80
28	Netherlands	0.931	28	Czech Republic	32.88	28	Czech Republic	1.63	28	Finland	148.46
29	Australia	0.944	29	Poland	32.88	29	Australia	1.69	*	2 Canada	#####
30	Ireland	0.950	30	Greece	33.18	30	Iceland	1.86	30	Iceland	259.24

Source: Author's calculations, IEA, 2011; UN, 2011

The “fossil fuel dependency effect” indicates the proportion of total primary energy supply obtained from coal, oil and natural gas. Across the OECD, there is a wide range in this

dependency on fossil fuels, from only 15.7% in Iceland through to fully 95% in Ireland. Sweden clearly fares extremely well on this indicator, with a very low level of dependency on fossil fuels (second only to Iceland at 32.7%), whereas Canada falls closer to other OECD countries on this front, with roughly three quarters (74.9%) of its primary energy supply obtained through the burning of fossil fuels. In terms of relative rank, Sweden ranks 2nd only to Iceland whereas Canada actually fares slightly better than most (with a rank of 12th overall across 30 countries).

While “fossil fuel dependency” is fundamental in understanding why Sweden’s per capita carbon footprint is so much lower than Canada’s (i.e. on the most basic level, Sweden is not nearly as reliant on fossil fuels), it does not explain why Canada’s carbon footprint is so high relative to elsewhere in the OECD. With regard to fossil fuel use, Canada is actually quite close to the OECD European average (76.0%), and in fact lower than its North American neighbors (in particular, its dependency is lower than for its major trading partner, the United States, which ranks 20th overall with 84.1% of its energy supply derived from either oil, coal or natural gas). Sweden (along with Iceland) are clearly the outliers on this component, whereas Canada is much closer to where other OECD countries cluster (for example, only 8 of the 30 OECD countries as listed in Table 1 fall below 70% on this index). As will be discussed below, Canada has actually invested more than most in the development of both hydroelectricity and nuclear energy in meeting its domestic needs.

In terms of the second technology term, the “carbon intensity effect”, Canada is no worse than most OECD countries (rank 10th), which is not only lower than the OECD average but also slightly lower than Sweden’s (rank 13th). While Canada does use coal, primarily in the generation of electricity, it is not nearly as reliant on this energy source as in other countries (as for example, only 16% of Canada’s electricity comes from the burning of coal relative to 45% in the United States). As the ratio of CO₂ emissions to total fossil fuel combustion, Canada’s 2.735 Mt of CO₂ per Mtoe of energy is lower than the OECD’s average of 2.837, just as Sweden’s “carbon intensity” is also slightly better than this average, at 2.805 MT of CO₂ per Mtoe of energy consumed. A large proportion of fossil fuels consumed in Sweden are used in the transportation sector of the economy (oil and diesel), whereas Canadians use fossil fuels for a wider variety of uses, both in terms of the generation of electricity, household consumption and the widespread use of natural gas in the heating of homes as well as industrial and commercial uses. In trying to explain why Sweden’s carbon footprint is so much lower than Canada’s, this “carbon intensity effect”, in isolation, does not appear to be particularly important.

With regard to the third technology component (i.e. the conversion efficiency effect”), Canada’s rank of 7th is again better than most – with its ratio of primary energy supply to final consumption (1.31) lower than what is observed in Europe (1.42), for the OECD overall (1.46), as well as Sweden (1.42) – albeit the differences as observed are not large. Sweden is near the middle of the pack in the OECD, with a slightly lower ratio of primary energy supply relative to final energy consumed. Sweden does not perform as well on this indicator as does Canada (15th relative to 7th overall), although the consequences in terms of CO₂ emissions are not great – relating back to the simple fact that Sweden overall burns much less fossil fuel relative to most countries. This ratio is slightly higher in Sweden given its reliance upon certain non-conventional energy sources,

including the burning of peat and biomass (including wastes from agriculture, their forests and forest industries). Interestingly, across all OECD countries, Iceland actually ranks the highest on this component (30th overall) given the conversion effect associated with geothermal energy, while this has in turn a negligible environmental impact. In contrast, the consequences in terms of CO₂ emissions and environmental impact are most serious in those countries that continue to rely heavily on fossil fuels, often with rather inefficient and dirty conversion technologies (consider the many coal fired power plants in Central and Eastern Europe for the generation of electricity).

