Going the Distance: Estimating the Effect of Provincial Borders on Trade when Geography (and Everything Else) Matters*

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Abstract

In the presence of often-cited provincial non-tariff trade barriers, one should observe provincial border effects in Canada. However, using provincial trade data leads to upward biased estimates of the border effect, because intra-provincial trade is skewed towards short distance flows that are poorly estimated by gravity models. We overcome this bias by using sub-provincial trade flows generated from a transaction-level transportation dataset. The results show that border effects fall as geographies are more fine-grained and uniform. In contrast to the U.S., where state border effects were eliminated using similar approaches, provincial border effects remain, with an implied 6.9% tariff equivalent.

Keywords: Border effects, inter-provincial trade, transportation costs, gravity model.

JEL classification: F15; F14; R12; R15.

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1 Introduction

It is well known that for some goods (e.g., dairy products and alcoholic beverages) there are significant (non-tariff) barriers to inter-provincial goods trade. Less well understood is the degree to which these barriers are reflected in the level of inter-provincial trade—that is, whether there are provincial border effects. The first and obvious objective of this paper is to assess the presence and magnitude of provincial border effects. To date, the estimation of these effects has been hampered by a lack of data with sufficient geographic detail. This paper overcomes the problem by using a dataset of transaction-level truck and rail shipments to develop estimates of intra- and inter-provincial trade. These fine-grained data permit the estimation of a rich set of models that account for many of the biases endemic to gravity model-based border effect estimates. Therefore, the second and subtler objective of this paper is to illustrate how these detailed data can be used to develop more accurate border effect estimates. The underlying motivation for this requires some context.

Building on McCallum's (1995) initial work, a large literature has developed to measure border effects, be they national or sub-national. While much of the empirical literature has focussed on measuring national border effects, these same methods have also been applied to trade between sub-national regions. The arc of the sub-national border effects literature has been one where the application of more refined methods reduces estimated border effects. But, unlike the international literature,[1] this has led in some instances to the elimination of border effects altogether. In the United States, initially high estimates of inter-state border effects (Wolf, 2000) were reduced by developing more accurate measures of distance (Hillberry and Hummels, 2003; Head and Mayer, 2009; Crafts and Klein, 2015), restricting trade flows to shipments from manufacturers (Hillberry and Hummels, 2003), using a panel specification and controlling for internal migration (Millimet and Osang, 2007), and the use of more fine-grained geographies to define the sub-national trading units (Hillberry and Hummels, 2008, see also Coughlin and Novy, 2016).

Of particular importance are the effects of measured distance (Head and Mayer, 2009) and especially geography (Hillberry and Hummels, 2003, 2008) on border effect estimates. Head and Mayer (2009) show that the inaccurate estimate of distance substantially biases upwards estimates of the border effect, because intra-regional distances tend to be overestimated relative to inter-regional distances. Hillberry and Hummels (2008) demonstrate that estimated state border effects fall to zero as the size of the geographic unit of analysis is reduced, because short distance, large value flows are better estimated. State border effects are an artefact of the geographic scale at which the estimates are made. The sensitivity of border effect estimates to the scale of geographic unit chosen (Coughlin and Novy, 2016) is an instance of the modifiable areal unit problem (MAUP), which can only be addressed by developing a large set of estimates across a broad spectrum of geographies using units that

[1] At the national level, estimated border effects have been reduced as McCallum's initial specification was modified to take into account the effects of market access and competition on trade (see Anderson and van Wincoop, 2003; Anderson, 2011), estimates of distance have been refined (see Head and Mayer, 2009) and as new estimators have been applied (see Head and Mayer, 2014). Still, a consistent finding has been that trade is stronger within countries than between them.

are preferably of uniform shape and size (Arbia, 1989).

To be precise, the methodology requires data on trade between a fine-grained set of sub-provincial regions. The dataset developed here consists of shipments, where each shipment is characterised by its value, transportation cost, distance travelled, and origin and destination. Because origins and destinations are geo-coded with a latitude and longitude, an almost limitless set of geographies can be applied, making it possible to test the sensitivity of border effect estimates to the geography chosen. The distance shipped is measured along the highway/railway network, eliminating the need to estimate the distance goods travel within and between geographic areas. Finally, because the cost to shippers (revenue to carriers) is measured, as well as the value of the shipment, transportation costs can be directly measured and used to estimate the *ad valorem* tariff equivalent of provincial border effects (see Head and Mayer, 2014). The main contribution of this paper, therefore, is the development of a transaction-level trade dataset that allows an arbitrary number of traditional trade datasets and a wide set of model specifications that address these econometric issues. It is after simultaneously addressing these problems the magnitude and significance of provincial border effects can be more confidently established.[2]

The analysis demonstrates that smaller geographic units typically result in lower border effects, but the adoption of uniform geographic units (hexagons) reduces border effects even more. Their use helps to mitigate the effects of MAUP on the estimates, while also providing a means to test their sensitivity to the geography and model specification chosen. This is accomplished in the spirt of Briant et al. (2010) by randomly shifting and populating the hexagonal lattice and re-estimating the model each time. These simulations demonstrate the placement of the lattice matters more than size, with the variance of the estimates reduced by using smaller units. The obvious lesson is that border effect estimates are more reliable the smaller and more uniform the unit chosen.

Keeping this in mind, the analysis shows that intra-provincial trade is consistently stronger than inter-provincial trade after taking into account the distance between the trading regions, and the ability of the trading units to generate and absorb trade flows. When sub-provincial areas are used instead of provinces, the border effect tariff equivalent is almost halved, falling from 13.6% to 6.9%. The latter represents the estimate that held after applying an extensive set of checks to mitigating the (typically) upward biasing effects of model misspecification (e.g., non-linear effects of distance) and geography (i.e., the size and shape of the geographic units) on border effects. It stands in sharp contrast to the finding from the United States (Hillberry and Hummels, 2008), where state border effects are eliminated when similar approaches are applied.

The remainder of the paper is organized as follows. Section 2 (Data development) reviews the method used to estimate trade between sub-provincial geographic units. Particular attention is paid to explaining how these estimates are benchmarked to known intra- and inter-provincial trade totals and more broadly to the underlying validity of these estimates.

[2]Another strategy, complementary to this one, is to further refine the now standard estimators in order to mitigate issues of measurement error and missing variable bias. This is the approach taken by Agnosteva et al. (2014), who take advantage of the panel nature of current measures of intra- and inter-provincial trade to develop estimates of provincial border effects.

Section 3 (Model and estimation strategy) outlines the structure of the trade model and the identification of an appropriate estimator. Section 4 (Model estimates) presents the estimates, starting from standard inter- and intra-provincial trade estimates, continuing through trade based on sub-provincial geographic units, finishing with a set of robustness checks that test for biases associated with misspecification and the Modifiable Areal Unit Problem. Section 5 (Tariff equivalent of border effects) estimates the tariff-equivalent barriers to inter-provincial trade. Section 6 (Conclusions) finishes the paper with a summary of the results and their implications.

2 Data development

To date, analysis of Canada's internal trade has been limited to the provincial level, relying on trade tables from the provincial input-output accounts or from reported provincial trade patterns from the Annual Survey of Manufacturers (see Brown, 2003 for the latter). This paper develops a very flexible transaction-level point-to-point dataset. As such, it permits the measurement of trade flows between an almost limitless set of sub-provincial geographic units, providing a means to address many of the econometric issues raised in the borders and trade literature. Since this database is new, however, it is useful to begin by outlining how it was constructed and describing some of its basic characteristics before moving on to discuss the econometric strategy and results.

The data are derived from the Trucking Commodity Origin Destination Survey (TCOD) and railway waybills from 2002 to 2012, with the analysis limited to the 2004 to 2012 period.[3] As these data cover the two primary surface modes, the file is termed the Surface Transportation File (STF). The STF measures the movement of goods from the point where they are picked up to the point where they are dropped off. It is in essence a 'logistics file.' As such, these points do not necessarily represent locations where goods are made or where they are used. However, the analysis requires a database that captures the level of trade between sub-provincial regions, which is embedded as a concept in the gravity-based trade model applied here.

In order to transform the STF from a logistics file to a trade file, provincial trade flows from the input-output accounts are used to benchmark intra- and inter-provincial flows by commodity. That is, each transaction in the STF file is given a weight such that the aggregate adds to the total for the corresponding intra-/inter-provincial flow from the input-output tables. In formal terms, the nominal value of trade between sub-provincial regions (hereafter regions) i and j, X_{ij}, is the sum of the survey weighted value of shipment x indexed by l between origin region i and destination region j,[4] multiplied by the benchmark weight

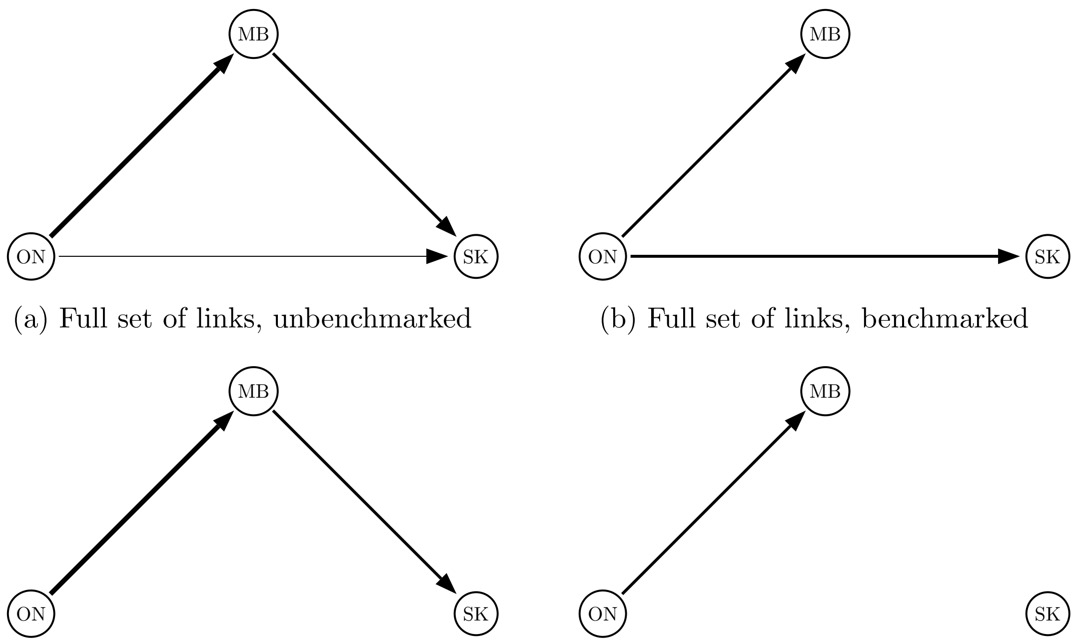
[3]The discussion focuses on data from 2004 onward because 2002 and 2003 had more limited geographic detail, among other factors that affect comparability across years.

[4]Shipments are geocoded by latitude and longitude. For shipments by truck, the latitude and longitude are derived from the postal code of the origin and destination, while for rail shipments is based on the latitude and longitude, and the Standard Point Location Code of the station (yard or siding) where shipments are picked up or dropped off. Note that for trucking shipment just over half of the postal codes are imputed

for shipment l, w_l^b:

$$X_{ij} = \sum_l w_l^b x_{lij}, \text{ where } w_l^b = w_l \times w^b. \tag{1}$$

The shipment benchmark weight is the shipment-based survey weight, w_l, multiplied by the province pair benchmark weight w_b for the commodity being shipped, with notation for the province pair and commodity suppressed in order to simplify the exposition. The benchmark weight is set such that trade between a given province pair (or within the same province) add to known totals from the provincial trade accounts by detailed commodity and year. The proof of this proposition and a more detailed discussion of the benchmarking procedure is developed in Appendix 7.1.3.



