Does Trade Respond to Diesel Price?
An Empirical Investigation using Canada and United States Trade Flows.

(Working Draft)

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Abstract

This paper empirically investigates the impact of diesel price on interprovincial Canadian trade flows, interstate trade flows of the United States, and trade flows between provinces of Canada and states of the United States transported by commercial trucks and tractor trailers. A gravity equation is modified to include an elasticity that measures the responsiveness of trade flow to diesel price and is estimated through cross-section and panel data regressions. The modification is based on gravity equations used in Brun et. al (2002) and McCallum (1995). This paper has two key findings. First, the large border effect reported in McCallum (1995) falls significantly. Secondly, a simplistic modification of the gravity equation is not rich enough to estimate a realistic elasticity of trade flow to diesel price and needs to be amended to explicitly include wages paid to drivers of commercial trucks and tractor trailers.

I. Introduction

The majority of interprovincial Canadian trade flows, interstate trade flows of the United States, and trade flows between provinces of Canada and states of the United States are delivered by commercial trucks and tractor trailers which burn diesel fuel. The value of Canadian exports moved by commercial trucks and tractor trailers to the US has increased from C$58.2 billion in 1989 to C$125.1 in 1996. The value of imports has increased from C$76.3 billion in 1989 to C$145.2 billion in 1996.[1]

The primary costs incurred by transportation of goods using commercial trucks and tractor trailers are diesel fuel costs and the wage paid to the driver(s).[2] In 1997, the total average tax inclusive price of diesel fuel per gallon was $1.80 with a standard deviation of 0.16 for the Canadian provinces that border the United States.[3] In 1997, the total average tax inclusive approximated price of diesel fuel per gallon in the US was $1.21 with a standard deviation of 0.07.[4] Diesel prices differ from Canada and the US by $0.60 which stems mostly from higher taxes on diesel fuel in Canada.[5]

Commercial trucks and tractor trailers hold 200 to 500 gallons of diesel fuel and get 3 to 8 miles per gallon.[6] Commercial trucks and tractor trailers are designed to fill their tanks completely with diesel fuel at the origin and not to stop until reaching their destination. These specifications and the variation in diesel prices, especially between Canada and the US, beg the following question. Does trade flow respond to diesel price?

This question appears to not have answered in the literature but similar questions have been asked and answered. For instance, there have been several studies that have estimated how responsive gasoline demand is to a change in its price. Agras and Chapman (1999), using annual

[1] http://www.ontruck.org/stats/docs/stat98mar16.htm
[2] www.truckinginfo.com
[3] These border provinces are Alberta, British Columbia, Manitoba, New Brunswick, Ontario and Quebec. The diesel price for Saskatchewan was not available.
[4] The actual total Diesel price was not available so had to be approximated. Please see Appendix A for details.
[5] http://www.pcf.ab.ca/quick_answers/gasoline_pricing/international.asp
[6] These specifications were obtained from websites for commercial truck and tractor trailer producers such as MAC and INTERNATIONAL

US data from 1982-1995 find an overall short run elasticity of -0.25 and long run elasticity of -0.92 of gasoline demand with respect to its price. Gallini (1983) using Canadian data finds a short run elasticity that ranged from -0.3 to -0.4 and a long run estimate (ten year) in the range of -0.7 to -0.9. These small elasticities imply that gasoline demand is small in the short run but in the long run there is considerable response. The large response of gasoline demand in the long run can be attributed to the purchase of a more fuel efficient car or a shift to an alternative form of transportation such as the bus for example.

A study related more to the proposed question is by Brun et al. (2002). In this study, a panel gravity equation describing bilateral trade flow for 130 countries over the period 1962-1996 is estimated. Included in the explanatory variables of the gravity equation is a world price index divided by the unit value of imports. The coefficient on the explanatory variable has the interpretation as the elasticity of bilateral trade flow from country i to j with respect to world oil price index divided by the unit value of imports. The estimate of this elasticity was -0.097.

