Intra-national Trade Costs: Assaying Regional Frictions*†

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Abstract

New methods apply gravity to flexibly infer regional, interregional and international trade costs of Canada's provinces. A bilateral trade cost function aggregates interregional frictions with origin and destination region internal and border frictions. The ratio of border to intra-regional friction, the relative border friction, varies across regions and raises bilaterally varying Unexplained Trade Barriers (UTBs) to interregional trade. Small remote regions have high relative border frictions while large central regions have low relative border frictions. Our methods should be useful in future investigations of non-uniform regional trade frictions and analogous barriers to migration and direct investment.

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1 Introduction

A national economy is composite rock, discrete regions connected with varying strength to a matrix of interregional and international ties. A flexibly specified structural gravity method crunches trade flow data for an assay. A feature of the approach identifies each region's resistance at its border relative to its intra-regional trade friction, based on specifying a bilateral trade cost function that aggregates origin and destination intra-regional, regional border and pure interregional frictions. The results are consistent with regionally varying intra-regional trade costs and regional border barriers of varying thickness. The trade of small remote provinces is suppressed relatively more, controlling for variation of intra-national bilateral distance and size. Our methods and data are applied to 19 goods and 9 service sectors for Canada from 1997-2007. Previous investigations of intra-national border effects have been constrained by limited data and techniques mainly to price comparisons that cover a relatively small proportion of trade. Variation in distribution costs internal to the origin and destination coordinates of observation (regions or countries) is often suppressed in gravity models, but is generally consequential for distinguishing border effects and for comparative statics. Ramondo *et al.* (2014) emphasize that variation of internal trade costs helps resolve puzzles in the open economy macro literature.[1] Thus our methods are a useful extension of structural gravity to many types of questions to which it has been applied.

Intra-national trade cost structure comprises components of pure intra-regional, regional border and pure interregional costs. Our method disentangles them with a cost aggregation structure for the components combined with inference from two estimated variants of structural gravity. One variant uses bilateral fixed effects along with importer-time and exporter-time fixed effects to measure volume effects of trade costs for Canada's provinces.[2]

[1] Due to scale effects, endogenous growth models imply that larger countries should be richer than smaller countries. Similarly, standard trade models imply that real income per capita (domestic trade shares and relative income levels) increases too steeply with country size. Ramondo et al. demonstrate that these counterfactual implications are mitigated/disappear when the standard, but unrealistic, assumption of frictionless domestic trade is relaxed. Our methods of identifying internal frictions extend and complement theirs.

[2] Previous literature (including our own) has used the somewhat suspect concept of internal distance to proxy for internal frictions, imposing a uniform distance elasticity to provide sufficient degrees of freedom.

The other variant estimates volume effects from bilateral distance and contiguity along with importer-time and exporter-time fixed effects and a set of fixed effects for intra-regional trade.

The difference between the pair fixed effect and the fitted bilateral distance/contiguity effect is the Unexplained Trade Barrier (UTB). Unexplained Trade Barrier variation across regions is due to the volume effects of relative border frictions: the ratio of internal distribution costs to regional border costs in both origin and destination regions varies across regions.[3] The systematic portion of UTBs and the effect of the non-uniform provincial relative home bias is identified from a precisely estimated second stage regression of first stage bilateral fixed effects on the elements of the first stage gravity variables estimates. Identification of the relative home bias effects utilizes a Cobb-Douglas trade cost function to aggregate internal and interregional costs into full bilateral trade costs. UTBs could alternatively or additionally reflect a trade cost function more general than Cobb-Douglas. A translog test gives no support for rejecting the Cobb-Douglas specification.

We apply the structural gravity model to high quality provincial trade flow data[4] over the period 1997-2007. The discussion of results concentrates on estimates from aggregate manufacturing bilateral trade for simplicity. The results are qualitatively similar to those for the 19 goods and 9 services sectors briefly discussed.[5] Estimates are quite precise. Analysis of residuals and sensitivity experiments support our baseline specification.

Regionally varying internal trade fixed effects gain adequate degrees of freedom by judicious use of panel structure.

[3] "Unexplained" here applies Head and Mayer's (2013a) cosmological metaphor: gravity trade costs are *dark*. This paper moves the darkness one step by identifying systematic effects of border costs relative to internal costs, but shadow covers what these costs may be. More shadow covers intra-regional costs that are themselves aggregates across trade costs between smaller sub-regions. The darkness metaphor also acknowledges that "costs" in the usage of this paper (and much of the literature) may be resistance to inter-regional and international trade due to "buy local" bias of buyers.

[4] The paucity of research on intra-national trade costs is partly due to deficient data. To our knowledge, except for Canada, data on bilateral shipments within nations does not record true origin-destination trade. In particular, the widely used US Commodity Flow Survey does not control for entrepôt trade.

[5] Details are available on request, but we see the sectoral estimates as an input to investigate the relationship between border barriers and institutional and infrastructure variables, or for general equilibrium comparative statics. Sectoral disaggregation is generally important because previous work (Anderson and Yotov (2010)) has shown that estimates of trade costs from aggregate data are biased downward, a concern especially acute for estimating intra-national trade costs.

The more remote and smaller regions (e.g. YT, PE, and NT) are systematically subject to the largest UTBs. The effects of border barriers are measured relative to a national average, so economically developed and central regions (e.g. ON, AB, and BC) enjoy relative stimuli to trade from UTBs.[6] At one extreme, PE exports to YT are reduced 43% by their 2002 UTB in manufacturing. At the other extreme, ON exports to BC are raised 30% by their UTB. The details of variation across provinces and provincial pairs may indicate where policy intervention is needed most. The pattern of UTBs is also consistent with intra-regional cost variation because regions with larger internal distances (measured with the CEPII method) tend to have more trade, all else equal. Disentangling internal from border cost variation is an important but difficult task for future work.

Overall measures of resistance to interregional trade combine direct frictions (intra-regional and border frictions and pure interregional frictions) with the general equilibrium effects of multilateral resistance. Constructed Trade Bias (CTB) is the ratio of predicted (including multilateral resistance) to hypothetical frictionless trade flows for each bilateral pair. CTBs (consistently aggregated across provincial partners) in 2002 range from 14.2 for SK down to 2.3 for YT, confirming the familiar result of 'excess' interprovincial trade. The ratio of interregional to intra-regional CTB is Constructed Interregional Bias (CIB). CIB is transformed to a relative cost measure, the ratio of sellers' incidence of interregional trade costs to sellers' incidence of intra-regional trade costs. The transformation is based on estimated CIBs raised to the power $1/(1-\sigma)$ with elasticity of substitution $\sigma = 5$. Relative sellers' incidence in 2002 manufacturing ranges from 13.2 for Yukon Territory down to 1.2 for Ontario. Variation is even greater across provincial partners for each exporter.

Canada's provinces are mostly becoming more integrated with both the world and with each other over the period 1997 to 2007, despite the constant bilateral trade costs that we find. Intra-regional CTB (Constructed Home Bias) is falling, provinces are becoming more

[6] The provincial border barriers are inferred as deviations around a Canada-wide mean, so low border barrier provinces tend to enjoy relative stimulus due to the UTB. Due to collinearity we are unable to measure the level of border barriers, only the variation.

integrated with the world (extending Anderson and Yotov (2010)). The fall in CHBs is largest for the remote regions YT (79%) and NT (62%). The small exceptions are BC and NB with increases of 2% and 4.2% respectively. Interregional CTBs are mostly rising. The exceptions are YT (-83.8%) and NT (-41.3%) along with small falls in ON (-7.8%) and MB (-0.8%). CIB rises for all but YT (-4.8%), Canada's provinces are becoming more integrated. Increasing integration intra-nationally and internationally is due to changes in the incidence of trade costs that in turn are due to changes in location of production and expenditure.[7]

We depart from the existing literature on intra- and interregional trade costs in allowing maximum flexibility of estimated intra-regional and interregional trade costs.[8] We allow for non-uniform intra-regional trade costs, non-uniform regional border barriers and estimate a combination of them along with inter-regional trade costs. International border barriers are not our focus, though our estimation utilizes international as well as interregional trade flows. The flexible treatment of trade costs enables identification of the effects of provincial border variation on bilateral trade with potential implications for regional trade policy.

Tombe and Winter (2014) share our focus on intra-national Canadian trade costs inferred from gravity, but differ in not being able to identify provincial border barriers.[9] They infer

[7]See Anderson and Yotov (2010) for a discussion of the effect of changes in location of production and expenditure on incidence.

[8]For the United States see Wolf (2000), Head and Mayer (2002), Hillberry and Hummels (2003), Millimet and Osang (2007), Head and Mayer (2010), Coughlin and Novy (2012), Yilmazkuday (2012)); for the European Union see Nitsch (2000), Chen (2004), and Head and Mayer (2010); for OECD countries (Wei (1996)); for China see Young (2000), Naughton (2003), Poncet (2003, 2005), Holz (2009), Hering and Poncet (2010); for Spain see Llano and Requena (2010); for France see Combes et al. (2005); for Brazil see Fally et al. (2010); and for Germany see Lameli et al. (2013) and Nitsch and Wolf (2013). A summary table that reviews home bias estimates is available by request. This literature has mainly adopted two methods of estimating internal trade barriers: using the gravity model with a uniform effect of intra-regional relative to inter-regional trade costs or using proxies for inter-regional trade borders. A more distantly related literature infers trade costs from price differences (e.g., Engel and Rogers (1996)) at a much more disaggregated level. As with trade flows, distance and borders account well for price differences. Very highly detailed price comparisons often imply very large intra-national price gaps in developing countries (Atkin and Donaldson (2013)); much less so in developed countries. The price comparison method is limited in coverage due to the difficulty of matching prices for truly comparable items across locations. Trade flow inference includes substitution on the extensive margin that price comparison necessarily excludes. Moreover, price comparison can only find trade costs that show up in prices, in contrast to inference from trade flows that includes all non-price costs borne by buyers (travel time, contracting costs, etc.). Inference from trade flows provides complementary evidence on trade costs for these reasons.

[9]Our work is more remotely related to the literature on the international border barrier to Canada's trade: e.g., McCallum (1995), Anderson and van Wincoop (2003). Apart from gravity, a number of case studies

pure inter-regional trade costs from observed bilateral trade relative to the geometric mean of origin and destination internal trade using the "tetrads" approach of Head and Mayer (2000). By construction tetrads includes random elements excluded from our fitted pairwise fixed effects estimator. The two estimators are highly correlated, though the fixed effects estimates differ significantly from their tetrads counterparts in the statistical sense. Tombe and Winter (2014) then infer bilateral frictions apart from distance by parametrically removing bilateral distance effects. This resembles our difference between estimated bilateral pair fixed effects and estimated standard gravity variables. But our second stage regression allows us to identify variation in provincial border effects and to decompose UTBs into border effects and unexplained components.

Our methods should be applicable widely to flexible inference of intra-national trade costs and international border barriers in multi-country and multi-regional studies. The flexible fixed effects treatment of trade costs can also be applied to quantify barriers to immigration and FDI, about which we know much less than about trade costs. The methods can be used to decompose those barriers to isolate border effects with implications for immigration and FDI policy.

Section 2 sets out the theoretical foundation and introduces Constructed Trade Bias indexes. Section 3 describes our data and presents the econometric specification and identification strategy. Section 4 presents our main findings and sensitivity experiments. Section 5 discusses sectoral estimates. Section 6 concludes.

2 Theoretical Foundation

A review of structural gravity theory (Anderson and van Wincoop (2003, 2004)) sets the stage for extensions. Next, we define Constructed Trade Bias (CTB), the generator of

have also examined the economic costs of internal trade barriers in Canada. Grady and Macmillan (2007) provide a descriptive overview of the academic and non-academic literature on barriers to internal trade in Canada and also evaluate the economic costs brought about these impediments to trade. Beaulieu et al. (2003) describe in great detail the various trade policies and reforms initiated by the Canadian government in order to liberalize inter-provincial trade.

a family of Constructed Bias indexes with two novel ones useful for understanding intra-national trade. Then we analyze bilateral trade costs as a combination of intra-regional and pure interregional costs, developing implications for comparative statics and econometric identification. Finally, consistent aggregation of bilateral trade costs is developed.

The structural gravity model assumes identical preferences or technology across countries for national varieties of goods or services differentiated by place of origin for every good or service category k, represented by a globally common Constant Elasticity of Substitution (CES) sub-utility or production function.[10] Use of the market clearing condition for each origin's shipments and each destination's budget constraint yields the structural form:

$$X_{ij}^k = \frac{E_j^k Y_i^k}{Y^k} \left(\frac{t_{ij}^k}{P_j^k \Pi_i^k} \right)^{1-\sigma_k} \tag{1}$$

$$(\Pi_i^k)^{1-\sigma_k} = \sum_j \left(\frac{t_{ij}^k}{P_j^k} \right)^{1-\sigma_k} \frac{E_j^k}{Y^k} \tag{2}$$

$$(P_j^k)^{1-\sigma_k} = \sum_i \left(\frac{t_{ij}^k}{\Pi_i^k} \right)^{1-\sigma_k} \frac{Y_i^k}{Y^k}, \tag{3}$$

where X_{ij}^k denotes the value of shipments at destination prices from region of origin i to region of destination j in goods or services of class k. The order of double subscripts denotes origin to destination. E_j^k is the expenditure at destination j on goods or services in k from all origins. Y_i^k denotes the sales of goods or services k at destination prices from i to all destinations, while Y^k is the total output, at delivered prices, of goods or services k. $t_{ij}^k \geq 1$ denotes the variable trade cost factor on shipments of goods or services from i to j in class k, and σ_k is the elasticity of substitution across goods or services of class k. P_j^k is the inward multilateral resistance (IMR), and also the CES price index of the demand system. Π_i^k is the outward multilateral resistance (OMR), which from (2) aggregates i's outward trade costs relative to destination price indexes. Multilateral resistance is a general distributional

[10] Two alternative theoretical foundations for (1)-(3) feature selection — substitution on the extensive margin in either supply or demand. See Anderson (2011) for details. In practice, either type of substitution or both may be the interpretation.

equilibrium concept, since $\{\Pi_i^k, P_j^k\}$ solve equations (2)-(3) for given $\{Y_i^k, E_j^k\}$.