(a) Full set of links, unbenchmarked

(b) Full set of links, benchmarked

(c) Broken set of links, unbenchmarked

(d) Broken set of links, benchmarked

Figure 1: Transformation of logistic to trade flows, full and broken sets.

Notes: Example flows for provinces Ontario (ON), Manitoba (MB) and Saskatchewan (SK).

Conceptually, Figure 1 illustrates the benchmarking procedure. Consider the example of flows of vehicles made in various locations in Ontario and ultimately used at various locations in Manitoba and Saskatchewan. They may be first shipped to a distribution centre in Manitoba, with a portion of the shipment sent on to Saskatchewan, which is represented by the unbenchmarked flows in the upper left-hand quadrant of the figure. From a logistics perspective this is a correct representation of the flows, but from a trade perspective the flow from where the vehicles are made in Ontario to where they are used in Saskatchewan

and so the level of precision is not a strong as implied by the postal codes.

Table 1: Benchmarked intra-/inter-provincial flows as a share of actual flows.

	Destination							
	A.C.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Total
Origin				Percent				
Atlantic Canada	99	99	89	94	77	94	89	95
Quebec	99	99	100	98	94	98	98	99
Ontario	100	100	100	99	98	100	100	100
Manitoba	93	97	95	96	95	97	95	96
Saskatchewan	87	96	96	95	98	97	97	97
Alberta	89	97	98	97	99	100	100	99
British Columbia	96	82	99	97	96	99	98	97
Total	98	99	99	97	98	99	98	99

Notes: A.C. stands for Atlantic Canada.

is underestimated and the flow from Manitoba to Saskatchewan is overestimated. As presented in Figure 1b, benchmarking to the input-output tables weights up at a micro-level the flow from Ontario to Saskatchewan and weights down (to zero) the flow from Manitoba to Saskatchewan.

The weighting strategy relies crucially on there being a flow on the STF file between each province pair. If there is not, there is nothing to weight up (or down): $w^b = 0$. The result is no flow between the province pairs (see Figures 1c and 1d). The risk is that if these 'broken links' are too common and/or correlated with the distance between the province pairs, the benchmarking exercise will result in biased estimates. One source of bias is simply replaced by another.

Table 1 presents the ratio of the benchmarked STF inter-/intra-provincial flows to the actual flows from the input-output tables. Because the Atlantic Provinces were found to have a larger number of broken links, particularly with western Canada, they were aggregated together for benchmarking purposes. After doing so, there are relatively few pairs where there was a serious loss of trade. The overall proportion is 99%. There is a tendency for intra-provincial flows to have less of a loss, but this is small. Otherwise, there does not appear to be large losses with distance. For instance, the loss for Atlantic Canada's exports to Alberta or B.C. is about the same as Ontario. The effect of these broken links are tested further below by estimating the gravity model with the input-output derived provincial flows and the benchmarked flows, with both sets of data providing qualitatively similar results (see Section 4).

While benchmarking adequately accounts for the level of intra- and inter-provincial trade, the pattern of trade especially within provinces may be affected by the functioning of the transport/distribution system—that is, shorter distance logistics driven flows may be more prevalent. This has important implications because, when pooled with inter-provincial flows, these shorter distance, intra-provincial flows may be underestimated, biasing upwards the estimated inter-provincial border effect.

The effect of benchmarking should be to stretch-out inter-provincial trade as short distance flows to/from distributions centres or wholesalers are weighted down and longer distance flows from points where goods are produced to where they are used are weighted up. This can be seen in Figure 2, which reports the shipment distance kernel densities with survey weights w_l and benchmark weights w_l^b, with shipment distances divided between intra- and intra-provincial flows. For inter-provincial shipments, as expected, benchmarking tends to reduce the importance of shorter distance flows (less than 1,000km) and increase the importance of longer distance flows, particularly those above 3,000km. For intra-provincial trade, after benchmarking short distance flows are reduced as imported commodities (e.g., shoes and apparel) that are distributed locally are weighted downwards. Still within provinces short distance logistics driven flows may be more prevalent. This effect can be tested more formally by observing whether distance has a stronger effect on intra- relative to inter-provincial trade. The results indicate that this is not the case (see Appendix 7.2.1 for a detailed discussion).

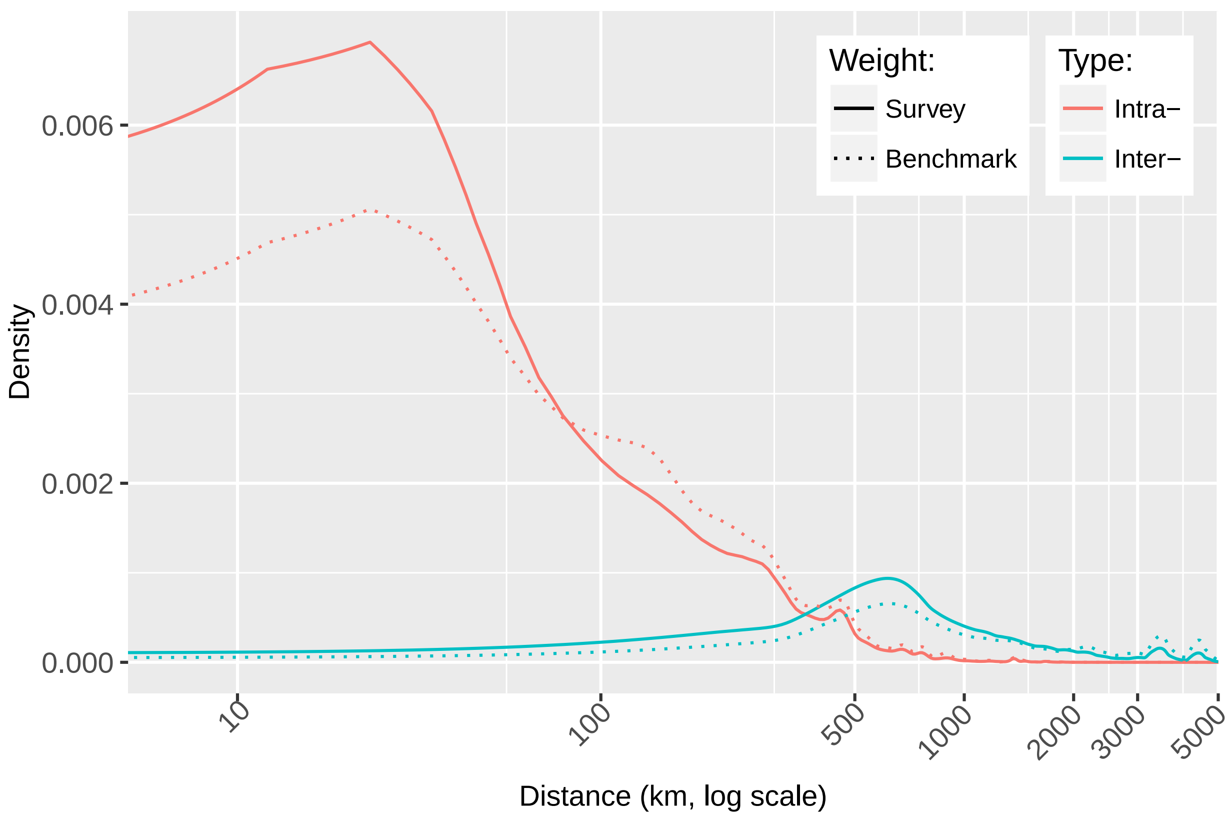


Figure 2: Intra- and inter-provincial distance shipped, benchmark and survey weights.

Notes: Distances are trimmed at 5000km for inter-provincial shipments to avoid the long right tail and focus on more-meaningful distance patterns. Epanechikov kernel is computed in R using the levels of distance (in km), and then converted to a log-scale.

3 Model and estimation strategy

The estimation of provincial border effects relies on the development of data of sufficient quality and richness to generate defendable estimates and a model and an estimator that is appropriate for the data at hand. This section addresses the latter concern.

3.1 Trade model

As is now standard in the literature (see Head and Mayer, 2014),[5] trade between regions i and j is treated as a multiplicative function of the capacity of i to serve export markets (S_i), the absorptive capacity of the export market in j (M_j), and a measure that captures the effect of trade costs between i and j (ϕ_{ij}):

$$X_{ij} = GS_iM_j\phi_{ij};\; 0 < \phi_{ij} < 1, \tag{2}$$

where G is a constant term. The export capacity can be defined by $S_i \equiv X_i/\Omega_i$, where $X_i \equiv \sum_j X_{ij}$ is the value of output in i and is the sum of exports across all trading partners (including itself). The absorbtive capacity can be defined by $M_i \equiv X_j/\Phi_j$, where $X_j \equiv \sum_i X_{ij}$ is the value of consumption in j and is the sum of imports across all trading partners (including itself). The terms Ω_i and Φ_j are multilateral resistance terms (Anderson and van Wincoop, 2003), where

$$\Omega_i = \sum_k \frac{\phi_{ik}}{\Phi_k} \text{ and } \phi_j = \sum_k \frac{\phi_{kj}}{\Omega_k}. \tag{3}$$

Ω_i is a measure of market access for exporting region i and Φ_j measures the level of competition in market j. Trade costs (ϕ_{ij}) are accounted for by the distance between i and j (d_{ij}), the effect of trading within-provinces (δ_p) and trading within sub-provincial regions (δ_r).

3.2 Estimator

Equation (2) can be estimated with OLS by adding a multiplicative error term, taking the natural logarithm of both sides:

$$\ln X_{ij} = \ln G + \ln S_i + \ln M_j + \underbrace{\beta \ln d_{ij} + \delta_p + \delta_r}_{\ln \phi_{ij}} + \ln \epsilon_{ij}, \tag{4}$$

with a set of origin and destination fixed effects to estimate $\ln S_i$ and $\ln M_i$, respectively. While this estimation strategy results in a loss of information regarding the underlying theoretically derived structure of the gravity model (Anderson and Yotov, 2010), it has become the standard means to estimate the gravity model[6] (see Anderson and Yotov, 2012),

[5]This basic exposition is borrowed from Head and Mayer (2014), albeit in a modified form.

[6]This functional form is, in fact, a very well-known variant of a family of gravity models (for reviews see Sen and Smith, 1995 and Fotheringham and O'Kelly, 1989). These constrained gravity models recognize that origin-destination flows often depend not only on the sizes of each origin and destination, but also their relative locations. The economics literature (see Anderson and van Wincoop, 2003), however, provides a firm micro behavioral foundation for the model, particularly within the trade setting.

in part because of ease of estimation, but also because the fixed effects may pick up origin- and destination-specific unobservables that can bias full information-based estimates (Anderson and Yotov, 2010; Head and Mayer, 2014).

Missing variable bias is particularly important in the context of this work. While every effort is made to assign trade flows to where goods are made and used, there may be cases where a destination is acting as a distribution centre, inflating its level of exports and imports. In a similar vein, some provinces may have stronger ties with world markets than other provinces (e.g., British Columbia) reducing their role as a domestic trading partner. In both instances, the fixed effects should take into account these unobservables that affect the level of trade in and out of a region (Head and Mayer, 2014).

