Energy Price-Differentials and Canada-US trade

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ABSTRACT: 156 words

The factor content theorem suggests that higher energy prices will reduce exports of more energy-intensive goods while simultaneously raising exports of less energy intensive sectors. The suggestion is that climate based regulations, such as carbon taxes, will impact the trade-competitiveness of energy-intensive industries. Following Sato and Horbach (2012), I test this using gravity equations by looking at energy prices, both electricity and natural gas, and trade between Canadian Provinces and US States for the period 1997-2008 for 29 three-digit NAICS merchandise sectors.

I find that, in general, electricity prices are not correlated with province-state trade along any dimension. However, natural gas prices do matter in the way we expect. I find that higher natural gas prices in a jurisdiction reduces the volume of exports. Beyond this volume effect, we get an additional compositional effect in that, indeed, higher natural gas prices lead to lower embodied energy in trade and a shift towards less energy intensive sectors.

1 INTRODUCTION: last modified May 02

Industries targeted by national greenhouse gas initiatives have raised concerns about their ability to compete in international markets given competitor nations have not implemented such policies. One response, such as the proposed Waxman-Markey Bill, has been to treat these sectors preferentially by exempting them from some or all regulations, offering explicit and/or implicit financial support, or offering protection from foreign competition.

However, not all sectors will necessarily suffer as they may be able to pass on costs through higher prices, pressure input suppliers for lower input costs, invest in new technologies that abate pollution easily, or have sufficiently profitable operations that they can absorb some moderate additional costs.

From a public policy perspective, the challenge is to assess whether their concerns are warranted and, if so, what to do about it. We need to know which sectors are likely to be affected, in what way, and by how much. From a researcher's perspective, the challenge is to find a counter-factual; what will happen if a carbon policy is implemented given we have little experience or data to evaluate them.

One way to identify the impact of potential GHG regulations is to look at previous trade performance under some other cost shock/regulation. For instance, if a new regulation reduces exports (or raises imports) in a sector, then the regulation would be deemed to hurt international competitiveness. If trade is unaffected, then it appears that firms in the sector are capable of absorbing those costs. The smaller the impact on trade, the better able the firms are to manage the impacts in one or more of the ways noted above.

My plan is to identify a 'natural experiment' that would be expected to impact costs differentially across sectors and then to see whether we can discern any significant trade-induced effects. If we do, then environmental regulations may be expected to have similar impacts.

My natural experiment, following the lead of Sato and Horbach (2012), is to look at existing energy price-differentials between US States and Canadian Provinces. Sato and Horbach consider trade among 30 countries and find small but statistically significant effects of differential electricity prices on trade. Their idea is that energy-intensive sectors will be more sensitive to increases in electricity prices-differentials and may be more willing to locate production to low price jurisdictions (see Khan and Mansur 2013 who look at US county data). Since US states and Canadian Provinces differ markedly in average energy prices (see the section below), we could expect to see production move both within

Canada, between, and across US states. This shift in production should be mirrored in trade patterns and flows which we can observe.

An alternative approach would have been to look at some existing environmental regulation such as the Sofia Protocol or Greenhouse Gas Measures. However, using energy prices offers particular empirical advantages. First, measuring the intensity of environmental regulation is difficult since there is not always a simple metric. Energy prices offer a ready-made price metric. Second, energy prices differ significantly across jurisdictions so provides good cross-sectional variation, something that may be difficult to assess for international treaties. Third, sector specific energy intensities and measures of reliance on energy provide sectoral variation that also vary across jurisdictions. Fourth, energy prices are likely exogenous to a particular industry whereas many environmental regulations account for sectoral characteristics and can make regulatory stringency endogenous.

Looking at CAN-US trade pattern is relevant to current Canadian and US regulations. The US is Canada's largest trading partner by far. Similarly, Canada is also the largest trading partner for many US states. Our trading relationship is longstanding, stable, and broad based. We share excellent trade infrastructure with low formal and informal barriers to trade. Cross-border investments are also strong. If you were going to find trade inducing effects from energy prices, you should find it here. That is, even small differences in sectoral costs across North American jurisdictions can play out in the observed pattern of trade. These small differences may not be important in a global context since transportation and other formal and informal barriers to trade could mask small cost difference.

Further, the Canadian Environmental Protection Act, through equivalency agreements, allows provinces to implement regulations differently (at least to some extent). Hence differences across provinces could emerge even within federal regulations. So a provincial analysis is warranted in addition to looking at Canada as a whole. The US federal system also allows for state-specific responses as well. For instance, the Clean Air Act forces responses at the county level.

I use a gravity equation of the 50 bilateral Province-State imports and exports for the period 1997-2008 to identify the elasticity of exports with respect to energy prices. I regress aggregated exports, embodied energy exports, and disaggregated sectoral exports using 29 three-digit NAICS merchandise goods sectors to identify whether energy prices affect the value and/or composition of goods trade. I consider both electricity and natural gas prices for industrial users as drivers. I use a Tobit regression with clustered standard errors clustering on Province-State pairs to account for the large number of zero-trade observations in bilateral sectoral trade.

I find that, in general, electricity prices have no discernable effect on bilateral Province-State trade. However, I do find that natural gas prices have significant effects. These effects are consistent with theory and show a coherent pattern. Higher natural gas prices in a province or state will reduce their value of exports, measured in nominal dollars, reduce the volume of embodied energy flows, measured in GJ, and shift the composition of exports towards less energy-intensive goods.

The layout of the paper is as follows. Section 2 looks at province-state energy prices. Section 3 looks at sectoral energy intensity. Section 4 considers energy embodied in province-state trade. Section 5 uses Tobit regressions to identify whether energy prices are systematically correlated with the volume of trade, embodied energy in trade, and the composition of trade. Section 6 finishes with a discussion of the results.

2 Energy Prices by State and Province:

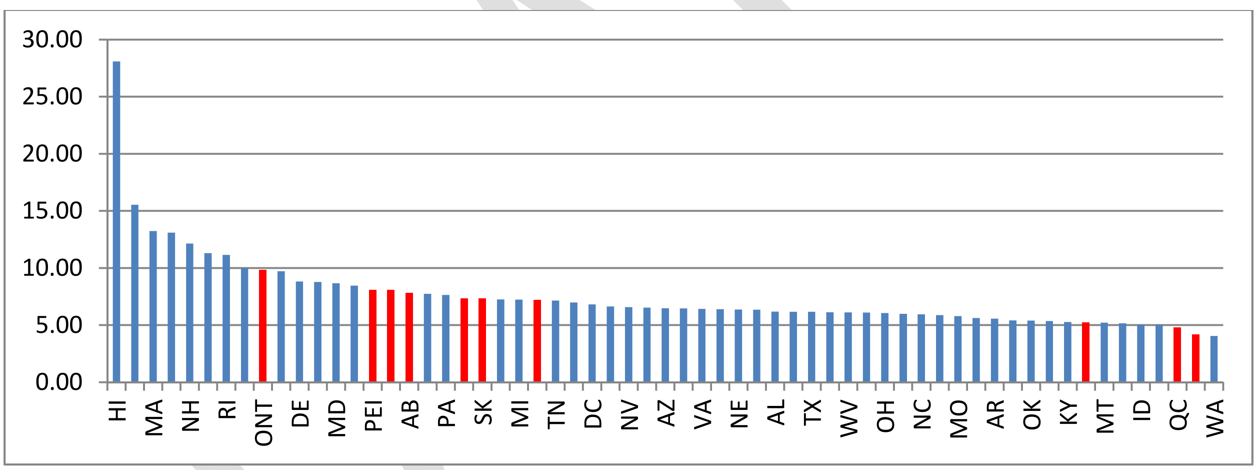
2.1 Prices

Both electricity and natural gas prices differ markedly across provinces and states.