The right hand side of (1) comprises two parts, the frictionless value of trade $E_j^k Y_i^k / Y^k$ and the distortion to that trade induced by trade costs $(t_{ij}^k/\Pi_i^k P_j^k)^{1-\sigma_k}$ directly with t_{ij}^k and indirectly with $\Pi_i^k P_j^k$. Anderson and Yotov (2010) note that P_j^k and Π_i^k are respectively the buyers' and sellers' overall incidence of trade costs to their counter-parties worldwide. Incidence here means just what it does in the first course in economics: the proportion of the trade cost factor t_{ij}^k paid by the buyer and seller respectively. The difference is that purchase and sales are aggregated across bilateral links, such that conceptually it is as if each seller's global sales travel to a hypothetical world market with equilibrium world price equal to 1. The seller receives $1/\Pi_i^k$, hence pays incidence factor Π_i^k. Each buyer makes purchases from all origins on the world market, paying incidence P_j^k to bring them to destination j. These overall incidence measures further imply bilateral incidence: t_{ij}^k/P_j^k is seller i's incidence of trade costs on sales to destination j for good k, and t_{ij}^k/Π_i^k is buyer j's incidence of trade costs on purchase from origin i for good k. $t_{ij}^k/\Pi_i^k P_j^k$ is interpreted as either bilateral buyer's incidence, $(t_{ij}^k/\Pi_i^k)/P_j^k$ relative to overall buyers' incidence, or bilateral sellers' incidence $(t_{ij}^k/P_j^k)/\Pi_i^k$ relative to overall sellers' incidence.

2.1 Constructed Trade Bias

Constructed Trade Bias is defined as the ratio of the econometrically predicted trade flow $\widehat{X}_{ij}^k$ to the hypothetical frictionless trade flow between origin i and destination j for goods or services of class k. Rearranging the econometrically estimated version of equation (1), Constructed Trade Bias is given by:

$$CTB_{ij}^k \equiv \frac{\hat{X}_{ij}^k}{Y_i^k E_j^k / Y^k} = \left(\frac{\hat{t}_{ij}^k}{\hat{\Pi}_i^k \hat{P}_j^k} \right)^{1-\sigma_k}. \tag{4}$$

In the hypothetical frictionless equilibrium $CTB_{ij}^k = 1$, i's share of total expenditure by each destination $j, X_{ij}^k/E_j^k$, is equal to Y_i^k/Y^k, i's share of world shipments in each sector k. This would be the pattern in a completely homogenized world. "Frictionless" and "trade costs" are used here for simplicity and clarity, but the model can also reflect local differences in tastes that shift demand just as trade costs do, suggesting "resistance" rather than costs. The second equation in (4) gives the structural gravity interpretation of CTB, the $1 - \sigma_k$ power transform of the ratio of predicted bilateral trade costs to the product of outward multilateral resistance at i and the inward multilateral resistance at j. (The Constructed Home Bias index of Anderson and Yotov (2010) is the special case $CTB_{ij}^k; i = j$ home bias of i's internal trade.)

Five properties of CTB are appealing. First, CTB is independent of the normalization needed to solve system (2)-(3) for the multilateral resistances.[11] Second, CTB is independent of the elasticity of substitution σ_k, because it is constructed using the inferred (estimated) volume effects that are due to $1 - \sigma_k$ power transforms of the t_{ij}^k's, the Π^k's and the P^k's. Third, CTB can be consistently aggregated to yield a family of useful general equilibrium trade costs indexes at the country and at the regional level. One is developed below to measure aggregate inter-regional trade bias facing sellers.[12] Fourth, because it measures the proportional displacement of volume from the observable frictionless benchmark, CTB is comparable across sectors and time as well as across provinces and countries.[13] Fifth, CTB infers central tendency out of the random errors that beset notoriously mis-measured bilateral trade flow data. Specifically, the ratio of observed bilateral trade to hypothetical frictionless trade is an observation of CTB while our estimated CTB is its conditional expectation. CTB shares the good fit properties of gravity models, so this distinction is important.

Intra-provincial and inter-provincial trade both are raised relative to their frictionless benchmark values by large international trade costs, but intra-provincial trade is increased by

[11] Note that (2)-(3) solves for $\{\Pi_i^k, P_j^k\}$ only up to a scalar. If $\{\Pi_i^0, P_j^0\}$ is a solution then so is $\{\lambda\Pi_i^0, P_j^0/\lambda\}$.

[12] Other CTB aggregates have been defined and reported in Anderson and Yotov (2010) and Anderson, Milot and Yotov (2013).

[13] In contrast, because gravity can only identify relative bilateral trade costs, constructed trade costs depend on normalizations by unobservable levels of bilateral cost that in principle vary across sectors and time, vitiating comparability along these dimensions. The same issue arises with the multilateral trade cost (multilateral resistance) measures that can be inferred from structural gravity.

much more. To focus on internal barriers to trade, a useful and natural index is Constructed Interregional Bias (CIB):

$$CIB_{ij}^k = CTB_{ij}^j / CTB_{ii}^k = \left(\frac{t_{ij}^k / P_j^k}{t_{ii}^k / P_i^k} \right)^{1-\sigma_k} = \left(\frac{t_{ij}^k}{t_{ii}^k} \right)^{1-\sigma_k} / \left(\frac{P_j^k}{P_i^k} \right)^{1-\sigma_k}. \qquad (5)$$

In a frictionless world, $CIB_{ij}^k = 1 = CTB_{hl}^k, \forall h, i, j, k, l$. The left hand side of equation (5) gives the relative reduction of inter-provincial trade due to trade costs in the world system. The middle equation gives CIB as the $1 - \sigma_k$ power transform of seller i's incidence on sales to j relative to i's internal sales. The rightmost equation breaks the ratio into the $1 - \sigma_k$ power transforms of two components. The numerator component is the interprovincial part of the total shipment cost from i to j, t_{ij}^k / t_{ii}^k. The denominator component is P_j^k / P_i^k, the additional buyer's incidence facing seller i when selling to destination j.

2.2 Modeling Full Bilateral Costs

The composition of full bilateral costs has usually been submerged in the gravity literature. Intra-regional or intra-national costs and their relation to full costs are omitted without apparent effect on inference of bilateral costs modeled as iceberg log linear functions of geographic proxies.[14] In contrast, intra-national costs are consequential for comparative statics and regional policy analysis. In particular, regional border barriers are a key concern of this paper.

Time-invariant components of bilateral trade frictions are estimated alternatively with bilateral fixed effects (identified off the time variation of panel data) and with a log-linear function of geographic proxies. The difference between the fixed effects and gravity variables estimates is the Unexplained Trade Barrier. Systematic variation in the estimated UTBs due to border barriers is identified based on a structural relationship between intra-regional

[14] An exception is the Helpman, Melitz and Rubinstein (2008) specification that includes a fixed export cost component. Their identification strategy to distinguish variable from fixed cost uses common religion to determine fixed but not variable cost, controversial in any case but unavailable for Canada's provinces.

and interregional cost components. Idiosyncratic components of UTBs may contain bilateral border barrier information, but also contain random error.

Full interregional trade costs are modeled as a degree one homogeneous increasing and concave function $t_{ij} = g(r_{ij}, r_{ii}, r_{jj})$ of three components, the resource costs ($r_{hl}, \ \forall h, l$) of delivering one unit of distribution activity within the origin, destination and transit between them respectively. (In the Ricardian case $r_{ij} = wa_{ij}$ where w is the wage and a_{ij} is the unit labor requirement in activity ij.) Homogeneity of degree one is consistent with iceberg trade costs with no indivisibilities. Concavity is implied by cost-minimizing behavior. The base case is the Cobb-Douglas specification

$$t_{ij} = r_{ij}^{\rho_1} r_{ii}^{\rho_2} r_{jj}^{\rho_3}, \tag{6}$$

where $\rho_1 + \rho_2 + \rho_3 = 1$.

The base case simplifies identifying border barriers. If the full cost of i shipping to j includes border crossing components $b(i), b(j)$, their effect on full cost is $b(i)^{\rho_2} b(j)^{\rho_3}$. The border crossing costs are combined with the pure intra-regional costs in the estimation, but identification of the border costs (up to a normalization) is made possible by the structure, as shown in Section 4.2

The Cobb-Douglas restriction yields a very useful theoretical property: system (1)-(3) is neutral with respect to (invariant to) intra-regional trade costs. Neutrality follows because $r_{ii}^{\rho_2}, \ r_{jj}^{\rho_3}$ form part of the composite multilateral resistances $r_{ii}^{-\rho_2}\Pi_i \ , r_{jj}^{-\rho_3}P_j$ that solve (2)-(3), hence the composite multilateral resistances are invariant to the level of intra-regional trade costs. In the econometric specification of bilateral trade costs below, the composite multilateral resistance terms are controlled for with origin and destination fixed effects and the bilateral cost identified is the pure inter-regional cost. Comparative static effects of intra-regional trade costs in the Cobb-Douglas case are confined to upper level inter-sectoral allocation due to invariance of (2)-(3) for given Es and Ys.

Neutrality is violated by general cost function specifications $g(\cdot)$. For example, in the translog case $\ln(t_{ij}/\Pi_i P_j)$ decomposes into the Cobb-Douglas invariance term analyzed above plus a second order effect term that contains the intra-regional trade cost. Non-neutrality implies that intra-regional trade cost changes affect all bilateral trade patterns by changing all the multilateral resistances. Evidence below is weakly consistent with rejecting non-neutrality. Future work should probe further for possible non-neutrality.

2.3 Consistent Aggregation of Trade Bias and Trade Costs

Aggregation of volume concepts such as CTBs and trade cost concepts such as multilateral resistance and t_{ij} or t_{ij}/t_{ii} is useful for many purposes. Aggregation procedures are set out here for CTBs and multilateral resistances that are consistent with maintaining a constant aggregate volume of trade given the theoretical model. (Volume consistent trade cost aggregation can be done following Anderson and Neary (2005), pp. 177-83.) Aggregation over regions is the focus, but similar principles apply to consistent aggregates over sectors.

The aggregate (export) trade volume from origin i to some subset of destinations $C(i) = \{j \in C, j \neq i\}$ is

$$\sum_{j \in C(i)} X_{ij} = \sum_{j \in C(i)} \frac{Y_i E_j}{Y} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma}. \tag{7}$$

$C(i)$ excludes internal trade, and can also exclude other bilateral trade depending on what is defined to be contained in C. In the present application, C designates within country C (Canada), so it excludes international trade, thus $C(i)$ is the set of interprovincial partners of province i. Constructed Trade Bias for i's export trade to $C(i)$ is given by the ratio of the theoretical aggregate volume given above to the frictionless benchmark aggregate export volume $Y_i E_{C(i)}/Y$ where $E_{C(i)} \equiv \sum_{j \in C(i)} E_j$. Using equation (4), the ratio is equal to

$$CTB_{C(i)} = \sum_{j \in C(i)} \frac{E_j}{E_{C(i)}} CTB_{ij}. \tag{8}$$

The aggregate CTB for set C (Canada's overall CTB for interprovincial trade) is given by

$$CTB_C = \sum_{i \in C} \frac{E_{C(i)}}{E_C} CTB_{C(i)} = \sum_{i \in C} \sum_{j \in C(i)} \frac{E_j}{E_C} CTB_{ij}, \tag{9}$$

where $E_C = \sum_i E_{C(i)}$.[15]

The $CTB_{C(i)}$ concept is illustrated by Canadian province i's interprovincial exports, but can be applied to any arbitrary set of regions' interregional exports or, *mutatis mutandis*, to imports rather than exports.[16] For example, the concept can usefully be applied to preferential trade arrangements.

The aggregate CIB for region i is defined as $CIB_{C(i)} \equiv CTB_{C(i)}/CTB_{ii}$. $CIB_{C(i)}$ measures the average amount by which trade costs directly and indirectly reduce interregional volume relative to intra-regional volume for region i with its partners in C. The aggregate CIB for set C is given by $CIB_C/[\sum_i CTB_{ii} E_i/E_C]$.

Turning to relative cost counterparts to the aggregate volume concepts, power transforms of the CIBs give relative sellers' incidence measures, just as in equation (5). This follows because $CTB_{C(i)} = \sum_{j \in C(i)} (t_{ij}/P_j)^{1-\sigma} E_j/E_{C(i)} = \Pi_{C(i)}^{1-\sigma}$ where the first equation follows by substituting (1) into (4) and (29), and the second equation formalizes the interpretation of the result by defining the sellers' incidence of i on sales to $C(i)$. $\Pi_{C(i)}^{1-\sigma}$ is the expenditure weighted average of the volume effect of the bilateral sellers' incidences $(t_{ij}/P_j)^{1-\sigma}$. Then the region i's sellers' incidence on sales to $C(i)$ relative to local sales is given by:

$$\frac{\Pi_{C(i)}}{\Pi_{ii}} = \left(CIB_{C(i)}\right)^{1/(1-\sigma)}, \tag{10}$$

where $\Pi_{ii} \equiv t_{ii}/P_i$. The relative incidence measure (10) is the economic driver of the volume response of the sellers, $CIB_{C(i)}$, representing how the system of bilateral trade costs directly and indirectly determines seller behavior.

[15] The Constructed Foreign Bias (CFB) and the Constructed Domestic Bias (CDB) indexes of Anderson et al. (2013) are focused on aggregation across destinations to measure outward resistance to trade.