This paper estimates a modified gravity equation that includes a diesel price explanatory variable using cross-section and panel fixed effect regressions. The coefficient on the diesel price has the interpretation of the elasticity of merchandise trade flow with respect to diesel price. The modified gravity is similar to those used by Brun et. al (2002) and McCallum (1995). The gravity equation used in McCallum (1995) is also estimated for more recent data sets.

This paper will be organized as follows. Section I discusses the methodology. Section II presents the results of interest and corresponding analysis. Section III concludes the paper. Appendix A discusses in detail the construction of the data. Appendix B provides the complete results from all the regressions performed.

II. Methodology

The basic gravity equation which describes bilateral intra-industry trade between two countries/regions has the following formulation,

(1) $T_{ij} = C\dfrac{X_i^{\beta_1} X_j^{\beta_2}}{D_{ij}^{\beta_3}}$

where T_{ij} is the trade flow from region origin i to destination j at time t, X_i and X_j are the gross domestic product of region i and j respectively, D_{ij} is the distance from region i to region j in kilometers, and C is a constant. β_1, β_2 and β_3 are weights to be estimated. The gravity equation can be derived from monopolistic competition models along with Heckscher-Ohlin and Ricardian models that have a continuum of goods. Taking natural logs of both sides of equation (1) derives

(2) $\ln T_{ij} = \beta_0 + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \varepsilon_{ij}$

The coefficients on the explanatory variables are interpreted as elasticities. The panel regression equation is as written as

(3) $\ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j^t + \beta_3 \ln D_{ij} + v_{ij} + \varepsilon_{ij}^t$

where α_{ij} is a unit specific constant and v_{ij} is a unit specific residual. The fixed effect or within estimator used in the panel regressions performed in STATA is derived as follows. Rewrite equation (3) as,

(4) $y_{ijt} = \alpha_{ij} + \beta x_{ijt} + v_{ij} + \varepsilon_{ijt}$

where $y_{ijt} = \ln T_{ij}^t$, $\beta = [\beta_1, \beta_2, \beta_3]'$, $x_{ijt} = [\ln X_i^t, \ln X_j^t, \ln D_{ij}]$, and $\varepsilon_{ijt} = \varepsilon_{ij}^t$. Averaging each cross section over time yields

(5) $\bar{y}_{ij} = \alpha_{ij} + \beta \bar{x}_{ij} + v_i + \bar{\varepsilon}_{ij}$

where $\bar{y}_{ij} = \sum_t \dfrac{y_{ijt}}{T_{ij}}$, $\bar{x}_{ij} = \sum_t \dfrac{x_{ijt}}{T_{ij}}$ and $\bar{\varepsilon}_{ij} = \sum_t \dfrac{\varepsilon_{ijt}}{T_{ij}}$. Subtracting (5) from (4) yields

(6) $(y_{ijt} - \bar{y}_{ij}) = \beta(x_{ijt} - \bar{x}_{ij}) + (\varepsilon_{ijt} - \bar{\varepsilon}_{ij})$

The fixed effect estimation routine used in STATA performs OLS on equation (6).

McCallum (1995) modifies the gravity equation to investigate the impact of the Canada-U.S border on regional trade patterns using interprovincial Canadian trade flows and trade flows between provinces of Canada and states of the United States. This modified equation is now written as,

$$(7)\quad T_{ij} = C\frac{X_i^{\beta_1} X_j^{\beta_2}}{\theta_{ij}^{\sigma}}$$

where $\theta_{ij} = (D)^{\gamma} e^{\delta CA}$ is the standard trade barrier function. Brun et. al (2002) The additional CA is a dummy variable that equals 1 for trade between Canadian provinces and equals 0 otherwise. Taking natural logs of both sides of equation (7) derives

$$(8)\quad \ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \varepsilon_{ij}$$

where $\beta_3 = \sigma * \gamma$ and $\beta_4 = \sigma * \delta$. The panel regression estimating equation is as follows,

$$(9)\quad \ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j^t + \beta_3 \ln D_{ij} + \beta_4 CA + v_{ij} + \varepsilon_{ij}^t$$

The inclusion of interstate trade flows of the United States was not available at the time of McCallum (1995). Equation (4) is modified to include this trade as follows,

$$(10)\quad \ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 US + \varepsilon_{ij}$$

where US is a dummy variable that equals 1 for trade between US states and equals 0 for trade between Canadian provinces and U.S. states or among Canadian provinces.