The standard approach to estimating Equation (4) is to use ordinary least squares (OLS), but it introduces two potential sources of bias. First, starting with Santos Silva and Tenreyro (2006), it has been recognized that OLS estimates of a log-linearized multiplicative model are biased in the presence of heteroscedastic errors. Second, OLS estimates are biased in instances with a larger number of zero flows, which are dropped when the gravity model is estimated using OLS (see Head and Mayer, 2014). The latter is particularly important in this instance, because the models are estimated using flows between sub-provincial regions, resulting in many instances with zero flows between actively trading region pairs.

To address these problems, the first step is to assess whether the error term is heteroscedastic. To do so, the Manning and Mullahy (2001) test is applied using the following specification:

$$\ln \hat{\epsilon}_{ij}^2 = \alpha + \lambda \widehat{\ln X}_{ij}, \tag{5}$$

where $\widehat{\ln X_{ij}}$ is the predicted log-level of trade from the OLS estimation of (4) and $\hat{\epsilon}_{ij} = X_{ij} - \exp(\widehat{\ln X_{ij}})$ is the difference in levels between the data and the fitted values from the same estimator. Without zero flows, Head and Mayer (2014) find $\lambda \approx 2$ when the data generating process produces log normal errors, but $\lambda \approx 1.6$ when the data generating process produces (Poisson) heteroscedastic errors. In Table 2, the estimates of λ are presented for estimates by province, economic region (ER) and census division (CD), where each is a subunit of the other, respectively.

For provincial trade, the point estimate for λ is 2.11, suggesting log-normal errors. However, when the model is estimated by ER and CD the point estimates for λ are about 1.7. For ERs, where the number of zero flows is about 8%, the estimate is about what would be expected based on Monte Carlo simulations (see Figure 4 in Head and Mayer, 2014). For the CD estimates, where almost half of the pairs have zero flows, the expected value of λ is 1.6, with the actual estimate coming in again at about 1.7. However, this estimate is near what Head and Mayer (2014) obtain when they estimate λ from real data. The upshot is that in both instances the estimate for λ is significantly different from 2, suggesting the OLS estimator is inappropriate.

The second step is to assess the potential estimator in the presence of zero flows *and* heteroscedastic errors. Based on Monte Carlo simulation results, Head and Mayer (2014) find the Poisson Pseudo-Maximum-Likelihood estimator (Poisson-PML) of an appropriately transformed version of Equation (4) tends to produce the least bias. Therefore, it is our

Table 2: Manning and Mullahy (2001) test by province, economic region and census division.

Geography	λ	95% c.i.	N
Province	2.11	(1.92, 2.30)	100
Economic Region	1.71	(1.68, 1.74)	5,069
Census Division	1.68	(1.67, 1.69)	47,156

Notes: λ is estimated using Equation (5) for Provinces, Economic Regions, and Census Divisions. When λ is significantly different from 2, the test can be interpreted as indicating ordinary least squares is not the appropriate estimator.

preferred estimator, especially when estimates are based on flows between sub-provincial regions. It is also generally preferred because it perfectly replicates the Anderson and van Wincoop (2003) structural equation estimates (see Fally, 2015).

3.3 Geography and estimation

The analysis is based ultimately on the aggregation of point data into a set of geographic units of which the Standard Geographic Classification (hereafter standard geography) based units (e.g., ERs and CDs) are but one of an almost limitless number of geographies. As demonstrated by Hillberry and Hummels (2008), estimates of barriers to trade can be strongly influenced by the geography chosen. Hence, the sensitivity of the results to geography cannot be easily swept aside.

As noted above, Hillberry and Hummels' (2008) findings are an instance of the well-known and quite frankly terrifying Modifiable Areal Unit Problem (MAUP). MAUP is defined as "...the sensitivity of analytical results to the definition of units for which real data are collected" (Fotheringham and Wong, 1991, pg. 1025). MAUP is characterized by both a scale and zoning effect. That is, analytical results depend on the spatial resolution (scale effect) and the morphology (zoning effect) of the geography used to aggregate the data (Páez and Scott, 2004).

As has been shown elsewhere, these problems apply to multivariate statistics, including spatial interaction models like the gravity model (see Fotheringham and Wong, 1991; Amrhein and Flowerdew, 1992; Briant et al., 2010). In particular, Briant et al. (2010) show gravity model results are more sensitive to scale and to a lesser degree to zoning effects, but these are of secondary importance when compared to model specification problems (e.g., missing variable bias). Still, as Amrhein (1995) demonstrates, MAUP can emerge as a problem even when we abstract from model specification issues.

The effects of geographic aggregation need to be taken into account. This is accomplished by applying different geographies to the data. Here, two strategies are followed. The first is to see how sensitive the results are to the application of standard geographies, namely defining trading regions on the basis of Provinces, ERs, and CDs. The second strategy is to take advantage of the guidance provided by Arbia (1989) who shows analytically that biases resulting from the scale and zoning of the geography can be minimized by ensuring the geographic units are identical and spatially independent. Hence, a hexagonal lattice[7] is overlaid on the geocoded origin and destination points, creating an identical and spatially independent geography (see Figure 3). Hexagons that cross provincial borders are split and treated as discrete geographic units.

Of course, the use of a hexagonal geography, while perhaps minimizing the bias generated by aggregating data, does not eliminate it. Issues of scale and zoning remain. As there is no theoretically predetermined scale for the hexagons, the sensitivity of the results to size requires testing. For instance, compare the geographic coverage of the 75km and 225km per side hexagons in Figures 3a and 3b, respectively. The smaller hexagons cover portions of metropolitan areas, while the larger can envelop several. Similarly, while the hexagons do not change in shape, zoning still matters because they are arbitrarily positioned over the origin and destination points. For instance, in Figure 3a Toronto is split across two hexagons, while in Figure 3c it is split across three. Scaling and zoning effects will be tested by running the model across different scales and zonings.

4 Model estimates

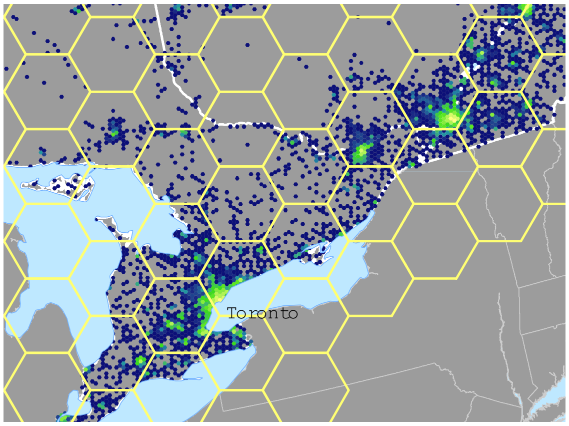
The presentation of the estimates proceeds first by estimating border effects using province-level estimates of trade flows and therein providing a base case. The exposition then shifts to the estimation of border effects using sub-provincial geographies, which forms the core of the analysis. The remainder of the discussion focuses on a set of robustness checks, with particular attention paid to the sensitivity of the estimates to MAUP, alternative specifications of the model, or combinations thereof.

4.1 Standard province-based estimates

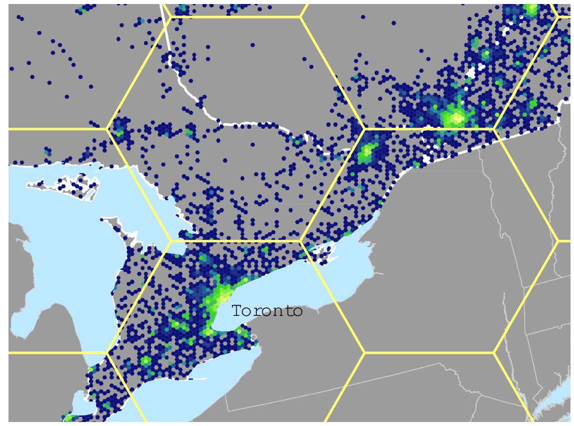
To begin, inter-provincial barriers to trade are measured by comparing intra- and inter-provincial aggregate trade levels. This serves several purposes. First, by comparing the actual level of inter-provincial trade to the benchmarked estimates the sensitivity of the results to the loss of trade from the benchmarking can be identified. Second, the OLS, Poisson-PML and Gamma-PML estimates can be compared absent zero flows. Based on their first-order conditions, the Poisson estimator puts more emphasis on the absolute deviation between the actual and predicted flows, while the OLS and Gamma-PML place more emphasis on the percentage deviation and as such are expected to give similar results (Head and Mayer, 2014). Third, the provincial results form a baseline to compare the estimated barriers to inter-provincial trade using trade between sub-provincial regions.

Table 3 (Panel A) presents the estimated effects of distance and own province on provincial trade using the input-output-based flows and those derived after benchmarking. The model is estimated using an appropriately transformed version of Equation (4) with the

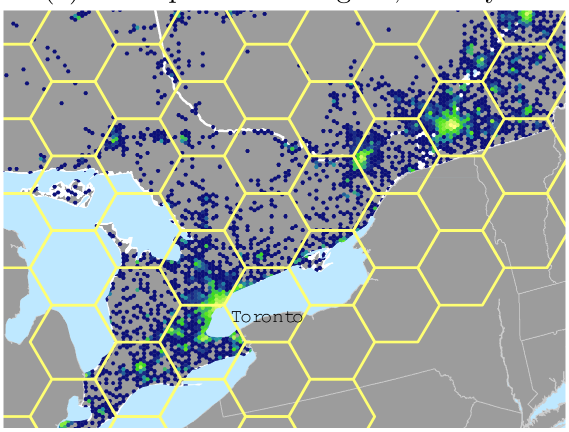
[7] Other geometries could have been used, such as squares or triangles, but hexagons are used because they would form trade market areas in an idealized world.



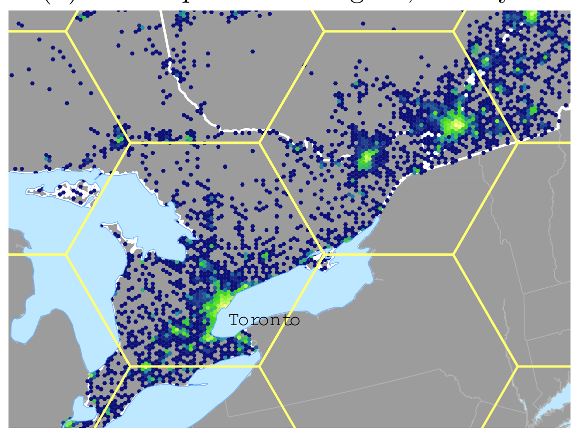
(a) 75km per side hexagons, overlay 1



(b) 225km per side hexagons, overlay 1



(c) 75km per side hexagons, overlay 2



(d) 225km per side hexagons, overlay 2

Figure 3: Size and placement of hexagonal lattices.

Notes: Figures 3a and 3c present two different overlays of hexagons with 75km sides on southern Ontario and Quebec, while Figures 3b and 3d do the same for hexagons with 225km sides. Hexagons must respect provincial boundaries and are split across provinces. Each 'point' in these maps is a 4km-sided (42km^2) hexagon with one or more origins/destinations (postal codes or railway terminals). The gradation in colour from blue to green to yellow denotes a greater number of origins/destinations. The 4km-sided hexagons are only for demonstration purposes, they are not used to determine which points fall into which hexagons in the econometric models.

mean level of provincial trade from 2004 to 2012 as the dependent variable. There are several points to be drawn from the table. First, estimates based on the input-output and benchmarked flows are similar. There is a tendency for the own province estimates to be lower when using the benchmarked estimates, but this effect is relatively small, particularly when the Poisson estimator is used. There is relatively little loss of generality resulting from the benchmarking and so the remainder of the discussion will focus on these estimates.