[16] In the import case, the expenditure share weights are replaced by sales share weights.

3 Empirical Foundation

This section details the econometric specification and procedures used to infer the volume displacement and trade cost indexes describing inter-provincial trade in Canada. An extension of now standard gravity methods that exploits the panel nature of the data permits measurement of potential unobservable barriers at provincial borders — Unexplained Trade Barriers (UTBs). The section closes with a brief description of our data, supplemented by a detailed Data Appendix.

3.1 Econometric Specification

The fixed effects econometric approach estimates Constructed Trade Biases for each pair of regions and each year in the sample directly (except where necessary the sectoral index k is suppressed):

$$\frac{x_{ij,t}Y_t}{Y_{i,t}E_{j,t}} = \exp[\alpha'\mathbf{T}_{ij,t} + \gamma_{ij} + \eta_{i,t} + \theta_{j,t}] + \epsilon_{ij,t}. \tag{11}$$

The dependent variable is size-adjusted trade. Hence the CTB is the predicted value from (11). The last two terms in the square brackets of (11) account for the structural multilateral resistances. Specifically, $\eta_{i,t}$ denotes the set of time-varying source-country dummies that control for the unobservable outward multilateral resistances and any other time varying source country factors, and $\theta_{j,t}$ encompasses the time varying destination country dummy variables that account for the inward multilateral resistances and any other destination country factors. The first two terms on the right hand side of equation (11) account for bilateral trade costs.

Bilateral trade costs in (11) are decomposed into time-dependent and time-invariant components:

$$\left(t_{ij,t}^{FE}\right)^{1-\sigma} = \exp[\alpha'\mathbf{T}_{ij,t} + \gamma_{ij}]. \tag{12}$$

Here, $t_{ij,t}^{FE}$ denotes bilateral trade costs between regions i and j at time t, and the superscript FE captures the fact that we use the full set of pair-fixed effects, γ_{ij}, to account for the time invariant portion of trade costs. In addition to absorbing the vector of time-invariant covariates that are used standardly in the gravity literature (e.g. distance), the pair-fixed effects will control for any other time-invariant trade costs components that are unobservable to researchers and to policy makers.[17]

The first term in (12), $\mathbf{T}_{ij,t}$, is a vector of time-varying gravity variables intended to capture changes in bilateral trade costs over time. The changes are restricted to sensibly pick up suspected effects.[18] The evolution of internal trade costs in Canada is captured by two time-varying covariates. $INTRAPR\_T_{ij,t} = INTRAPR_{ij} \times T_t$ is the interaction between a dummy variable for intra-provincial trade $INTRAPR_{ij}$ and a time trend T_t. The estimated coefficient of $INTRAPR\_T_{ij,t}$ would capture any changes in intra-provincial trade costs over the period of investigation. Similarly, $INTERPR\_T_{ij,t} = INTERPR_{ij} \times T_t$ is the interaction of $INTERPR_{ij}$, a dummy variable for inter-provincial trade with a time trend, and its estimated coefficient has a similar interpretation. By construction, the estimated coefficients of $INTERPR\_T_{ij,t}$ and $INTRAPR\_T_{ij,t}$ should be interpreted as deviations of internal (intra-provincial or inter-provincial) Canadian trade costs from the changes in international trade costs over time.

With these restrictions, specification (11) becomes:

$$\frac{x_{ij,t}Y_t}{Y_{i,t}E_{j,t}} = \exp[\alpha_1 INTERPR\_T_{ij,t} + \alpha_2 INTRAPR\_T_{ij,t} + \gamma_{ij} + \eta_{i,t} + \theta_{j,t}] + \epsilon_{ij,t}. \tag{13}$$

The benefit of using pair-fixed effects in specification (13) is that these fixed effects control

[17] Using bilateral fixed effects in the gravity equation is not new. For example, Baier and Bergstrand (2007) use pair fixed-effects to successfully account for potential endogeneity of FTAs. However, to the best of our knowledge, ours is the first paper to use bilateral pair fixed effects to properly measure bilateral trade costs. More importantly, as emphasized below, we are the first to construct and to study the difference between the trade costs from the fixed effects specification, and the trade costs from a standard specification with gravity variables.

[18] The usual components of $\mathbf{T}_{ij,t}$, when the gravity model is applied to international trade data, control for tariffs, for the presence of free trade agreements (FTAs), monetary unions (MUs), World Trade Organization (WTO) membership, etc. Given the specifics of our sample, we cannot include any of these variables.

for all possible time-invariant bilateral trade costs. The estimates of the bilateral trade costs from (13) are in principle directly comparable to estimates of trade costs that are obtained from a specification with standard gravity variables. We exploit the comparability below to construct the Unexplained Trade Barriers estimate as the difference between the two.

Perfect collinearity requires restrictions on the pair-fixed effects in order to estimate specification (13).[19] Perfect collinearity arises because the sum of the dummy variable vectors corresponding to the full set of γ_{ij}s is equal to the sum of dummy variable vectors corresponding to the full set of province dummies, either as exporter or importer.

The restriction we impose scales the time-invariant bilateral trade costs so that internal trade costs are suppressed: interprovincial trade costs are measured relative to intra-provincial costs. The restriction relates γ_{ij} from a theoretical original set of Γ_{ij}s subject to $\gamma_{ij} = \Gamma_{ij} - (\zeta_O \Gamma_{ii} + \zeta_D \Gamma_{jj}) \Rightarrow \gamma_{ii} = \gamma_{jj} = 0$. Here $\zeta_O \geq 0, \zeta_D \geq 0, \zeta_O + \zeta_D = 1$ are unobserved weights interpreted within the Cobb-Douglas cost assumption as $\zeta_O = \rho_2/(\rho_2 + \rho_3)$ for Origin internal cost and $\zeta_D = \rho_3/(\rho_2 + \rho_3)$ for Destination internal cost. The estimated bilateral fixed effects for interprovincial trade are thus understood as relative to an index of intra-provincial fixed effects: $\exp(\gamma_{ij}) = \exp[\Gamma_{ij} - (\zeta_O \Gamma_{ii} + \zeta_D \Gamma_{jj})] = [r_{ij}^{\rho_1}/(r_{ii}^{\rho_2} r_{jj}^{\rho_3})]^{(1-\sigma)/(\rho_2+\rho_3)}$.

A second restriction is to impose symmetry on the interprovincial fixed effects: $\gamma_{ij} = \gamma_{ji}; \forall i, j \in CA$.[20] The symmetry restriction is imposed for comparability with the necessarily symmetric gravity variables specification. In contrast we do not impose any restrictions on trade costs between the Canadian regions, the U.S. and the rest of the world. This helps control for complications and biases associated with measuring trade costs among these aggregate regions.[21]

[19] Another collinearity problem, which is standard in gravity estimations, arises because the sum of the province/territory dummy variable vectors corresponding to origin and destination regions respectively are equal to each other in each period. This problem is solved by dropping one province as a destination in each year, meaning that the remaining province origin and destination coefficients for that period are interpreted as relative to the coefficient of the dropped province. To use a constant term, the same province is also dropped once as an origin.

[20] In robustness checks, allowing for asymmetry of pairwise fixed effects has little effect on results.

[21] In the Supplementary Appendix, we demonstrate that our internal trade costs estimates are robust to the exclusion of the U.S. and the rest of the world in our sample.

Under the restrictions, the inter-provincial volume effects of trade costs from specification (12) are:

$$\left(\hat{t}_{ij}^{FE}\right)^{1-\sigma} = [\hat{r}_{ij}^{\rho_1}/(\hat{r}_{ii}^{\rho_2}\hat{r}_{jj}^{\rho_3})]^{(1-\sigma)/(\rho_2+\rho_3)} = e^{\hat{\Gamma}_{ij}}/e^{(\zeta_O\hat{\Gamma}_{ii}+\zeta_D\hat{\Gamma}_{jj})} = e^{\hat{\gamma}_{ij}}, \tag{14}$$

where the last equality reflects the estimated value. Given separately obtained estimates of the intra-regional trade costs, the full interregional volume effect $\hat{t}_{ij}^{1-\sigma} = \exp(\hat{\Gamma}_{ij})$ can be obtained. Alternatively, $\left(\hat{t}_{ij}^{FE}\right)^{1-\sigma} = e^{\hat{\gamma}_{ij}}$ is interpreted as trade volume displacement due to inter-regional (interprovincial) trade costs relative to the Cobb-Douglas index of intra-regional trade costs. The corresponding tariff equivalent index is:

$$\hat{\tau}_{ij}^{FE} = \left(e^{\hat{\gamma}_{ij}/(1-\hat{\sigma})} - 1\right) \times 100, \tag{15}$$

where, $\hat{\sigma}$ is the trade elasticity of substitution. Following the existing literature, in our empirical analysis we choose the standard value for the elasticity of substitution $\hat{\sigma} = 5$.[22]

Fixed effects specification (14) is related in theory to the tetrads measure proposed by Head and Mayer (2000) and used since by others. Using only observables, they propose $\sqrt{X_{ij}X_{ji}/X_{ii}X_{jj}}$ as representing $[\hat{t}_{ij}/(\hat{t}_{ii}\hat{t}_{jj})^{1/2}]^{1-\sigma}$. The theoretical difference is that $\zeta_O \neq \zeta_D \neq 1/2$, though in practice for our Canadian manufacturing data the estimated values are close to 1/2. The more important practical difference with our bilateral fixed effects approach is that our estimated $\hat{\gamma}_{ij}$ is fitted, controlling for random errors, whereas the tetrads 'estimate' includes the error terms. Moreover, specification (13) controls for origin- and destination-time effects in the random errors. Tests below indicate that the tetrads estimator and the pairwise fixed effects estimator are close economically but differ statistically.

The gravity counterpart to $\left(t_{ij}^{FE}\right)^{1-\sigma}$ in equation (17) is:

$$\left(t_{ij,t}^{GRAV}\right)^{1-\sigma} = \exp[\alpha'\mathbf{T}_{ij,t} + (1-\delta_{ij})\beta'\mathbf{GRAV}_{ij} + \delta_{ij}\psi_{ii}]. \tag{16}$$

[22]In the sensitivity analysis, we experiment with $\hat{\sigma} = 3$ and $\hat{\sigma} = 7$.

Here, $\mathbf{GRAV}_{ij}$ is a vector of time-invariant covariates that replace the vector of pair-fixed effects γ_{ij} from specification (12) for $i \neq j$ and δ_{ij} is the Kronecker delta. The explanatory variables in $\mathbf{GRAV}_{ij}$ include the logarithm of bilateral distance between partners i and j, and a contiguity indicator for whether or not the two trading regions share a common border. The gravity variables regression continues to use a pair fixed effect for provincial flows to or from the US and the ROW (Rest of the World). Since the inter-provincial fixed effects for $i \neq j$ are replaced with observable variables, it is feasible to estimate the full set of intra-provincial fixed effects ψ_{ii}, which now appear explicitly in specification (16).

The intra-provincial fixed effect ψ_{ii} is a 'relative home bias' index that controls for intra-regional cost relative to the provincial border effect that is implicitly absorbed in specification (16). Moreover, this provincial border effect is measured relative to *all* bilateral trade after controlling for distance and contiguity, so it is implicitly normalized by an economy wide average border cost.[23] The theoretical interpretation of the intra-provincial fixed effect (up to a normalization) is $\psi_{ii} = (1-\sigma)\ln[t_{ii}/(\bar{b}(i)/\bar{b})^{\rho_2})]$ where t_{ii} denotes the true intra-provincial trade cost, $\bar{b}(i)$ the provincial border cost and $\bar{b}$ the national average border cost.

To compare bilateral trade volume effect estimation results from the full fixed effect estimator to results from the gravity variables estimator, estimated $\hat{\psi}_{ii}$s must be used to adjust the $\left(t_{ij,t}^{GRAV}\right)^{1-\sigma}$ estimates. Specifically, ignoring the time dimension, the adjusted inter-provincial trade costs from specification (16) are $[\hat{t}_{ij}^{GRAV}/(\hat{t}_{ii}^{\zeta_O}\hat{t}_{jj}^{\zeta_D})]^{1-\sigma}$. The $t_{ii}^{1-\sigma}$s are not directly inferred from ψ_{ii} unless there are no border effects, but our procedures below handle this problem.

The Unexplained Trade Barrier (UTB) is defined as the difference between the logarithm of the volume effect of bilateral trade costs constructed from the specification with fixed

[23]This combined effect arises because the indicator variable for i's internal trade measures internal relative to interprovincial trade, all else equal. Specification (16) is constructed without regional border indicator variables due to collinearity. In principle, the ψ_{ii} estimates can be regressed on various potential determinants of domestic trade costs. We defer this investigation to future work. Using internal log distance measures for the 12 provinces plotted against the estimated ψ_{ii}s reveals a positive slope, suggesting important variation as is intuitive. But the data is too weak to use believably to decompose sources of variation in ψ_{ii}. Indeed, even this positive distance elasticity emerges only after excluding outliers YT and PE, which are relatively compact and small in population.

effects, $\left(t_{ij,t}^{FE}\right)^{1-\sigma}$, and the corresponding trade costs obtained from a specification where the pair-fixed effects γ_{ij} from specification (12) are replaced with gravity variables such as distance and contiguity. Formally, the Unexplained Trade Barrier is defined as:

$$\ln UTB_{ij,t} = \ln\left(\hat{t}_{ij,t}^{FE}\right)^{1-\sigma} - \ln\left(\hat{t}_{ij,t}^{GRAV}/[(\hat{t}_{ii,t}^{GRAV})^{\zeta_O}(\hat{t}_{jj,t}^{GRAV})^{\zeta_D}]\right)^{1-\sigma} + \nu_{ij,t}. \tag{17}$$

On the right hand side, the interregional cost estimated from gravity variables is measured relative to the Cobb-Douglas mean intra-regional cost, to make it consistent with the inferred measure from bilateral fixed effects under the dropped variable specification above. $\nu_{ij,t}$ is a residual. At a minimum, analysis of variance of (17) gives a measure of how well the standard parsimonious gravity treatment of trade costs performs.[24] But more structure can be identified from a second stage regression based on (17) using the Cobb-Douglas full trade cost specification. The coefficients ζ_O ,ζ_D are identified and the slopes of the gravity variables first stage estimates reveal systematic effects of provincial borders, as shown in Section 4.2.