Cross section regressions using equation (8) will be performed using 1993, 1997,1998 and 1999 data and panel fixed effect regression using equation (9) for 1997-1999. These estimates will be compared with the estimates of McCallum (1995) which uses 1988 data in the results/analysis section. In addition, the results of cross section regressions of equation (9) will be provided using 1993 and 1997 data.

To estimate the elasticity of trade flow with respect to diesel price, the standard trade barrier function needs to be augmented to reflect the primary costs to commercial trucks and

tractor trailers moving from Canadian province to province, Canadian province to US state, and Canadian province to US state. The two primary costs to trucking are diesel fuel and the wages paid to truckers.

The augmented trade barrier used in this paper is based on the work of Brun et. al (2002) is as follows,

(11) $\theta_{ij} = (D_{ij})^{\gamma} (DIESEL_i)^{\alpha} e^{\delta CA + \lambda US}$

where $DIESEL_i$ is the total annual nominal annual tax inclusive price of diesel fuel per gallon from origin i at time t. Average wages paid to truckers moving from region i to region j are not available so D_{ij} is assumed as a proxy.[7] Substituting equation (11) into (7) and taking natural logs of both sides yields the cross section estimating equation,

(12) $\ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 US + \beta_6 \ln DIESEL_i + \varepsilon_{ij}$

where $\beta_6 = \sigma\alpha$ is the elasticity of trade flow from region i to region j with respect to the price of a gallon of diesel in region i. The fixed effect panel regression equation is as follows,

(13) $\ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_6 \ln DIESEL_i^t + v_{ij} + \varepsilon_{ij}^t$

Equations (12) and (13) do not produce economically sensible results when the regressions included trade between Canadian provinces and US states. This will be discussed in the results/analysis section. Consequently equation (11) was amended as follows,

(14) $\theta_{ij} = (D_{ij})^{\gamma} (DIESEL_i)^{\alpha} e^{\delta CA + \lambda US + \kappa CAN}$

where CAN is a dummy variable that equals one when trade is from Canadian province origin to

[7] Wages in the trucking industry are often positive functions of the distance traveled or an hourly wage paid to the driver. The realism of assuming that distance is a proxy for wages paid to truckers will be discussed in the results/analysis section. http://www.collegegrad.com/industries/trans06.shtml

US state destination and zero otherwise. Substituting (14) into (7) and taking natural logs yields equation (15)

$$\ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 CAN + \beta_6 US + \beta_7 \ln DIESEL_i + \varepsilon_{ij}$$

Equation (16) is the alternative panel fixed effect regression and is written as,

$$\ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j^t + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 CAN + \beta_6 US + \beta_7 DIESEL_i^t + v_{ij} + \varepsilon_{ij}^y$$

III. Results/Analysis

The complete set of results for all regressions in this section can be found in Appendix B. The first sets of results to be reported and discussed are estimates of the border effect displayed below in Table I.

Table I

$$\ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \varepsilon_{ij}$$
$$\ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j^t + \beta_3 \ln D_{ij} + \beta_4 CA + v_{ij} + \varepsilon_{ij}^t$$

	#1	#2	#3	#4	#5	#6	#7	#8
β_4	3.09*	2.80*	2.02*	1.99*	1.96*	2.75*	2.29*	1.90*
	(0.10)	(0.14)	(0.14)	(0.15)	(0.15)	(0.11)	(0.13)	(0.09)
β_5						0.40*	0.80*	
						(0.06)	(0.04)	

N - number of observations, R^2 - adjusted except for column #7 and #8 which is the overall R^2