Second, there is evidence of a border effect, regardless of estimator used. The one exception is the OLS estimator, which is not significant for the benchmarked flows. Using

Table 3: Provincial border effect estimates based on provincial average flows (2004 to 2012).

	Input-output			Benchmarked		
	OLS	Poisson	Gamma	OLS	Poisson	Gamma
Panel A: Network distance						
Distance	-1.025^{***}	-0.661^{***}	-0.999^{***}	-1.077^{***}	-0.686^{***}	-1.078^{***}
	(0.0458)	(0.0496)	(0.0453)	(0.0576)	(0.0522)	(0.0537)
Own province	0.607^{***}	0.865^{***}	0.775^{***}	0.479	0.816^{***}	0.634^{**}
	(0.223)	(0.0807)	(0.190)	(0.289)	(0.0827)	(0.254)
Constant	12.31^{***}	9.916^{***}	12.42^{***}	11.70^{***}	9.515^{***}	12.08^{***}
	(0.410)	(0.559)	(0.373)	(0.630)	(0.877)	(0.535)
Border effect	1.83	2.38	2.17	1.61	2.26	1.89
N	100	100	100	100	100	100
Panel B: Great-circle distance						
Distance	-1.058^{***}	-0.778^{***}	-1.037^{***}	-1.100^{***}	-0.806^{***}	-1.106^{***}
	(0.0462)	(0.0571)	(0.0436)	(0.0613)	(0.0591)	(0.0564)
Own province	0.747^{***}	0.780^{***}	0.840^{***}	0.653^{**}	0.728^{***}	0.743^{***}
	(0.194)	(0.0907)	(0.171)	(0.274)	(0.0882)	(0.249)
Constant	12.01^{***}	10.49^{***}	12.17^{***}	11.29^{***}	10.12^{***}	11.70^{***}
	(0.405)	(0.547)	(0.360)	(0.644)	(0.848)	(0.535)
Border effect	2.11	2.18	2.32	1.92	2.07	2.10
N	100	100	100	100	100	100

Notes: Models include fixed effects for origins and destinations. ***, **, and * indicate significance at the 0.01, 0.05 and 0.10 levels, respectively. Robust standard errors are in parentheses. The border effect is given by exp(own province).

the input-output benchmarked estimates, the border effect ranges from 1.61 (OLS) to 2.26 (Poisson)—that is, within province trade is between 61 and 126% higher than inter-provincial trade after taking into account distance and multi-lateral resistance.

One of the benefits of building the trade estimates up from shipment data is that it is possible to obtain a more accurate measure of the distance goods travel within and between provinces. The sensitivity of the results to the distance measure can be tested by comparing estimates based on the network distance to the great-circle distance typically used in the literature (see Appendix 7.1.4). In a nutshell, how distance is measured matters. On average, great-circle distances are 66% of the actual distance shipped. As a result of the compression of distance, the parameter on distance should be more negative for the great-circle distance-based estimates, which is true regardless of the estimator. It is also the case that the great-circle within-province distances are, in relative terms, over-estimated (see Appendix 7.1.4 Table 7). This over-estimation will have the effect of biasing upwards the own province effect. The OLS and Gamma estimators show this effect, but not the Poisson where the bias appears to be captured by the coefficient on distance.

4.2 Estimates by sub-provincial geography

Estimates of provincial border effects based on the comparison of intra-provincial to inter-provincial trade flows may still suffer from bias, if these units do not effectively capture the pattern of trade. As shown by Hillberry and Hummels (2008), if short distance flows predominate and these are not properly captured by the internal distance measure, the estimated border effect may be upward biased.

To further establish the presence and strength of provincial barriers to trade, intra- and inter-provincial trade flows are measured using sub-provincial geographies of different sizes and morphologies. Since trade can be both within and between sub-provincial geographic units, a binary variable is included for within unit trade (own region). It should capture non-linearities with respect to the effect of distance for these shorter distance flows and/or differences in the nature of own unit versus between region trade. Within region trade is more likely to include short distance flows between manufactures and distribution centres, between distribution centres and retail stores (Hillberry and Hummels, 2003) or between upstream suppliers and downstream users of intermediate inputs (Hillberry and Hummels, 2008).

Moving from the provinces down to the scale of sub-provincial units introduces the problem of zero flows between trading units. The set of trading units is defined as those units that either make or use the good. Excluded are units that do not engage in goods trade, either within themselves or with other units. This may result from no measurable goods production in the unit or because of sampling variability. Since the estimates are based on the average value of trade over 9 years, the effect of sampling variability is likely to be low. Of course, those units included in the trading set do not trade with all potential units, resulting in zero flows. Zero flows may be due to random chance (again sampling variability) or they may be structural (producers incur costs above the trading threshold). To permit the presence of zeros, the Poisson estimator is used. For zero flows, the distance between regions is measured using the out-of-sample predicted values of a regression of the network distance on the great-circle distance.

As noted above, there are four geographic units used for the analysis. Two are based on standard geographies, ERs and CDs. The other geographic units are two hexagon lattices with sizes of 75km and 225km per side. Choosing hexagons with areas larger than 225km per side results in some smaller provinces having very few hexagons. On the other hand, using hexagons smaller than 75km per side results in such a large number of fixed effects that the estimation often fails to reliably converge, which is problematic for the simulations to follow.

Focussing first on ERs as the trading unit, the distance parameter tends to be less negative than the province-based estimates, with own region likely picking up the non-linear effect of

Table 4: Provincial border effect estimates based on flows between large and small hexagons (2004 to 2012).

	Geography				
	Standard		Hexagon		
	Economic Region	Census Division	225km	75km	FSA
Distance	-0.551^{***}	-0.573^{***}	-0.820^{***}	-0.742^{***}	-0.426^{***}
	(0.0461)	(0.0278)	(0.062)	(0.0357)	(0.0146)
Own region	0.408^{***}	0.467^{***}	-0.101	-0.0215	1.052^{***}
	(0.138)	(0.121)	(0.127)	(0.117)	(0.0966)
Own province	0.743^{***}	0.679^{***}	0.472^{***}	0.483^{***}	0.909^{***}
	(0.0951)	(0.0633)	(0.0872)	(0.0783)	(0.0421)
Constant	6.981^{***}	7.094^{***}	3.142^{***}	2.540^{***}	2.015^{***}
	(0.490)	(0.359)	(0.776)	(0.477)	(0.383)
Border effect	2.10	1.97	1.60	1.62	2.48
N	5,329	77,274	8,619	132,862	2,574,640

Notes: All models utilize a Poisson-PML estimator and include fixed effects for origins and destinations. ***, **, * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively. Robust standard errors are presented in parentheses. Large hexagons are 225km per side while small hexagons are 75km per side. Own region refers to flows within the geographic unit of analysis: Economic Region, Census Division, hexagon or Forward Sortation Area (FSA). The border effect is given by exp(own province).

short distance flows (see Table 4). More to the point, the own province estimate is smaller, resulting in an estimated border effect of 2.10. Using CDs—a fundamental building block of ERs—the number of potential trading pairs rise from 5,329 to 77,274. For this much larger set of smaller trading units, the border effect falls slightly to 1.97.

For both the small and large hexagons, the own region effects were not statistically significant, while the own province effect remained significant but notably smaller in magnitude than standard geographies. The result is an estimated border effect that falls in a narrow range from 1.60 (large hexagons) to 1.62 (small hexagons) (see Table 4).

On the surface, these results stand in contrast to Hillberry and Hummels (2008), who find state border effects are an artefact of the geography used to measure internal trade. However, they found border effects only disappeared when using an even finer grained geography than applied here, namely 5-digit ZIP codes. To account for this, the model was re-run using Forward Sortation Areas (FSAs), which are the closest Canadian analogue to ZIP codes.[8]

[8]FSAs are defined by the first three alphanumeric characters of a postal code. While the mean area of FSAs

Importantly, the point estimates for own province remains positive and significant (see Table 4). Provincial border effects remain even with a very fine-grained geography, a finding, as will become apparent, that is robust to a wide set of specifications (see Section 4.3.4).

The obvious conclusion to be drawn from the provincial- and sub-provincial-based estimates of the border effect is that the geography chosen matters, but at this point there is still insufficient information to draw strong conclusions. Two issues in particular need to be addressed. The first is the question of how sensitive the results are to the MAUP, namely scaling and zoning effects (i.e., the size and placement of the hexagons). It is unknown whether the variation in provincial border effects across hexagons of different sizes (or lack thereof) is outstripped by variability resulting from the placement of the hexagonal lattices. The second is whether there is a still unaccounted for non-linear effect of distance on trade that may, in turn, influence estimates of provincial border effects. The elasticity on distance varies considerably across geographies and estimators and, as Head and Mayer (2014) note, variation on the distance term between the Poisson and Gamma estimators may be an indication of model misspecification, which is observed in Table 3. The necessary next step, therefore, is to more rigorously assess how the geography and model specification, particularly non-linear effects of distance, influence estimated border effects.

4.3 Sub-provincial estimates robustness checks

To test the robustness of the estimates, the analysis proceeds in four steps. The first tests how sensitive the results are to the MAUP. The second step tests whether there is a non-linear effect of distance on trade that may, in turn, influence estimates of provincial border effects. The third combines the first two by asking how sensitive the results are to taking into account both MAUP and the non-linear effect of distance, and the fourth and final step returns to Hillberry and Hummels' (2008) results and asks whether provincial border effects remain using FSAs as trading units after applying their specification and estimator, as well as our fully-specified model.

4.3.1 Modifiable areal unit problem

The sensitivity of the results to the MAUP is tested by re-running the models on randomly shifted hexagonal lattices of varying sizes. Mechanically, the process is as follows. For a given size of hexagon, the lattice is superimposed on Canada's landmass, with each origin and destination point coded to their respective province and hexagon. The lattice is then perturbed by shifting the centroid of each hexagon to any random point within a circle circumscribed by its borders. The set of points is limited to the circumscribed circle, because shifting over more than one unit simply repeats the pattern. The origin and destination points are recoded to their province and hexagon. The lattice is randomly shifted 100

is much greater than ZIP code areas (5,894km^2 versus 229km^2), this is due to a few extremely large FSAs in Canada. In fact, the median FSA area is smaller than the median ZIP code area (41km^2 versus 96km^2) and FSAs remain smaller up to the 70th percentile. Given that these smaller FSAs are in dense metropolitan areas, they should be capturing the non-linear effect of distance on trade for these short distance flows.

times,[9] resulting in a set of parameters that describes how sensitive the estimates are to the placement of the lattice (i.e., the MAUP zoning effect) for a given size of hexagon. This is repeated for seven sizes of hexagons increasing in 25km per side increments from 75km to 225km. This accounts for how sensitive the results are to the size of hexagons (i.e., the MAUP scaling effect).

To represent the distribution of coefficients resulting from the simulations for the main variables—own province, own region (hexagon) and distance—Figure 4 presents box plots by size of hexagon. The boxes represent the inter quartile range, with the line intersecting the box being the median coefficient value. The ends of the whiskers—the upper and lower adjacent values—represent the ranked coefficient value that is nearest to but not above (below) 1.5 times the inter-quartile range from above (below). The dots signify extreme values.