The general equilibrium volume effects of trade costs are captured by Constructed Trade Bias estimates. We construct CTBs using the pair-fixed effects gravity specification (13). The corresponding Constructed Trade Bias (for a generic sector) is:

$$\widehat{CTB}_{ij,t} = \widehat{\left(\frac{t_{ij}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}} = \exp[\hat{\alpha}_1 INTERPR\_T_{ij,t} + \hat{\alpha}_2 INTRAPR\_T_{ij,t} + \hat{\gamma}_{ij} + \hat{\eta}_{i,t} + \hat{\theta}_{j,t}] \tag{18}$$

The CTB measure (18) can be compared across sectors and over time because it is a pure volume displacement ratio, predicted volume relative to an observable frictionless benchmark. We capitalize on the sectoral dimension of our data to study CTB variation across industries. CTB variation over time is driven by two sources. First, it reflects how the changing patterns in production and expenditures change the general equilibrium multi-

[24] Henderson and Millimet (2008) examine the consistency of the assumptions needed for an empirical implementation of the gravity equation using parametric and non-parametric models. Our empirical specification is a hybrid of parametric and non-parametric approaches that allows for heterogeneity of intra- and inter-regional border effects.

lateral resistance terms and thus the CTBs. The importance of this channel, i.e. changing specialization and consumption patterns as key determinants of trade costs and globalization is emphasized in Anderson and Yotov (2011). Second, CTB changes reflect any changes in bilateral trade costs $t_{ij,t}$ over time. The two time-varying components, $\widehat{INTERPR\_T}_{ij,t}$ and $\widehat{INTRAPR\_T}_{ij,t}$, in specification (18) are intended to capture such changes. In addition, we look for other time-varying factors that influence Canadian trade costs by studying the behavior of the estimated error term from specification (18):

$$\widehat{\epsilon}_{ij,t} = \frac{x_{ij,t}Y_t}{Y_{i,t}E_{j,t}} - \widehat{CTB}_{ij,t}. \tag{19}$$

Without measurement or other random error, and if the theory is correct, the estimated error term can be attributed exclusively to unobserved changes in the bilateral trade costs $t_{ij,t}$ over time.[25] While trade, production and expenditure data are all subject to measurement error (see Anderson and van Wincoop (2004)), it may be that there are systematic changes in trade costs hiding amidst the noise.

3.2 Data

Our sample combines the data sets from Anderson and Yotov (2010), Anderson, Milot, and Yotov (2013), and Anderson, Vesselovsky and Yotov (2012). In order to estimate the Constructed Trade Bias indexes and internal trade costs in Canada, we use data on Canadian trade flows (including inter-provincial, intra-provincial and international trade with the U.S. and with the rest of the world (ROW), defined as an aggregate region that includes all countries other than Canada and the U.S.), and data on production and expenditure for each Canadian province and territory, for the U.S., and for ROW, all measured in current ('00,000) Canadian dollars.[26] A notable feature of our data set is that it covers most of

[25] $\widehat{\epsilon}_{ij,t}$ is the difference between CTB obtained directly from the data as if the observation exactly fit the theory and the $\widehat{CTB}_{ij,t}$ estimated from (13).

[26] We aggregate the Northwest Territories and Nunavut in one unit, even though they are separate since April 1st, 1999. Thus, our sample consists of a total of 14 regions including 12 Canadian provinces and

Canada's economy at the sectoral level for a total of 28 industries including agriculture, 17 manufacturing sectors, aggregate manufacturing, and 9 service categories for the period 1997-2007. Finally, we also construct variables that measure bilateral distance and whether two regions share a common border. A detailed description of our data set and sources as well as summary statistics are included in a supplementary Data Appendix.

4 Estimation Results

This section presents interprovincial trade cost estimates and CTBs for total Canadian manufacturing. Bilateral interprovincial trade cost estimates (the t_{ij}s) come first. The key provincial border effect components, the UTBs follow. The general equilibrium effects of the trade cost system on bilateral and relative interregional trade, the CTBs and CIBs, come next. Credibility checks conclude, with analysis of residuals and sensitivity to variations of model specification.

4.1 Intraprovincial and Interprovincial Trade Costs

Results from pair fixed effects specification (13)[27] are reported in column (1) of Table 1 for Total Manufacturing trade of Canada's provinces, 1997-2007. Coefficient estimates on $INTERPR\_T$ and $INTRAPR\_T$ indicate no significant intertermporal change on trade with international partners, so static results are presented. The estimates of the interprovincial fixed effects γ_{ij} of specification (13) are reported in Panel A of Table 2. The first column in Table 2 lists each region as an exporter, while the label of each column stands for each region as an importer.[28] The last column of Table 2, labeled CA, reports aggregate inter-

territories, US, and the rest of the world.

[27]The main estimates use the Poisson pseudo-maximum-likelihood (PPML) estimator advocated by Santos Silva and Tenreyro (2006 and 2011). OLS results are reported in the sensitivity analysis.

[28]The order of the Canadian provinces and territories in our tables follows the preamble of the Agreement on Internal Trade. Specifically: Newfoundland and Labrador, Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, the Northwest Territories and Yukon.

provincial log volume reduction estimates for each province, obtained using the consistent aggregation procedure from Section 2.2. The diagonal elements are all zeros, reflecting the fact that the intra-provincial fixed effects are used as a reference group. In addition, due to our symmetry assumption, we only report the interprovincial γ_{ij}'s above the diagonal. The latter should be interpreted relative to the geometric mean of the omitted intra-provincial fixed effects, as explained above.

The off-diagonal $\hat{\gamma}_{ij}$'s of Table 2 are all negative, large in absolute value, and statistically significant. The estimates are quite precise but to avoid clutter, the standard errors are suppressed. The estimates vary widely across provincial partners for each origin and by origin for each destination. The economic significance of the estimated interprovincial fixed effects is shown in percentage trade volume effects, as defined in equation (14), and tariff equivalent effects, as specified in equation (15) using an assumed elasticity of substitution equal to 5. Estimates of the trade volume effects of interprovincial trade costs are reported in Panel B of Table 2. All off-diagonal elements in Panel B of Table 2 are less than 100. Thus, after controlling for origin and destination province-specific characteristics, interprovincial trade is significantly smaller than intra-provincial trade. For example, the estimate of 9.49 for pair NL-NS implies that trade between these two provinces is only about 10 percent of the average internal trade for these regions. Second, Panel B reveals significant heterogeneity in the estimates of bilateral trade costs across different pairs. Finally, the aggregate estimates at the provincial level, reported in column CA reveal that YT, NT and NL are the regions with the largest deviation of interprovincial from intra-provincial trade, while ON, AB, and QC are the regions with the smallest corresponding deviation. The bottom right element of Panel B reports that overall interprovincial manufacturing trade in Canada is about 5.2 percent of the intra-provincial trade.

The tariff equivalent measures in Panel C of Table 2 tell a similar story. The large and significant interprovincial trade costs estimates translate into large and significant tariff equivalents. After controlling for all possible province-specific characteristics, trade between more developed regions is subject to lower tariff equivalent inter-provincial trade costs, while trade between more remote regions faces much larger tariff equivalents. The latter is captured by the very large numbers clustered in the last two columns of Panel C (NT and YT). Using the consistent aggregation procedures from Section 2.2, we find that the average interprovincial trade costs in Canada are equivalent to a tax of 109%, varying between 82% for ON and 319% for YT. The magnitude and the pattern of variation depict geographical forces but may indicate regulatory and other barriers.

The fixed effects estimates in Panel A of Table 2 are in principle comparable to the directly observable tetrads estimates $\sqrt{X_{ij}X_{ji}/X_{ii}X_{jj}}$. Tetrads estimates contain the random error terms that are minimized in specification (13) by controlling for origin-time and destination-time fixed effects (and a particular form of time variation in the bilateral fixed effects). We test the fit of tetrads to our estimator by estimating:

$$\ln(\sqrt{X_{ij}X_{ji}/X_{ii}X_{jj}}) = a_0 + a_1\hat{\gamma}_{ij} + \epsilon_{ij}, \tag{20}$$

If tetrads is accurate, estimates should satisfy $a_0 = 0$, $a_1 - 1 = 0$ with a very high R^2.

Results are in Table 3. The first column of Table 3 reports findings with panel data while the remaining columns report yearly results. First, very high R^2 values obtain throughout. Second, while all estimates of $\hat{\gamma}_{ij}$ are statistically significant and close to one,[29] formal chi-squared tests for $a_1 = 1$ fail to reject the null hypothesis for the panel specification and for 6 of the 11 yearly specifications. Third, estimated constant terms are small, but only five of the estimates of a_0 are not statistically different from zero. Furthermore, as can be seen from the last row in both panels of Table 3, chi-square tests reject all of the joint tests $a_0 = a_1 - 1 = 0$. We conclude that tetrads estimator and the fixed effects estimator are highly correlated but the two are statistically different. Mechanically, the difference occurs because the origin- and destination-time fixed effects of our estimator control for systematic

[29] All standard errors are bootstrapped and clustered by country-pair.

elements in the random variables that enter the tetrads measure.[30]

Next, we replace the country-pair fixed effects from specification (13) with observable geographic trade cost proxies, bilateral distance and contiguity. In order to isolate and emphasize the novel internal (intra-provincial and inter-provincial) trade cost measures and to construct consistent UTB indexes for Canada's internal trade, we retain the most flexible (directional pair-fixed effects) specification to model international trade costs. In principle, we can use the same gravity variables to model international trade costs. However, we choose to keep the flexible specification for two reasons. First, there is evidence of significant asymmetries in the trade barriers between Canada and the US. Second, more importantly, we use the pair fixed effects structure in order to stay consistent with the fixed effects gravity specification from the previous section. As we demonstrate below, this will enable us to construct consistent estimates of unexplained provincial trade barriers in Canada.

Recent gravity studies decompose distance effects into intervals. Eaton and Kortum (2002), for instance, use aggregate world data and split the effects of distance into four intervals.[31] Following these studies, we split distance in four intervals, which correspond to the four quantiles of our distance variable. In addition, we define $CONTIG\_PR\_PR_{ij}$ as an indicator variable that takes the value of one when two provinces or territories share a common border, and it is equal to zero otherwise.[32] The estimating equation becomes:

$$\begin{aligned}\frac{x_{ij,t}Y_t}{Y_{i,t}E_{j,t}} &= \exp[(1-\delta_{ij})(\sum_{m=1}^{4}\beta_m^k DISTANCE\_m_{ij} + \beta_{contig}CONTIG\_PR\_PR + INTERPR\_T_{ij,t})] * \\ &\quad \exp[(INTRAPR\_T_{ij,t} + \psi_{ii}\delta_{ij} + \eta_{i,t} + \theta_{j,t}] + \epsilon_{ij,t}, \qquad (21)\end{aligned}$$

where δ_{ij} is the Kronecker delta, $DISTANCE\_1$ corresponds to the smallest quartile and

[30] Our time-pairwise fixed effect coefficients are not statistically significant.

[31] They find that the estimate of the distance coefficient for shorter distances is larger (in absolute value) than for longer distances. Anderson and Yotov (2011) find a non-monotonic (inverted u-shape) relationship between distance and disaggregated goods trade flows in the world.

[32] When applied to international trade flows, the gravity model consistently delivers positive and significant estimates on $CONTIG\_PR\_PR_{ij}$ suggesting that, all else equal, countries that share a common border trade more with each other.

$DISTANCE\_4$ corresponds to the largest quartile. Importantly, (21) enables us to obtain province-specific estimates of intra-provincial trade costs (ψ_{ii}) in the same specification with inter-provincial and international trade costs. This is a notable distinction from the existing literature, which is mostly focused on international trade costs or delivers average domestic trade costs that do not distinguish between intra-regional and inter-regional trade costs within a country.