While Canada's record does not depart significantly from most other OECD countries on the first three technology terms, it is with the 4th term – the energy intensity effect – that Canada's performance differs most dramatically (rank 29th across 30 OECD countries). This fourth technology term is merely total final energy consumption relative to the total size of a given economy, with the Canadian ratio substantially higher than the OECD average (166.73 Mtoe/\$US billion relative to 99.62). Whereas Sweden is clearly an outlier with regard to the first technology component (i.e. rank 2nd, with a much lower environmental impact due to low fossil fuel dependency), Canada is clearly an outlier on this 4th term (i.e. rank 29th, increasing Canada's environmental impact due to the high level of energy consumed).

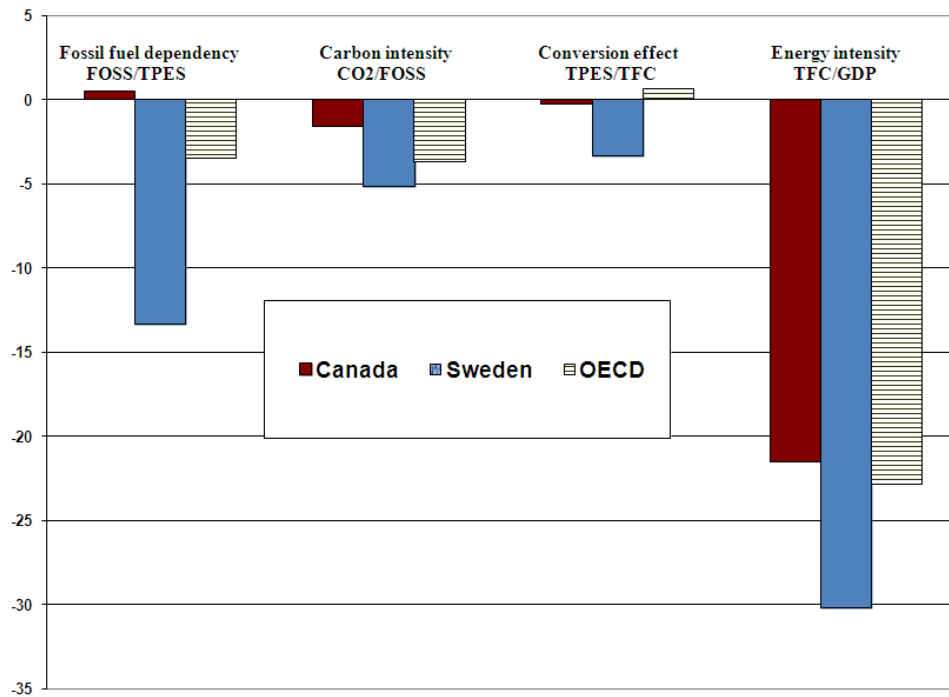
A country's performance in terms of energy intensity reflects both investments in energy efficiency as well as the nature of economic activity and economic structure. Both Canada and Sweden have resource based economies that are highly export oriented (Canada to the U.S. and Sweden to other parts of Europe). By both OECD and global standards, Canada's energy use is very high - a simple observation which we shall return to in the concluding discussion and summary. Yet Sweden also uses considerable energy in driving its economy, without the comparable environmental impact (rank 22nd – 106.53 Mtoe/\$US billion). On this index, Sweden is actually closer to the United States (115.75 Mtoe/billion) than it is to most other European countries (OECD Europe reports an average of 84.24 Mtoe/billion).