*Significantly different from zero at the 95% confidence level

*Standard error in parenthesis

#1 McCallum (1995) cross-section regression 1988 CA-CA and CA-US trade flows

#2 Cross-section regression using Feenstra (2003) data for 1993 CA-CA and CA-US trade flows

#3 Cross-section regression for 1997 CA-CA and CA-US data

#4 Cross-section regression for 1998 CA-CA and CA-US data

#5 Cross-section regression for 1999 CA-CA and CA-US data

#6 Cross-section regression for 1993 CA-CA, CA-US, and US-US data

#7 Cross-section regression for 1997 CA-CA, CA-US, and US-US data

#8 Panel fixed effect regression for 1997-1999 CA-CA and CA-US

#9 Panel fixed effect regression for 1997-1999 CA-CA

In 1988 Canada and the United States signed a free trade agreement. Using 1988 merchandise trade flow data, McCallum (1995) estimates the first gravity equation in Table 1 and finds a large coefficient of 3.09 on the CA dummy variable. This coefficient is interpreted as all other things being equal; trade between two provinces is more than 22 times larger than trade between a state and a province. $[e^{3.09} \cong 22]$ The border effect is quite sizable despite the signing of the free trade agreement.

This paper estimates the gravity equation in McCallum (1995) for a different, more recent data set. The merchandise trade flow data used in this paper is for trade flow between Canadian provinces and US states delivered by commercial trucks and tractor trailers while merchandise trade flow data for all modes of transportation is used in McCallum (1995). [8] In addition, the merchandise trade flow data between Canadian provinces and US states includes only the provinces that border the US which differs from McCallum (1995). The data sets used do not include the non-border provinces for two reasons. First, 90 percent of Canadian citizens live 90 minutes from the US border. Vilasuso and Mentz (1998) Secondly, diesel prices were not available for all of the non-border provinces. The merchandise interprovincial trade flow data includes only the data for the seven provinces that border the US.[9] This differed from the data in McCallum (1995) which included the non-border provinces

This paper uses 1993, 1997, 1998, and 1999 data to estimate the gravity equation in McCallum (1995) with cross-section and fixed effect panel regressions. The 1993 data was obtained from an empirical exercise in Feenstra (2002). The results in Table 1 show that the border effect has fallen from significantly from 1988 to 1999 using cross section and panel fixed effect regressions. For instance, the results of the cross-section regression for 1997 in column 3

[8] 70% of trade between Canada and the United States is delivered by commercial trucks and tractor trailers. http://www.ontruck.org/stats/docs/stat98mar16.htm

[9] The seven border provinces are Alberta, British Columbia, Manitoba, New Brunswick, Ontario, Quebec and Saskatchewan. Trade flows where Saskatchewan was the origin and the US States or the other six Canadian provinces were the destination were not used because diesel price was not available for Saskatchewan. This was done to keep the results consistent with those that include the diesel price. Trade flows from US states and six Canadian provinces to Saskatchewan were used.

imply all things being equal; trade between two provinces is more than 8 times larger than trade between a state and a province. $[e^{2.02} \cong 8]$ There are two reasons for this. First, the data set may have influenced the results of the regressions. Second, integration of trade is not instantaneous after the signing of a free trade agreement but takes time.

The second set of results to be discussed is the elasticity of merchandise trade flow transported by commercial trucks and tractor trailers with respect to diesel price. Estimates of the elasticity of gasoline demand with respect to gasoline price reported in the introduction ranged from -0.25 to -0.90. Brun et al. (2002) report a significant estimate of -0.09 for the elasticity of bilateral trade flow with respect to a world oil price index that was divided by an index of the unit value of imports. These two studies imply that the elasticity of merchandise trade flow with respect to diesel price should be somewhere between 0 and -1. It is clear from Table II below that the results of the first set of cross-section and panel fixed effect regressions are of the wrong sign and indicates there is something fundamentally wrong with the regressions.