Inter-provincial trade costs. Estimation results from specification (21) are reported in column (2) of Table 1. As expected, distance is a significant impediment to interprovincial trade: all of the four distance estimates are sizable, negative, and statistically significant. In addition, the smallest estimate (in absolute value) is for the smallest distance interval ($DISTANCE\_1$), and the largest estimate is for the largest interval ($DISTANCE\_4$). We also see evidence of non-monotonic effects, as the estimate on ($DISTANCE\_3$) is smaller than the estimate on ($DISTANCE\_2$). Second, the estimate on $CONTIG\_PR\_PR_{ij}$ is positive but statistically insignificant and very small in magnitude, $\beta_{contig} = 0.055$ (std.err. 0.041). The small and economically insignificant estimate on $CONTIG\_PR\_PR_{ij}$ is in contrast with the large, positive and statistically significant estimates from the international gravity literature. Based on the results, contiguity is not a significant determinant of inter-provincial trade in Canada, though it plays an important role in international trade.[33]

Intra-provincial trade costs. Column (2) of Table 1 also reports estimates of the volume effects of intra-provincial relative trade costs for each Canadian region. Several findings stand out. First, large, negative, and statistically significant estimates are obtained for the volume effects of intra-provincial trade costs for all provinces and territories, save YT with a positive (but small) estimate of γ_{ii}. These results are consistent with theory, recognizing that gravity identifies only the *relative* displacement of trade due to internal

[33] A possible explanation for the failure of contiguity to matter much is that it matters differently for trade between the large contiguous provinces and their partners, such as ON and QC, than it does for trade between small and remote contiguous provinces such as NT and YT. This hypothesis can be tested by introducing individual indicator variables for each possible pair of contiguous provinces in our sample. We choose not to do this since it essentially introduces 15 of the bilateral fixed effects.

friction relative to border friction. The smaller the absolute value of internal volume, the larger the relative effect of reductions of external volume. The large heterogeneity across the estimates of the γ_{ii}'s across provinces makes intuitive sense because it is inversely related to the economic and geographic size of the provinces after controlling for distance and contiguity in inter-provincial trade. Relatively large home bias tends to reflect fixed interregional trade costs acting on the trade of economically small regions while geographic compactness lowers intra-regional cost. These factors explain the largest home biases in Table 1. YT has the largest value of γ_{ii}. Its population of about 33,000 is 75% concentrated in Whitehorse, the capital. PE, with next largest value of γ_{ii} has almost 5 times YT's population, little more than a fifth in Charlottetown, the capital. Most of the remainder is dispersed in sizable towns around the compact island. NT, the third highest, has population over 20% larger than YT, less than half in Yellowknife, the capital. Much more significantly, NT has the highest GDP per capita in Canada due to natural resources. At the other extreme, ON exhibits the lowest home bias, followed by AB and BC. The statistically significant heterogeneity of the γ_{ii}s among the lower tier of more populous provinces with good infrastructure strongly suggests the influence of internal border barriers.

We compare interprovincial and intra-provincial trade costs in Table 4. To construct inter-provincial trade costs, we combine the estimates on the gravity covariates from Table 1 with data on inter-provincial distance and contiguity. These estimates are reported in Panel A of Table 4. Several intuitive patterns are evident. First, there is wide variability of the volume effects of inter-provincial trade costs across provinces and across pairs. Second, the inter-regional patterns observed in Panel A of Table 4 are consistent with the ones reported in Panel A of Table 2. Third, interprovincial trade costs are always significantly larger than intra-provincial trade costs, reducing interprovincial trade relative to intra-provincial trade.[34] However, the volume effect difference between interprovincial trade costs and intra-provincial trade costs varies by province. For example, the difference is smaller for the

[34]Recall that only relative trade costs are identified by gravity, so the positive estimated coefficient for YT's internal trade does not literally imply a subsidy.

developed provinces (ON, AB, BC) and larger for the smaller and remote regions (YT, PE, NT). There is significant heterogeneity across provincial pairs too.

Panel B of Table 4 reports the relative tariff equivalents corresponding to the volume effects of Panel A using an assumed elasticity of substitution equal to 5. Small and distant provinces (like YT and NT) exhibit relatively low intra-provincial tariff equivalents and large interprovincial tax equivalents. Consistently aggregated average relative trade costs in Canada are equivalent to a tax of 346%, ranging from 292% for Quebec to 456% for Yukon.[35]

The relative performance of the gravity variables and pairwise fixed effects estimator is reported in row AIC of Table 1. The Akaike Information Criterion (AIC) gives a rough comparison of these non-nested specifications.[36] The difference between AIC for the bilateral fixed effects specification and AIC for the gravity specification is 1.82, less than the threshold of 2 that the usual rule of thumb suggests, which provides 'substantial' support for the gravity specification relative to the bilateral fixed effects specification (Burnham and Anderson (2002)). This finding suggests that distance alone is a powerful predictor of bilateral trade costs within Canada, since contiguity effects are insignificant. Nevertheless, a systematic pattern in the difference between fixed effects and gravity variables estimators emerges from a second stage regression.

4.2 UTB Estimates and Patterns

UTBs are based on the difference between the pair fixed effects $\hat{\gamma}_{ij}$ and the deflated gravity variables estimators. The difference should not be a function of $\hat{\psi}_{ii}$ and $\hat{\psi}_{jj}$ under the Cobb-Douglas specification, except as these estimated intra-regional fixed effects contain systematic border effects. Evidence presented at the end of this section is consistent with the Cobb-Douglas restriction.

Parameters ζ_O and ζ_D are estimated, and systematic UTBs identified by estimating

[35]Relative trade costs alone are meaningful. Normalizing all trade costs by the reported negative intra-provincial cost of YT, add 19% to all elements of Panel B of Table 4.

[36]AIC is theoretically founded for maximum likelihood estimators, so its use for PPML estimators is a rough guide only.

specification:

$$\hat{\gamma}_{ij}^{FE} = \omega_0 + \omega_1 \ln \left(\hat{t}_{ij}^{GRAV}\right)^{1-\sigma} + \omega_2 \; \hat{\psi}_{ii}^{GRAV} + \omega_3 \; \hat{\psi}_{jj}^{GRAV} + \nu_{ij}, \quad \forall i \neq j. \tag{22}$$

Here, $\hat{\gamma}_{ij}^{FE}$ are the estimated volume effects of trade costs from the bilateral fixed effects specification (12), $\ln(\hat{t}_{ij}^{GRAV})^{1-\sigma}$ are the bilateral gravity variables volume effects and $\hat{\psi}_{ii}^{GRAV}$, $\hat{\psi}_{jj}^{GRAV}$ are intra-provincial fixed effects in the gravity variables specification (16).

UTBs in log form are calculated as the difference between $\hat{\gamma}_{ij}^{FE}$ and $\ln\left(\hat{t}_{ij}^{GRAV}\right)^{1-\sigma}$ deflated by $[\hat{\zeta}_O \hat{\psi}_{ii} + \hat{\zeta}_D \hat{\psi}_{jj}]$. The deflator is estimated with the theoretical Cobb-Douglas cost function coefficient estimated from (22) results as $\hat{\omega}_2/(\hat{\omega}_2 + \hat{\omega}_3) = \hat{\zeta}_O$ and $\hat{\omega}_3/(\hat{\omega}_2 + \hat{\omega}_3) = \hat{\zeta}_D$. Thus

$$\begin{aligned} \ln \widehat{UTB}_{ij} = \hat{\omega}_0 + (\hat{\omega}_1 - 1) \ln \left(\hat{t}_{ij}^{GRAV}\right)^{1-\sigma} \\ + [\hat{\omega}_2 + \hat{\omega}_2/(\hat{\omega}_2 + \hat{\omega}_3)]\, \hat{\psi}_{ii} + [\hat{\omega}_3 + \hat{\omega}_3/(\hat{\omega}_2 + \hat{\omega}_3)]\, \hat{\psi}_{jj} + \hat{\nu}_{ij} \end{aligned} \tag{23}$$

Systematic UTBs based on (23) combine elements of border barrier variation with intra-regional trade cost variation, using the structural interpretation of ψ_{ii}:

$$\psi_{ii} = (1-\sigma) \ln[t_{ii}/\bar{b}(i)^{\rho_2}] = (1-\sigma) \ln t_{ii} - (1-\sigma)\rho_2 \ln \bar{b}(i), \; \forall i. \tag{24}$$

[Equation (24) omits the normalization factor $\bar{b}$ absorbed in the constant term of (23).] If there is no variation in $\ln t_{ii}$, variation of $\ln \widehat{UTB}_{ij}$ with ψ_{ii} reflects border barrier variation only. Conversely, if there is no border barrier variation, the terms multiplying ψ_{ii} and ψ_{jj} in (23) should equal zero, and the deflator adjusts the gravity variables bilateral cost for internal trade cost variation alone as in (17), the theoretical definition of UTBs.

Turning to estimation of (22), homogeneity implies $\omega_0 = 0$, $\omega_1 + \omega_2 + \omega_3 = 0$. The Cobb-Douglas specification implies $\omega_2 + \omega_3 = -1$. Specification (22) permits tests of these restrictions. Rejection of the null hypothesis is indicates the presence of systematic UTBs, calculated using (23).

An initial benchmark estimates (22) subject to $\omega_2 = \omega_3 = 0$. Bootstrapping (required due to the use of generated regressors) delivers standard errors and confidence intervals for the coefficients. The results reported in column (1) of Table 5 reveal that the coefficient estimate on $\ln\left(\hat{t}_{ij}^{GRAV}\right)$ is not significantly different from 1; the $R^2 = .47$; and the estimate of the constant term is statistically significant and very large.

Column (2) of Table 5 presents estimates of (22) with unrestricted ωs. (i) $R^2 = .94$ increases substantially; (ii) $\hat{\omega}_1$ is closer to 1 and not statistically different from 1; (iii) $\hat{\omega}_2$ and $\hat{\omega}_3$ are each greater in absolute value than $-1/2$ and their sum is statistically smaller than -1, all at the 1% level of confidence; (iv) $\hat{\omega}_0$ is smaller in absolute value, but statistically and quantitatively significantly less than 0; (v) $\hat{\omega}_1 + \hat{\omega}_2 + \hat{\omega}_3 < 0$. Result (i) implies that intra-national trade cost variation picked up by volume effect $\hat{\psi}_{ii}$ contributes significantly to the variation of bilateral fixed effects, doubling the variation explained by distance.

Results (i) and (ii) together indicate that intra-national cost variation is almost uncorrelated with bilateral distance. Result (iii) implies that intra-national trade costs are correlated with an unobserved variable affecting inter-regional trade costs that is not neutralized by origin and destination fixed effects. Results (iv) and (v) imply that homogeneity of degree zero is rejected: the chi-squared test for the combined restrictions $\omega_0 = 0,\ \omega_1 + \omega_2 + \omega_3 = 0$ is rejected (p-value of 0.0001). Given the Cobb-Douglas structure, the hypothesis tests in (iii)-(v) are consistent with the presence of systematic UTBs.

Column (3) of Table 5 reports estimates of (22) subject to the constraint $\omega_2 + \omega_3 = -1$. The results imply that, subject to the constraint, the values of $\omega_1 = 1$ and $\omega_0 = 0$ cannot be rejected. The homogeneity hypothesis in the constrained model is not rejected: the chi-squared test for the combined restrictions $\omega_0 = 0,\ \omega_1 + \omega_2 + \omega_3 = 0$ has a p-value of 0.1754. Columns (2) and (3) taken together imply non-random residuals of the constrained regression.

The UTBs generated by the estimated version of (23) using the coefficients in column

(3) of Table 5 are given by (25) below. Standard errors are reported in parentheses.

$$\ln \widehat{UTB}_{ij} = \underset{(0.283)}{-1.059} - \underset{(0.035)}{0.035} \ln(\hat{t}_{ij}^{GRAV})^{1-\sigma} - \underset{(0.022)}{0.1122} \hat{\psi}_{ii} - \underset{(0.023)}{0.1149} \hat{\psi}_{jj} + \hat{\nu}_{ij}. \tag{25}$$

The structural interpretation of UTBs includes the adjustment term $z_{ij} = (\hat{\omega}_1 - 1) \ln(\hat{t}_{ij}^{GRAV})^{1-\sigma}$ and the relative border cost terms. The interpretation of the latter is based on substituting the right hand side of (24) for ψ_{ii}, ψ_{jj} on the right hand side of (23). Note that $\rho_2 = \zeta_O(\rho_2 + \rho_3) = \zeta_O(1 - \rho_1)$ and $\rho_3 = \zeta_D(1 - \rho_1)$. Then:

$$\begin{aligned}
&(\hat{\omega}_2 + \hat{\omega}_2/(\hat{\omega}_2 + \hat{\omega}_3))\, \hat{\psi}_{ii} + (\hat{\omega}_3 + \hat{\omega}_3/(\hat{\omega}_2 + \hat{\omega}_3))\, \hat{\psi}_{jj} = \\
&- 0.112(1-\sigma) \ln t_{ii} - 0.115(1-\sigma) \ln t_{jj} + 0.112(1-\sigma)\rho_2 \ln \bar{b}(i) + 0.115(1-\sigma)\rho_3 \ln \bar{b}(j).
\end{aligned} \tag{26}$$

(26) implies that the larger is intra-regional cost t_{ii}, the larger is interregional trade (since $\sigma > 1$), while the larger is origin or destination border cost $\bar{b}(i)$ or $\bar{b}(j)$ the lower is interregional trade. With no variation in intra-regional costs, the effect of border cost variation alone is measured by (26) and hence that portion of $\ln \widehat{UTB}_{ij}$ in (23).

The importance of variation in relative home bias ψ_{ii} and z_{ij} in explaining $\ln \widehat{UTB}_{ij}$ is described by standardized (beta) coefficients of 0.583 (z_{ij}), -0.491 ($\hat{\psi}_{ii}$) and -0.534 ($\hat{\psi}_{jj}$). Idiosyncratic border effects have relatively small influence, because the residual ($\hat{\nu}_{ij}$) variance is 6.6% of the variance of $\hat{\gamma}_{ij}^{FE}$ based on the unconstrained regression (22).

The provincial border barrier effects in (25) are inherently non-discriminatory, though producing systematic effects. Systematic discriminatory effects, if any, are part of the error term ν_{ij}. In principle, groups of regions could form samples to pick up systematic discriminatory effects through different $\hat{\omega}_k$ coefficients. With only 12 Canadian provinces this suggested technique has too few degrees of freedom to be useful. The discriminatory implications of the residuals ν_{ij} of (23) may be informative in some cases where added information can be brought to bear on discriminatory provincial border effects.

Table 6 reports expected (fitted) UTBs, $E[\widehat{\ln UTB}_{ij}]$, the systematic portion of equation (25).[37] There are some positive and some negative UTBs. For instance, YT, NT and PE exhibit a large number of negative UTBs, while most of the UTBs for AB, BC and ON are positive. Relatively large (arithmetic) estimated intra-provincial volume effects $\hat{\psi}_{ii}$ for small and remote provinces and relatively small (arithmetic) $\hat{\psi}_{ii}$ for large and central provinces have non-neutral effects, diverting interprovincial trade positively on some bilateral links and negatively on others. The pattern is consistent with the interpretation of the measured UTBs as based on deviations from the mean log border barriers of partners. These patterns and the variation across provinces and provincial pairs may indicate where policy intervention has larger payoffs.