The simple fact that Sweden has managed to move away from fossil fuels whereas Canada has not - is a large part of why the two countries are almost at opposite extremes in terms of per capita CO₂ emissions. In demonstrating this simple fact, it is useful to consider these same four technology components, yet shifting our emphasis to the change as observed over the 1990-2009. Figure 6 returns to these technology terms, yet this time presenting “percentage change” for Canada and Sweden separately, relative to what has been observed for the OECD overall. Briefly, in terms of all four technology terms, it is striking how Sweden has managed to reduce environmental impact whereas Canada has lagged behind.

Overall emissions are down in Sweden despite both population and economic growth. This achievement can be explained by a reduction across all four technology components: by reducing its fossil fuel dependency (-13.3%), the carbon intensity of its fossil fuels used (-5.2%), its losses through energy conversion (-3.4%) as well as the energy intensity of its economic activity (-30.2%). Canada, while also making gains across 3 of the 4 technology terms, did so much less than either Sweden or the OECD in general: with fossil fuel dependency up slightly (+0.5%), carbon intensity down slightly (-1.6%), negligible change in its conversion effect (-0.2%), and a decline in energy intensity (-21.5%). Systematically, for all four technology

indicators, Sweden's performance has been superior to Canada's, just as the Sweden experience compares favorably with the rest of the OECD. Canada, on the other hand, has not only lagged behind Sweden, but also the OECD average - with the sole exception of its conversion effect whereas the OECD overall witnessed a very small increase (+0.598).

Figure 6. Percentage Change in the Technology Components (1990-2009), Canada, Sweden and the OECD Total



Source: author's calculations

Discussion

In explaining Canada's high carbon footprint, of fundamental importance is the simple reality that Canada is a resource rich country with major reserves of fossil fuels, a situation that it shares with its North American neighbors, the United States and Mexico. This has arguably left it "without" the same sorts of incentives to move away from fossil fuels as is observed elsewhere. While Canada is a resource rich country, with major reserves of coal, natural gas and oil (including both conventional and oil sands reserves), it is certainly far from fully exploiting these resources. Much of existing production of fossil fuels is currently generated for export, with net exports currently equivalent to roughly 1/10th, 1/3rd and 2/3rds of total domestic production of coal, crude oil and natural gas, respectively.

Governments and industry in Canada continue to encourage growth in the Canadian energy sector, with investments producing an expanding supply of fossil fuels, for both domestic

consumption and export. Of particular importance in Canada has been ongoing efforts to expand access to major reserves of bitumen in western Canada (oil sands), with total production already reaching 47% of Canadian petroleum production in 2007 (Government of Alberta, 2008). Oil sands extraction is more environmentally damaging than conventional crude oil, with much higher energy demands and significant water requirements in moving from the well-to-pump. Fossil fuels are used in extracting and upgrading bitumen reserves into synthetic crude, with roughly one barrel of oil equivalent of energy required to produce 5-6 barrels of oil for the market (National Energy Board, 2006). Canada's willingness to satisfy burgeoning North American energy demands (as now the largest exporter of crude oil to the United States) has only added to the energy intensity of Canadian industry and compromised the country's ability to meet its climate change commitments. As summarized by Harper and Fletcher (2011), there are few regulatory limits on fossil fuel consumption and emissions in those sectors most responsible for GHG emissions, including transportation (25%), fossil fuel development (19%), electricity generation (17%) and industrial activities (15%).

Of importance in the Canadian context has been the implementation of the North American Free Trade Agreement (NAFTA) which has had a dramatic impact on the Canadian economy. Canada has become increasingly a part of the continental energy market, with high levels of foreign ownership and constrained governmental policy flexibility. On a deeper level, in both Canada and the United States, energy use remains very high in an energy policy context of relatively low taxes (in contrast to OECD Europe) and low energy prices.² In the North American context, lower taxes on energy (relative to elsewhere in the OECD) are responsible for relatively low prices for both consumers and industry, which have arguably undercut some of the potential for conservation, with fewer incentives to increase efficiencies. In addition to fossil fuel, Canada's export oriented economy is particularly energy intensive, as it produces far more than its population would suggest; Canada currently produces over 10% of the world supply of aluminum, 5% of its copper, 9% of gypsum, 12% of nickel, 15% of wood pulp, 23% of newsprint and almost about 30% of the world's supply of potash fertilizers – all for a country that has less than 0.5% of global population (Environment Canada, 2006). As all of these industries are particularly energy