Table II

$$\ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 US + \beta_6 \ln DIESEL_i + \varepsilon_{ij}$$

$$\ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_6 \ln DIESEL_i^t + v_{ij} + \varepsilon_{ij}^t$$

	#1	#2	#3	#4	#5	#6
β_6	0.68*	0.64*	0.85*	0.17*	0.74*	-1.11*
	(0.21)	(0.19)	(0.22)	(0.16)	(0.13)	(0.91)

N - number of observations, R^2 - adjusted except for column #5 and #6 which is the overall R^2

*Significantly different from zero at the 95% confidence level

*Standard error in parenthesis

#1 Cross-section regression for 1997 CA-CA and CA-US data

#2 Cross-section regression for 1998 CA-CA and CA-US data

#3 Cross-section regression for 1999 CA-CA and CA-US data

#4 Cross-section regression for 1997 CA-CA, CA-US, and US-US data

#5 Panel fixed effect regression for 1997-1999 CA-CA and CA-US

#6 Panel fixed effect regression for 1997-1999 CA-CA

The data were studied to understand why the regressions produced nonsensical estimates of β_6. Two key findings coupled together explain the poor performance of the regressions. First, diesel prices in Canada are $0.60 higher than the US. Second, Canada ran surpluses for merchandise trade transported by commercial trucks and tractor trailers with the US of $36 billion in 1997; $27 billion in 1998; $38 billion in 1999.[10] Since diesel prices are higher in Canada, the positive coefficient is picking up the merchandise trade surplus. To control for the trade surpluses, the gravity was modified further. A dummy variable CAN was added to the regression equation that equaled one when Canadian provinces were the origin of trade and a US state was the destination while zero otherwise. The results of the regressions with the additional dummy variable CAN are reported below in Table III.

Table III

$$\ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 CAN + \beta_6 US + \beta_7 \ln DIESEL_i + \varepsilon_{ij}$$

$$\ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j^t + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 CAN + \beta_6 US + \beta_7 \ln DIESEL_i^t + v_{ij} + \varepsilon_{ij}^t$$

	#1	#2	#3	#4	#5
β_7	-1.71*	-1.51*	-1.87*	-0.98*	-1.78*
	(0.55)	(0.46)	(0.50)	(0.26)	(0.30)

N - number of observations, R^2 - adjusted except for column #5 which is the overall R^2

*Significantly different from zero at the 95% confidence level

*Standard error in parenthesis

#1 Cross-section regression for 1997 CA-CA and CA-US data

#2 Cross-section regression for 1998 CA-CA and CA-US data

#3 Cross-section regression for 1999 CA-CA and CA-US data

#4 Cross-section regression for 1997 CA-CA, CA-US, and US-US data

#5 Panel fixed effect regression for 1997-1999 CA-CA and CA-US

[10] 1997 CA exports to US, $151136748073; CA imports from US, $115113100000
1998 CA exports to US, $151855778002; CA imports from US, $124998367494
1999 CA exports to US, $172026517310; CA imports from US, $133481696533

The estimates of β_7 are the now of the correct sign; however, are now too large in magnitude. The estimates were expected to be somewhere between 0 and -1. The best explanation is that the transport costs are not modeled properly. Diesel fuel and wages are the two primary costs incurred in the transport of goods. Diesel fuel is modeled as an explanatory variable while distance is assumed as a proxy for wages..

There are two reasons why the assumption of distance as a proxy for wages be may be inappropriate. First, wages paid to truckers are not uniform across the US. For instance, there is a -6,482 difference between the average annual wage per employee in the trucking industry in 1997 for Wyoming and the US average.[11] Since wages are not uniform across the country they may not be between the US and Canada. Second, wages differ are higher the larger the type of commercial truck and tractor trailer operated. Drivers with more experience tend to have higher wages.[12] These two facts imply that there is likely considerable variation in wages in Canadian provinces and US states. The distance explanatory variable cannot pick up this variation and probably leads to a bias upward in magnitude in the estimates of the elasticities.