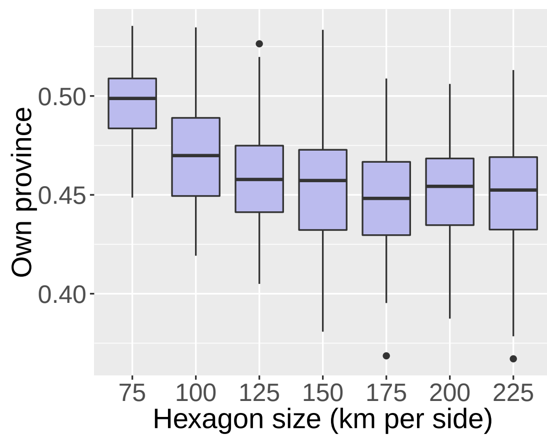
Regarding own province, the median coefficient values range from 0.50 for the smallest hexagons to 0.45 for the largest (scaling effect), with the coefficients converging towards the lower median value as the size of hexagons increase. This is consistent with Coughlin and Novy's (2016) analytical finding that if trade is particularly strong within small units as the size of the unit expands, the border effect will tend to fall. The placement of the hexagonal lattice (zoning effect) has a larger effect on the estimates, with the difference between the box plot lower and upper adjacent values being greater than the difference in the medians across the size of hexagons, which contrasts with Briant et al. (2010) who find the scaling effect is more important. More broadly, the lesson to be drawn is that shifting to a uniform geography has a qualitative effect on estimated border effects, and this result holds after taking into account the effect of the size and placement of the hexagons on the estimates.

4.3.2 Non-linear effects of distance

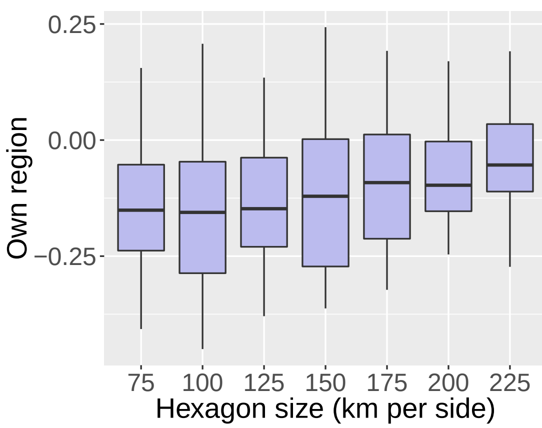
Variation in the results across hexagons of varying sizes may stem from a non-linear effect of distance on trade, a telltale sign of which is the negative association between hexagon size and the distance coefficient (see Figure 4). As the hexagons become smaller the average distance shipped falls. If these more prevalent shorter distance flows are underestimated, the provincial border effect will be overestimated, because intra-provincial trade occurs over shorter distances more than inter-provincial trade (see Figure 2). This appears to be the case as there is a positive association between the own province and the distance coefficients (see Figure 4).

There are at least two reasons why the effect of distance on trade is expected to vary with itself. First, prices charged by trucking firms, for instance, include fixed and variable (line-haul) cost components. Since fixed costs per shipment are around $200 and line-haul costs increase at about $0.80 per km (see Brown, 2015), prices inclusive of transport costs will be (effectively) uniform over short distances. Second, the endogenous clustering of upstream

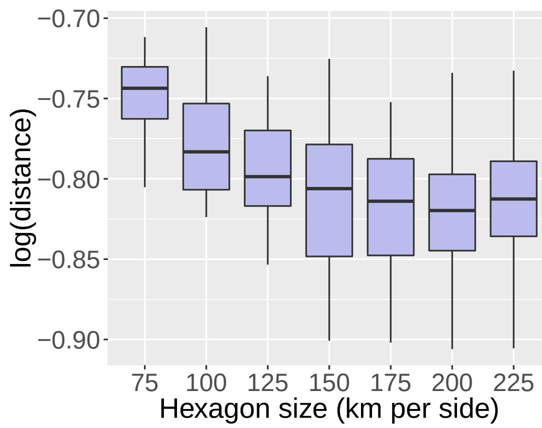
[9] It would have been preferable to randomly shift the lattices more than 100 times and increase the number of size categories used, but this is a computationally burdensome process, both in terms of geo-coding the flows to a given lattice and with respect to the Poisson PML estimations.



(a)



(b)



(c)

Figure 4: Coefficient estimates for Own Province (4a), Own Region (4b), and log(*distance*) (4c), by size (km per side) and placement of hexagons.

Notes: The boxes represent the inter quartile range, with the line intersecting the box being the median coefficient value. The ends of the whiskers—the upper and lower adjacent values—represent the ranked coefficient value that is nearest to but not above (below) 1.5 times the inter-quartile range from above (below). The dots signify extreme values.

suppliers and downstream firms[10] and hub and spoke distribution networks[11] (Hillberry and Hummels, 2008) may result in a large volume of trade over short distances with a steep drop as distance shipped moves beyond these 'just down the street' shipments. Uniform prices

[10] As shown in Behrens et al. (2015), plants tend to cluster geographically and this is negatively associated with distance from upstream suppliers and downstream intermediate goods users.

[11] If short distance trips from manufactures to distribution centres or from distribution centres to retail stores are captured by the data, which may still be the case despite the steps taken to adjust for these effects, the same pattern of trade will be observed as resulting from clustering.

over short distances combined with clustering/distribution effects results in a complicated set of expectations. For very short distance flows, the effect of distance on trade may be very negative (or at least after a short plateau), but the negative effect of distance on trade beyond these very short distance flows is expected to be initially weak, but increasing as variable costs outstrip the effect of fixed costs on transportation rates. This pattern in the data requires moving beyond the standard quadratic form to account for non-linearities.

To account for these non-linear effects of distance, the model is re-estimated using a spline with knots at 25km, 100km and 500km (see Table 5) employing the same hexagonal lattices used for the estimates presented in Table 4.[12] Focussing on the smaller hexagon results, the distance elasticities are consistent with a steep drop in shipments over very short distances (reflecting the co-location of input-output linked plants, for instance), while the insignificant effect of distance for 25 to 100km distance flows is consistent with a relatively constant transportation rate charged by firms over short distances. Importantly, accounting for the non-linear effect of distance causes the coefficient on own province to become more similar across hexagon size classes. Still, given the sensitivity of the result to the placement of the hexagonal lattices, it remains unclear from this one set of point estimates how truly similar the border effect estimates are between the large and small hexagons.

Finally, as is standard in the literature, a binary variable is added for hexagons that share a border (contiguous regions). The expectation is that the contiguity measure will account for short distance flows across boundaries. For both the large and small hexagons, the contiguous region coefficients is insignificant, and the own province coefficient falls while remaining significant.

4.3.3 Non-linear effects of distance and the modifiable areal unit problem

This next check assesses whether accounting for the non-linear effects of distance reduces the degree of variation in results across different sizes and placement of hexagons. This is again accomplished by randomly perturbing the hexagonal lattices for the largest (225km per side) and smallest (75km per side) hexagons, but also across model specifications. The 'base' model estimates replicate those presented in Figure 5 (which use the specification presented in Table 4), while Model 1 and Model 2 match those in Table 5.

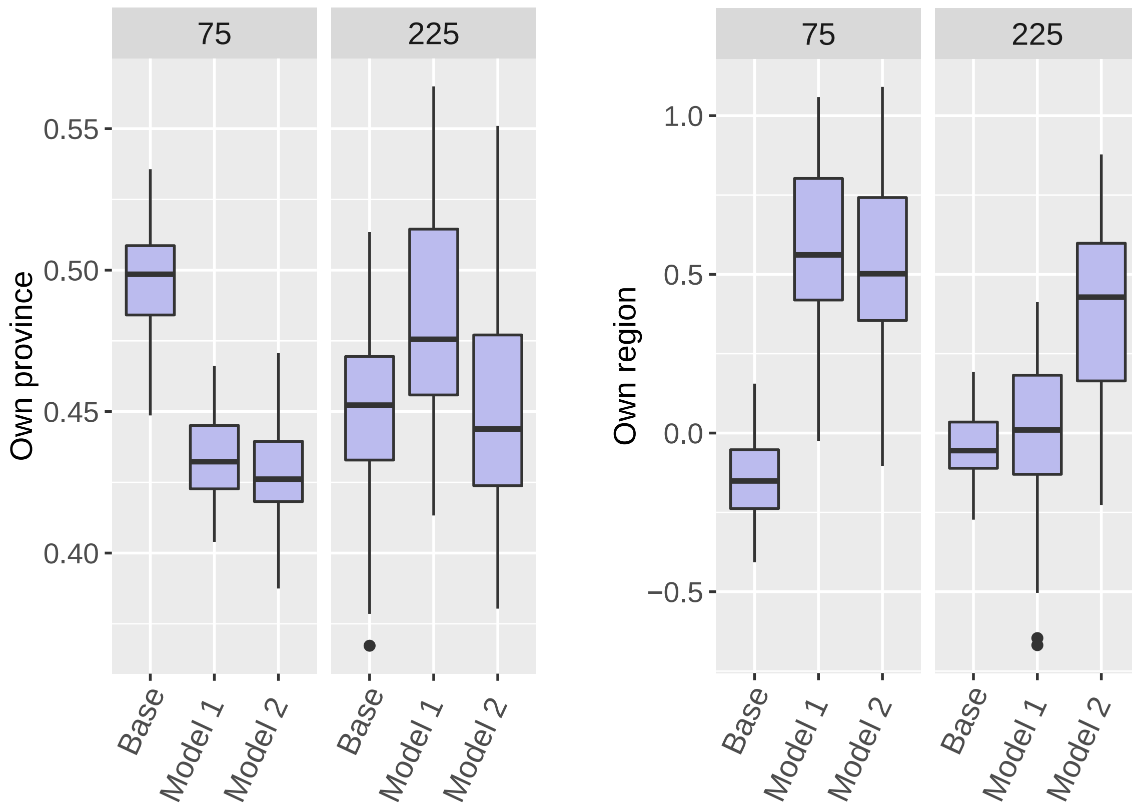
Taking into account the non-linear effect of distance reduces the median coefficient of the small hexagons, but increases that of the large hexagons (see Figure 5), effectively reversing the pattern in Figure 4. The addition of contiguity to the model (Model 2) produces large and small hexagon-based provincial border effects that are statistically indistinguishable. The coefficients on own hexagons also converge, but this only occurs when contiguity is taken into account. While the central tendencies of the small and large hexagon coefficient distributions are the same, their variances are not, with the large hexagons having more than double the inter-quartile range of the small hexagons. Hence, on this basis, the small hexagon border effects are the most reliable.

[12]These particular hexagonal lattices are used to maintain comparability across the models.

Table 5: Robustness of provincial border effect estimates to non-linear effects of distance and contiguity.

