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ABSTRACT

We develop and apply a procedure to flexibly estimate intra-national border barriers and intra-regional trade costs. Bilateral border barriers very significantly depress Canadian inter-provincial trade for some pairs, though the overall effect is rather small. Bilateral distance imposes much larger inter-provincial trade costs. Contiguity between provinces accounts for little. Intra-regional trade cost variation affects relative bilateral costs and trade flows, and alters comparative statics except in a neutral case rejected by the data. Consistent trade cost aggregation procedures are developed and applied for groups of regions and/or sectors.

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An online appendix is available at:
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1 Introduction

Trade is highly localized, within as well as between nations. Intra-regional and interregional trade costs are an explanation, but intra-national trade costs and their composition are poorly understood. A special policy concern is intra-national border barriers, cross-border trade volume effects that appear after controlling for bilateral distance and contiguity effects. The small gravity literature on intra-national trade costs has at best estimated an assumed uniform inter-regional border barrier while neglecting intra-regional costs. This paper develops a new structural gravity method to flexibly estimate inter- and intra-regional trade costs, including internal border barriers. The coarse aggregation of the prior literature provided degrees of freedom necessary for estimation, alternatively provided here by judicious use of panel structure. Our measures of intra-national Canadian trade costs have potentially useful policy implications. Estimated internal border barriers reduced interprovincial manufacturing trade in 2002 by almost 20%, an average concealing much larger reductions for some provinces and provincial pairs. Our results on variation of intra-provincial trade costs suggest changes in comparative statics simulation practice with gravity models. Except in a neutral case that is strongly rejected by the data, accounting for intra-regional cost variation matters. Our methods and implications apply widely, for example to cross country gravity modeling.

Inter-regional border effects are flexibly inferred from bilateral trade flows over time using a two part procedure. One part estimates bilateral trade costs using bilateral fixed effects along with importer-time and exporter-time fixed effects. The other part estimates bilateral trade costs using 'standard gravity' variables: bilateral distance, contiguity and international borders. Both parts allow for (but do not find) limited time variation of trade costs. The difference between the volume deflection inferred from bilateral fixed effects and the standard gravity variables is dubbed the Unexplained Trade Barrier (UTB), connoting ignorance about a policy cause of the inter-regional border barrier.[1]

[1]Yilmazkuday (2012) uses estimated residuals from gravity regressions of intra- and inter-state trade in

Intra-regional trade costs are also inferred in the paper with flexible fixed effects, an improvement on previous efforts, including our own, that relied on the somewhat problematic concept of internal distance. Estimated intra-regional costs vary substantially across regions. Internal distribution intuitively should be part of full bilateral costs, suggesting that intra-regional and inter-regional trade costs are related in a full bilateral cost function. In a neutral special case, intra-regional trade costs are not identified separately from region fixed effects, bilateral trade is independent of variation of intra-regional trade costs and the common practice of suppressing intra-regional trade costs is harmless for comparative statics. Neutrality is resoundingly rejected at the 0.01% level of significance in a hypothesis test derived from our analysis.[2] Intra-regional trade costs matter. Their relationship to inter-regional and international trade costs deserves attention in future research.

Aggregation of inter-regional trade costs is important for many purposes, and consistent aggregation is important because such costs vary widely across partners. Consistent aggregators across partner regions are defined as the uniform trade cost that preserves the same aggregate volume (Anderson and Neary (2005)) for each region, similarly aggregating across origin regions for national inter-regional trade. We use these as convenient summary indexes below. The consistent indexes differ substantially and consequentially from atheoretic trade-weighted indexes, as we demonstrate.

Estimates of inter-provincial and intra-provincial trade costs (along with international trade costs) are inferred by applying the structural gravity model to high quality provincial trade flow data[3] over the period 1997-2007. The discussion of results concentrates on estimates from aggregate manufacturing bilateral trade for simplicity, illustrating the power of

the U.S. to construct 'home bias' effects interpreted as taste parameters. The residual method is loosely related to ours, while the 'home bias' applies to all the state partners of the home state, less flexibly than our UTB specification. As is well known, home bias in tastes is indistinguishable from a uniform border barrier. Large variation of estimated flexible border effects suggests that home bias in tastes is not adequate as an interpretation.

[2]Neutrality implies that bilateral trade costs are not identified separately from multilateral resistances, so rejection also implies identification.

[3]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.

the methods. The results are qualitatively similar to those for the 19 goods and 9 services sectors briefly discussed.[4] Estimates are quite precise. Analysis of residuals and sensitivity experiments support our baseline specification.

Bilateral distance effects account for most of the variation in the estimated bilateral fixed effects (the correlation coefficient is 0.95), but UTBs directly account for a 19.7% overall reduction in 2002 interprovincial manufacturing trade, worth CAD 20.3 billion. Volume effects converted to tariff equivalents using an elasticity of substitution equal to 5 yield an implied 'tariff' equivalent of 5.6%. This relatively low average conceals some much larger average provincial border costs (notably for Quebec and some remote provinces) that may merit policy concern. Still more variation is observed bilaterally (e.g. Quebec with its provincial partners).

Constructed Trade Bias (CTB), defined as the ratio of predicted to hypothetical frictionless trade flows for each bilateral pair, measures the general equilibrium effects of *all* bilateral trade costs on volume.[5] The ratio of interregional to intra-regional CTB is Constructed Interregional Bias (CIB), a measure of interregional volume deflection. Typically, CTB is greater than one due to the common deflection of trade away from the international border, while CIB is generally less than one, usually much less. A negative power transform of the CIB ratio is equal to the ratio of sellers' incidence on interregional sales to sellers' incidence on intra-regional sales. Relative sellers' incidence in 2002 manufacturing (consistently aggregated across provincial partners) ranges from 13.2 for Yukon Territory down to 1.2 for Ontario based on estimated CIBs raised to the power $1/(1-\sigma)$ with elasticity of substitution $\sigma = 5$. Variation is even greater across provincial partners for each exporter.

Notably, over the period 1997 to 2007, despite our finding of constant bilateral trade

[4]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.