IV Conclusion

This paper has two findings. First, a gravity equation used by McCallum (1995) to study the impact of Canada-US border on regional trade patterns was estimated for slightly different recent data sets. The large border effect reported in McCallum (1995) was found to have fallen. Second, the elasticity of merchandise trade with respect to diesel price was estimated using cross-section and panel regressions of a gravity equation. The estimates of the elasticities were too large in magnitude. It is concluded that using distance as a proxy for wages could bias the estimates of the elasticities upward.

[11] http://doe.state.wy.us/lmi/0801/t1a1.htm
[12] http://www.collegegrad.com/industries/trans06.shtml

References

Agras, J., and D. Chapman. "The Kyoto Protocol, CAFÉ Standards, and Gasoline Taxes," *Contemporary Economic Policy*, 17:3, 1999, 296-308.

Brun, Jean-Francois; Carrere, Celine; Guillaumont, Patrick and de Melo, Jaime. "Has Distance Died? Evidence from a panel Gravity Model," 2002 Unpublished.

Engel, Charles and John H. Rogers. "How Wide is the Border?," *The American Economic Review*, 86:5, 1996, 1112-1125.

Feenstra, Robert. "Advanced International Trade: Theory and Evidence" Princeton University Press. Will be published Fall 2003.

Gallini, Nancy T. "Demand for Gasoline in Canada," *The Canadian Journal of Economics*, 16:2, 1983, 299-324.

Head, Keith. "Gravity for Beginners," Unpublished.

Hummels, David. "Time as a trade barrier." Unpublished.

McCallum, John. "National Borders Matter: Canada-U.S. Regional Trade Patterns," *The American Economic Review*, 85:3, 1995, 615-623.

Nivola, Pietro S. and Robert W. Crandall. The Extra Mile: Rethinking Energy Policy for Automobile Transportation, 1995, The Brookings Institution, Washington D.C.

Vilasuso, Jon and Fredric C. Mentz. "Domestic Price, (Expected) Foreign Price, and Travel Spending by Canadians in the United States," *The Canadian Journal of Economics*, 31:5, 1998, 1139-1153

Appendix A

McCallum (1995) used a data set from 1988 for his cross-section estimation and was contacted about its availability. The data were not available so the results were just reported. The 1993 data were acquired from an empirical exercise used in Feenstra (2002).

The remainder of Appendix A will discuss the collection and construction of the data for the remaining cross-section and panel estimations.

Some of the annual data were in Canadian dollars and needed to be converted to American dollars. The annual exchange rate data used in this conversion was constructed by averaging monthly exchange rate data. The monthly exchange rate data was found on the Federal Reserve Bank of Saint Louis website. The URL is as follows,

http://research.stlouisfed.org/fred/data/exchange.html

The trade data used in this paper differs two ways from the data used by McCallum (1995) and Feenstra (2002). First, this paper uses merchandise trade between US states and Canadian provinces transported by trucks while the data in McCallum (1995) and Feenstra (2002) is for all modes of transportation. Secondly, only data for seven Canadian provinces that border the US, (Alberta, British Columbia, Manitoba, New Brunswick, Ontario, Quebec and Saskatchewan) were used. Trade data when Saskatchewan is the origin were not used because data on diesel price was not available. The data for Canadian included only the border provinces because 90 percent of Canadian citizens live 90 minutes from the US border according to Vilasuso and Mentz (1998). In addition, diesel prices were available for all of the non-border provinces and to prevent arbitrariness, all were excluded.

The merchandise trade data (value in millions of US dollars) for US State origin to Canadian Province destination and Canadian Province origin to US State destination transported by truck for 1997, 1998, and 1999 were obtained from the Bureau of Transportation Statistics website. The URL is as follows,

http://www.bts.gov/ntda/tbscd/reports/can_flow3_new.html

The US State origin to US destination merchandise trade data (value in millions of US dollars) was not available to McCallum (1995). This data set is published only for 1993 and 1997. The 1993 data set used in gravity estimates was obtained from the empirical exercise by Feenstra (2002). The 1997 data set was obtained from the Bureau of Transportation Statistics website. The URL is as follows,