² The IEA (2011) produces summary statistics on the cost of energy, allowing for systematic comparisons across the OECD. In drawing international comparisons, the price of gasoline has been lower in Canada than in any other OECD country (with the exception of the United States and Mexico) for well over a decade. Similarly, Canadian electricity prices have consistently been second lowest only to Norway, while the price of natural gas demanded of Canadian households and industry has consistently been second lowest only to Finland. In reviewing IEA data, countries with higher prices – which clearly would include Sweden - also tend to consume less, an observation often raised by environmentalists in advocating carbon taxes in order to reduce environmental impact.

intensive, production of these commodities contribute significantly to a very high demand for energy.

Sweden is in a very different situation in terms of energy resources, i.e. it has long been reliant upon others in meeting its demand for oil and natural gas. As it is almost completely reliant on imports in meeting this demand, in response to scarcity, it has developed alternatives, as it first produced hydroelectricity in a major way during the early 20th century (benefiting from a geography and topography that allowed for it) and since the 1970s, nuclear energy. In combination, these two energy sources provide for almost 90% of Sweden's electricity supply, with the remainder produced by either the burning of fossil fuels, and/or other non-conventional energy sources, including wind and bio-energy, and to a very limited extent, solar cells, wave energy and geothermal. One can only speculate as to how Sweden's record might have differed had it been in a similar situation to Canada, i.e. with major fossil fuel reserves. While Sweden can be credited for being politically committed to reducing its carbon footprint, its relatively favorable record at least partially relates to the necessity of seeking out alternatives to fossil fuels in the absence of domestic supply.

There is little disputing the fact that North Americans use a great deal of energy, and that the typical Canadian uses more energy than the typical Swede (although this difference should not be overstated or exaggerated). North Americans tend to drive less fuel efficient vehicles and drive them further, live in larger homes and heat them more, and work in buildings that use more energy than do Europeans (Environment Canada, 2006). In terms of Canada's particularly heavy energy use, at least part of this situation relates to the simple fact that its climate is among the coldest in the OECD, requiring far more heating days than most other countries. Yet this is a situation that it shares with Sweden among other northern Scandinavian countries. While average winter temperatures are roughly the same in Toronto and Stockholm, Sweden has been innovative in reducing its demand for energy, with major infrastructure investments in "district heating" and "heat co-generation". Sweden also faces lower energy demands than Canada in terms of transportation, with a smaller landmass and greater population densities (toward the south of the country) with major investments in both public transit and rail. Canada is a particularly large country (second to only Russia), which in combination with low overall population density serves to increase the costs and energy required in transportation. The distances travelled in Canada in moving both freight and people tends to surpass those as observed in most much smaller European countries, including Sweden (MKJA, 2005). In turn, the transportation sector –both personal and freight - is responsible for a large proportion of Canada's energy use – reported at roughly 29% of total secondary energy use in 2007 (NRC, 2010). In Sweden, the comparable figure for transportation is roughly 24% (European Commission, 2007).