[5]Intra-regional CTB is the Constructed Home Bias (CHB) proposed by Anderson and Yotov (2010), and aggregated inter-regional CTB is the Constructed Domestic Bias of Anderson, Milot and Yotov (2013).

costs, Canada's provinces are generally becoming more integrated with both the world, intra-regional CTB is generally falling; and with each other, CIB is generally rising. The increasing integration is due to secular changes in the incidence of trade costs that are in turn due to the changing location of production and expenditure. (See Anderson and Yotov, 2010, for discussion of the effect of changes in location of production and expenditure on incidence.)

The Unexplained moniker for UTBs is a call for explanation, in the spirit of Head and Mayer (2013) who call gravity "trade costs" *dark* in a cosmological metaphor.[6] UTBs can be related in future work to information on province-sector regulatory and other barriers combined with infrastructure. At least some of the darkness may be illuminated. Meanwhile, our intra-national trade cost and relative incidence measures for Canada may suggest directions of policy reform to raise efficiency and/or reduce regional inequality.

This is the first study to infer and quantify intra-provincial and inter-provincial trade costs for each province and each provincial pair in Canada. A strand of the existing literature evaluates the impact of regional borders on trade flows within other economies, with methods that differ from ours in details of the gravity model approach and level of aggregation.[7] Our

[6]Resistance is inferred from deflection of observed trade from a theoretical benchmark, just as cosmology infers dark energy from the accelerating expansion of the universe and dark matter from the spin of galaxies inexplicable from their observed mass. Extending the metaphor, dark energy is associated with the failure of the distance elasticity of trade to fall despite technological improvements and dark matter is associated with the trade-reducing effect of borders. Specific to the theme of this paper, more shadow falls because the intra-regional costs are themselves aggregates across trade costs between smaller sub-regions. Dropping the metaphor, "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.

[7]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. Also, the price comparison method

average estimates of internal border barriers are the smallest in the literature (though some provincial averages are much larger). The difference in methods is an explanation, but it could also reflect more complete Canadian integration. Tombe and Winter (2013) share our focus on intra-national Canadian trade costs but differ in their methods. They flexibly infer pure inter-regional trade costs from observed bilateral trade relative to internal trade using the "tetrads" approach of Head and Mayer (2000). They parametrically remove the effect of bilateral distance from the tetrads pairwise relative costs. By construction tetrads includes random elements excluded from our fitted pairwise fixed effects estimator. Our fixed effects estimates systematically differ significantly from their tetrads counterparts, though the two are highly correlated. More importantly, we estimate intra-regional trade costs that are necessarily normalized in the Tombe and Winter (2013) approach. Our work is also related to the literature on the international border barrier to Canada's trade: McCallum (1995), Anderson and van Wincoop (2003) to name a few.[8]

The rest of the paper is organized as follows. Section 2 sets out the theoretical foundation and introduces the Constructed Trade Bias index. Section 3 describes our data and develops the econometric specification. Section 4 presents our main findings and robustness checks. Section 5 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 a family of Constructed Bias indexes with two novel ones useful for understanding intra-

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.

[8]Apart from gravity, a number of case studies 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.

national trade.[9] 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:

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

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

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

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. Here and henceforth in the paper, 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

[9] Previous members of the family were introduced in Anderson and Yotov (2010) and Anderson et al. (2013).

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

resistance is a general distributional 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.

[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.

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

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

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

Trade costs t_{ij}^k are arbitrary in the theory above, while compromises with observability, econometric identifiability and parsimony dictate restrictions in the empirical literature.[14] The usual restrictions are theoretically consequential, motivating the alternative restrictions used in this paper described in Section 3.1.

Gravity models treat bilateral trade costs as if the origin volume melted en route to destination like an iceberg melting, i.e. the loss is in proportion to volume.[15] Iceberg trade costs customarily are modeled as multiplicative functions of component factors that affect resistance to trade, preserving the proportionality feature in components. Thus they are

[14] It is technically possible to calculate $\{t_{ij}^k, \Pi_i^k, P_j^k\}$ from (1)-(3). Since bilateral trade data, and production data are rife with measurement error, this 'zero degrees of freedom econometrics' has no inferential validity. Restrictions on the trade costs specification generate the degrees of freedom that permit inference.

[15] An enormously useful simplification, the iceberg assumption implies separability of the distribution of goods from the production and consumption of goods.

log-linear functions of observable trade cost components (tariffs) or proxies (distance).[16] The overall good fit of estimated gravity equations suggests that this specification is fairly accurate, but the specification cannot pick up idiosyncratic barriers to interregional trade such as unobservable responses to regulatory and informal discriminatory 'buy local' barriers.

To pick up unobservable idiosyncratic barriers, a generalization of the standard gravity specification is feasible in panel data settings. The generalization allows for trade cost components that are time invariant, such as geographic proxies, and time varying components that are suitably restricted, such as before and after a policy reform (joining a Free Trade Agreement, harmonizing regulations) or infrastructure improvement (highway link, container port). The time-invariant components can be estimated with either bilateral fixed effects (identified off the time variation of the panel) or with the log-linear function of geographic proxies, which is standard in the gravity literature. The difference between the fixed effects and gravity variables estimates is defined below as the Unexplained Trade Barrier. UTB provides important clues to policy analysis (it may indicate hidden regulatory or other border barriers) and to future research (its pattern suggests possible explanations of UTB). At a minimum, the fixed effects comparison gives a measure of how well the standard parsimonious gravity treatment of trade costs does.

The empirical literature usually sets intra-regional trade costs to zero, when treated explicitly at all. Zero intra-regional trade costs imply $t_{ii}^k = 1, \forall i$. One normalization in some form (e.g., set the smallest region's intra-regional trade cost factor to 1) is required in each sector k because relative trade costs only can be inferred from system (1)-(3).[17] At issue is the consequential further restriction of *all* intra-regional trade costs.

Allowing for general intra-regional trade costs is required for accurate evaluation of policy reforms. Changes in any of the bilateral trade costs t_{ij}^k, t_{ii}^k and t_{jj}^k generate changes in all the

[16] Generalized iceberg melting can include fixed costs and non-proportional dependence on volume.