Canadian electricity prices comes from Hydro Quebec which reports prices for some North American cities in ¢ per kW for large power consumers (over 5000kW with 85% load factors). I then use provincial electricity index from Statistics Canada to impute the electricity price for each province[1] for industrial consumers over 5000kW for 1983-2013.

For the US states, the EIA reports average industrial electricity prices for all the US states. Converting to Canadian dollars allows us to compare state and province prices directly. Figure 1 shows this comparison of state and provincial electricity prices for 2011. The average price in the US states is slightly above that in Canada and has a higher dispersion (even if we eliminate Hawaii). It is this difference in the state/province prices that could drive energy intensive sectors to low price jurisdictions.

FIGURE 1: Electricity Prices by State and Province 2011 (¢per kW, 5000kW usage)



Sources: Hydro-Quebec (2011) "Comparison of Electricity Prices in Major North American Cities"
Statistics Canada Table 329-0050 Electric power selling price indexes (non-residential)
EIA http://www.eia.gov/electricity/data/state/

Though relative price rankings from year to year are fairly stable within Canada and within the US, there are some significant changes that take place over time across provinces and states. For instance, in 2000, Alberta had one of the lowest prices (60th) but by 2011 was ranked 13th highest. Nova Scotia also went from 40th to 12th. Prices in the Southern States tended to fall relative to the north. For

[1] Statistics Canada does not report a price index for PEI. I assume the price index is the same as Nova Scotia though benchmark prices will differ since we do have data for PEI in 2011.

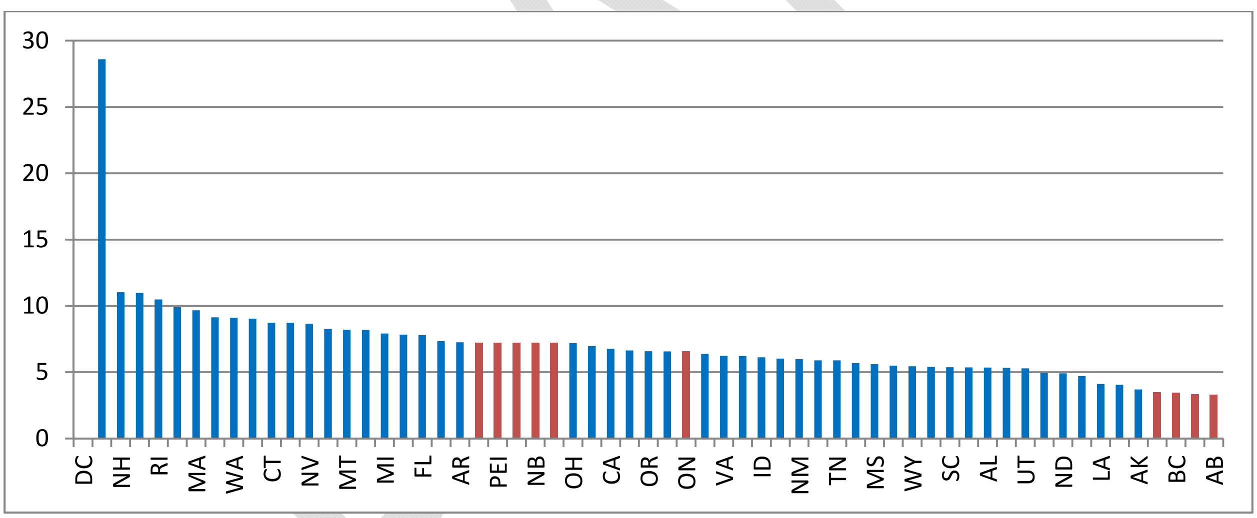
instance, Louisiana fell from 15^{th} to 54^{th} while New Mexico fell from 23^{th} to 40^{th}. This change in rankings reflects differences in electricity price inflation, overall price growth, as well as exchange rate changes.

Like electricity prices, natural gas prices differ markedly between provinces and US states. Data for Canada comes from Statistics Canada. However, because Atlantic Provinces do not have a broad distribution of natural gas, I assume they have the same price as Quebec. US data comes from the EIA and converted from $US in cubic feet to $CAN in million BTU.

Figure 2 shows this comparison of state and provincial natural gas prices for 2011. As with the price of electricity, there is a broad range of prices across states and provinces. The average price in the US states 4.90 $CAN per million BTU. This is close to the average in Canada though the 4 Western provinces recorded the lowest prices in 2011.

The rankings for Electricity prices are quite different for the most part from that for Natural Gas though States/Provinces with high electricity prices tend to have higher than average gas prices. However, the correlation is only 0.36 (excluding Hawaii) for 2011 suggesting that the two energy markets are not that closely linked.

FIGURE 2: Natural Gas Prices by State and Province 2011 ($CAN per million BTU ≈ $CAN ft^3)

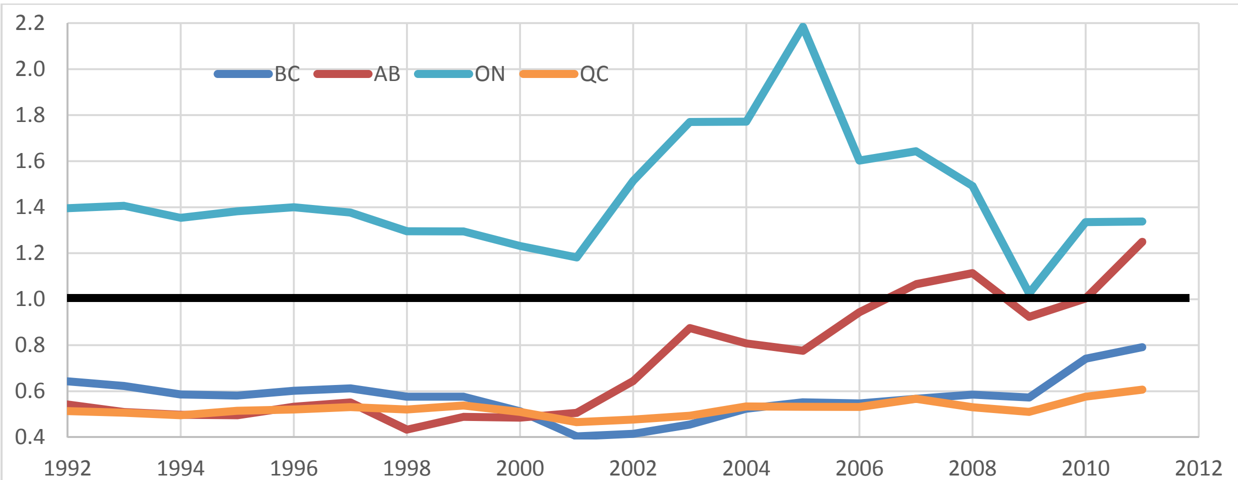


Sources: Statistics Canada Table 129-0003 - Sales of natural gas, monthly
Energy Information Administration, Natural Gas Prices

2.2 Trade Weighted Average Prices

One way to compare province and state prices is to look at a trade-weighted average price. In the figures below, I show the average price for each province relative to the average price of their US state counterparts using provincial exports as weights. I show only 4 provinces: Ontario, Quebec, Alberta, and British Columbia