Canada uses more energy (per unit of GDP) than practically any other country in the OECD, i.e. Iceland is the only country with a higher energy intensity as of 2009. In many respects, it is Iceland rather than Sweden that is the most atypical country in the OECD - this small North Atlantic country that hovers the Arctic Circle has managed to navigate into the 21st century with an economy that is even more energy intensive than Canada (30th in the OECD), while simultaneously having a modest environmental impact. As was the case with Sweden, this country

is atypical in terms of the (T) component in IPAT, or more specifically, its reported “fossil fuel dependency” is very low. Iceland located along the mid Atlantic ridge in a highly geologically and volcanically active location has managed to exploit an abundance of geothermal energy, using technologies that tap into this primary energy source with negligible environmental effect. The crux of the matter for Iceland is its abundant, almost unlimited amount of geothermal energy. The crux of the matter for Sweden is its shift away from fossil fuels through the development of both nuclear and hydro electricity. The crux of the matter for Canada is that it continues to rely on fossil fuels in a context of high energy use. While all three societies have relatively high demands in terms of energy (true by both OECD and world standards) in a predictable manner, it is Canada that has the particularly poor record on CO₂ emissions (both overall and on a per capita basis).

While Sweden’s economy uses less energy than Canada’s, somewhat surprisingly, its energy intensity is actually greater than most OECD countries (as aforementioned, Sweden’s rank of 22nd is actually not too far from Canada’s rank of 29th overall). The Swedish economy also has an important resource sector that uses heavy energy input in the production of timber, mining and iron ore, among many other basic commodities. Sweden’s manufacturing sector is relatively important, although like in Canada, the overall proportion of Swedes employed in this sector has been steadily declining. In terms of overall energy use, Sweden’s energy intensity (106.63 Mtoe/billion) is actually higher than the OECD average (99.62 Mtoe/billion), and substantially higher than OECD average for Europe (84.24 Mtoe/billion).

In suggesting the importance of the technology component, Sweden’s energy intensity is near identical to Luxembourg’s (106.84 Mtoe/billion), a country which is actually the OECD’s worst performer in terms of CO₂ - with per capita emissions that are more than 4 times the levels recorded in Sweden. While Sweden has been at the forefront in terms of environmental initiatives and eco-innovation, it would be a misrepresentation to indicate that its environmental impact is low due to low energy consumption. While there are clearly important differences in political culture across OECD countries, including greater support for environmental initiatives in Sweden than elsewhere, it would be somewhat simplistic to try to explain differences in overall CO₂ emissions exclusively through individual consumption patterns and life style choices. More basic in this context are observed differences in economic structure along with some rather dramatic differences in terms of “energy supply”. Consumption patterns are not that dramatically different in comparing Canada with Sweden (consumers in both countries have a very high standard of living by both OECD and global standards, as maintained by a high demand for energy). Yet Canada’s exports are more energy intensive than are Sweden’s, while it continues to heavily rely on fossil fuels in driving its economy.

There are certainly other economic and political factors, not easily operationalized in the context of the current decomposition that should at least be briefly raised in this attempt to explain differences as observed between Canada and Sweden. In particular, when it comes to explaining recent trends in CO₂ emissions, it is useful to highlight a few concurrent economic trends, including the increased globalization of trade, with the corresponding interconnectedness of national economies and peoples. With the decline in manufacturing across many western economies, other economies (e.g. China, India, Brazil) have corresponding increased economic

activity in the production of these same manufactured goods. This shift in the location of manufacturing has been driven by a wide assortment of factors, including the cost of labor, without a comparable shift in terms of where these same goods are consumed. As China has recently surpassed the United States as the world's largest emitter of CO₂, it is difficult to ignore the simple fact that much of what is produced in China is produced for export. The increased interconnectedness of the world economy further complicates an analysis of consumption and environmental impact.

As Davis and Caldeira (2010: 5687) point out, "much attention has been focused on the CO₂ directly emitted by each country" (i.e. what is referred to as "production based" inventories), which in fact has been the primary emphasis of the current paper, in the application of the IPAT accounting framework. This is also the convention followed by most international organizations concerned with charting recent trends in energy use and CO₂ emissions. For example, national inventories are published annually by parties subject to the UN Framework Convention on Climate Change, in order to document the progress or lack thereof for member states in meeting international commitments. Alternatively, it is pointed out that "relatively little attention has been paid to the amount of emissions associated with the consumption of goods and services in each country, regardless of where the goods might have been produced" - i.e. a "consumption based" accounting of CO₂ emissions. This is considered important as the record of many countries is blemished to a certain extent - when looking beyond the CO₂ produced within their borders to that which is produced elsewhere, in the production of goods that are eventually consumed domestically through imports.