[17] A uniform $t > 1$ implies that bilateral trade is equal to its frictionless benchmark everywhere, and furthermore a uniform increase $\lambda > 1$ applied to an initial set of t_{ij}^ks will result in no change in the observed trade pattern. This theoretical property of (1)-(3) means that level of estimated trade costs is meaningless; they must be normalized by some convenient benchmark bilateral trade cost. It is natural to use the smallest such cost, normally the smallest intra-regional trade cost.

multilateral resistances, locally evaluated with the comparative static derivatives of system (1)-(3) that depend on *all* the trade costs. Estimation of $t^k_{ij},\ i \neq j$, in contrast, is unbiased regardless of intra-regional trade costs because the elegant simplicity of structural gravity in (1) implies that third party effects such as t^k_{ii} on trade between i and j are captured by (Π^k_i and P^k_j), and controlled with origin and destination region fixed effects.

The comparative statics of (2)-(3) for given Es and Ys (conditional general equilibrium) are invariant to intra-regional trade costs in a special neutral case that restricts the combination of intra-regional and inter-regional costs in the full origin-destination bilateral trade cost. Econometrically, the neutral case implies that the level of bilateral cost cannot be identified in gravity regressions separately from multilateral resistance. The neutral case analysis is developed here and a hypothesis test based on it is reported below. Neutrality is rejected at the 0.01% level of significance in the results for the Canadian case.

Bilateral trade costs can generally be 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 in each of the origin, destination and transit between them. Homogeneity of degree one is consistent with the iceberg trade cost context that suppresses indivisibilities. Concavity is implied by cost-minimizing behavior. Neutrality obtains whenever $g(\cdot)$ can be factored into multiplicative components $r^{\rho_1}_{ij} r^{\rho_2}_{ii} r^{\rho_3}_{jj}$, a Cobb-Douglas structure under the homogeneity restriction $\rho_1 + \rho_2 + \rho_3 = 1$. The origin and destination effects $r^{\rho_2}_{ii},\ r^{\rho_3}_{jj}$ form part of the composite multilateral resistances $r^{-\rho_2}_{ii}\Pi_i\ , r^{-\rho_3}_{jj}P_j$ that solve (2)-(3). The composite terms are invariant to the 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.

More general specifications violate neutrality. For example, specialize the bilateral trade cost function $g(\cdot)$ by imposing separability with respect to the partition between intra-regional and inter-regional costs: $g(\cdot) = c[r_{ij}, f(r_{ii}, r_{jj})]$ where $f(\cdot)$ is a degree one homogeneous concave increasing function of the intra-regional trade costs. By homogeneity of degree one, $c(\cdot) = f(\cdot)c[r_{ij}/f(\cdot), 1]$. The neutral case for intra-regional costs is the Cobb-Douglas specification:

$$f(r_{ii}, r_{jj}) = r_{ii}^{\omega} r_{jj}^{1-\omega},\ \omega \in [0,1],\ i \neq j. \tag{6}$$

Neutrality does not obtain unless $c[r_{ij}, f(\cdot)] = fc[r_{ij}/f(r_{ii}, r_{jj})]$ is further restricted to the Cobb-Douglas function $r_{ij}^{\mu} f^{1-\mu}$, hence $\mu = \rho_1,\ (1-\mu)\omega = \rho_2, (1-\mu)(1-\omega) = \rho_3$. Without the further restriction $c[r_{ij}/r_{ii}^{\omega} r_{jj}^{1-\omega}, 1]$ remains a function of the origin and destination intra-regional resistances, so factorization using (6) does not provide invariance of the composite multilateral resistances solved from (2)-(3) to the size of intra-regional trade costs. Departing from the Cobb-Douglas (6) for intra-regional costs or departing from separability provide still more avenues for violating neutrality.[18]

Specification (6) is somewhat plausible in tackling local distribution costs at either end onto a pure interregional cost, generalizing the intuitive notion that multiplicative internal distribution margins apply in the destination to all goods, local and imported. But (6) is too restrictive to apply uncritically, especially when intra-regional trade costs are a primary concern. Neutrality fails a hypothesis test on Canadian data. Future applications to other data should include tests for local distribution neutrality.

2.3 Consistent Aggregation of Trade Bias and Trade Costs

Aggregation of volume concepts such as CTBs and trade cost concepts such as t_{ij} or t_{ij}/t_{ii} is useful for many purposes. Aggregation procedures are set out here that are consistent with maintaining a constant aggregate volume of trade given the theoretical model. 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 $C(i) =$

[18] The Cobb-Douglas form of $g(\cdot)$ is sufficient for neutrality and it appears to be nearly necessary except for trivial cases such as $f = 1$.

$\{j \in C, j \neq i\}$ 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 $E_C = \sum_i E_{C(i)}$.[19]

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. (In the import case, the expenditure share weights are replaced by sales share weights.) 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 $CIB_C/[\sum_i CTB_{ii} E_i/E_C]$.

[19]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.

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 (8), 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.

The direct relative trade costs $\{t_{ij}/t_{ii}, j \in C(i)\}$ also have a useful aggregate. The subset of bilateral trade costs t_{ij} is to be aggregated consistently so as to preserve the aggregate export volume from i to destinations j in the subset $j \in C(i), j \neq i$.[20] For small subsets (where smallness is defined in terms of trade volume shares), it is approximately accurate and practically quite useful to ignore the effect of changes in $t_{ij}, j \in C(i)$ on the multilateral resistances Π_i, P_j. Then, for each origin i the volume equivalent uniform bilateral trade cost index $b_{C(i)}$ is implicitly defined by

$$\sum_{j \in C(i)} X_{ij} = \sum_{j \in C(i)} \frac{Y_i E_j}{Y} \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} = \sum_{j \in C(i)} \frac{Y_i E_j}{Y} \left(\frac{b_{C(i)}}{\Pi_i P_j}\right)^{1-\sigma}. \tag{11}$$

Divide both sides of equation (11) by $(Y_i/\Pi_i^{1-\sigma} Y) E_{C(i)}$. The result is

$$\sum_{j \in C(i)} \frac{E_j}{E_{C(i)}} \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} = \sum_{j \in C(i)} \frac{E_j}{E_{C(i)}} \left(\frac{b_{C(i)}}{P_j}\right)^{1-\sigma} = \Pi_{C(i)}^{1-\sigma}. \tag{12}$$

[20]While atheoretic weights are often used to form such indexes, Anderson and Neary (2005) emphasize the practical importance of theoretically consistent weights.