FIGURE 3: Trade-weighted average Electricity price by Province 1992-2011

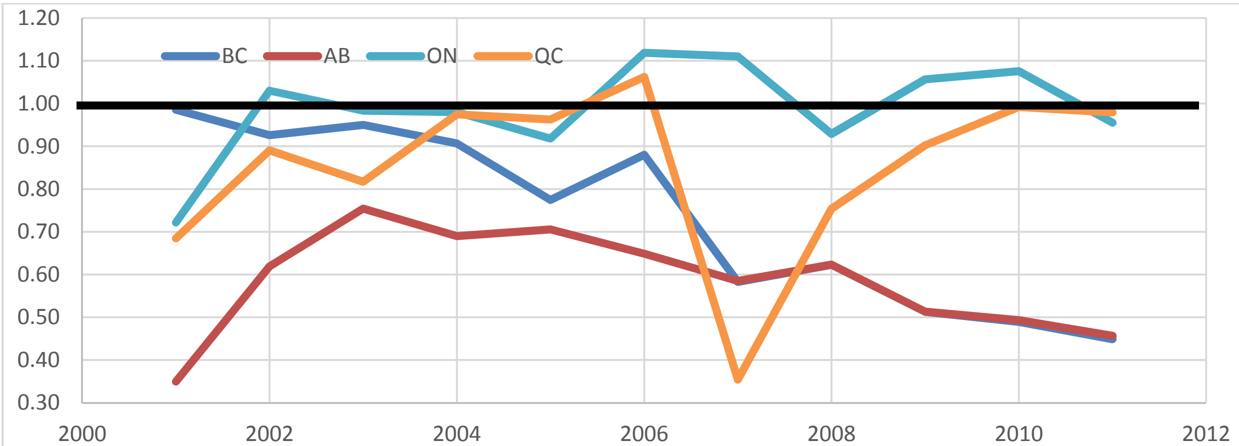


Sources: Hydro-Quebec (2011) "Comparison of Electricity Prices in Major North American Cities"
Statistics Canada Table 329-0050 Electric power selling price indexes (non-residential)
EIA http://www.eia.gov/electricity/data/state/
Industry Canada Trade by Sector

The data show that, on average, Ontario's industrial electricity prices are systematically higher than their major US state trading partners. Ontario prices are, on average, about 20-40% higher than US counterparts but with significantly higher prices in the mid-2000s. Most provinces have lower electricity prices than their American counterparts. For instance, Quebec's prices are less than 60% of those in the US. Alberta now has electricity prices close to the American average though they were significantly lower in the early 1990's.

We can do the same thing for Natural Gas though US price data limits us to 2001-2011 comparisons. As with electricity prices, Canadian provincial prices tend to be lower than their US counterparts. The exception is Ontario with prices slightly higher than US prices while Quebec prices are on par. In western Canada, natural gas prices are lower than US prices and tending lower through to 2011.

FIGURE 4: Trade-weighted average Natural Gas price by Province 2001-2011



Sources: Statistics Canada Table 129-0003 - Sales of natural gas, monthly
Energy Information Administration, Natural Gas Prices
Industry Canada Trade by Sector

It is these differences between provinces that I will exploit in the regression analysis. The idea is to see if these observed differences in provincial-state prices can explain the pattern and volume of trade between US states and Canadian provinces. For instance, do low electricity prices in Quebec lead it to export more energy intensive products than Ontario?

3.0 Sectoral Energy Intensity:

Two sectoral characteristics are relevant in this research. First, industrial sectors differ in terms of their reliance on overall energy. Second, they differ in the source of energy they use with electricity playing a larger role in only some sectors.

To illustrate the importance of energy in production, we first look at the expenditure share on energy inputs. Statistics Canada reports energy expenditures and revenues by 6-digit NAICS Manufacturing sectors for 2004-2008.

Table 1 shows a summary of the relative importance of energy in each 3-digit NAICS sector for 2008, the last year available. Energy expenditures are significant but only in some sectors. Overall, manufacturing sectors spent about 2.7% of total revenues on energy from all sources. But this varies from less than 1% in *Transportation Equipment* to over 6% in *Non-Metallic Minerals* production. In terms of value added, the shares are higher and vary from under 2% to over 29% in *Paper Production*.

Drilling down to the 6-digit NAICs level shows that about 13% of the sectors (35 of260 sectors) have energy expenditures above 5% of the value of shipments. In general, the higher the energy intensity for a 3-digit sector, the larger the share of 6-digit sectors that expend more than 5% of revenues on energy. For instance, *Non-Metallic Mineral Products* have 6 of 12 sub-sectors with energy expenditures above 5% of revenues. Note that many more sectors have high expenditures as a ratio to value added. 105 of the 260 sectors have energy expenses as a share of value added above 5%. Also, almost every 3 digit sector has some sub-sector that expends at least 5% of value added on energy.

However, expenditures on energy are, in most cases, much less than expenditures on payroll. On average, energy expenditures are about 21% of payroll expenditures in manufactures. The notable exception is *Petroleum and Coal products* where energy expenditures are more than double payroll. The implication is that firms may be able to squeeze wages when energy prices rise and so absorb small changes in energy prices. .

American data (from the NBER) shows that, since 2000, energy expenditures relative to payroll have risen by about 36% on average reflecting a rise in energy prices relative to wages. However, in some sectors, this ratio has fallen suggesting changes in production processes away from energy. Also, sectors with larger energy expenditure shares are positively correlated (0.34) with sectors that have larger energy expenditures relative to payroll. This follows from the fact that energy-reliant sectors tend to have larger K/L ratios so rely less on labour.

TABLE 1: Shipments and Energy Use by Manufacturing Sector Canada (2008) NAICS 311-339

NAICS MANUFACTURING SECTORS	Energy expenditures/Revenues			Energy/VA		Energy/Payroll
	ratio $/$	#6-digit sectors >5%	Out of	ratio $/$	#6-digit sectors >5%	Ratio $/$100
311 - Food	0.019	3	33	0.064	21	0.186
312 - Beverage and Tobacco Product	0.016	0	6	0.026	2	0.153
313 - Textile Mills	0.036	1	7	0.088	6	0.169
314 - Textile Product Mills	0.019	0	4	0.044	1	0.092
315 - Clothing	0.008	0	17	0.020	0	0.031
316 - Leather and Allied Product	0.014	0	3	0.034	1	0.055
321 - Wood Product	0.031	3	14	0.091	8	0.170
322 - Paper	0.103	7	12	0.287	9	0.747
323 - Printing and Related Activities	0.015	0	6	0.026	0	0.054
324 - Petroleum and Coal Products	0.014	0	4	0.156	4	1.145
325 - Chemical	0.050	9	20	0.174	12	0.582
326 - Plastics and Rubber Products	0.025	0	15	0.068	11	0.139
327 - Non-Metallic Mineral Product	0.059	6	12	0.133	9	0.355
331 - Primary Metal	0.064	5	13	0.202	12	0.707
332 - Fabricated Metal Product	0.016	1	21	0.037	6	0.072
333 - Machinery	0.009	0	17	0.022	0	0.043
334 - Computer and Electronic Product	0.007	0	9	0.013	0	0.029
335 - Electrical, Appliance and Comp	0.010	0	12	0.027	1	0.057
336 - Transportation Equipment	0.008	0	18	0.028	2	0.068
337 - Furniture and Related Product	0.013	0	10	0.027	0	0.051
339 - Miscellaneous	0.009	0	7	0.022	0	0.041
TOTAL	**0.027**	**35**	**260**	**0.099**	**105**	**0.214**

Source: Statistics Canada Table 301-0006 - Principal statistics for manufacturing industries, by North American Industry Classification System (NAICS), annual

3.1 Energy Intensity Index by SECTOR

Statistics Canada reports direct plus indirect energy use by NAICS sectors as well as identifying all energy sources used by a sector. The three main sources of energy are electricity, natural gas, and fuels. This breakout allows us to identify which sectors rely heavily on electricity or on natural gas. Reliance on a particular energy source is a combination of energy intensity and share derived from that source. The most energy intensive sectors need not be all that reliant on electricity.