http://www.bts.gov/ntda/cfs/prod.html

The Canadian Province origin to Canadian Province destination merchandise trade data for all modes of transportation (value in millions of Canadian dollars) for 1997, 1998, and 1999 were purchased from the Statistics Canada website. These data had to be converted to US dollars using the exchange rates mentioned previously. The URL is as follows,

http://www.statcan.ca/start.html

The US State GDP for 1997, 1998, and 1999 were obtained from the Bureau of Economic Analysis website. The URL is a follows,

http://www.bea.gov/bea/regional/gsp/

The Canadian Province GDP data for 1997, 1998, and 1999 were obtained from the Statistics Canada website. These data were converted to US dollars using the aforementioned exchange rates. The URL is a follows,

http://www.statcan.ca/english/Pgdb/econ15.htm

The distance data from origin to destination in kilometers were calculated using

www.mapquest.com

The largest city of the origin and destination were used in the calculation. These data were obtained from the 2002 Rand McNally Road Atlas.

The total US Diesel price/gallon data for 1997, 1998, and 1999 for each state were not directly available so they were approximated indirectly. The gasoline base price/gallon for each state were found at the following URL,

http://www.eia.doe.gov/emeu/states/_states_pet.html

The base gasoline price/gallon was multiplied by the ratio, "the average base diesel price in the US / the average gasoline price in the US", which yields the approximate base diesel price/gallon for each state. The data for the ratio can be found at the following URL,

http://www.eia.doe.gov/emeu/states/oilprices/oilprices_us.html

The federal tax and state taxes for diesel price/gallon were found at the following URL

http://www.fhwa.dot.gov/ohim/hs00/mf205.htm

The total US diesel price/gallon for each state was calculated by summing the total approximate base diesel price, the federal tax on diesel and the state tax on diesel.

The total price of diesel/liter for the following provinces Alberta, British Columbia, Manitoba, New Brunswick, Ontario and Quebec, which border the US, were purchased from the Statistics Canada website. The total diesel price/gallon was not available for Saskatchewan. These data were converted to gallons and dollars using the aforementioned exchange rates.

Appendix B

Table I

$$\ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \varepsilon_{ij}$$

$$\ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j^t + \beta_3 \ln D_{ij} + \beta_4 CA + v_{ij} + \varepsilon_{ij}^t$$

	#1	#2	#3	#4	#5	#6	#7	#8	#9
β_1	1.21*	1.22*	0.74*	0.75*	0.71*	1.13*	0.95*	0.76*	1.17*
	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.02)	(0.02)	(0.03)	(0.06)
β_2	1.06*	0.98*	0.75*	0.75*	0.77*	0.97*	0.96*	0.75*	0.79*
	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.06)
β_3	-1.43*	-1.35*	-1.08*	-1.03*	-1.02*	-1.11*	-0.96*	-1.03*	-1.02*
	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.03)	(0.02)	(0.04)	(0.09)
β_4	3.09*	2.80*	2.02*	1.99*	1.96*	2.75*	2.29*	1.90*	
	(0.10)	(0.14)	(0.14)	(0.15)	(0.15)	(0.11)	(0.13)	(0.09)	
β_5						0.40*	0.80*		
						(0.06)	(0.04)		
N	683	679	403	406	412	1511	2443	1113	108
R^2	0.81	0.76	0.68	0.68	0.67	0.85	0.80	0.67	0.84

N - number of observations, R^2 - adjusted except for column #7 and #8 which is the overall R^2

*Significantly different from zero at the 95% confidence level

*Standard error in parenthesis

#1 McCallum (1995) cross-section regression 1988 CA-CA and CA-US trade flows

#2 Cross-section regression using Feenstra (2003) data for 1993 CA-CA and CA-US trade flows

#3 Cross-section regression for 1997 CA-CA and CA-US data

#4 Cross-section regression for 1998 CA-CA and CA-US data

#5 Cross-section regression for 1999 CA-CA and CA-US data

#6 Cross-section regression for 1993 CA-CA, CA-US, and US-US data

#7 Cross-section regression for 1997 CA-CA, CA-US, and US-US data

#8 Panel fixed effect regression for 1997-1999 CA-CA and CA-US

#9 Panel fixed effect regression for 1997-1999 CA-CA

Table II

$$\ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 US + \beta_6 \ln DIESEL_i + \varepsilon_{ij}$$

$$\ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_6 \ln DIESEL_i^t + v_{ij} + \varepsilon_{ij}^t$$