The terms in brackets on either side of the equation are the $1-\sigma$ power transforms of the bilateral sellers' incidence for each sale $j \in C(i)$, the weights $E_j/\sum_{j\in C(i)} E_j$ are the frictionless equilibrium shares of i's trade to j; and the equation requires that the average seller's incidence on sales to $C(i)$, $\Pi_{C(i)}$, be maintained when hypothetically shifting to the uniform bilateral trade cost. $b_{C(i)}$ has an explicit solution from equation (12):

$$b_{C(i)} = [\sum_{j\in C(i)} w_j^{'} t_{ij}^{1-\sigma}]^{1/(1-\sigma)} \tag{13}$$

where $w_j^{'} = E_j P_j^{\sigma-1}/\sum_{j\in C(i)} E_j P_j^{\sigma-1}$. The weights $w_j^{'}$ are recognized as 'market potential' weights. In the econometric application, $E_j P_j^{\sigma-1}$ is identified as an importer fixed effect. The direct relative trade cost for region i exporting to its partners in $C(i)$ is $b_{C(i)}/t_{ii}$.[21]

Finally, it is useful to aggregate components of trade costs, such as UTBs. The Unexplained Trade Barrier has a tax equivalent equal to the inferred proportional tax rate that equates the bilateral trade cost estimated using bilateral fixed effects with the same bilateral trade cost estimated using the standard gravity variables (with details in Section 3.1). The index of the bilateral UTB tax equivalents is formed from the ratio of $b_{C(i)}$ calculated with bilateral fixed effects to $b_{C(i)}$ calculated with gravity variables: $b_{C(i)}^{FE}/b_{C(i)}^{GRAV} - 1$. Note that the weights $w_j^{'}$ in (13) differ between the bilateral fixed effects and gravity variables estimates, not just the estimated bilateral trade costs. The difference is due to the difference in inward multilateral resistances estimated with and without inter-provincial border effects. $b_{C(i)}^{FE}/b_{C(i)}^{GRAV} - 1$ is the uniform proportional tax by which the gravity estimates of the vector of bilateral trade costs must be multiplied to yield the same sellers' incidence on sales to

[21] It is also possible to construct an aggregate direct relative trade cost b_C/t_{CC}. The overall uniform interregional trade cost b_C is defined by extension of the operations of (10) and (11). Summing over i on both sides of (12) after weighting by expenditure shares and implicitly solving for the common b_C yields:

$$\sum_{i\in C}\sum_{j\in C(i)} \frac{E_j}{E_{C(i)}} \left(\frac{b_{C(i)}}{P_j}\right)^{1-\sigma} \frac{E_{C(i)}}{E_C} = \sum_{i\in C, j\in C(i)} \frac{E_{C(i)}}{E_C} \left(\frac{b_C}{P_j}\right)^{1-\sigma} (= \Pi_C^{1-\sigma}). \tag{14}$$

Here Π_C is the overall sellers' incidence of interprovincial trade costs in C. b_C is the common interprovincial trade cost that preserves overall sellers' incidence on interprovincial sales. The common t_{CC} is similarly constructed from the expenditure weighted volume effects of sellers' incidence on internal sales.

$C(i)$, $\Pi_{C(i)}$, as the fixed effects estimate.

Index (13) is partial equilibrium in the sense that multilateral resistances of seller i and buyers $j \in C(i)$ are held constant in switching to the uniform equivalent cost factor $b_{C(i)}$. In comparing two situations, as with the fixed effects and gravity variables estimators where the latter suppress the inter-regional border effect, the index includes general equilibrium effects on the multilateral resistances. The difference this makes is illustrated below by constructing a fully partial equilibrium index where the weights in the two calculations of $b_{C(i)}$ remain the same.

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 econometric approach produces Constructed Trade Biases and bilateral trade costs for each pair of regions and each year in the sample directly (except where necessary the sectoral index k is suppressed):

$$\frac{x_{ij,t} Y_t}{Y_{i,t} E_{j,t}} = \exp[\alpha' \mathbf{T}_{ij,t} + \gamma_{ij} + \eta_{i,t} + \theta_{j,t}] + \epsilon_{ij,t}. \tag{15}$$

The dependent variable is size-adjusted trade. Thus, CTB is the predicted values from (15). The last two terms in the square brackets of (15) 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 (15) account for bilateral trade costs.

Bilateral trade costs in (15) are decomposed into time-dependent and time-invariant components:

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

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.[22]

The first term in (16), $\mathbf{T}_{ij,t}$, 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.[23] 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

[22] 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.

[23] 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.

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 (15) becomes:

$$\frac{x_{ij,t}Y_t}{Y_{i,t}E_{j,t}} = \exp[\alpha_1 INTERPR\_T_{ij,t} + \alpha_2 INTRAPR\_T_{ij,t} + \gamma_{ij} + \eta_{i,t} + \theta_{j,t}] + \epsilon_{ij,t}. \tag{17}$$

The benefit of using pair-fixed effects in specification (17) is that these fixed effects control for all possible time-invariant bilateral trade costs. The estimates of the bilateral trade costs from (17) 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 Barrier (UTB) estimate as the difference between the two. In practice, however, collinearity requires restrictions on the pair fixed effects estimator. Intra-regional pair fixed effects are dropped in the restricted pair fixed effects approach while the specification with gravity variables includes intra-regional fixed effects. Consistent comparison between the two specifications that form the UTB estimates requires developing the implications.