TABLE 2: Energy Intensity by NAICS Sector 111-339 in Canada (2008)

NAICS SECTORS 2008	Energy Intensity gJ/$1000	index	Rank
111 - Crop Production	9.61	0.186	9
112 - Animal Production	9.61	0.186	9
113 - Forestry and Logging	7.66	0.127	17
114 - Fishing, Hunting Trapping	10.04	0.199	8
115 - Support Activities for Agriculture and Forestry	10.59	0.215	7
211 - Oil and Gas Extraction	8.78	0.161	14
212 - Mining	7.16	0.112	20
221 – Utilities	36.70	1.000	1
311 - Food	7.33	0.117	18
312 - Beverage and Tobacco Product	4.47	0.031	29
313 - Textile Mills	8.81	0.162	12
314 - Textile Product Mills	8.81	0.162	12
315 - Clothing	4.72	0.039	28
316 - Leather and Allied Product	5.29	0.056	27
321 - Wood Product	8.38	0.149	16
322 - Paper	18.36	0.449	2
323 - Printing and Related Activities	7.22	0.114	19
324 - Petroleum and Coal Products	13.60	0.306	5
325 - Chemical	13.51	0.303	6
326 - Plastics and Rubber Products	9.15	0.172	11
327 - Non-Metallic Mineral Product	14.12	0.321	4
331 - Primary Metal	17.47	0.422	3
332 - Fabricated Metal Product	8.55	0.154	15
333 - Machinery	5.97	0.076	25
334 - Computer and Electronic Product	3.43	0.000	30
335 - Electrical, Appliance, Component s	7.05	0.109	21
336 - Transportation Equipment	6.74	0.100	22
337 - Furniture and Related Product	5.65	0.067	26
339 - Miscellaneous	6.05	0.079	15
TOTAL			

Source: Statistics Canada: Table 153-0031 - Direct plus indirect energy intensity, by industry, annual

Table 2 shows the direct plus indirect energy intensity for NAICS sectors 111 to 339. To compare sectors, we can create an index by setting the bounds between 0 and 1 so that each sector's intensity is relative to the highest and lowest sectors. No surprise that *Utilities* are the most energy intensive sector having twice the energy requirement of the next highest *Paper Products Manufacturing*. *Computer and Electronic Products* are the least energy intensive using about 10 of the energy to produce the same value of output as Utilities.

3.2 ELECTRICTY and GAS SHARES by SECTOR

Table 3 shows the sectoral reliance on electricity. This is measured as the share of direct energy derived from electricity. Unfortunately, data for this is reported only for the manufacturing sectors rather than all goods sectors. *Computer and Electronic Products* are the most reliant on electricity taking over 74% of total energy from electricity. *Petroleum and Coal Products* are the least reliant at 6%. On average, Canadian manufacturing uses electricity for 30% of its energy.

We can multiply the energy intensity by the share derived from electricity to get a measure of reliance on electricity. Again, this is expressed as an index ranging from 0 to 1. This changes the relative rankings. *Primary Metals* are most reliant on electricity though only the third most energy intensive sector. Because only 29% of *Paper Products* direct energy comes from electricity, it is ranked 2^{nd} in terms of reliance on electricity.

The last three columns record reliance on Natural Gas. This also changes the relative rankings. For instance, *Primary Metals* is only ranked 8^{th} in terms of gas reliance despite its high energy intensity. *Chemical manufacturing* is most reliant on natural gas though its overall energy intensity is ranked 5^{th} for manufactures.

TABLE 3: Electricity and Natural Gas Reliance by NAICS Manufacturing Sectors 311-339

NAICS SECTORS	Energy Intensity	Electricity Intensity			Natural Gas Intensity		
2008	**gJ/$1000**	**Share**	**Index**	**rank**	**Share**	**index**	**Rank**
311 - Food	7.33	0.33	0.207	18	0.61	0.489	6
312 - Beverage and Tobacco	4.47	0.27	0.049	20	0.72	0.321	11
313 - Textile Mills	8.81	0.44	0.405	6	0.56	0.548	5
314 - Textile Product Mills	8.81	0.44	0.395	7	0.56	0.552	4
315 - Clothing	4.72	0.55	0.230	16	0.45	0.170	18
316 - Leather and Allied Product	5.29	0.59	0.299	12	0.39	0.161	19
321 - Wood Product	8.38	0.23	0.139	19	0.17	0.074	20
322 - Paper	18.36	0.29	0.597	2	0.12	0.191	17
323 - Printing and Related Activities	7.22	0.55	0.411	5	0.45	0.320	12
324 - Petroleum and Coal Products	13.60	0.06	0.000	21	0.17	0.202	16
325 - Chemical	13.51	0.29	0.414	4	0.61	1.000	1
326 - Plastics and Rubber Products	9.15	0.56	0.571	3	0.44	0.424	7
327 - Non-Metallic Mineral Prod	14.12	0.22	0.305	10	0.38	0.622	2
331 - Primary Metal	17.47	0.48	1.000	1	0.22	0.412	8
332 - Fabricated Metal Prod	8.55	0.38	0.312	9	0.60	0.583	3
333 - Machinery	5.97	0.47	0.259	15	0.53	0.311	13
334 - Computer and Electronic Prod	3.43	0.74	0.224	17	0.26	0.000	21
335 - Electrical, Appliance, Component s	7.05	0.51	0.361	8	0.49	0.351	10
336 - Transportation Equipment	6.74	0.42	0.260	14	0.57	0.404	9
337 - Furniture and Related Product	5.65	0.56	0.304	11	0.44	0.221	15
339 - Miscellaneous	6.05	0.50	0.286	13	0.48	0.279	14
TOTAL		**0.30**			**0.28**		

Source: Statistics Canada: Table 128-0006 - Energy fuel consumption of manufacturing industries in gigajoules
Table 153-0031 - Direct plus indirect energy intensity, by industry, annual

The correlations between the indices is positive but not that strong. The electric index is positively correlated to total energy intensity but only at 0.570. It is correlated with natural gas intensity only at 0.260. This implies that those sectors that may be sensitive to electricity prices may be less sensitive to natural gas prices. However, energy intensive sectors tend to reliant on both forms of energy.

TABLE 4: Correlation between energy indices.

2008 correlation	Total Energy Intensity Index	Electricity Index	Natural Gas Index
Total Energy Intensity Index	1	0.570	0.359
Electricity Index		1	0.260
Natural Gas Index			1

4 EMBODIED ENERGY TRADE.

4.0 National Embodied Energy Trade.

In this section I look at the total energy embodied in trade with the US at a national and provincial level. I make a clear distinction between *direct trade* in energy (or *latent* energy) with *indirect* (or embodied) *trade* in energy. Trade in latent energy is the energy potential of oil, gas, coal, fuels and electricity that is traded across borders. For instance, the IEA reports that Canada exported a total of 230 million tonnes of oil equivalent (mtoe) in 2008. Almost all of this was with the US. Canada imported 85 mtoe from the world, again, mostly from the US.

Embodied energy, on the other hand, is the energy used to produce goods, including these energy products, while excluding latent energy. When we export goods we are, in effect, exporting the factors of production such as labour, capital, and energy used to produce those goods. As we saw, each sector requires different amounts of energy to produce the same value of goods. We use the direct and indirect energy intensities for production of Canadian NAICS sectors to impute the total amount of energy embodied in our traded goods. By summing across sectors we account for the volume of trade and also the composition of trade. I focus only on total embodied energy embodied in trade since it is the competitiveness of energy using sectors that is at the forefront of policies concerns. I could, but do not, look at embodied electricity or natural gas as well.

First we look at province-state bilateral trade in embodied energy. The first step is to calculate the embodied energy between each province and state. This is calculated as

$$E_{pst} = \sum_{i=1}^{I} e_t^i \, x_{pst}^i$$

Where E_{pst} is the total embodied energy in exports between province p and state s in period t.