Davis and Caldeira documented that while the Swedes can be credited for their commitment toward reducing CO₂ emissions within their boundaries, a substantial proportion of what is consumed in Sweden is actually produced elsewhere, with substantial CO₂ emissions associated with these imports. Davis and Caldeira have estimated that Sweden, like much of Western Europe, is clearly a "net importer" of CO₂ whereas Canada is a modest "net exporter". Briefly, some countries (like Canada) can be thought of as "net exporters of CO₂" as they produce more emissions in the extraction and production of goods for export than they do indirectly through the consumption of goods produced elsewhere (emissions embodied in imports). Other countries (like Sweden) can be thought of as "net importers of CO₂" as they produce fewer emissions in the production of goods for export than they do in the consumption of goods produced abroad yet consumed domestically.

More specifically, Davis and Caldeira estimate that Sweden is responsible for almost as much CO₂ produced outside of its border in meeting its national needs as it actually produces within its borders i.e. roughly 40% of all the emissions associated with Swedish consumption are associated with "net imports". While Canada likewise imports CO₂ emissions, its exports an even larger amount - such that about 5% of total emissions are associated with "net exports". As a result, roughly one-half of the original discrepancy between Canada and Sweden disappears when we shift from the current "production based" accounting of CO₂ to the alternative "consumption based" accounting framework. In a sense, it is not so much that Canada's record is that much better when we consider the impact of international trade (i.e. per capita emissions are only

reduced modestly), but alternatively, that the emissions associated with most of the OECD looks that much worse.

Summary

We have applied the IPAT model to both Sweden and Canada, in an effort to better understand some of those factors most responsible for their divergent records on CO₂ emissions. As aforementioned, total CO₂ emissions produced in Canada have risen by roughly +20% over the 1990-2009 period whereas Swedish emissions have declined by roughly the same percentage (-21%). Sweden's success in this context clearly relates to the progress it has made in terms of reducing environmental impact across all four technology terms defined above, i.e. it has reduced its fossil fuel dependency, carbon intensity, conversion losses and energy intensity. On the other hand, Canadian emissions have continued to rise in a context of rapid demographic and economic growth, without the same sort of success on these same technology terms.

Canada's population continues to grow at a relatively robust pace - up by 21.6% over the 1990-2009. Sweden has not experienced nearly the same sort of demographic pressure, with its population up by 8.8% over this same period. In a general sense, Canadian society is committed to continued demographic growth, with wide popular support for current immigration and multicultural policy. While Sweden also relies upon immigration in maintaining its population, it does not receive nearly as many immigrants as Canada, as is the case with much of Western Europe. The question that was been raised in the context of the current paper is "to what extent the Canadian and Swedish records on CO₂ emissions have differed as a result of demography"? While admittedly the impact of population growth on CO₂ emissions is not necessarily straight forward, there is little disputing the simple fact that increased population implies increased consumption, with a corresponding environmental impact.

The obvious by-product of this demographic reality is that Canada must achieve greater reductions in per capita emissions in efforts to achieve its international commitments whereas Sweden does not have the same sorts of demographic pressures. In a sense, GHG emissions as associated with specific source countries (i.e. countries witnessing much emigration) are shifted to their respective countries of destination (countries witnessing much immigration). Population growth, as increasingly driven by the movement of peoples across international borders, is relevant in explaining why some countries in the OECD have had greater success than others in meeting international commitments. Yet the net impact on global emissions is much the same, unless levels and patterns of consumption change dramatically after migration from one country to the next.