Perfect collinearity requires restrictions on the pair-fixed effects from specification (17).[24] For clarity, temporarily suppress the time varying part of specification (17). 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. We solve the collinearity problem by imposing two

[24]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 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.

restrictions that are standardly used in the trade literature and that allow us to obtain and to interpret meaningfully a set of bilateral interprovincial trade costs for each possible pair in our sample.

First, we scale the time-invariant bilateral trade costs so that internal trade costs are suppressed: interprovincial trade costs are measured relative to intra-provincial costs. Effectively, we generate the γ_{ij} estimates from a theoretical original set of Γ_{ij}s by imposing $\gamma_{ij} = \Gamma_{ij} - (\Gamma_{ii} + \Gamma_{jj})/2 \Rightarrow \gamma_{ii} = \gamma_{jj} = 0$. The estimated bilateral fixed effects for interprovincial trade are thus understood as relative to an index of intra-provincial trade costs: $\exp(\gamma_{ij}) = \exp[\Gamma_{ij} - (\Gamma_{ii} + \Gamma_{jj})/2] = [t_{ij}/(t_{ii}t_{jj})^{1/2}]^{1-\sigma}$, where the denominator is a geometric mean of intra-provincial trade costs. The second restriction is to impose symmetry on the interprovincial fixed effects: $\gamma_{ij} = \gamma_{ji}; \forall i, j \in CA$.[25] Under symmetry $[t_{ij}/(t_{ii}t_{jj})^{1/2}]^{1-\sigma}$ is the volume effect of the geometric mean of the two interprovincial relative trade cost factors.

Under the restrictions, the inter-provincial volume effects of trade costs from specification (16) are:

$$\left(\hat{t}^{FE}_{ij,t}\right)^{1-\sigma} = [\hat{t}_{ij}/(\hat{t}_{ii}\hat{t}_{jj})^{1/2}]^{1-\sigma} = e^{\hat{\Gamma}_{ij}}/e^{(\hat{\Gamma}_{ii}+\hat{\Gamma}_{jj})/2} = e^{\hat{\gamma}_{ij}}, \tag{18}$$

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, $\left(\hat{t}^{FE}_{ij,t}\right)^{1-\sigma} = e^{\hat{\gamma}_{ij}}$ is interpreted as trade volume displacement due to inter-regional (interprovincial) trade costs relative to (the geometric mean of) intra-regional trade costs. The corresponding tariff equivalent index is:

$$\hat{\tau}^{FE}_{ij} = \left(e^{\hat{\gamma}_{ij}/(1-\hat{\sigma})} - 1\right) \times 100, \tag{19}$$

where, $\hat{\sigma}$ is the trade elasticity of substitution. Following the existing literature, in our

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

empirical analysis we choose the standard value for the elasticity of substitution $\hat{\sigma} = 5$.[26]

Fixed effects specification (18) is closely 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 difference with our bilateral fixed effects approach in practice is that our estimated $\hat{\gamma}_{ij}$ is fitted, controlling for random errors, whereas the tetrads 'estimate' includes the error terms. Moreover, specification (17) controls for origin- and destination-time effects in the random errors. Tests below indicate systematic deviations of tetrads from the pairwise fixed effects estimator.

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 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 (16) are replaced with gravity variables such as distance and contiguity:

$$UTB_{ij} = \ln\left(\hat{t}_{ij,t}^{FE}\right)^{1-\sigma} - \ln\left(\hat{t}_{ij,t}^{GRAV}/(\hat{t}_{ii,t}^{GRAV}\hat{t}_{jj,t}^{GRAV})^{1/2}\right)^{1-\sigma}, \quad \forall i \neq j \tag{20}$$

On the right hand side, the interregional cost estimated from gravity variables is measured relative to the geometric mean intra-regional cost, to make it consistent with the inferred measure from bilateral fixed effects under the dropped variable specification above. An important property of the UTB estimator (20) is that it is independent of the scaling by internal trade costs. Rewrite the fixed effects estimate $\ln(\hat{t}_{ij,t}^{FE})^{1-\sigma}$ as $\hat{\gamma}_{ij} = \hat{\Gamma}_{ij} - (\hat{\Gamma}_{ii} + \hat{\Gamma}_{jj})/2$. Then with consistent estimation of intra-regional trade costs from the gravity variables estimator, the UTB estimator is $UTB_{ij} = \hat{\Gamma}_{ij} - \ln(\hat{t}_{ij,t}^{GRAV})^{1-\sigma}$.

The gravity counterpart to $\left(t_{ij,t}^{FE}\right)^{1-\sigma}$ in equation (20) is:

$$\left(t_{ij,t}^{GRAV}\right)^{1-\sigma} = \exp[\alpha'\mathbf{T}_{ij,t} + \beta'\mathbf{GRAV}_{ij} + \psi_{ii}]. \tag{21}$$

[26]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 (16) for $i \neq j$. When the gravity model is applied to international trade data, the explanatory variables in $\mathbf{GRAV}_{ij}$ usually include the logarithm of bilateral distance between partners i and j, whether or not the two trading countries share a common border, whether they share a common official language, etc. More importantly, when the bilateral 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 (21). The intra-provincial fixed effect includes effects of intra-provincial distance and also other unobservable effects.

The inclusion of $\psi_{ii} = \ln(t_{ii}^{1-\sigma})$ estimates in the (21) specification implies that in comparing estimation results with the full fixed effect estimator, the estimates of intra-provincial trade costs have to be deducted from the $\left(t_{ij,t}^{GRAV}\right)^{1-\sigma}$ estimates before comparison with the corresponding indexes from the bilateral fixed effects specification. Specifically, ignoring the time dimension, the inter-provincial trade costs from specification (21) are:

$$\left(t_{ij,t}^{GRAV}\right)^{1-\sigma} = [\hat{t}_{ij}/(\hat{t}_{ii}\hat{t}_{jj})^{1/2}]^{1-\sigma} = e^{\hat{\beta}'\mathbf{GRAV}_{ij}}/e^{(\hat{\psi}_{ii}+\hat{\psi}_{jj})/2} = e^{\hat{\beta}'\mathbf{GRAV}_{ij}-(\hat{\psi}_{ii}+\hat{\psi}_{jj})/2}, \tag{22}$$

and the corresponding tariff equivalent measure is:

$$\hat{\tau}_{ij}^{GRAV} = \left(e^{(\hat{\beta}'\mathbf{GRAV}_{ij}-(\hat{\psi}_{ii}+\hat{\psi}_{jj})/2)/(1-\hat{\sigma})} - 1\right) \times 100. \tag{23}$$