	#1	#2	#3	#4	#5	#6
β_1	0.77* (0.04)	0.79* (0.04)	0.75* (0.04)	0.95* (0.02)	0.79* (0.03)	1.13* (0.07)
β_2	0.72* (0.04)	0.72* (0.04)	0.74* (0.04)	0.96* (0.02)	0.72* (0.02)	0.79* (0.06)
β_3	-1.06 (0.06)	-1.03 (0.06)	-1.02 (0.06)	-0.96* (0.02)	-1.03* (0.03)	-1.00* (0.09)
β_4	1.87* (0.15)	1.84* (0.15)	1.79* (0.15)	2.26* (0.14)	1.74* (0.09)	
β_5				0.83* (0.05)		
β_6	0.68* (0.21)	0.64* (0.19)	0.85* (0.22)	0.17* (0.16)	0.74* (0.13)	-1.11* (0.91)
N	403	406	412	2443	1113	108
R^2	0.69	0.69	0.69	0.80	0.68	0.84

N - number of observations, R^2 - adjusted except for column #5 and #6 which is the overall R^2

*Significantly different from zero at the 95% confidence level

*Standard error in parenthesis

#1 Cross-section regression for 1997 CA-CA and CA-US data

#2 Cross-section regression for 1998 CA-CA and CA-US data

#3 Cross-section regression for 1999 CA-CA and CA-US data

#4 Cross-section regression for 1997 CA-CA, CA-US, and US-US data

#5 Panel fixed effect regression for 1997-1999 CA-CA and CA-US

#6 Panel fixed effect regression for 1997-1999 CA-C

Table III

$$\ln T_{ij} = \beta_o + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 CAN + \beta_6 US + \beta_7 \ln DIESEL_i + \varepsilon_{ij}$$

$$\ln T_{ij}^t = \alpha_{ij} + \beta_1 \ln X_i^t + \beta_2 \ln X_j^t + \beta_3 \ln D_{ij} + \beta_4 CA + \beta_5 CAN + \beta_6 US + \beta_7 \ln DIESEL_i^t + v_{ij} + \varepsilon_{ij}^t$$

	#1	#2	#3	#4	#5
β_1	0.75* (0.04)	0.77* (0.04)	0.75* (0.04)	0.94* (0.02)	0.78* (0.03)
β_2	0.71* (0.04)	0.71* (0.04)	0.72* (0.04)	0.96* (0.02)	0.71* (0.02)
β_3	-1.09* (0.06)	-1.04* (0.06)	-1.05* (0.05)	-0.95* (0.02)	-1.06 (0.03)
β_4	2.89* (0.26)	2.84 (0.24)	2.89 (0.23)	2.85* (0.17)	1.67* (0.09)
β_5	1.08* 0.23	1.06* 0.21	1.18* (0.20)	0.74* (0.13)	1.15* (0.13)
β_6				0.97* (0.06)	
β_7	-1.71* (0.55)	-1.51* (0.46)	-1.87* (0.50)	-0.98* (0.26)	-1.78* (0.30)
N	403	406	412	2443	1113
R^2	0.70	0.71	0.71	0.80	0.70

N - number of observations, R^2 - adjusted except for column #5 which is the overall R^2

*Significantly different from zero at the 95% confidence level

*Standard error in parenthesis

#1 Cross-section regression for 1997 CA-CA and CA-US data

#2 Cross-section regression for 1998 CA-CA and CA-US data

#3 Cross-section regression for 1999 CA-CA and CA-US data

#4 Cross-section regression for 1997 CA-CA, CA-US, and US-US data

#5 Panel fixed effect regression for 1997-1999 CA-CA and CA-US