	Hexagons			
	225km per side		75km per side	
	Model 1	Model 2	Model 1	Model 2
Distance				
0 to 25km	−1.356***	−1.338***	−0.932***	−0.923***
	(0.284)	(0.281)	(0.122)	(0.122)
25 to 100km	−0.544	−0.561	−0.268	−0.276
	(0.471)	(0.469)	(0.227)	(0.227)
100 to 500km	−0.836***	−0.720***	−0.711***	−0.801***
	(0.119)	(0.120)	(0.0598)	(0.0915)
greater than 500km	−0.818***	−0.772***	−0.862***	−0.858***
	(0.0854)	(0.109)	(0.0684)	(0.0689)
Own region	−0.0608	0.233	0.312*	0.179
	(0.173)	(0.237)	(0.161)	(0.199)
Own province	0.458***	0.412***	0.431***	0.418***
	(0.0839)	(0.0755)	(0.0713)	(0.0709)
Contiguous regions		0.195		−0.132
		(0.138)		(0.0972)
Constant	4.513***	4.184***	2.638***	2.746***
	(0.807)	(0.833)	(0.494)	(0.501)
Border effect	1.58	1.51	1.54	1.52
Observations	8,619	8,619	132,862	132,862

Notes: All models utilize a Poisson-PML estimator and include fixed effects for origins and destinations. ***, **, * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively. Robust standard errors are presented in parentheses. For the 75km per side hexagons (Model 4), origins and destinations with very few flows were dropped in order to estimate the standard errors. The point estimates remain qualitatively unchanged compared to the full-sample results. The border effect is given by exp(own province).



(a) (b)

Figure 5: Coefficient estimates for Own Province (5a) and Own Region (5b) by model, hexagon size (km per side) and placement.

Notes: The 'base' model estimates replicate those presented in Figure 4 (which use the specification presented in Table 4), while Model 1 and Model 2 match those in Table 5. The boxes represent the inter quartile range, with the line intersecting the box being the median coefficient value. The ends of the whiskers—the upper and lower adjacent values—represent the ranked coefficient value that is nearest to but not above (below) 1.5 times the inter-quartile range from above (below). The dots signify extreme values.

4.3.4 Provincial border effects based on Forward Sortation Areas

As a last robustness check, the analysis revisits Hillberry and Hummels' (2008) finding that state border effects are eliminated when trade is measured using 5-digit ZIP codes. This entails initially using the same estimator (OLS) and model specification (quadratic term on distance) used in their analysis and then applying the preferred estimator (Poisson) and model used above (distance effects estimated using a spline).

While the model and estimators can be equated, it should also be kept in mind results may vary because of differences in the underlying data. First, because Hillberry and Hummels'

(2008) Commodity Flow Survey data are shipper-based, shipments can be limited to those of manufactures, rather than wholesalers and distributors. As the data used here are carrier-based, it is not possible to distinguish between the two. To the extent that shipments from wholesalers are more localized, stronger trade is more likely at short distances, which should be accounted for by the own region (FSA) term.

Second, because of benchmarking and Canada's geography, the STF data are weighted towards longer distance flows, with the average distance shipped between FSAs being 1,679km (1049 miles), while the average distance between ZIP codes is 837km (523 miles) (see Hillberry and Hummels 2008). Since the distance elasticity increases (in absolute terms) with distance shipped, the expectation is that the effect of distance is likely to be stronger here.

Table 6 shows the estimates, with the first three columns of results based on the equivalent model used in Hillberry and Hummels (2008, Table 2). The first column presents the OLS-based estimates, while the second and third columns present the Poisson-based estimates with and without zeros included, respectively. Evaluating the effect of distance using the CFS mean distance of 837km (523 miles) the elasticity is -0.42, more than double the ZIP code-based estimate of -0.19. Also found is a much higher point estimate for own region (FSA). These results are in line with our expectations given the differences between the underlying data. Notably, the own province effect is positive and significant using the same estimator, model and equivalent geography as Hillberry and Hummels (2008).

The application of the Poisson estimator reduces the effect of distance, because larger, (typically) short distance flows are weighted more heavily. Evaluated at 837km, the elasticity on distance is -0.25, and only slightly lower when zero flows are added. The Poisson estimator also produces smaller but still significant own region and province effects. The inclusion of zero flows, results in a positive coefficient on distance up to 5km, and then a declining point estimate thereafter. The effect of adding zeros also raises the point estimates on own region and province. The highly non-linear effect of distance when the Poisson estimator is applied suggests the influence of distance on trade has to be treated in a very flexible manner. This is accomplished, as above, by estimating a spline on distance.

Model 2 uses the same structure as Model 1 in Table 5, with knots at 25km, 100km and 500km. The estimated provincial border effect is lower than when the quadratic is used on distance, but remains significant. Unlike when hexagons are used, there is no strong negative effect on distance between 0 and 25km. The effect of short distance flows is captured by the own region term instead, with a strong positive coefficient, because the vast majority of FSAs are small and located in metropolitan areas. Hexagons, whose size distribution by construction is not associated with the density of short distance flows, have a weaker relationship. The estimated provincial border effect is unchanged with these modifications to the specification. In short, unlike Hillberry and Hummels (2008), the adoption of very small trading units does not eliminate border effects. Therefore, provincial border effects, while sensitive to the specification of the model and geography, are never eliminated. The remaining question is whether they are economically meaningful.

Table 6: Provincial border effect estimates for Forward Sortation Areas (FSA).

	OLS	Poisson				
	Model 1	Model 1		Model 2	Model 3	Model 4
Distance	-0.490^{***}	-0.0105	0.217^{***}			
	(0.0220)	(0.0517)	(0.0566)			
Distance squared	0.0104^{***}	-0.0353^{***}	-0.0661^{***}			
	(0.00178)	(0.00446)	(0.00479)			
Distance						
0 to 25km				-0.0678		
				(0.0587)		
0 to 10km					0.303^{***}	
					(0.110)	
0 to 5 km						0.542^{**}
						(0.245)
5 to 10km						0.0223
						(0.347)
10 to 25km					-0.461^{***}	-0.393^{***}
					(0.116)	(0.131)
25 to 100km				-0.296^{***}	-0.198^{***}	-0.206^{***}
				(0.0668)	(0.0669)	(0.0667)
100 to 500km				-0.497^{***}	-0.507^{***}	-0.505^{***}
				(0.0377)	(0.0374)	(0.0375)
greater than 500km				-0.767^{***}	-0.764^{***}	-0.764^{***}
				(0.0235)	(0.0235)	(0.0235)
Own region	2.357^{***}	1.316^{***}	1.494^{***}	1.472^{***}	1.561^{***}	1.551^{***}
	(0.104)	(0.101)	(0.101)	(0.104)	(0.0998)	(0.101)
Own province	1.211^{***}	0.468^{***}	0.616^{***}	0.592^{***}	0.592^{***}	0.593^{***}
	(0.0154)	(0.0361)	(0.0385)	(0.0393)	(0.0393)	(0.0393)
Constant	-3.117^{***}	1.618^{***}	1.123^{***}	1.416^{***}	0.793^{*}	0.551
	(0.217)	(0.399)	(0.408)	(0.415)	(0.442)	(0.472)
Observations	652,214	652,214	2,574,640	2,574,640	2,574,640	2,574,640
Border effect	3.36	1.60	1.85	1.81	1.81	1.81
Dist. elasticity, 832km	-0.42	-0.25	-0.23			
Includes zero flows	No	No	Yes	Yes	Yes	Yes

Notes: All models utilize a Poisson-PML estimator and include fixed effects for origins and destinations. ***, **, * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively and are based on robust standard errors. The border effect is given by exp(own province).

5 Tariff equivalent of provincial border effects

To estimate the tariff equivalent of the provincial border effect the approach described in Head and Mayer (2014, pgs. 32–34) is applied. δ_p denotes the provincial border effect coefficient, which reflects the reduction in trade costs between sub-provincial regions by simply being part of the same province. Given that $\delta_p = \eta(\ln \rho^{inter} - \ln \rho^{intra})$, where ρ^{inter} and ρ^{intra} are inter-provincial and intra-provincial trade costs, respectively, and η is the trade elasticity with respect to transportation costs, if t is the tariff that must be removed to equate the cost of moving goods within and between provinces, then the inter-provincial trade tariff equivalent is

$$t = (1+\nu)\left[\exp(\delta_p/\eta) - 1\right], \tag{6}$$

where ν is the tariff equivalent of within-province barriers to trade, which are assumed to be zero. Hence the only missing information, is the trade cost elasticity of trade:

$$\ln X_{ij} = \phi_i + \xi_j + \eta \ln \tau_{ij} + \mu_{ij}, \tag{7}$$

where τ_{ij} is 1 plus the *ad valorem* transportation costs, ϕ_i and ξ_j are respectively origin and destination fixed effects and μ_{ij} is the error term. *Ad valorem* transportation costs are derived from the STF, which reports both the price charged to shippers and the estimated value of each shipment. The estimated[13] price elasticity based on (7) is -6.40, which is between the median (-5.03) and average (-6.74) price elasticities identified in Head and Mayer's (2014) meta-analysis.

For the median provincial border effect coefficient on the 75km per side hexagon (see Figure 5, Model 2), $t = \exp(0.426/6.40) - 1 = 0.069$, or 6.9%. To provide some perspective, using a very different methodology, Agnosteva et al. (2014) arrive at a lower, but statistically indistinguishable,[14] estimate of 5.6%.

The tariff equivalent of the border effect across the standard and hexagonal geographies are presented in Figure 6 and illustrate the impact of the trading unit chosen on the border effect. The hexagons use the median point estimates from the simulations presented in Figures 4 and 5. The provincial estimates are the highest at 13.6% followed closely by the ER- and CD-based tariff equivalents of 12.3% and 11.2%, respectively. It is the imposition of a uniform hexagonal geography that causes the most notable drop in the tariff rate. As the hexagons become larger, the point estimates converge to tariff equivalent of 7.3%. The tariff equivalent for the 75km and 225km per side hexagons that takes into account the non-linear effect of distance and contiguity (see Figure 5, Model 2) provides the lowest estimates that are essentially indistinguishable.

Therefore, in the fully specified model the size of hexagon chosen is of little consequence. At 6.9%, the 75km per side hexagons provide the preferred estimate, because of the smaller inter-quartile range relative to the 225km per side hexagons. Compared to this estimate, relying on provincial trade would increase border effect estimates by 6.7 percentage points. This difference is non-trivial. To put it into some perspective, this value is about the same as Canada's mean tariff rate (4.9%)[15] and larger than *ad valorem* transportation costs on internal trade (2.5%)[16].

[13] Equation (7) is estimated using ordinary least squares. ERs are used as the trading unit because of the lack of zero flows that can bias the estimates.

[14] For instance, the 5.6% point estimate falls within the 90% confidence interval using the point estimates from Model 2 in Table 5 using the 75km per side hexagons.

[15] The estimate is based on the unweighted mean MFN tariff rate for the period 2004 to 2008. Source: `http://data.worldbank.org/indicator/TM.TAX.MRCH.SM.FN.ZS` (accessed: July 14, 2015).

[16] This is the average ad valorem transportation cost across 2-digit SCTG commodities for internal Canadian trade.