The tariff equivalent UTB is obtained as the difference between the tariff equivalent measures from the fixed effects specification and from the gravity variables specification of trade costs:

$$\hat{\tau}_{ij}^{UTB} = \hat{\tau}_{ij}^{FE} - \hat{\tau}_{ij}^{GRAV}. \tag{24}$$

The UTB provides important potential clues to policy analysis (it may indicate hidden regulatory or other border barriers) and to future research (its pattern suggests possible explanations of UTB). The bilateral UTBs can be consistently aggregated using the methods of Section 2.3 to highlight overall internal barriers facing individual regions and give perspective on their importance. We use the agnostic term Unexplained to caution that it may not indicate an actual barrier. At a minimum, (20) gives a measure of how well the standard parsimonious gravity treatment of trade costs performs.[27]

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 (17). The corresponding Constructed Trade Bias (for a generic sector) is:

$$\widehat{CTB}_{ij,t} = \left(\widehat{\frac{t_{ij}}{\Pi_{i,t}P_{j,t}}}\right)^{1-\sigma} = \exp[\hat{\alpha}_1 INTERPR\_T_{ij,t} + \hat{\alpha}_2 INTRAPR\_T_{ij,t} + \hat{\gamma}_{ij} + \hat{\eta}_{i,t} + \hat{\theta}_{j,t}] \quad (25)$$

The CTB measure (25) 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 multilateral 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 (25) 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 (25):

$$\widehat{\epsilon}_{ij,t} = \frac{x_{ij,t}Y_t}{Y_{i,t}E_{j,t}} - \widehat{CTB}_{ij,t}. \quad (26)$$

[27] 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.

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.[28] 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.[29] A notable feature of our data set is that it covers most of 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.

[28] $\widehat{\epsilon}_{ij,t}$ 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 (17).

[29] 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 territories, US, and the rest of the world.

4 Estimation Results

This section presents interprovincial trade cost estimates and CTBs for total Canadian manufacturing. At the end of the section, we offer a brief summary of the results for individual sectors and an overview of a battery of sensitivity experiments performed to test the robustness of our findings. A detailed description of all sectoral estimates and sensitivity specifications is provided in a Supplementary Appendix.

We begin with a discussion of the bilateral interprovincial trade costs (the t_{ij}s) and their key border effect component, the UTBs. Next we report on the neutrality test. We close with discussion of estimates of general equilibrium effects of trade costs on bilateral and relative interregional trade, the CTBs and CIBs.

4.1 Interprovincial Trade Costs

Estimates of interprovincial trade costs from the pair-fixed effects specification (17) are reported first, followed by estimates based on the standard geographic proxies for bilateral trade costs in specification (21).[30] Finally, the difference between the two estimators yields the interprovincial UTB variable, equation (20).

Results from pair fixed effects specification (17) are reported in column (1) of Table 1. The estimates of the coefficients on $INTERPR\_T$ and $INTRAPR\_T$ indicate that the deflection of trade from international partners into internal trade in Canada has not significantly changed for Total Manufacturing during the period of investigation. The estimates of the interprovincial fixed effects γ_{ij} of specification (17) 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.[31] The diagonal elements are all zeros, reflecting the

[30] Our main estimates are obtained with the Poisson pseudo-maximum-likelihood (PPML) estimator advocated by Santos Silva and Tenreyro (2006 and 2011). We also report OLS results in the sensitivity analysis.

[31] 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.

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. Finally, the last column of Table 2, labeled CA, reports aggregate interprovincial log volume reduction estimates for each province, obtained using the consistent aggregation procedure from Section 2.2. Three properties of the pair-fixed effects estimates stand out. First, the off-diagonal $\hat{\gamma}_{ij}$'s are all negative, large in absolute value, and statistically significant. The estimates are quite precise but to avoid clutter, the standard errors are suppressed. Second, the estimates vary widely across provincial partners for each origin. Third, the estimates vary by pair.

The economic significance of the estimated interprovincial fixed effects is shown in percentage trade volume effects, as defined in equation (18), and tariff equivalent effects, as specified in equation (19) 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 include 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 (17) 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:

$$\ln(\sqrt{X_{ij}X_{ji}/X_{ii}X_{jj}}) = a_0 + a_1\hat{\gamma}_{ij} + \epsilon_{ij}, \tag{27}$$

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,[32] 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 has systematic difference from the bilateral fixed effects estimator, despite being very highly correlated. Mechanically, the rejection occurs because the origin- and destination-time fixed effects of our estimator control for systematic

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

elements in the random variables that enter the tetrads measure.[33]

Next, we replace the country-pair fixed effects from specification (17) with observable geographic trade cost proxies, bilateral distance and contiguity. Recent gravity studies decompose distance effects into intervals. Eaton and Kortum (2002) use aggregate world data and split the effects of distance into four intervals. 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. 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.[34] The estimating equation becomes:

$$\begin{aligned} \frac{x_{ij,t}Y_t}{Y_{i,t}E_{j,t}} &= \exp[\sum_{m=1}^{4}\beta_m^k DISTANCE\_m_{ij} + \beta_{contig}CONTIG\_PR\_PR + INTERPR\_T_{ij,t}] * \\ & \exp[INTRAPR\_T_{ij,t} + \psi_{ii} + \eta_{i,t} + \theta_{j,t}] + \epsilon_{ij,t}, \end{aligned} \tag{28}$$

where $DISTANCE\_1$ corresponds to the smallest quantile and $DISTANCE\_4$ corresponds to the largest quantile.

Estimation results from specification (28) 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

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

[34] 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.