Direct and indirect energy intensity of sector i in period t is denoted by e^i_t. Since we do not have province-specific intensities, we use national intensities for Canada. The assumption is that coefficients across sectors for provinces are the same or, at least, have the same relative magnitudes. For instance, Ontario's energy intensities for each sector are assumed to be proportional to the national intensity for all sectors.

Exports from province p to state s in period t for sector i is denoted by x^i_{pst}.

The sum of products across sectors gives us the total energy embodied in the trade between a province and state. We can calculate the analog for exports from state to province.

Table 5 shows total trade with the US as well as embodied energy. For Canada, total exports to the US have increased by 55% in nominal terms from 1997 to 2008. At the same time, imports from the US have increased by 21%. For 1997, Canadian exported the equivalent of 3,941 million GJ of energy embodied in its goods from all energy sources. The export flow of embodied energy increased through the early 2000s but, by 2008, was below that of 1997. Canada imported less embodied energy from the US though much of this is due to the smaller import volumes.

I can also calculate the average *embodied energy intensity of trade* as the ratio of embodied energy divided by the value of exports. These are shown in table 5. For instance, in 1997, Canada exported 17.13 Gj per $1000 of exports. By 2008, this intensity had fallen by 39% to 15.42. Note that import intensities are smaller and they fell at a slower rate. That is, though Canadian exports in 1997are 11 % more energy intensive than imports on a per dollar basis, they were only 4% more intensive in 2008. This means that, if the value of exports were equal to the value of imports (eg we had balanced trade with the US), then Canada would still have been a net exporter of embodied energy to the US though the net volume would be much smaller than what table 5 shows.

TABLE 5: Total and Embodied Energy in Canada-US trade 1997-2008 NAICS 111-339

	EXPORTS			**IMPORTS**		
	Value $M	Energy M GJ	INTENSITY GJ/$1000	Value $M	Energy M GJ	INTENSITY GJ/$1000
1997	230,053	3,941	17.13	177,008	2,729	15.42
1998	251,817	4,400	17.47	196,625	3,088	15.70
1999	285,756	4,583	16.04	208,274	3,083	14.80
2000	333,605	4,963	14.88	221,944	3,081	13.88
2001	325,035	4,837	14.88	210,706	3,015	14.31
2002	317,723	4,607	14.50	210,694	2,833	13.45
2003	304,348	4,309	14.16	196,088	2,645	13.49
2004	326,554	4,207	12.88	200,838	2,525	12.57
2005	344,784	4,184	12.13	205,293	2,398	11.68
2006	338,941	3,827	11.29	206,608	2,184	10.57
2007	336,336	3,790	11.27	208,358	2,137	10.26
2008	355,706	3,743	10.52	213,425	2,154	10.09
Growth	55%	-5%	-39%	21%	-21%	-35%

Source: author's calculations

4.1 Embodied Energy by Province

Table 6 shows these calculations for each of the provinces. The data illustrates the importance of accounting for provincial differences. Our provinces are simply quite different in important dimensions. To start, columns 1 to 3 of the table show the embodied energy intensity of exports and imports in 1997. The average export intensity for Canada was 17.1 with an import intensity of 15.4. Moving down we see quite dramatic differences across provinces. For instance, NF, NB, and AB have much higher export intensities than the Canadian average. Recall that I am using the identical energy intensity for each sector in all provinces. The provincial differences reflects provincial specialization. Import intensities tend to more similar than exports suggesting that the composition of imports to each province from the US is fairly similar.

TABLE 6: Embodied Energy in Canada-US trade 1997-2008

	Energy Intensity 1997			**Energy Intensity 2008**			**Composition effects 1997-2007**	
	Exp	imp	exp/imp	exp	imp	exp/imp	exp	imp
CAN	17.1	15.4	1.11	10.5	10.1	1.04	0.06	0.00
NF	28.5	26.0	1.10	9.9	11.7	0.85	-0.50	0.02
PEI	14.1	18.3	0.77	8.1	12.5	0.65	-0.02	0.07
NS	16.9	18.6	0.91	10.3	10.1	1.02	0.08	-0.03
NB	25.9	15.7	1.65	13.3	10.1	1.32	0.07	0.02
QU	19.4	18.1	1.07	13.2	11.6	1.14	0.02	-0.05
ON	14.3	15.0	0.95	10.2	9.9	1.03	0.07	0.00
MN	18.2	13.9	1.31	11.5	9.4	1.23	0.04	0.03
SK	21.3	14.2	1.50	8.8	8.9	0.99	-0.03	0.00
AB	24.4	16.4	1.49	9.4	10.2	0.92	-0.02	-0.07
BC	16.6	16.8	0.99	11.7	10.8	1.09	0.09	0.04

Source: author's calculations

Taking a ratio of the export and import intensities (also known as the *embodied energy terms of trade*) shows whether exports are more energy intensive than imports. For Canada, exports were 11% more energy intensive on average than imports in 1997. Moving down we see that, for 4 of the 10 provinces, export intensities are actually smaller than for imports. For instance, Ontario's export intensity is below the national average with its import intensity higher than its export intensity.

By 2008, all provinces had lower trade intensities. However, the degree to which they changed was quite different. For instance, in NF, export intensity fell dramatically to below the national average while import intensity fell but remained above the national average. By 2008, NF exports were less energy intensive than its exports. Notably, in NS, QU, ON, and BC, we see a switch from exports being less energy intensive in 1997 to being more energy intensive in 2008. For AB, SK, and NF the opposite occurs.

Energy intensity of trade can decline over time for a number of reasons. First, trade volumes are measured in nominal terms whereas energy is a real variable. Hence provincial inflation partially explains the decrease in intensity.[2] Second, intensities change when the techniques of production change altering the direct and indirect energy uses. A third possibility is that the composition of trade has changed towards less energy intensive sectors.

We can decompose the change in overall intensity to identify how the composition of trade has changed holding other factors constant. That is, if we account for inflation and changes in the techniques of production, we can identify what fraction of the change in intensity is solely because the pattern of trade has changed. Table 6 shows these calculations. What we find is that, between 1997 and 2008, the energy intensity of Canadian exports to the US, holding both nominal prices and techniques of production constant, has shifted marginally toward more energy-intensive exports. All told, total embodied energy exported would have risen by 6% over this period. The total decline in intensity in 1997-2008 was because energy intensities in each sector declined enough to offset the small shift toward more energy-intensive sectors. On the import side however, there was no overall change in the composition of trade to or away from energy intensive sectors.

For provinces we again see large variations. In all provinces, except AB, SK, PEI and NF, there has been a relative shift in exports towards more energy intensive sectors. All provinces, save NS, QU, and AB also saw a relative shift in imports towards more energy intensive sectors.

The differences in the intensity of traded goods as well as changes over time could be related to provincial differences in energy prices. To identify this thou, we need to use a regression analysis.

[2] Though we can attempt to convert trade volumes into real values, finding appropriate Province-specific and sectoral-specific price discount factors is difficult and not attempted.

5 Tobit Regression Analysis

The goal of the regression analysis is to see if Province and State energy prices influence bilateral trade in a systematic way and, if it does alter trade, by how much.

There are two ways in which we can proceed. I use both approaches.

The first approach is to consider aggregate trade and to identify the impact of differential energy prices on the energy embodied in bilateral trade. The *Factor Content Theorem* suggests that jurisdictions that are relatively abundant in energy, and so have low energy prices, will be 'net exporters' of energy embodied in trade[3]. If energy prices matter, then we should see a decrease in the flow of embodied energy in bilateral trade as prices in a jurisdiction rises relative to others. For instance, if energy prices in Ontario rise relative to, say, New York, we can test whether embodied energy exports to New York falls. If prices rise in New York, we should see more energy imports embodied in traded goods. Whether the sensitivity of exports to prices is the same as imports is an empirical matter.