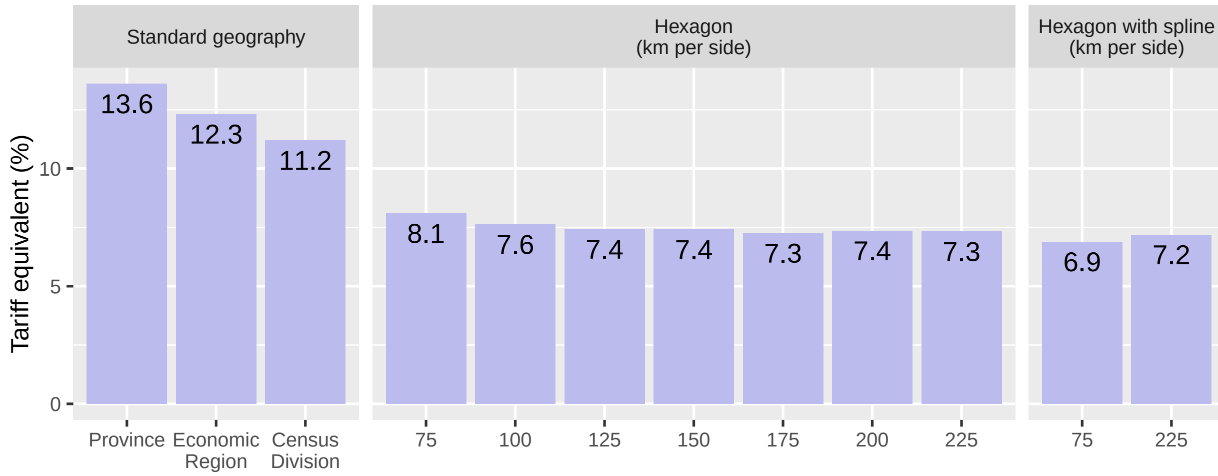


Figure 6: *Ad valorem* tariff equivalent by standard and hexagonal geographies.

Notes: All tariff equivalents are estimated using a price elasticity on transportation costs of -6.40. The standard geography *ad valorem* tariff equivalents are based on the provincial border effect estimates from Table 3 (Poisson estimate of the benchmarked flows using the network measure of distance) and Table 4. The hexagon-based tariff equivalents are based on the median point estimate from Figure 4, while the hexagon with spline-based tariff equivalents use the median point estimate from Figure 5 based on Model 2 from Table 5.

6 Conclusions

Intra-national border effects have proven difficult to measure because of a lack of geographically detailed data on trade within and across provinces. Using a very flexible transaction-level transportation data file to generate regional trade flows within and across provincial borders, the analysis show that regardless of the model or geography chosen provincial border effects are always significant, with an implied *ad valorem* tariff equivalent of 6.9%. This stands in contrast to the U.S.-based estimates, where state border effects are eliminated when similar approaches—i.e., same model and geography—are applied (Hillberry and Hummels, 2008).

Beyond this substantive contribution, the paper's other contributions are methodological. The development of geocoded transaction-level data made it possible to test the effects of geography and model specification simultaneously through a set of simulations. From this several points can be drawn. First, while the results are sensitive to the size of geographic unit chosen (i.e., provinces, economic regions, census divisions and hexagons) there is no simple linear relationship between (average) size and border effects. In fact, choosing a uniform shape (à la hexagons) is more important than size, which speaks to Arbia's (1989) analytical finding that biases resulting from the scale and zoning of the geography are minimized when using identical units.

Second, after taking into account the non-linear effects of distance, the median smallest and largest hexagon's parameters converge. In other words, with a correctly specified model, the geographic scale of the unit does not matter. Finally, considerable variation in the estimates result from the simple shifting of the hexagonal lattice, even after applying the full model. These effects are, perhaps unsurprisingly, minimized by using smaller geographic units. In total, the most precise estimates come from a model that carefully accounts for the effect of distance on flows between small, uniform geographic units.

There is, of course, more work that needs to be done. Identifying the effect of provincial non-tariff barriers on estimated border effects will require direct information on the extent of these barriers, and other factors that influence inter-provincial trade (e.g., firm linkages and migratory flows across provincial borders). Furthermore, while this work is able to estimate provincial border effects and their tariff equivalents, there remains the question of the overall welfare implications if they were eliminated, which as Albrecht and Tombe (2016) demonstrate can be substantial.

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7 Appendix

7.1 Data Appendix

7.1.1 Valuing shipments

The waybills on which the Surface Transportation File (STF) is based describe the commodity and tonnage for each shipment, but not its value. To generate an estimate of value, required is a measure of the value per tonne. This is derived from an experimental transaction level trade file that measures the value and tonnage of goods by detailed HS commodity in 2008. Since the trade file identifies the mode used for each shipment, the value per tonne for each commodity also varies by the mode used. Export prices indices are used to project the value per tonne estimates through time (see Brown, 2015 for a more detailed discussion).

7.1.2 Geocoding shipment origins and destinations

Using postal code data from the Trucking Commodity Origin Destination (TCOD) survey and Standard Point Location Codes (SPLC) from the rail waybill file, each shipment is geocoded (given a latitude and longitude for the origin and destination) from 2004 to 2012. These are then used to give the file a 2006 Standard Geographic Classification. As a result, each origin and destination is coded to its ER and CD. Prior to 2004, the TCOD did not use postal codes to identify origins and destinations. For these years the flows are only coded to ERs and CDs. Note that because origins and destinations are given latitudes and longitudes other non-standard geographies can also be applied, such as the hexagonal lattices used here. Just over half of the postal codes are imputed, which likely reduces their accuracy. Nevertheless, when mapped, those postal codes that were imputed and not imputed presented similar geographic patterns.

7.1.3 Benchmark weights

When constructing the file, one of the primary goals is to ensure that the value of trade on a shipment basis in the STF adds to known trade totals by commodity from the inter-provincial trade flow file. To do so there are two problems that need to be overcome as the files represent different trade concepts and use different commodity classifications.

In the interprovincial trade flow file, a source represents the point of production, while a destination represents a point of consumption. However, in the STF, a source represents the point at which the shipment is picked up, while the destination is the point at which the shipment is dropped off, including warehouses that act as transportation waypoints. A commodity that is produced in Quebec and consumed in BC would be recorded as a flow from Quebec to BC in the inter-provincial trade flow database, but that flow may have multiple sources and destinations in the STF if it stops at warehouses in different provinces along the way. For instance, a Quebec to BC trade flow might be counted as flows from Quebec to Ontario and then from Ontario to BC in the STF. This results in the STF overestimating the flows between close provinces and underestimating the flows between provinces that are farther away from each other, potentially biasing upwards border effect estimates. The benchmarking is an attempt to re-weight the surface transportation shipments to reflect the inter-provincial trade flow concept.

In addition to representing different concepts, the two files use related, but in practice, different commodity classification systems. Although both commodity classifications are built from the commodity-based Harmonized System (HS), the resulting aggregate classifications used are so different as to eliminate any possible one-to-one matching between them. The STF uses the Standard Classification of Transported Goods (SCTG 1996),[17] while the inter-provincial trade flow file uses the Input-Output Commodity Code system (IOCC). At every level of aggregation, there are SCTG codes that map to multiple IOCC codes, and vice versa. Since the number of multiple matches is large, no attempt is made to force a

[17] http://www.statcan.gc.ca/subjects-sujets/standard-norme/sctg-ctbt/sctgmenu-ctbtmenu-eng.htm.

single IOCC code to any SCTG code. Instead, the goal is to benchmark the transportation file so that it represents the same values as the interprovincial flow file without taking a stand on which transported commodities represent which input-output commodities. That is, instead of forcing a one-to-one concordance between the files, we employ a strategy where the benchmark weights are set such that flows add total commodity flows generated by the input-output system. The process for doing so is set out in a series of steps.

In the first step each file is aggregated to include values of flows by year, origin province, destination province and commodity (SCTG for the surface transportation file and IOCC for the inter-provincial flow file). This generates two vectors of the value of trade for IOCC commodity flows and SCTG commodity flows: X_I and X_S, respectively.

The second step builds a concordance between SCTG and IOCC by province pair and year. This is done through one-to-many mappings from SCTG to HS and from IOCC to HS, which combine to form a many-to-many map from SCTG to IOCC forming a concordance matrix C used in the third and final step.

In the final step the benchmark weights are calculated. To do so, for each year and origin and destination province pair, the two commodity vectors, X_I and X_S, are combined with the concordance matrix C, of which all values are either 0 or 1 (depending on whether a given SCTG commodity maps to a given IOCC commodity). Defining the number of IOCC commodities as M and the number of SCTG commodities as N, then X_I has length M, X_S has length N, and C is an $M \times N$ matrix. Then the benchmarking problem can be written:

$$(B \circ C)X_S = X_I, \tag{8}$$

where B is the $M \times N$ matrix of benchmark values, and $\circ$ is the element-wise matrix product (Hadamard product). Any B that solves this system of equations will benchmark X_S to X_I. The problem is to find a solution to M equations given $M \times N$ unknowns. A typical solution is to force C to be one-to-one such that if $c_{mn} = 1$, then $c_{mo} = 0$ for all $o \neq n$ and $c_{on} = 0$ for all $o \neq m$, where i and j index elements of C. In that way, the matrix $B \circ C$ has only M non-zero values and the benchmark weight is $b_{mn} = V_{I_m}/V_{S_n}$. In this case, the concordance would be static. There would be no need to undertake a concordance by year let alone province pair. However, this approach throws away considerable amounts of information regarding the underlying trading relationships between provinces as the commodity profile of trade varies across province pairs. For instance, the commodity in a forced pairing may not be found in the trade between the two provinces. Hence, the benchmarking concordance should reflect and indeed take advantage of those differences.

In order to preserve information in the face of a particularly severe many-to-many concordance problem in C, each element of B is separated into two parts, $b_{mn} = b_m \hat{b}_{mn}$, where

$$\hat{b}_{mn} = \left(\frac{X_{S_n}}{\sum_o c_{mo} X_{S_o}} \right) \left(\frac{X_{I_m}}{\sum_o c_{on} X_{I_o}} \right). \tag{9}$$

Equation (9) is simply the product of the trade shares of the concorded SCTG- and IOCC-based flows. It is assumed that the SCTG- and IOCC-based flows are an accurate representation of the patterns of trade and therein provide appropriate splits against which to benchmark. b_m is the value that solves the equation

$$b_m \sum_n \hat{b}_{mn} c_{mn} X_{S_n} = X_{I_m}, \tag{10}$$

for each equation in the system, with the convention that $b_m = 0$ if $X_{I_m} = 0$ or the sum on the left-hand-side of Equation (10) is zero. The only remaining issue is to calculate a single benchmark value for one SCTG code given by

$$w_n^b = \sum_m b_{mn} c_{mn}, \tag{11}$$

which is considered the benchmark weight for all shipments of SCTG commodity m in that year and province origin-destination pair. In other words, w_n^b is the sum of the values of column n of $B \circ C$.

Again, any B that solves this equation will be a benchmark, but the choice is made to maximize the information available. Specifically, $\hat{b}_{mn}$ is picked to use the value of an SCTG commodity flow relative to the total SCTG flows that point to the same IOCC code m, and also the value of the flow of that IOCC code relative to all of the IOCC codes that are pointed *at* by SCTG commodity n. In addition, although we cannot compare two commodities directly, we know the total value of benchmarked trade is that same as the total value of inter-provincial trade (for each year-province-province observation), because

$$\sum_n w_n^b X_{S_n} = \sum_m X_{I_m}. \tag{12}$$

Hence, the procedure achieves the ultimate goal of ensuring trade flows add to know totals from the provincial accounts. Unfortunately, in some cases the sample of shipments will not cover all of the SCTG commodities between two provinces in a year (see Figure 1 in Section 2). In this case, for some IOCC commodity m, the i-th element of the vector $(B \circ C)X_S$ is zero because $X_{S_n} = 0$ for all the possible commodities that map to I_m (i.e., those for which $c_{mn} = 1$). In this case, the element X_{I_m} is included in the total interprovincial trade, but the corresponding X_{S_n} is zero on the right-hand-side, which means the total trade the STF is less than the total trade in the interprovincial flows,

$$\sum_n w_n^b X_{S_n} < \sum_m X_{I_m}. \tag{13}$$

Finally, in the main body of the text the subscript n is supressed such that the benchmark weight is w^b.