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 interprovincial trade in Canada, though it plays an important role in international trade.[35]

Comparing the standard gravity variables estimator with the pairwise fixed effects estimator account for interprovincial trade costs in Canada, row AIC of Table 1 reports estimates of the Akaike Information Criterion (AIC), used to compare non-nested alternative econometric specifications. 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)). Combined with the insignificant estimate of the effects of contiguity, this finding suggests that distance alone is a very powerful predictor of bilateral trade costs within Canada. Second, the correlation between the trade costs constructed from the fixed effects specification (17) and the corresponding trade costs constructed from gravity variables specification (28) is $\rho = 0.95$. This very high correlation coefficient suggests that distance and contiguity alone predict *the order* of intra-provincial trade costs very well. Furthermore, the volume effects and the tariff equivalent indexes from the specification with gravity variables (see Panels A and B of Table 4), depict trade cost patterns that are similar to those form Table 2.

Despite high correlation, there are significant differences in the *size* of estimated interprovincial trade costs. The difference between the results of the estimators (17) and (28), pushing inference to the limit, indicates provincial border barriers or stimuli. The border tax equivalent is the difference between the interprovincial tax equivalents from Panel C of

[35]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.

Table 2 (τ_{ij}^{FE}, obtained from the bilateral fixed effects specification (19)) and the corresponding tariff equivalent estimates from Panel B of Table 4 ($\hat{\tau}_{ij}^{GRAV}$, obtained from the gravity variables specification (23)). The ad-valorem border tax equivalent of the UTB is thus:

$$\hat{\tau}_{ij}^{UTB} = \hat{\tau}_{ij}^{FE} - \hat{\tau}_{ij}^{GRAV}. \tag{29}$$

$\hat{\tau}_{ij}$ estimates are reported in Panel C of Table 4. Note first that there are significant differences from zero in many cases. (Standard errors are not reported to avoid clutter, but the bilateral fixed effect estimates are very precise, indicating statistical significance of the UTBs.[36]) Second, there are some positive and some negative $\hat{\tau}_{ij}^{UTB}$'s: some bilateral borders are dams and some are spillways. The dispersion of $\hat{\tau}_{ij}^{UTB}$s awaits explanation, but some patterns emerge from aggregation. Column *CA* of Table 4 reports consistently aggregated tariff equivalent differences for each province with its Canadian partners using (13) with and without border effects. Overall interprovincial trade is subject to a 5.63% internal border tax equivalent on aggregate manufacturing, reported in Table 4, Panel C, at the bottom of the column headed CA. The 5.63% border tax equivalent is associated with a 19.7% volume reduction of aggregate Canadian manufacturing sales, worth CAD 20.3 billion.[37] Disaggregating by province of origin produces the results in the remainder of that column. The positive overall $\hat{\tau}_{ij}^{UTB}$s for ten of the twelve regions suggest pervasive internal border frictions. The $\hat{\tau}_{ij}^{UTB}$s are the largest for YT, NT and QC. A striking finding is the relatively high 15% internal border tax faced on average by Quebec. Language difference is directly controlled for by origin and destination fixed effects, so some other force must be involved that varies bilaterally. Two provinces (NS and PE) enjoy the equivalent of a small export subsidy for interprovincial trade.

[36] 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.

[37] $1 - \tau_{C(i)}^{1-\sigma} = 1 - (1.0563)^{1-5} = 0.197$. The total value of inter-regional manufacturing trade in 2002 is CAD 103 billion. The product is equal to CAD 20.3, a simple partial equilibrium measure of efficiency gains from the removal of interprovincial trade barriers.

Third, the rightmost column, labeled CA(FE), records the partial equilibrium average tariff equivalent obtained using the fixed weights associated with the multilateral resistances from the bilateral fixed effects estimation. The large differences between columns CA and CA(FE) demonstrate the importance of consistent aggregation. The difference is due to general equilibrium forces acting on inward multilateral resistance (buyers' incidence): in this case most of the economic significance of UTBs is due to the general equilibrium effects.

Fourth, $\hat{\tau}_{ij}^{UTB}$ varies across provincial pairs across any exporter row, usually being larger for the more remote and small regions and smaller for the more developed regions. Thus, gravity variables 'explain' more of trade costs between the larger provinces/territories, although our gravity estimation explicitly controls for size with origin and destination fixed effects and for remoteness with bilateral distance. The observed patterns suggest that something apart from log-linearity is involved.

The variation across provinces and provincial pairs may indicate where policy intervention is needed most. But $\hat{\tau}_{ij}^{UTB}$ interpretation is tentative only, due to unknown bilateral effects.[38]

4.2 Neutrality Test

Section 2.2 showed that system (1)-(3) is invariant to any intra-regional trade cost t_{ii} if the general trade cost function $g(r_{ij}, r_{ii}, r_{jj})$ is Cobb-Douglas: the neutral case of comparative statics. Econometrically, intra-regional trade costs are not identified separately from multilateral resistance. The Cobb-Douglas restriction can be tested by estimating specification:

$$\hat{\gamma}_{ij}^{FE} = \omega_0 + \omega_1 \ln \left(\hat{t}_{ij}^{GRAV}\right)^{1-\sigma} + \omega_2 \, \hat{\psi}_{ii}^{GRAV} + \omega_3 \, \hat{\psi}_{jj}^{GRAV} + \nu_{ij}, \quad \forall i \neq j. \tag{30}$$

[38]For example, if the set of gravity variables in (28) 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 who signed the Trade, Investment and Labour Mobility Agreement (TILMA) in 2007. Due to data limitations, we cannot study the effects of TILMA here.

Here, $\ln(\hat{t}_{ij}^{FE})^{1-\sigma} = \hat{\gamma}_{ij}^{FE}$ are the estimated volume effects of trade costs from the specification with fixed effects, and $\ln(\hat{t}_{ii}^{GRAV})^{1-\sigma} = \hat{\psi}_{ii}^{GRAV}$, $\ln(\hat{t}_{jj}^{GRAV})^{1-\sigma} = \hat{\psi}_{jj}^{GRAV}$ are the estimated volume effects based on the specification with gravity variables. (Note that this specification is independent of the elasticity of substitution.) Neutrality requires satisfying two restrictions on estimated coefficients: $\omega_2 + 1/2 = 0$ and $\omega_3 + 1/2 = 0$. Violation of the pair of restrictions means that the fixed effect estimates still contain some influence of r_{ii} and r_{jj}, contrary to neutrality. Homogeneity implies $\omega_0 = 0,\ \omega_1 + \omega_2 + \omega_3 = 0$. Specification (30) permits tests of these restrictions.