The interpretation here of systematic UTBs is tentative for two reasons. First, omitted bilateral effects could be components of the error term in (25) and hence (23).[38] Second, specification (25) assumes a Cobb-Douglas cost function. But the results of estimating (23) could be indicative of non-CD cost structure for costs other than UTBs, with no UTBs. This implies omitted variables in the test based on equation (25).

The translog is natural to use as the alternative nesting the Cobb-Douglas. The translog adds 6 second order parameters to be estimated (using symmetry and the number of permutations of 3 activities: one for Origin, one for Destination, and one for the pure Interregional).[39] The first order parameters are constrained to sum to one as in the Cobb-Douglas case; the second order parameters are constrained to sum to zero.

[37]Standard errors are not reported to avoid clutter, but the bilateral fixed effect estimates are very precise, indicating statistical significance of the UTBs. A theoretically satisfactory standard error can be constructed from bootstrapping over repeated estimation of both specifications and generation of the UTBs. We eschew this computationally intensive method in this report.

[38]If the set of gravity variables in (21) is incomplete, $\hat{\tau}_{ij}^{UTB}$ will be biased. In other words, more information might be extracted with more details about the types of bilateral relationships (i.e., infrastructure details) between the provinces in our sample. This point is especially relevant at the sectoral level. In addition, it is possible that the gravity variables that we use already proxy for institutional and policy measures intended to promote interprovincial trade. For example, contiguous provinces are more likely to cooperate with each other. As an example of close cooperation between contiguous provinces consider Alberta and British Columbia, partners in the Trade, Investment and Labour Mobility Agreement (TILMA) in 2007. Due to data limitations, we cannot study the effects of TILMA here.

[39]Special case restrictions can reduce this number.

For the Canadian case, with 12 provinces, the data are rather sparse ($12 \times 11 = 136$ observations of interregional fixed effects under symmetry) to believably estimate so many parameters. On datasets with more observations, the translog gains traction. But collinearity is a well-known issue. A translog example (simplified by zeroing out interregional second order effects) counterpart to (22) is

$$\hat{\gamma}_{ij} = \omega_0 + \omega_1 \ln(\hat{t}_{ij}^{GRAV})^{1-\sigma} + \omega_2 \hat{\psi}_{ii} + \omega_3 \hat{\psi}_{jj} + \omega_4 \hat{\psi}_{ii}^2 + \omega_5 \hat{\psi}_{jj}^2 + \omega_6 \hat{\psi}_{ii} \hat{\psi}_{jj} + \nu_{ij}. \tag{27}$$

Theory implies $\omega_2 + \omega_3 = -1$ and $(\omega_4, \omega_5) < 0$ and $\omega_4 + \omega_5 + \omega_6 = 0$.

Column (4) of Table 5 reports the results from the translog specification in equation (27). None of the new terms is statistically different from zero and joint test cannot reject the hypothesis that $\omega_4 + \omega_5 + \omega_6 = 0$. The p-value for the corresponding chi-squared test is 0.4908. (We also cannot reject the hypotheses that $\omega_1 = 1$, $\omega_0 = 0$, $\omega_2 = -1/2$, $\omega_3 = -1/2$, and $\omega_2 + \omega_3 = -1$.) In sum, our findings do not reject the CD functional form, while the multicollinearity of the translog form blows up the standard errors. The significant changes in the estimates of the CD terms (compare columns 2 and 4) point to potential caveats in the assumption of CD to identify UTBs. If non-CD cost functions obtain, accurate comparative statics (e.g. the effect of an intra-regional improvement on bilateral costs) need to use them.[40] This is an important task for future research.

[40] The estimate of $\ln UTB_{ij}$ is constructed as:

$$\begin{aligned} \ln \widehat{UTB}_{ij} = \hat{\omega}_0 + (\hat{\omega}_1 - 1) \ln \left(\hat{t}_{ij}^{GRAV}\right)^{1-\sigma} \\ + \left(\hat{\omega}_2 + \hat{\omega}_2/(\hat{\omega}_2 + \hat{\omega}_3)\right) \hat{\psi}_{ii} + \left(\hat{\omega}_3 + \hat{\omega}_3/(\hat{\omega}_2 + \hat{\omega}_3)\right) \hat{\psi}_{jj} \\ + \hat{\omega}_4 \hat{\psi}_{ii}^2 + \hat{\omega}_5 \hat{\psi}_{jj}^2 + \hat{\omega}_6 \hat{\psi}_{ii} \hat{\psi}_{jj} \\ + u_{ij} \end{aligned} \tag{28}$$

The second and third lines decompose $\ln UTB$ into the 'true' UTB and the contribution of non-neutrality to UTB respectively. (27) estimates of $\omega_4, \omega_5, \omega_6$ may not sum to zero. That deviation forms part of the adjusted constant term in line 1 of (28).

4.3 CTB Estimates

CTB estimates for manufacturing within and between provinces for 2002, the mid-year in our sample, are reported in Panel A of Table 7. In the absence of trade frictions, all elements of the CTB matrices would be equal to 1. Constructed Home Bias, CTB_{ii}, is massive: all diagonal elements in Table 7, Panel A, are much larger than 1. More developed and central provinces exhibit smaller CHBs than relatively distant and less developed regions like YT, NT, and PE. This is due to the strong tendency for larger regions to have lower multilateral resistances because they naturally do more trade with themselves (Anderson and van Wincoop (2003); Anderson and Yotov (2010)). Variation in the pattern of bilateral trade costs faced by regions plays a role, but the size-multilateral-resistance link is dramatic.

The off-diagonal elements in Panel A are generally larger than 1 but smaller than the intra-provincial bias for all regions. For example AB and BC have Constructed Home Bias 4 to 6 times larger than their bilateral CTBs. International borders deflect foreign trade into domestic trade, but the deflection into local trade is much greater. The off-diagonal estimates in Panel A of Table 7 also reveal that more developed provinces demonstrate larger inter-provincial biases as exporters than as importers. In contrast, less developed and more remote regions, such as YT, PE, and NT, tend to have larger inter-provincial biases as importers than as exporters.[41]

Provincial overall CTBs for each province as an exporter are reported in the last column of Table 7 using the aggregation procedures from Section 2.2. YT, NT, and NL are the regions with the lowest average export CTBs. This is due to the strong tendency for larger economic regions to have lower inward multilateral resistance P_j. Thus, smaller regions selling to larger ones face tougher average competition.[42]

[41]Notably, the only three CTB indexes that we obtain that are lower than or equal one are for exports from NT to ON, and for exports from YT to QC and ON.

[42]The reason for the negative association of economic size and inward multilateral resistance is essentially because small regions naturally have to trade more with the outside and thus incur higher trade costs than do big regions. See Anderson and van Wincoop (2003), and especially Anderson and Yotov (2010) for more details on this argument.

Constructed Interregional Bias formalized in equation (5) measures the relative deflection of interprovincial trade into intra-provincial trade. $\Pi_{ij}/\Pi_{ii} = (CIB_{ij})^{1/(1-\sigma)}$ measures relative sellers' incidence on inter-provincial trade, from equation (10). Panel B of Table 7 reports this relative sellers' incidence for each province/territory on sales to each province. The off-diagonal elements in Panel B are all greater than one, reflecting the larger frictions that each province faces when shipping to the rest of Canada as compared to shipping internally.[43] Panel B shows that more developed regions face lower relative resistance than less developed regions. The aggregated provincial estimates in the last column of Panel B emphasize this pattern because ON and QC, the two largest provinces, enjoy the lowest relative sellers incidence while YT and NT face the largest relative sellers' incidence.

The UTB contribution to CTB is a general equilibrium complement to the partial equilibrium UTB measures in Panel C of Table 4. Panel C of Table 7 reports percentage differences between CTBs from the pairwise fixed effects estimator and the gravity variables estimator. First, note that the diagonal elements in Panel C are very small, all less than 1 percent in absolute value. This result should be expected, because in both specifications the intra-regional trade costs are normalized to 1 and the difference between the two is due entirely to the difference in the multilateral resistances in the two specifications.[44] Second, the off-diagonal elements are sizable and vary in sign. Interestingly, the signs of the corresponding general equilibrium UTB estimates from Panel C of Table 7 and those from Panel C of Table 4 are often opposite. Thus the general equilibrium effects of UTBs are strong and often outweigh their direct partial equilibrium effects.

Percentage changes in CTBs over time in Manufacturing from 1997 to 2007 are reported in Table 8.[45] First, CHBs (intra-provincial CTBs) have decreased for all provinces save BC and NB, with increases of 2% and 4.2%, respectively. Most provinces are becoming more integrated with the world. The fall in CHBs is largest for the remote regions YT

[43]The exception is relative sellers incidence equal to one on shipments from ON to NT.

[44]That is, the origin and destination fixed effects differ in the two estimations.

[45]It should be noted that comparisons of the CTB estimates over time are subject to reliability of ROW data, which is used to construct the value of world output for each sector.

(79%) and NT (62%). Second, the changes in inter-provincial CTBs off the diagonal are mixed, but with some consistent patterns. More remote regions experience a fall in the CTBs for exports, exemplified by decreases for NT and for YT with any other region in our sample. CTB changes at the province level are summarized in the last column in Table 8, where we report consistently aggregated provincial numbers. Subtracting the diagonal terms gives the percentage change in CIBs. All provinces except YT (-4.8%) experience a rise in CIB; Canada's provinces are become more integrated. NT, ON and MB are provinces that experience lower CTBs for their exports to most provinces and territories, but their fall in CHBs implies a rise in CIBs. All the inter-temporal variation is due to changes in the provincial output and expenditure shares acting on multilateral resistances. As discussed earlier, there is little evidence of time variation in the bilateral trade costs.

4.4 Intra-national and Provincial Home Bias

The variation of relative provincial home bias $\exp(\psi_{ii}) = [t_{ii}/\bar{b}(i)]^{1-\sigma}$ exerts important effects on general equilibrium intra-national home bias. Intra-national home bias for province i is the ratio of its predicted to theoretical frictionless trade within Canada, $i \in C(i)$, a measure incorporating the effects of trade costs on multilateral resistances:

$$CTB_{C(i)} = \sum_{j \in C(i)} \frac{E_j}{E_{C(i)}} CTB_{ij}. \tag{29}$$

The importance of flexibly specifying provincial home bias is revealed by estimating (21) alternately with $\psi_{ii} = 0$ and $\psi_{ii} \neq 0$, then calculating the $CTB_{C(i)}$ under each specification.

Table 9 presents the results. Column (1) reports $CTB_{C(i)}$ constructed with $\hat{\psi}_{ii} = 0$ and Column (2) reports $CTB_{C(i)}$ with $\hat{\psi}_{ii} \neq 0$, as in column (2) of Table 1. The correlation between values in the two columns is only 0.67. CTBs obtained with $\psi_{ii} \neq 0$ are mostly larger than their counterparts in column (1). The differences are smaller for the smaller, more remote provinces (e.g. YT, NT, and PE). In contrast, for ON, AB, and BC the dispersion of relative intra-provincial trade costs reduces their CTBs.

The difference between columns (1) and (2) of Table 9 is not driven by the direct effect of ψ_{ii} on CTBs alone. This is evidenced by a correlation of 0.38 between the CTB difference from Table 9 and $\hat{\psi}_{ii}$ (differenced from 0) from Table 4.

4.5 Credibility Checks

The credibility of our results is buttressed by analysis of the residuals and sensitivity to variations of the model specification.

Residuals are defined in equation (19) as the difference between the actual data and the fitted CTBs. Residuals are primarily due to measurement error in the trade, output and expenditure data, but may also indicate time-varying trade costs or a specification error. Systematic sign switches of residuals over time could vitiate our use of panel structure to identify UTBs. Systematic under- or over- prediction for pairs could indicate departure from the iceberg (log-linearity of) trade costs assumed in (11). The residuals data reveal very few instances where the residuals for a given pair are steadily positive or negative up to a given year and then switch signs until the end of the period, suggesting that the model does not omit a systematically important time-varying explanatory variable.[46] The examination of residuals combines with the finding of no significant time-varying effects captured by $INTERPR\_T_{ij,t}$ and $INTRAPR\_T_{ij,t}$ from specification (13) to suggests that internal trade costs in Canada were stable between 1997 and 2007.

Systematic under- or over-predictions across years occur for only 18 of the 144 possible pairs of provinces and territories in our sample.[47] The scarcity of such examples indicates randomness rather than non-iceberg trade costs.

[46] The data set of residuals is available by request.

[47] For example, on average, the largest (as percent) over-predictions of our model are for 'exports' from NT to MB and from NT to SK, and the largest under-prediction is for shipments from YT to BC. In most cases, the model over-predicts or under-predicts either the exports or the imports for a given province/territory from another province or territory. In a few instances there are systematic differences in each direction for a given pair. For instance, the model over-predicts shipments from AB to BC but under-predicts shipments from BC to AB.

A full cross section display of residuals for 2002 (the mid-year of the sample) is expressed in percentage terms for comparability in Table 10. Note first that the residuals are mostly not systematically signed: each row and column contains positive and negative elements. This is consistent with the process generating the ϵ realizations being a zero mean random generator. Second, in terms of distribution across provinces and across provincial pairs, the biggest discrepancies between the data and the model predictions (based on the dispersion of the residuals) are for YT and NT, followed by NL and PE. In contrast, the model performs best for QC, followed by AB, BC and ON. Thus, the model performs best for the big provinces and worst for the smallest provinces. Note that this is so even after the rich system of fixed effects controls for time-varying province-specific effects (both as importer and exporter) and for time-invariant bilateral effects. This pattern is explained by less efficient estimators for YT and NT (due to lack of data for these territories), or it may reflect meaningless randomness. It certainly implies some heteroskedasticity not controlled for in our econometric specification.