There are two components of this embodied energy. The first is a *volume effect*: the dollar value of trade may fall with higher energy prices. This could occur if merchandise trade falls while services trade rises. For instance, higher energy prices in Ontario may induce a fall in manufacturing with a concomitant increase in financial services. Since services are largely unmeasured, the volume of trade to the US could fall since only merchandise goods trade is measured.

The second component of embodied energy relates to the *composition of trade*. Even if the volume of exports is unaffected, what is traded can change towards less energy intensive goods. This is what the factor content theorem predicts.

However, there are two reasons to think that trade in embodied energy may not be sensitive to energy prices at all. First, as noted above, energy prices make up only small fraction of total costs in most sectors. Other prices, such as wages and capital costs would tend to be more important and so may dominate any changes in energy prices. We may not see any systematic compositional changes in trade related to prices. Second, even if higher energy prices reduce exports in some sectors, theory tells us that exports will rise in other sectors as resources flow between sectors. The volume may not change. Further, even though the direct and indirect energy intensity across sectors differ, the

[3] I am not testing the Factor Content Theorem directly as I am only looking at the correlation with energy prices. As energy markets tend to be regulated, prices may not reflect relative abundance of resources. Why energy prices differ is not relevant, only that they do differ is important.

aggregate of all energy embodied in trade may not change much even as the composition of trade changes.

Nonetheless, the Provincial data above shows that average energy intensity of exports and imports do differ across provinces. What we want to see is whether this is related to energy prices and, if so, how sensitive is embodied energy trade to these prices.

The second regression approach is to identify whether differential energy prices alter the composition of bilateral trade directly. Here we keep direct track of the sectoral flow of goods across borders rather than the imputed energy of aggregated trade. The idea is that exports of energy intensive sectors, such as *Chemicals*, may decline with higher energy prices while non-energy intensive sectors, such as *Transport Equipment*, should increase.

There are different ways one could approach this. The first is to identify and aggregate exports in, say, the five most energy intensive sectors and compare the impact of energy prices on exports relative to, say, the five least energy intensive sectors. If the coefficient on energy prices differs, then energy prices matter.

One issue that arises with this approach is due to 'breaking the chain of comparative advantage'. Theory tells us that higher energy prices would tend to disadvantage energy intensive sectors. But theory also tells us that the reallocation of resources in response to changing input prices could raise exports even in the most energy intensive sector. It would be unusual to see this but we cannot, *a priori*, exclude the possibility. Aggregating the five most energy-intensive sector will tend to mitigate this problem but not solve it.

The alternative approach used in this paper is to pool data from all sectors and employ an index of energy intensity to account for sectoral differences in energy intensity. Theory tells us that high energy prices should reduce exports for energy-intensive goods but simultaneously raise it for non-energy-intensive goods. By interacting energy prices with energy intensity, we can test whether higher energy prices reduce exports on average for the more energy intensive sectors. The benefit of this approach is that we can account for differences in energy intensity even among the most energy intensive sectors. Second, by including more data we can get more precise estimates.

5.2 GRAVITY EQUATIONS:

To identify how prices affect the flow of goods or embodied energy, we will us the Gravity equation approach. The basic idea behind the gravity equation is that the volume of trade between any two economies is a function of their economic mass and the distance between them. The larger the economic sizes of the economies, the greater the volume of trade we should see. The greater the distance between economies, the smaller the volume of trade we should observe. Of course, other factors, such as common language and currencies, participation in free-trade agreements, etc., also matter and can be incorporated into the regressions. See Bacchetta et al (2012) for a very good review of Gravity Equations. Much of what follows is derived directly from them.

The baseline Gravity equation in natural log form looks like:

$\ln T_{ijt} = a_0 + a_1 X_{it} + a_2 X_{jt} + a_3 \ln t_{ij} + a_4 I_t + a_5 S_t +$

where Xit and Xjt are importer and exporter time-varying individual effects. For our purposes we include (logged) GDP and (logged) per capita GDP. We also include (logged) energy prices and (logged) wages. For a sample of T periods there are T of these variables. Note that Xit are importer time-varying effects; they therefore allow us to take into account the fact that multilateral trade resistance may change over time. There is a set of *2nT* of these variables.

In *tij* is the logarithm of trade costs between two countries *i* and *j*. As usual, I can proxy this by distance between capital cities of each prov-state pair. I also can include a dummy variable for states that share a border with a province (adjacent).

As an alternative, I can estimate the trade costs using prov-state-pair fixed effects. This generates 500 dummy variables that capture non-time varying effects between each province-state pair. The idea is that it will capture all the pair specific factors that may influence trade. These could include, for instance, historical immigration patterns (Texans working in Alberta, Quebecers working in New England), particular trade enhancing infrastructure (airplane hubs in Colorado and Alberta, absence of direct air connection between Sask and Nebraska), historical investment flows (Bombardier production sites in Quebec and Pennsylvania), as well as distance and adjacency.

I_t is a year dummy variable.

Tobit versus OLS. An important issue that arises in this data set is that there are many province-state pairs that have no recorded trade in a particular sector and year. For instance, trade between PEI and North Dakota is often zero in many sectors. For disaggregated sectoral data, the fraction of zero-trade is quite high; about 30% of the samples have zero trade. The approach taken here is to use a Tobit regression using zero trade as a left-hand censure.

In general the frequency of zeros does not change across time periods but does across sectors. Some sectors are simply more geographically specific. However, the dominant feature is that some provinces simply have little trade with some states. Given this feature, I also use clustered standard errors to account for the possible correlation in errors along province-state pairs. Using clustered errors did not matter for aggregated trade but did for the disaggregated data with clustered standard errors double the robust standard errors.

5.2 Tobit Regression Results for Volume of Trade and Embodied Energy

I first consider the volume of trade between province-state pairs. Here I aggregate all merchandise trade NAICS 311-339. Data is from Industry Canada. They record provincial exports and imports from all US state as low as the 6-digit NAICS level. I aggregate this into total export and total import volumes. Data spans 1992-2012 but I restrict my analysis to 1997-2007 since this corresponds to the embodied energy data I use below.

Electricity prices are from 1990 to 2011 while natural gas prices are from 2001-2008. Data on energy intensity for 29 NAICS sectors (111 to 339) comes from Statistics Canada and covers 1997 to 2008. However, if we want to account only for embodied electricity or natural gas then the number of sectors falls to the 21 manufacturing sectors (311 to 339). Distances are calculated using the great-circle between province and state capitals. GDP, population, and wages come from respective national statistical agencies.

The panel has 8000 observations (10 province x 50 states x 2 x 8 years) as there is no natural gas price data for the District of Columbia. Of the 8000 observations, only 127 record zero traded goods between provinces and states. All of these observations are from the smaller Maritime Provinces. When we drill down to look at embodied electricity or natural gas, the number of zero trade observations rises somewhat.

The first column in Table 7 looks at the volume of exports and imports between a province-state pairs as a function of (logged) GDP, per capita income, relative wages, and energy prices. I account for state-province specific trade factors using pair fixed effects. I also use a time fixed effect to account for time varying effects. I use clustered standard errors clustering on state-province pairs to account for correlation across periods within a particular pair. Trade includes all NAICS 29 sectors from 111 to 339, excluding 213 which is untraded.

The results for the standard gravity variables are much as expected. Higher GDP raises trade with an elasticity close to 1. Per capita income is not significant which is not surprising given that per capita income is not that different across jurisdictions. Higher relative wages in a state or province reduce exports with an elasticity around 0.9.

The results show that electricity prices are not systematically correlated with trade flows. The coefficients are very very close to zero.