7.1.4 Comparing network and great-circle intra- and inter-provincial distances

The analysis relies on the network distance between geocoded origins and destinations, which is the average of transaction-level intra- and inter-provincial distances. Traditionally, intra- and inter-provincial distances are measured using the origin-destination population-weighted great-circle distance (hereafter great-circle distance) between sub-provincial units (see, for example, Brown and Anderson, 2002). This is calculated for the set of sub-provincial units (census divisions) within each province for intra-provincial trade and between the sets of sub-provincial units for each province pair:

$$d_{op} = \sum_{i \in o} \sum_{j \in p} \left(\frac{pop_i pop_j}{\sum_{i' \in o} \sum_{j' \in p} pop_{i'} pop_{j'}} \right) d_{ij}, \tag{14}$$

where o and p index provinces, i and j index census divisions, pop is the population of the census division and d is the great-circle distance between the centroids of census divisions. For intra-provincial trade ($o = p$), within census division distance is the radius of a circle of an area equal to that of the census division: $d_{ii} = \sqrt{area_i/\pi}$.

It might reasonably be assumed that network distance is always longer than great-circle distance. However, because the actual (network) distance travelled is skewed towards short distance trips, when short distance trips are more prevalent (e.g., for intra-provincial trade or trade between contiguous provinces), the measured network distance may be shorter. That is, for the great-circle distance, holding population constant, the distance between nearer census division pairs is weighted the same as between the more distant census division pairs. The network distance estimates, because they are derived from actual trips, will weigh more highly closer census division pairs.

This pattern in the data is evident in Table 7, which presents the network and great-circle distance within and between provinces. On average, network distance is 33% greater than the great-circle distance. However, there is a tendency for intra-provincial distances and distances between contiguous provinces to be closer to (or even less than) the network distance. For intra-provincial, contiguous province, and non-contiguous provinces network distance is 9%, 25% and 38% greater than great-circle distance, respectively. The exceptions are the Atlantic provinces, which form a *de facto* archipelago whose internal network distances quite naturally outstrip great-circle distances by a wide margin (see Table 7).

There are two implications that follow from these distance patterns for the econometric analysis. First, because great-circle distance is less than network distance, the elasticity on distance will be less when network distance is used. Second, the relatively shorter intra-provincial great-circle distances will tend to inflate the intra-provincial trade coefficient (border effect), because the underestimated intra-provincial trade given the actual distance travelled. Both effects are seen in the estimates.

7.2 Additional Robustness checks

7.2.1 Testing for the differential effect on distance on intra- and inter-provincial trade

If intra-provincial trade is populated with a large set of logistics-truncated flows, the distance parameter on intra-provincial flows should be more negative than inter-provincial flows, whose pattern results from benchmarking to the flows from the provincial input-output

Table 7: Network and great-circle distance.

	N.L.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta	B.C.
Panel A: Network distance (km)										
Newfoundland and Labrador	386	1,364	1,226	1,344	1,567	2,789	4,650	5,223	6,074	6,902
Prince Edward Island	1,412	61	333	272	1,115	1,706	3,584	4,209	4,810	5,696
Nova Scotia	1,326	324	136	389	1,173	1,815	3,616	4,308	4,977	5,802
New Brunswick	1,359	240	396	153	692	1,357	3,293	3,946	4,588	5,307
Quebec	1,478	1,095	1,222	728	280	584	2,459	3,114	3,734	4,607
Ontario	2,818	1,730	1,819	1,456	599	191	2,026	2,798	3,429	4,320
Manitoba	4,573	3,526	3,627	3,236	2,410	1,707	213	654	1,340	2,207
Saskatchewan	5,249	4,127	4,322	3,929	3,118	2,692	621	221	683	1,570
Alberta	5,806	4,907	4,908	4,578	3,720	3,248	1,316	660	219	905
British Columbia	6,873	5,750	5,872	5,476	4,640	4,283	2,244	1,631	1,010	204
Panel B: Great-circle distance (km)										
Newfoundland and Labrador	261	715	762	894	1,407	1,987	3,056	3,539	4,056	4,717
Prince Edward Island	715	39	193	211	756	1,322	2,547	3,071	3,621	4,274
Nova Scotia	762	193	143	290	805	1,344	2,635	3,167	3,723	4,374
New Brunswick	894	211	290	140	578	1,134	2,377	2,909	3,464	4,115
Quebec	1,407	756	805	578	208	615	1,893	2,442	3,010	3,648
Ontario	1,987	1,322	1,344	1,134	615	226	1,541	2,107	2,688	3,292
Manitoba	3,056	2,547	2,635	2,377	1,893	1,541	145	604	1,173	1,780
Saskatchewan	3,539	3,071	3,167	2,909	2,442	2,107	604	234	628	1,233
Alberta	4,056	3,621	3,723	3,464	3,010	2,688	1,173	628	221	709
British Columbia	4,717	4,274	4,374	4,115	3,648	3,292	1,780	1,233	709	213
Panel C: Difference between network to great-circle distance (percent)										
Newfoundland and Labrador	48	91	61	50	11	40	52	48	50	46
Prince Edward Island	98	59	72	29	47	29	41	37	33	33
Nova Scotia	74	67	-5	34	46	35	37	36	34	33
New Brunswick	52	14	37	9	20	20	39	36	32	29
Quebec	5	45	52	26	34	-5	30	28	24	26
Ontario	42	31	35	28	-3	-15	31	33	28	31
Manitoba	50	38	38	36	27	11	47	8	14	24
Saskatchewan	48	34	36	35	28	28	3	-6	9	27
Alberta	43	36	32	32	24	21	12	5	-1	28
British Columbia	46	35	34	33	27	30	26	32	43	-5

accounts. To test for this effect, a modified version Equation (4) is estimated,

$$X_{ij} = \exp\left[\ln S_i^{intra} + \ln S_i^{inter} + \ln M_j^{intra} + \ln M_j^{inter} + (\beta + \theta_p)\ln d_{ij}\right]\epsilon_{ij}, \qquad (15)$$

with the distance parameter permitted to vary across intra- and inter-provincial flows using an indicator variable for intra-provincial flows (θ_p).[18] If the truncation effect predomi-

[18]If there are significant barriers to inter-provincial trade, the dampening effect of distance on trade would be expected to be less, as the lower level of competition would raise the cost cut-off (see Melitz and Ottaviano,

nates, the distance parameter on intra-provincial trade should be more negative than inter-provincial trade. To isolate this effect, the model is estimated with separate origin and destination fixed effects for intra- and inter-provincial trade, where p indicates the set of intra-provincial regions. Intra-region flows are excluded.[19] When estimated for ERs, the distance parameter was -0.769 for inter-provincial trade, but significantly *less negative* for intra-provincial trade -0.579 ($\hat{\theta}_p = 0.190; P > |z| = 0.037$). Using CDs, a subunit of ERs, the estimate was also positive but insignificant ($\hat{\theta}_p = 0.058; P > |z| = 0.235$). To the extent that it is present, the truncation of intra-provincial flows does not appear to be sufficient to bias the estimates.

7.2.2 Estimates by year

The estimates are presented for trade averaged across the 9-year study period stretching from 2004 to 2012. This is a long enough period to potentially observe changes in provincial border effects, such as from changes in policy or shifts in the macro-economy. To account for these effects, the baseline model was estimated with all of the variables interacted with time fixed effects, with 2004 being the excluded year. Whether the model is estimated using provinces, ERs, or CDs, as the trading units, there is no significant difference in the coefficients across years. Hence the average trade level-based estimates reported in the main body of the paper provide a reasonable picture of provincial border effects over the entire period.

7.2.3 Differential border effect estimates for Quebec

To test for the effect of Quebec on internal trade, own province is interacted with an indicator variable for internal Quebec trade flows. While the point estimate on the interaction term is positive, it is not significantly different than zero (see Table 9).

2008; Baldwin and Gu, 2009) at which firms would engage in trade across sub-provincial units. While this effect may be accounted for by multilateral resistance terms, the distance parameter may also be affected and, therefore, when both the effects of the transportation system and provincial barriers to trade are present, they will have confounding effects on the distance parameter.

[19] These flows are excluded in order to have a comparable set of inter-regional flows. Trade between region i and j within the same province can be compared to trade between i and k across provinces.

Table 8: Provincial border effect estimates based on flows between province, economic regions and census division allowing coefficients to vary across time (2004 to 2012), selected variables.

	Geography		
	Province	Economic Region	Census Division
Own province	0.756***	0.752***	0.747***
	(0.113)	(0.128)	(0.093)
2005	−0.021	0.0273	0.0716
	(0.149)	(0.194)	(0.150)
2006	−0.0449	0.0256	0.0595
	(0.143)	(0.180)	(0.134)
2007	0.0548	0.117	0.117
	(0.144)	(0.189)	(0.128)
2008	0.028	0.128	0.146
	(0.151)	(0.187)	(0.145)
2009	−0.0173	−0.031	−0.0495
	(0.158)	(0.173)	(0.131)
2010	0.0663	0.147	0.0619
	(0.180)	(0.196)	(0.134)
2011	0.0192	−0.0619	−0.142
	(0.174)	(0.190)	(0.132)
2012	0.263	−0.0598	−0.103
	(0.248)	(0.171)	(0.127)
N	900	47,961	713,480

Notes: All models utilize a Poisson-PML estimator and include distance, fixed effects for origins and destinations, own region (when applicable) own province, and year. All variables are interacted with the year fixed effects, with the excluded year being 2004. ***, **, * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively and are based on robust standard errors. Own region refers to flows within the geograhic unit of anlaysis (Economic Region and Census Division).

Table 9: Test of the effect of Quebec on provincial border effects.

	Hexagons			
	225km per side		75km per side	
	(1)	(2)	(3)	(4)
Distance				
0 to 25km	-1.329^{***}	-1.315^{***}	-0.939^{***}	-0.931^{***}
	(0.282)	(0.280)	(0.122)	(0.122)
25 to 100km	-0.596	-0.605	-0.265	-0.273
	(0.468)	(0.466)	(0.225)	(0.225)
100 to 500km	-0.833^{***}	-0.723^{***}	-0.707^{***}	-0.803^{***}
	(0.120)	(0.121)	(0.0602)	(0.0916)
greater than 500km	-0.835^{***}	-0.788^{***}	-0.880^{***}	-0.877^{***}
	(0.0795)	(0.103)	(0.0657)	(0.0661)
Own region	-0.0718	0.209	0.316^{**}	0.176
	(0.176)	(0.237)	(0.160)	(0.198)
Own province	0.396^{***}	0.361^{***}	0.362^{***}	0.346^{***}
	(0.0947)	(0.0919)	(0.0832)	(0.0844)
Quebec $\times$ Own province	0.195	0.169	0.216	0.224
	(0.222)	(0.221)	(0.208)	(0.209)
Contiguous regions		0.185		-0.139
		(0.137)		(0.0973)
Constant	4.543^{***}	4.224^{***}	2.702^{***}	2.819^{***}
	(0.812)	(0.835)	(0.494)	(0.503)
Observations	8,619	8,619	132,862	132,862

Notes: All models use a Poisson-PML estimator and include fixed effects for origins and destinations. ***, **, * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively and are based on robust standard errors. The border effect is given by exp(own province).