The OECD (2002) has used the term "decoupling" to refer to the breaking of the link between "environmental bads" and "economic goods". Typically, while population, economic growth and environmental impact tend to increase together, a few OECD countries, including Sweden, appear to have at least partially "decoupled" economic growth from CO₂ emissions. As portrayed in the current paper, most countries in the OECD have experienced considerable economic growth over the 1990-2009 period, and more specifically, GDP per capita has gone up

considerably (for example, by +27.9% and +31.1% in Canada and Sweden, respectively). Yet while the Swedes can be credited for their ability to reduce CO₂ emissions in this context, there are certainly complicating factors that blemish its environmental record. By ignoring the “consumption based” accounting of CO₂ emissions, the impact of climbing affluence (A) in specific countries can be misstated to an uncertain extent, i.e. there is considerable evidence to suggest that it is understated in the context of Sweden, and conversely, modestly overstated in Canada.

Globalization involves the continued expansion of international trade, through reduction of barriers and restrictions on the movement of capital and on investment. In this context, the Swedish government has recently committed itself to be completely “oil free” by the year 2020, anticipating a continuation of the progress achieved over the last several decades in reducing its dependency on fossil fuels. In direct contrast, the Canadian government is actively encouraging investment and export of crude oil to the United States, among other commodities. Even further, the Canadian government is promoting a diversification of markets for its oil beyond the United States, as for example, it is now actively promoting the construction of a major pipeline to the Pacific coast – with a direct targeting of Chinese among other Asian markets. In an obvious manner, Canada now seems positioned to become an even greater exporter of CO₂ emissions. There is little disputing the fact that Canada and Sweden appear to be moving in opposite directions – one toward a low carbon future (within its own borders) while the other shows no hesitancy in meeting an insatiable international appetite for fossil fuels. In this context, the IEA forecasts continued economic growth throughout the OECD, with a continued increase in the demand for energy.

While most countries in the OECD have managed to reduce the energy intensity of their economies (a situation which is also true of Canada), economic and demographic growth has typically more than not offset the progress made on this front. This has been particularly true when little progress is made in terms of reducing the carbon intensity and/or fossil fuel dependency of our economies. This has been true of Canada, as it has been true of a majority of OECD countries (fully 19 out of 30 experienced an increase in overall emissions over the 1990-2009 period). While the energy intensity of Canada’s economy declined somewhat, it actually lagged behind most OECD countries on this front, and remains one of the most energy intense economies in the world. As the Canadian geographer, Vaclav Smil (2010:149) has recently highlighted in reviewing the many myths and realities of energy use, both in Canada and internationally: “A world without fossil fuel combustion is highly desirable, and, to be optimistic, our collective determination, commitment, and persistence could accelerate its arrival. But getting there will be expensive and will require considerable patience. Coming energy transitions will unfold, as past ones have done, across decades, and not years”.

As argued here, the IPAT model is simple, robust and useful as a framework for research, as an elegantly simple way of illustrating different but related dimensions of environmental impact: as functions of the number of people, the technologies they employ to produce goods, and the amount of goods they consume. While the emphasis on a “production based” inventory has its problems, the analysis does provide insight as to how different OECD countries have performed in

terms of CO₂ emissions over recent years. Yet there are certainly limits to the IPAT equation, as for example, this model constrains a priori the effects of each component to be proportional. With this in mind, there have been important revisions of IPAT, as for example, Dietz and Rosa (1994) have reformulated this environmental accounting equation into stochastic form, meant to alternatively estimate the net effect of specific drivers, while also holding the potential for inclusion of theoretically relevant variables including political, social and cultural factors. While IPAT is particularly useful on a descriptive level, there are analytically complex models that hold considerable promise in terms of nomothetic explanation. York, Rosa and Dietz (2003) have provided a particularly useful overview of some of the options available in this regard, in terms of analysis and hypothesis testing, in efforts to more precisely specify the sensitivity of environmental impacts to the forces driving them. Davis and Caldeira's (2010) emphasis on consumption over production in the accounting of CO₂ hints at the potential for further methodological innovations in disentangling the complex relationship between population and environment, all in a context of globalization.

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