However, natural gas prices are statistically significant and rather large. A 1% rise in natural gas prices will reduce exports by about 0.19%. Meanwhile, a 1% rise in natural gas prices raises imports by the same 0.19%. These estimates are significant at the 1% level. These results suggest that jurisdictions with higher natural gas prices could be shifting trade into services and away from merchandise goods. Unfortunately, we do not have services trade to test this hypothesis.

TABLE 7: Tobit Regression of (logged) Exports and Embodied Energy 2001-2008

Dependent variable (in natural log):	(1) Trade Volume	(2) Embodied Total Energy	(3) Embodied Total Electricity	(4) Embodied Total Natural Gas
lnGDPx	**0.810*** **	**1.189*** **	**1.087*** **	**1.081*** **
Clustered St errors	0.390	0.376	0.300	0.323
lnGDPm	**0.852*** **	**1.336*** **	**1.149*** **	**1.211*** **
	0.308	0.378	0.301	0.324
lnPCAPx	**-0.043**	**-0.852***	**-1.362*** **	**-1.134*** **
	0.386	0.492	0.349	0.394
lnPCAPm	**-0.445**	**-1.008****	**-0.586***	**-0.576**
	0.366	0.473	0.352	0.396
lnW	**-0.906*** **	**-1.043*** **	**-0.341****	**-0.314****
	0.146	0.178	0.141	0.154
lnELx	**-0.039**	**0.127**	**-0.031**	**0.020**
	0.074	0.097	0.077	0.087
lnELm	**0.029**	**0.016**	**-0.015**	**0.041**
	0.073	0.092	0.075	0.082
lnGASx	**-0.189*** **	**-0.349*** **	**-0.198*** **	**-0.224*** **
	0.059	0.076	0.064	0.073
lnGASm	**0.187*** **	**0.296*** **	**0.138****	**0.158****
	0.058	0.074	0.066	0.075
N=	8000	8000	8000	8000
Censured (=0)	127	127	145	288
Year FE	YES	YES	YES	YES
Exp-Imp FE	YES	YES	YES	YES
Pseudo R2	0.5354	0.4708	0.5187	0.4927

Column 2 of table 7 shows regression results for total embodied energy between provinces and states. The results mimic those for trade volume but add some additional interpretation. Any factor that influences trade volume will also affect embodied energy. Hence higher GDP leads to more trade and more embodied energy. Note, however, that the elasticity is higher for embodied energy than for nominal trade volumes. That is, a 1% rise in GDP raises trade volume by 0.81% but raises the embodied energy by 1.19%. This suggests that there is a composition effect in addition to the volume effect. It appears that larger economies have higher energy intensity in their exports than smaller economies. This may reflect a larger relative capital stock, hence higher energy use, in larger economies.

Again we see that electricity prices do not matter to embodied energy. So not only is there no volume effect, there is no composition effect either.

Natural gas prices do matter with both a volume and a composition effect evident. From column 1, we see that a 1% rise in natural gas prices reduces exports by 0.19% but, from column 2, reduces embodied energy by 0.35%. This tells us that higher natural gas prices induce local economies to shift exports towards less energy intensive goods in addition to a shift out of merchandise trade.

Columns 3 and 4 look at embodied electricity and embodied natural gas in state-province trade. Sectors included are restricted to just the 21 manufacturing sectors (311-339) since energy share data is not available for the other sectors. As above, electricity prices are insignificant but natural gas prices are significant. The result that embodied electricity falls with higher natural gas prices can be attributed to the pure volume effect: higher natural gas prices reduce the volume of trade and so will lower the electricity embodied in trade. The elasticities with respect to natural gas prices from columns 1 and 3 are very close (at least for the exporter). Hoverer, as the sectors used to make the aggregates differ, comparing the elasticities across columns is inappropriate.

5.3 Tobit Regression Results for Sectoral bilateral trade

I now turn to the second approach. Here I use the disaggregated trade data at the 3-digit NAICS level and use the sectoral energy intensity to account for difference across sectors. There are 1000 observations per year per sector. The data yields a full panel of 232,000 observations for total embodied energy and total embodied electricity (10 province x 50 states x 2 x 29 merchandise sectors x 8 years).

Using this disaggregated data means that we observe more zero trade values. Observations of zero trade are about 34% of the total sample. Most of these zero trade observations are between the small Maritime Provinces and more distant small states. For instance, Newfoundland has positive trade in only 25% of a possible 18360 observations. Ontario has positive trade in 90% of all possible state and year observations. This suggests that trade between small economies, or distant economies, must clear a threshold before it takes place (or is recorded). We can account for this with exporter-importer pair fixed effects.

Zero-trade data is not concentrated in any particular year with only small variations across years. Each year has 20,000 +- 200 non-zero observations. Note that the volume of trade increases over time. We account for this using year fixed effects.

However, zero trades are more likely to arise in certain sectors. For instance, sector 211 (*Oil and Gas extraction*) has positive values for only 20 percent of the possible observations (total 12240). This arises since only some provinces and states produce oil and gas. However, for sector 333- *Machinery* we see non-zero trade 88% of the time. We can account for sector differences using sector fixed effects.

To account for the sectoral differences in energy intensity, I interact energy prices with the index of energy intensity. Recall that the index takes a value of zero for the least energy intensive sector and 1 for the most energy intensive. All the other sectors vary along the interval 0 - 1.

The interpretation of the coefficients is straight forward. The coefficient on energy price tells us the elasticity with respect to energy price of trade in the least energy-intensive sector. If energy prices matter in the way we expect, then this elasticity should be positive for an exporter. That is, if energy prices rise, we would expect production to shift towards less energy intensive goods and so exports of these less energy intensive goods should also rise. Converse for higher prices in the importer jurisdiction.

For the most energy-intensive sector, we add the coefficient of price to the interaction term. If energy prices matter in the way we expect, then this sum is also a price elasticity and should be negative for an exporter. That is, if energy prices rise, we would expect production to shift towards less energy intensive goods and so exports of more energy intensive goods should also fall. Converse for higher prices in the importer jurisdiction.

Results are reported in table 8. I report two regression. Column 1 includes all 29 merchandise sectors. These include the 21 manufacturing sectors (311-339) but also includes agriculture, forestry and logging, oil and gas extraction, mining and utilities. Column 2 uses only manufacturing. Both regressions use fixed effects for year, sector, and prov-state pair. I also use clustered standard errors clustering on the prov-state pair. It turned out that the clustered standard errors were almost double the robust standard errors so made a lot of difference in the regressions in terms of identifying significance.

The pseudo-r squares are fairly low relative to the aggregated trade (0.21 in the disaggregated regression versus 0.50 in the aggregated regression above). This is not unexpected. First, it is well know that the gravity equation does poorly at a disaggregated level. At these detailed levels, idiosyncratic sectoral characteristics matter. For instance, unionization is more important in some sectors than others. This suggests that wages in some sectors may be 'higher than average' or the sector suffers more production interruptions. When we aggregate trade, these idiosyncratic factors across sectors will tend to cancel out. The implication is that we explain less of the sectoral variation the greater the disaggregation we have since we are missing sectoral-specific factors. Sectoral dummies can only do so much.

Second, by pooling the sectors into one regression, we are forcing coefficients to be the same, at least along some dimensions. For instance, the coefficient on GDP is restricted to be identical across sectors. This is unlikely to be true. The alternative is to run 29 separate regressions, one for each sector. The problem though is that it becomes harder to identify a systematic relationship between energy intensity and the impact of energy prices.

The results for the standard gravity variables are as expected. Higher GDP results in more trade while higher per capita income results in less trade. One way to interpret this is as follows: high per capita jurisdictions will tend to spend a greater share of their income on services. As services are either non-traded (eg haircuts and housing) or unmeasured (eg financial services) we observe less trade with high per capita income jurisdictions.

Surprisingly, relative wages do not matter. Of course, we are already accounting for all prov-state non-time varying effects so all we are seeing is that relative wages do not have any marginal effects on trade.