We perform six robustness checks with variations on the model, described in detail in a Supplementary Appendix available by request. Our findings are robust to all six variations. First, we allow for asymmetric bilateral fixed effects in equation (11). Differences are small, hence symmetry is consistent with the data. Second, the base elasticity of substitution value ($\sigma = 5$) is replaced by values of 3 and 7. The interprovincial trade costs estimated using the fixed effects approach and the standard gravity variables are qualitatively identical to our main estimates and the quantitative differences are intuitive. Third, OLS estimation of the log-linearized gravity equation yields very similar results to the PPML estimation. Fourth, suspicious of the role played by large rest-of-the-world (ROW) aggregate and US regions, we exclude them consecutively from our sample. The estimates of interprovincial trade costs are unaffected.[48] Fifth, we replace all missing trade values in the data with zeros. The CTB indexes, the interprovincial trade costs and the tariff equivalents remain qualitatively

[48] The reason for insensitivity is that we use the most flexible fixed effects specification to account for trade costs with US and ROW.

unchanged with only minor quantitative changes. Sixth, we employ only data for the years 1997, 1997, 2001, 2003, 2005, and 2007.[49] There are no significant differences between the set of estimates with two-year lags and the main estimates.

5 Sectoral Estimates

The sectoral pairwise fixed effects and gravity estimates and their sectoral tariff-equivalent indexes are generally consistent with the findings for 'Total Manufacturing'. Across all sectors and all exporter-importer pairs, the interprovincial tax equivalents of all costs are greater than the intra-provincial tariff equivalents. 'Health', 'Education', and 'Finance' are the sectors with the largest tax equivalents, whereas 'Leather, Rubber, Plastic' and 'Hosiery and Clothing' are the sectors with the smallest tax equivalents.[50] The UTB sectoral border tax equivalents, consistently aggregated across all provinces, range from 86.3% for 'Health' to -12.6% for 'Agriculture'. We find some positive and some negative UTBs both across sectors for a given region and across regions for a given sector. Overall, the results suggest that provinces/territories face interprovincial trade costs beyond those associated with bilateral distance and contiguity.

Generally, the CTB indexes for the disaggregated sectors are consistent with the 'Total Manufacturing' findings. Constructed Home Bias $CHB_{ii} = CTB_{ii}$ is large and varies considerably by province i, largest for the small remote ones. Looking at CHB consistently aggregated over provinces across sectors for 2002, the largest values are for 'Agriculture', 'Hosiery and Clothing', and 'Health'. The CIBs ($CIB_{ij} = CTB_{ij}/CTB_{ii}$) for each sector are significantly less than one. Their $1/(1-\sigma)$ power transforms are thus greater than one, suggesting that inter-provincial sellers' incidence of trade costs is significantly higher than intra-provincial incidence. Overall $CIB^{1/(1-\sigma)}$ is higher for services sectors than for goods sectors, which implies that relative sellers' incidence to inter-regional trade is higher. Among

[49] Cheng and Wall (2005) argue against the use of fixed effects with "... data pooled over consecutive years on the grounds that dependent and independent variables cannot fully adjust in a single year's time."(p.8).

[50] A detailed analysis of the sectoral results is reported in the Supplementary Appendix available by request.

the services categories, the highest $CIB^{1/(1-\sigma)}$ values are for 'Health' and 'Finance', while 'Furniture', 'Textile Products, 'Wood, Pulp, Paper' exhibit the lowest $CIB^{1/(1-\sigma)}$ values. Over time, the average greater integration of Canada's provinces with each other and the world in both goods and services conceals some declines. All effects are due to changing location of sales and expenditure; we find no evidence of changing trade costs. 'Leather, Rubber, and Plastic', 'Hosiery and Clothing', and 'Fabricated Metal' are among the sectors with the steadiest CTB decline (trade is falling further below its frictionless benchmark). In contrast, consistent with the overall picture of rising integration, 'Wholesale', 'Education', and 'Health' generally exhibit increases in inter-provincial CTBs over time.

6 Conclusion

A novel econometric method is developed and applied to flexibly estimate bilateral intra-national trade costs from bilateral and internal trade flows. A key step is specifying a bilateral trade cost function that aggregates internal, border and pure interregional costs. Summary measures of bilateral trade displacements and related price measures, some new, are derived from consistent aggregation using structural gravity.

Our results show that, beyond the familiar trade-reducing effects of bilateral distance, provincial trade is differentially affected by variation in relative border frictions that depress the trade of small remote provinces and favor trade of large central provinces. The results suggest there is much to be learned from attempting to explain the variation in inter- and intra-regional trade costs and border barriers using detailed information on regulatory differences and intra-national infrastructure.

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Table 1: PPML Panel Gravity, Total Manufacturing, 1997-2007

	(1) Pair Fixed Effects	(2) Gravity Variables
INTERPR_T	-0.001	-0.000
	(0.097)	(0.132)
INTRAPR_T	-0.025	-0.023
	(0.097)	(0.132)
DIST_INTER_1		-0.777
		(0.042)**
DIST_INTER_2		-0.876
		(0.038)**
DIST_INTER_3		-0.844
		(0.035)**
DIST_INTER_4		-0.897
		(0.033)**
CONTIG_PR_PR		0.055
		(0.041)
$\psi_{AB,AB}$		-3.732
		(0.296)**
$\psi_{BC,BC}$		-3.619
		(0.317)**
$\psi_{MB,MB}$		-3.385
		(0.304)**
$\psi_{NB,NB}$		-2.565
		(0.257)**
$\psi_{NL,NL}$		-2.552
		(0.316)**
$\psi_{NS,NS}$		-2.681
		(0.245)**
$\psi_{NT,NT}$		-1.046
		(0.313)**
$\psi_{ON,ON}$		-3.969
		(0.340)**
$\psi_{PE,PE}$		-0.891
		(0.221)**
$\psi_{QC,QC}$		-2.972
		(0.322)**
$\psi_{SK,SK}$		-2.368
		(0.299)**
$\psi_{YT,YT}$		0.839
		(0.293)**
CONST	11.207	10.349
	(1.068)**	(1.482)**
N	2052	2052
AIC	6.38	8.20

Notes: This table reports PPML panel gravity estimates for Total Manufacturing, 1997-2007. The estimates in column (1) are obtained from the fixed effects specification (13). The estimates in column (2) are obtained from specification (21), where the bilateral fixed effects are replaced with gravity variables. Standard errors are clustered by pair and are in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. See text for more details.

Table 2: PPML with Pair Fixed Effects, Total Manufacturing, 2002

	NL	NS	PE	NB	QC	ON	MB	SK	AB	BC	NT	YT	CA
A. Pair Fixed Effects Estimates, γ_{ij}													
NL	0	-2.35	-3.21	-2.68	-3.4	-3.46	-4.31	-4.98	-4.53	-4.57	-5.9*	-8.4	-4.19
NS		0	-2.33	-1.67	-2.79	-2.68	-3.75	-4.34	-3.76	-3.88	-4.37*	-7.27*	-3.42
PE			0	-2.2	-3.37	-3.75	-4.56	-5.17	-5.04	-4.88	-6.66*	-7.94	-4.36
NB				0	-2.32	-2.34	-3.9	-4.26	-3.98	-4.2	-5.53*	-6.84	-3.42
QC					0	-1.52	-2.69	-3.33	-2.85	-3.09	-4.65	-6.46	-2.94
ON						0	-2.66	-2.85	-2.22	-2.67	-5.05	-6.05	-2.84
MB							0	-1.75	-1.9	-2.81	-4.84	-6.16	-3.1
SK								0	-1.67	-2.8	-5.61	-7.12*	-3.4
AB									0	-1.75	-4.2	-5.5	-2.89
BC										0	-4.67	-4.81	-3.21
NT											0	-5.9	-4.83
YT												0	-6.05
CA													-3.72
B. Volume Effects, $\exp(\hat{\gamma}_{ij}) \times 100$													
NL	1	9.49	4.04	6.88	3.33	3.14	1.34	.68	1.07	1.03	.27*	.02	2.5
NS		1	9.76	18.75	6.15	6.84	2.36	1.3	2.33	2.07	1.27*	.07*	4.86
PE			1	11.08	3.45	2.36	1.05	.57	.65	.76	.13*	.04	2.45
NB				1	9.84	9.65	2.02	1.42	1.86	1.49	.39*	.11	5.87
QC					1	21.84	6.81	3.57	5.79	4.54	.95	.16	8.69
ON						1	6.97	5.81	10.82	6.93	.64	.24	9.19
MB							1	17.36	14.93	6.01	.79	.21	6.68
SK								1	18.87	6.08	.37	.08*	6.33
AB									1	17.38	1.5	.41	8.78
BC										1	.93	.81	6.07
NT											1	.28	.87
YT												1	.32
CA													5.2
C. Tariff Equivalents, $\hat{\tau}_{ij}^{FE} = (\exp(\hat{\gamma}_{ij}/(1-\sigma)) - 1) \times 100$,													
NL	0	80	123	95	134	138	194	248	211	214	337*	716	152
NS		0	79	52	101	96	155	196	156	164	198*	516*	113
PE			0	73	132	155	213	264	253	239	428*	627	153
NB				0	79	79	165	190	171	186	299*	452	103
QC					0	46	96	130	104	117	220	403	84
ON						0	95	104	74	95	253	354	82
MB							0	55	61	102	236	366	97
SK								0	52	101	306	493*	99
AB									0	55	186	296	84
BC										0	222	233	101
NT											0	337	227
YT												0	319
CA													109

Notes: This table presents estimates based on specification (13), where trade costs are controlled for with bilateral fixed effects. Panel A reports estimates of the bilateral fixed effects γ_{ij} obtained with a panel PPML estimator. All estimates are highly statistically significant. Standard errors (clustered by pair) are omitted for brevity. Panel B and Panel C report the corresponding volume effects and tariff-equivalents, respectively. "*" is used to denote that only one-way trade flows are used to obtain the corresponding estimate. See text for more details.

Table 3: Tetrads Experiments

	(1) Panel	(2) 1997	(3) 1998	(4) 1999	(5) 2000	(6) 2001
$\hat{\gamma}_{ij}$	1.025	1.054	1.020	1.057	1.085	1.096
	(0.019)**	(0.044)**	(0.041)**	(0.037)**	(0.048)**	(0.027)**
cons	0.178	0.242	0.175	0.321	0.253	0.375
	(0.054)**	(0.120)*	(0.115)	(0.099)**	(0.134)+	(0.073)**
N	570	48	51	52	51	53
R^2	0.955	0.958	0.947	0.969	0.947	0.972
p-value($a_1 = 1$)	0.1995	0.1962	0.6804	0.0927	0.0165	0.0002
p-value($a_0 = a_1 - 1 = 0$)	0.0000	0.0005	0.0000	0.0000	0.0450	0.0000
	(7) 2002	(8) 2003	(9) 2004	(10) 2005	(11) 2006	(12) 2007
$\hat{\gamma}_{ij}$	1.052	0.998	0.976	1.023	1.003	0.923
	(0.027)**	(0.028)**	(0.029)**	(0.047)**	(0.056)**	(0.027)**
cons	0.257	0.153	0.092	0.139	0.083	-0.083
	(0.088)**	(0.074)*	(0.090)	(0.131)	(0.162)	(0.085)
N	54	54	52	51	53	51
R^2	0.967	0.969	0.971	0.947	0.931	0.974
p-value($a_1 = 1$)	0.0457	0.9248	0.4143	0.6865	0.9573	0.0003
p-value($a_0 = a_1 - 1 = 0$)	0.0003	0.0000	0.0000	0.0035	0.0238	0.0000

Notes: This table reports the results from the various tetrads experiments based on equation (20). Column (1) lists results from an estimation with panel data, while the remaining columns, (2)-(12), present yearly estimates. Rows p-value($a_1 = 1$) and p-value($a_0 = a_1 - 1 = 0$) report p-values from chi-squared tests of $a_1 = 1$ and for $a_0 = a_1 - 1 = 0$, respectively. See text for more details. Bootstrapped standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$

Table 4: PPML with Gravity Variables, Total Manufacturing, 2002

	NL	NS	PE	NB	QC	ON	MB	SK	AB	BC	NT	YT	CA
A. Trade Cost Estimates, $\beta'\mathbf{GRAV}_{ij}$													
NL	-2.55	-5.13	-5.1	-5.28	-6.29	-6.63	-6.78	-7.34	-7.46	-7.6	-6.81*	-7.64	-6.85
NS		-2.68	-4	-4.2	-5.17	-6.26	-6.65	-6.81	-7.38	-7.53	-6.83*	-7.61*	-6.48
PE			-.89	-4.07	-5.14	-6.26	-6.62	-6.79	-7.36	-7.51	-6.8*	-7.59	-6.4
NB				-2.56	-4.83	-5.41	-6.56	-6.74	-7.31	-7.47	-6.77*	-7.57	-6.13
QC					-2.97	-4.72	-6.6	-6.59	-6.76	-7.37	-6.73	-7.5	-6
ON						-3.97	-6.36	-6.71	-6.67	-6.85	-6.75	-7.46	-6.26
MB							-3.38	-4.89	-5.49	-6.57	-6.58	-6.64	-6.26
SK								-2.37	-4.87	-5.53	-6.44	-6.69*	-6.07
AB									-3.73	-5.04	-6.34	-6.47	-6.26
BC										-3.62	-6.57	-6.33	-6.56
NT											-1.05	-6.21	-6.6
YT												.84*	-7
CA													-6.41
B. Tariff Equivalents, $\hat{\tau}_{ij}^{FE} = (\exp(\hat{\beta}'\mathbf{GRAV}_{ij}/(1-\sigma)) - 1) \times 100$,													
NL	89	260	258	274	381	425	444	526	545	569	449*	576	420
NS		95	172	186	264	378	427	449	532	557	452*	571*	349
PE			25	176	261	378	423	446	529	554	447*	567	327
NB				90	235	287	415	439	522	548	444*	563	307
QC					110	226	421	419	443	530	438	551	292
ON						170	390	435	430	454	440	545	335
MB							133	240	294	417	419	427	361
SK								81	238	298	400	433*	319
AB									154	253	388	404	336
BC										147	417	387	362
NT											30	372	419
YT												-19*	456
CA													346

Notes: This table presents estimates based on specification (21), where trade costs are controlled for with the standard gravity covariates of distance and contiguity. Panel A and Panel B report the corresponding trade costs estimates and tariff-equivalents, respectively. Standard errors (clustered by pair) are omitted for brevity. "*" is used to denote that only one-way trade flows are used to obtain the corresponding estimate. See text for more details.