As in the regressions above, electricity prices do not seem to matter. The only exception is for the importer. The regression shows a negative coefficient on electricity price but is barely significant at the 10% level. It suggests that higher electricity prices in an importing jurisdiction lowers imports by 0.25%. Since the interaction term is insignificant, the implication is that imports in all sectors falls with higher electricity prices. However, these results are hardly significant. When we look at only the manufacturing sectors we again see that electricity prices in the exporting jurisdiction do not matter. But for the importer, we get a significant coefficient but only on the interaction term. But it is of the 'wrong sign' from what we would expect.

Natural gas prices seem to matter. In both columns we get the expected result for the exporter consistent with the regressions above. A rise in natural gas prices raises exports of the least energy intensive sector while exports in the most energy intensive sector falls. For the importer, we get mostly insignificant results though the signs are mostly expected.

TABLE 8: Tobit Regression of (logged) Bilateral Trade 2001-2008

Dependent variable (in natural log):	(1) Bilateral Trade 29-merchandise sectors	(2) Bilateral Trade 21-manufacturing sectors
lnGDPx	**3.626*****	**3.628*****
Clustered St err	0.492	0.463
lnGDPm	**3.773*****	**3.553*****
	0.494	0.466
lnPCAPx	**-5.111*****	**-5.531*****
	0.605	0.583
lnPCAPm	**-3.058*****	**-2.992*****
	0.649	0.627
lnW	**0.012**	**0.010**
	0.242	0.238
lnELx	**0.100**	**0.170**
	0.141	0.120
lnELa* INTENSITY	**-0.067**	**-0.039**
	0.486	0.189
lnELm	**-0.247***	**0.014**
	0.150	0.150
lnELma* INTENSITY	**0.249**	**-0.641*****
	0.506	0.228
lnGASx	**0.260****	**0.430*****
	0.130	0.118
lnGASx* INTENSITY	**-1.919*****	**-1.259*****
	0.423	0.206
lnGASm	**-0.014**	**-0.149**
	0.170	0.163
lnGASm*INTENSITY	**0.661**	**0.554****
	0.601	0.253
Intensity index	**-1.457**	**1.643***
	2.057	0.998
N=	232,000	168,000
Censured (=0)	72,754	35,139
Year FE	YES	YES
Exp-Imp FE	YES	YES
Sector FE	YES	YES
Pseudo R2	0.2101	0.2100

6.0 Discussion:

This paper tested whether energy prices were correlated with trade between Canadian Provinces and US states at the aggregate and the disaggregated 3-digit NAICs level for the period 1997-2008. I use a gravity approach accounting for province and state economic size, income, labour wages, and energy prices. I account for the large number of zero trade observations using Tobit analysis and utilize clustered standard errors.

I find that, in general, electricity prices are not correlated with province-state trade. This is despite some significant differences in local industrial electricity prices. Total price variation across provinces and states is about 300%. Though provinces differ markedly in the energy intensity of their trade with US states, it appears that electricity price differentials between provinces and states cannot explain the volume of trade, the embodied energy in trade, or the composition of trade in terms of energy intensity. Something else is driving the pattern and volume of trade. This is not to say that electricity prices are not correlated with trade for a given sector. Sector specific regressions have significant coefficients for electricity prices, some positive and some negative. It is just that the influence on trade is not systematically related to sectoral energy intensity.

However, I do find that natural gas prices do matter in the way we expect. I find that higher natural gas prices in a jurisdiction reduces their volume of its exports. In addition to this volume effect, we get an additional compositional effect in that, indeed, higher natural gas prices lead to lower embodied energy and a shift towards less energy intensive sectors. Results are robust across different specifications.

The conundrum is that natural gas, on a GJ basis, is about 1/5 as costly as electricity. On average though, natural gas and electricity contribute about the same amount of energy to the merchandise sectors studied. Hence we would have thought that, if energy prices did matter, then it would have been electricity that matters, not natural gas. This suggests that the regressions above may be missing something. My problem is that I cannot guess whether it is the insignificance of electricity prices that is the problem or the significance of the natural gas prices that is problematic.

That the two energy prices offer different results need not be surprising. The two energy markets are different in important ways. First, electricity production is ubiquitous: all states and provinces generate electricity with only small amounts crossing from one jurisdiction to the other. They may differ in their generation technique, but they all produce. The sources of natural gas, on the other hand, are geographically concentrated in Texas, Wyoming, Louisiana, and Alberta. Most jurisdictions import natural gas.

Second, though retail energy markets are regulated, the market for natural gas tends to be less regulated than for electricity. Nonetheless, prices seem to behave similarly. For instance, in the US, the data shows that the standard deviation divided by average price is about 0.418 for natural gas and 0.488 for electricity. Neither seems more volatile than the other. However, data on a higher frequency may show something different and it is these higher frequency changes that may be pertinent to firms.

So, what may be sources of bias in my results? First, the energy prices used are the average industrial price for a state or province. Actually prices paid by firms may be different due to individual contracts. The issue is that the salient price for trading firms may be different than the average firm. That is, we know from other research that firms that trade internationally tend to be larger and more productive than non-trading firms (Bernard *et al,* 2012) and are only a small fraction of all firms in a sector. Their larger size suggests that their price could be lower than the industry average.

This need not, of course, bias our results. First, if the salient price is a constant fraction of the average industrial price, then the regressions account for that as estimated coefficients are elasticities. The average price is simply a proxy for the salient price. Second, this logic applies to both electricity and natural gas prices. That is, why would our measure of average industrial price correctly apply to one source of energy and not the other?

A second problem with the price data is that we do not have energy prices by sector. We only have average prices by jurisdiction. The implicit assumption is that, at least on the margin, prices are equalized across sectors with a jurisdiction. This need not be the case. Some sectors are heavy energy users and so firms would likely get price discounts. But if the discounts follow the average, then the regressions are still fine. We only have a problem if jurisdictions with high average prices tend to also have high discounts so that the salient sectoral price is unconnected to the average jurisdiction price. I do not have access to any data that could test this.

Another source of problems may arise from some important missing variable. I can think of three possibilities. First, the security of supply of energy may be as important as the price. We know from Chinese data (see Fisher-Vanden *et al*, 2012) that firms that face frequent electrical blackouts behave differently than firms that do not. In general, they use more intermediate inputs from other firms as a form of risk management. Blackouts for electricity is not an issue in North America. However, security of supply for natural gas may be an issue. Many natural gas contracts allow the supplier to cut off gas forcing the user to switch fuels (need citation here). The issue here is that security of natural gas supply is likely higher the closer the user is to a gas field. It is better to be at the start of the gas pipeline than at the end. They will also have lower prices. Hence gas prices may be a proxy for gas security. I tested for this but found that adding local gas production (or access to gas) lowered the elasticity related to gas prices but did not eliminate them. I am not aware of any data set that would identify gas shortages at a local level that would be uncorrelated to price.

Second, we may need to account for the vintage of the capital stock in each state and province. States or provinces with higher investments rates could have greater energy efficiency. The data on energy use by sector is for Canada as a whole, not by province or state. It is entirely possible that high price jurisdictions are more energy efficient and so the impact of price on costs is muted. This would imply that jurisdictions with high energy prices are not disadvantaged in terms of competitiveness. Again we have the problem of why this matters for one energy source and not the other.

The third missing variable is the absence of services trade between provinces and states. The regressions above suggest that, if natural gas prices are shifting production, then some productive assets may be shifting into services which have low energy intensities. This could be happening with electricity prices only we lack the services trade data to account for this.

Altogether, I find that energy prices are correlated with province-state trade. However, the relationship between energy markets and trade is likely broader. Issues of access to supply and security, price variability, and fuel substitutability could also matter. I leave this for future study.

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