Table 5: Gravity Trade Costs, CA Mnufacturing 2002

	(1) BENCHMARK	(2) TEST	(3) CONSTRAINT	(4) TRANSLOG
$\ln(\hat{t}_{ij}^{GRAV})^{1-\sigma}$	1.141	0.965	0.997	0.959
	(0.090)**	(0.035)**	(0.036)**	(0.039)**
$\ln(\hat{t}_{ii}^{GRAV})^{1-\sigma}$		-0.607	-0.487	-0.473
		(0.035)**	(0.023)**	(0.213)*
$\ln(\hat{t}_{jj}^{GRAV})^{1-\sigma}$		-0.621	-0.513	-0.545
		(0.032)**	(0.023)**	(0.191)**
$\ln(\hat{t}_{ii}^{GRAV})^{2(1-\sigma)}$				0.003
				(0.021)
$\ln(\hat{t}_{jj}^{GRAV})^{2(1-\sigma)}$				-0.009
				(0.018)
$\ln(\hat{t}_{ii}^{GRAV})^{1-\sigma} \times \ln(\hat{t}_{jj}^{GRAV})^{1-\sigma}$				0.035
				(0.036)
CONST	4.259	-1.059	-0.077	-0.710
	(0.596)**	(0.283)**	(0.235)	(0.767)
N	126	126	126	126
R^2	0.475	0.938		0.939

Notes: This table reports results from neutrality tests based on specification (22). The regression in Column (1) includes only bilateral trade costs $\ln\left(\hat{t}_{ij}^{GRAV}\right)$. Column (2) adds intra-regional trade costs $\ln\left(\hat{t}_{ii}^{GRAV}\right)$ and $\ln\left(\hat{t}_{jj}^{GRAV}\right)$. Column (3) restricts the sum of the coefficients on $ln\left(\hat{t}_{ii}^{GRAV}\right)$ and $\ln\left(\hat{t}_{jj}^{GRAV}\right)$ to equal -1. Lastly, Column (4) tests the translog specification be including the squared terms of $ln\left(\hat{t}_{ii}^{GRAV}\right)$ and $\ln\left(\hat{t}_{jj}^{GRAV}\right)$ and their interaction. Bootstrapped standard errors in parentheses. See text for more details. + $p < 0.10$, * $p < .05$, ** $p < .01$

Table 6: UTB, Total Manufacturing, 2002, Cobb-Douglas Specification

	NS	PE	NB	QC	ON	MB	SK	AB	BC	NT	YT
NL	-.07	-.27	-.07	.01	.135	.07	-.02	.135	.13	-.19	-.375
NS		-.295	-.1	-.02	.135	.08	-.03	.15	.14	-.18	-.37
PE			-.305	-.22	-.065	-.125	-.23	-.055	-.065	-.38	-.57
NB				-.04	.09	.065	-.04	.13	.125	-.19	-.375
QC					.115	.11	0	.16	.17	-.145	-.335
ON						.22	.115	.27	.26	-.035	-.225
MB							-.015	.16	.19	-.105	-.315
SK								.025	.035	-.225	-.44
AB									.17	-.075	-.285
BC										-.08	-.305
NT											-.6

Notes: This table reports the UTBs constructed based on equation (25). See text for more details.

Table 7: CTB Indexes, Total Manufacturing, 2002

	NL	NS	PE	NB	QC	ON	MB	SK	AB	BC	NT	YT	CA
A. CTB Levels, 2002													
NL	1141	44.3	72	30.2	4.8	2	3.8	2.9	2.8	2.8	23.1	3.9	4.1
NS	178	579.7	248.5	117.5	12.7	6.1	9.5	7.8	8.7	8.1	153	17.1	11.4
PE	149.7	128.5	4371.1	137.1	14.1	4.2	8.3	6.7	4.7	5.9	30.6	17.3	11.5
NB	104.3	100.9	227.7	440	16.5	7	6.6	6.8	5.6	4.7	38.5	21.3	11.3
QC	22.7	14.9	31.9	22.5	65.6	7.1	10	7.8	7.9	6.5	41.9	13.9	7.9
ON	15	11.6	15.3	15.4	11.5	19.8	7.1	8.8	10.3	6.9	19.7	14.8	10.1
MB	18.1	11.3	19.2	9.1	10.1	4.5	251.6	74.7	40	16.9	68.6	37.5	11.5
SK	12.2	8.2	13.8	8.4	7	4.9	66.2	493.5	66.7	22.6	42	18.9	14.2
AB	11.2	8.7	9.2	6.5	6.7	5.4	33.5	63	181	38	101.4	56.1	11.4
BC	7.2	5.2	7.2	3.5	3.5	2.3	9	13.6	24.2	127.2	42.1	74.7	5.2
NT					3.2	.9	5.1	3.5	9	5.9	16927.4	109.1	2.7
YT					1	.7			4.9	10.3	106.9	68851.5	2.3
B. Relative Sellers' Incidence $(CTB_{ij}/CTB_{ii})^{1/(1-\sigma)}$, 2002													
NL	1	2.3	2	2.5	3.9	4.9	4.2	4.5	4.5	4.5	2.7	4.1	4.1
NS	1.3	1	1.2	1.5	2.6	3.1	2.8	2.9	2.9	2.9	1.4	2.4	2.7
PE	2.3	2.4	1	2.4	4.2	5.7	4.8	5	5.5	5.2	3.5	4	4.4
NB	1.4	1.4	1.2	1	2.3	2.8	2.9	2.8	3	3.1	1.8	2.1	2.5
QC	1.3	1.4	1.2	1.3	1	1.7	1.6	1.7	1.7	1.8	1.1	1.5	1.7
ON	1.1	1.1	1.1	1.1	1.1	1	1.3	1.2	1.2	1.3	1	1.1	1.2
MB	1.9	2.2	1.9	2.3	2.2	2.7	1	1.4	1.6	2	1.4	1.6	2.2
SK	2.5	2.8	2.4	2.8	2.9	3.2	1.7	1	1.6	2.2	1.9	2.3	2.4
AB	2	2.1	2.1	2.3	2.3	2.4	1.5	1.3	1	1.5	1.2	1.3	2
BC	2	2.2	2	2.5	2.5	2.7	1.9	1.7	1.5	1	1.3	1.1	2.2
NT					8.5	11.6	7.6	8.3	6.6	7.3	1	3.5	8.9
YT					16	17.8			10.9	9.1	5	1	13.2
C. $(CTB^{FE} - CTB^{GRAV})/CTB^{FE}$													
NL	.2	24.9	21.3	12.1	20.4	-7.8	-80.9	-26.2	-26.9	3.1	-82.2	-256.2	0
NS	3	-.7	-19.3	-15.3	-60.7	12.3	-42.3	-37	22.7	36.7	53	-44.6	8.7
PE	10.1	-5.5	.1	14.2	-13	2.6	-26.2	-22.2	-9	32.8	-84.4	-10	7.1
NB	-2.2	-3.9	12.7	.3	-25.3	-29.1	-61.9	-20.5	8	17.3	-42.4	12.6	8.8
QC	2.2	-53.1	-21.6	-32.4	-.3	-43.5	41.7	29.8	35.4	61.7	21.9	18.2	6.2
ON	-8.7	31.5	14	-11.9	-17.8	.8	-7.6	43	43.5	37.5	-69	16.7	8.9
MB	-50.3	8.3	8.2	-15.7	60.6	11.3	-.3	20.3	9.1	35.3	-10	-42.3	9.3
SK	3.3	18.6	18	20.5	56.2	56.7	26.5	-.1	23.3	-4.9	-58.1	-104.9	11.8
AB	-20.3	43.2	9.5	25	50.1	46.9	-3.8	5.1	.2	-31.3	6.3	-11.8	9.4
BC	-13	42.8	31.3	17	63.6	27.7	9.1	-59.7	-61.5	.9	-25.3	32.9	3
NT					-11.6	-194.3	-132.5	-262	-73.4	-88.4	0	23.6	-6.2
YT					-30.7	-62.1			-131.3	-12.9	14.6	0	-10.9

Notes: This table presents estimates of the Constructed Trade Bias index, as defined in specification (18). Panel A reports CTBs in levels for 2002, while Panel B reports Constructed Inter-provincial Bias values (as defined in (5)). Panel C reports percentage differences between the CTB indexes constructed using the fixed effects method (13), and the standard gravity variables approach, (21). See text for more details.

Table 8: CTB Percentage Changes, Total Manufacturing, 1997-2007

	NL	NS	PE	NB	QC	ON	MB	SK	AB	BC	NT	YT	CA
NL	-3.7	15.4	-7	6.4	15	23.8	17	-4.3	5.1	11.4	2.2	104.2	14.3
NS	15.8	-12.8	-11.3	1.5	9.6	18	11.6	-8.8	.2	6.1	-2.6	94.7	7
PE	45.6	38.3	-11.6	27.6	37.8	48.3	40.3	14.7	26	33.5	22.5	144.8	32.7
NB	50.2	42.6	15	4.2	42.1	52.9	44.6	18.2	29.9	37.6	26.3	152.4	42.6
QC	26.2	19.9	-3.4	10.5	-5.4	28.5	21.5	-.6	9.1	15.6	6.1	112.1	22.4
ON	1.1	-4	-22.6	-11.5	-4.4	-18.4	-2.7	-20.4	-12.6	-7.4	-15	69.9	-7.8
MB	2	-3.2	-21.9	-10.7	-3.5	3.8	-22.2	-19.7	-11.8	-6.6	-14.3	71.3	-.8
SK	49.4	41.9	14.4	30.9	41.4	52.2	43.9	-6.7	29.2	37	25.7	151.2	53.4
AB	9.7	4.2	-16	-3.9	3.8	11.8	5.7	-13.6	-24.8	.6	-7.7	84.4	5.8
BC	40.4	33.4	7.5	23	32.9	43	35.3	10.6	21.4	2	18.1	136	43.7
NT					-45.4	-41.2	-44.4	-54.5	-50.1	-47.1	-61.5	-3	-41.3
YT					-85.1	-84			-86.4	-85.6	-86.8	-79.1	-83.8

Notes: This table reports CTB percentage changes over the period 1997-2007.

Table 9: Intra-provincial costs and CTBs

	(1) $CTB_{C(i)}$ $(\gamma_{ii} = 0)$	(2) $CTB_{C(i)}$ $(\gamma_{ii} \neq 0)$
NL	9	11.6
NS	17.8	22.5
PE	19.1	20.5
NB	15.1	19.4
QC	18.2	19.6
ON	31.1	15.1
MB	12.5	16.4
SK	16.6	19.1
AB	28.6	23.9
BC	19.9	16.9
NT	28.1	30.9
YT	32.7	32.6

Notes: This table reports CTBs which are constructed without intra-provincial trade costs (column 1) and with intra-provincial trade costs (column 2).

Table 10: Gravity Residuals as Percent of CTB, Total Manufacturing, 2002

	NL	NS	PE	NB	QC	ON	MB	SK	AB	BC	NT	YT	CA
NL	-1.5	130.3	-13.5	-65.7	-20.9	-45.2	-55.2	10.6	-36.3	-77	-18.5	1.5	-9.8
NS	16	-2.5	15	-1.1	1.6	8.4	-18.8	61.4	10.4	-44.8	-39.2	52.6	2.6
PE	-14	-26.1	.1	1.9	-4.4	38.4	84.6	-43.4	7.9	-48.6	46	183.3	0
NB	8.1	-10.2	-11.5	4.3	43.9	-53.4	-29.5	-45	-42.3	-43.6	-.1	71.1	-13.3
QC	.7	-1.6	15.9	-32.4	.8	14.2	14.6	12.3	8.7	-4.4	-7.7	7.5	8.9
ON	3.8	-6.6	-20.2	16.6	-.4	.7	-31.3	17.9	1	-2.5	-15.1	29.4	0
MB	-20.9	3.7	3.5	21.2	-16.4	35	-4.7	-.2	.2	-8.4	11.9	15.9	3.5
SK	36.7	24	-30.8	16.7	-11.2	8.1	17.4	-1.8	-2.8	14	-6	-25.3	4.2
AB	-2	-7.3	-21.8	6.2	-14.1	-12.1	7.1	8.4	-.8	-19.8	-13.6	34.3	-10.5
BC	15.7	-2.4	22.8	13.8	-3	9.4	27.7	31	21.3	-3.7	-24.1	-.3	13.5
NT					-68.7	-3.6	-100	-55.6	-18.7	12.9	.7	-100	-25.9
YT					-51.6	-47.9			23.5	204	-41.5	0	78.3

Notes: This table reports estimates of the Gravity Residuals as a percentage of the CTB index for 2002. See text for more details.