An initial benchmark estimates (30) subject to $\omega_2 = \omega_3 = 0$. Bootstrapping delivers standard errors and confidence intervals for the coefficients.[39] The results, reported in column (1) of Table 5, reveal: (i) The estimate on $\ln\left(\hat{t}_{ij}^{GRAV}\right)$ is not significantly different from 1; (ii) the $R^2 = .48$; and (iii) the estimate of the constant term is statistically significant and very large. Thus, the pair-fixed effects estimates are rather weakly correlated with the bilateral gravity variables trade costs, effectively bilateral distances.

Column (2) of Table 5 presents estimates of (30) with unrestricted ωs. (i) The $R^2 = .94$ increases very significantly; (ii) $\hat{\omega}_1$ is closer to 1 and still not statistically different from 1; (iii) $\hat{\omega}_2$ and $\hat{\omega}_3$ are each statistically 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;[40] (v) $\hat{\omega}_1 + \hat{\omega}_2 + \hat{\omega}_3 < 0$. Result (i) implies that intra-regional trade cost $\hat{\psi}_{ii}$ variation is significant and contributes significantly to explaining the variation of bilateral fixed effects. Results (i) and (ii) together indicate that intra-regional cost variation is almost uncorrelated with bilateral distance. Result (iii) implies that neutrality is rejected, intra-regional trade costs have an effect on inter-regional trade costs that is not absorbed by origin and destination fixed effects. Results (iv) and (v) imply that Cobb-Douglas homogeneity of degree zero is rejected: the chi-squared

[39] Bootstrapping is required due to the use of generated regressors.

[40] $e^{-0.839} = 0.432$, meaning a volume reduction of 57%. The border tax equivalent of this volume effect is 23% given an elasticity of substitution equal to 5.

test for the combined restrictions $\omega_0 = 0,\ \omega_1 + \omega_2 + \omega_3 = 0$ is rejected (p-value of 0.0001).

Column (3) of Table 5 reports estimates of (30) subject to the constraint $\omega_2 + \omega_3 = -1$. The results imply that, subject to the constraint, the values of $\omega_1 = 1$ and $\omega_0 = 0$ and $\omega_2 = \omega_3 = -1/2$ used in constructing the UTBs 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 0.1274. Thus the constraint effectively imposes the homogeneity of degree one property of the general trade cost function on the structure of the pairwise fixed effects estimator.[41]

The residuals of the constrained regression necessarily have zero mean and the intercept is not significantly different from zero. The residuals are thus statistically equivalent to the constructed UTBs. Subject to the constraint, there is no average levels effect generating differences between the pairwise fixed effects and the gravity variables estimates, hence there is no average levels effect in the constructed UTBs. Columns (2) and (3) taken together imply nonrandom residuals of the constrained regression and hence nonrandom constructed UTBs. The regressors with unconstrained values of $\omega_0,\ \omega_2,\ \omega_3$, reported in column (2), pick up systematic patterns in the UTBs. Hence the deviation of the $\ln(t_{ij}^{FE})^{1-\sigma}$s from the $\ln(t_{ij}^{GRAV}/(t_{ii}^{GRAV}t_{jj}^{GRAV})^{1/2})^{1-\sigma}$s is nonrandom.

Taking specification (30) and the results in Table 5 seriously, rising (over the cross section) intra-national trade costs induce drops in inter-regional and international trade ($\approx -0.1(\psi_{ii} + \psi_{jj}) > 0$) due to the non-neutral structure of the full bilateral trade costs. The rejection of neutrality and the clues provided by the test pose a challenge for future research — exploring the connection between intra-regional and inter-regional trade costs.

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 6. In the absence of any trade frictions, all

[41] $\gamma_{ij}^{FE} = \ln(t_{ij}/\sqrt{t_{ii}t_{jj}})^{1-\sigma}$ is the specification, implying that if $g(\cdot)$ is homogeneous of degree one then γ_{ij} is homogeneous of degree zero in the ts.

elements of the CTB matrices, not just the diagonal elements, would be equal to 1. Home bias in provincial trade is massive as all diagonal elements in Table 6, Panel A, are much larger than their frictionless counterpart of 1. More developed and central provinces exhibit smaller intra-provincial biases than relatively distant and less developed regions like YT, NT, and PE. This is now a familiar pattern 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, as for AB and BC where Constructed Home Bias is 4 to 6 times larger than the CTBs for their bilateral trade. International borders deflect potential trade into domestic trade, but the deflection into local trade is much greater. The off-diagonal estimates in Panel A of Table 6 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.[42] This is also captured in the provincial overall CTBs in the last column of Table 6, using the aggregation procedures from Section 2.2 to calculate the interprovincial CTBs for each province as an exporter. YT, NT, and NL are the regions with the lowest average CTB indexes in the sample. These patterns are explained by equation (5) and the very strong tendency for larger economic regions to have lower inward multilateral resistance P_j. Thus, small economies have high costs of trade on average across all sources, so any particular exporter has a higher priced competition on average when selling to smaller regions.[43]

[42]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.

[43]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 due to trade costs both directly and indirectly. $\Pi_{ij}/\Pi_{ii} = (CIB_{ij})^{1/(1-\sigma)}$ measures relative sellers' incidence on inter-provincial trade, from equation (10). Panel B of Table 6 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.[44] A clear pattern in Panel B is that more developed regions face lower relative resistance as compared to less developed regions. This is captured clearly by the provincial estimates in the last column of Panel B, where we see that ON and QC are the two provinces that enjoy the lowest relative resistance to interprovincial shipments in Canada. Despite the fact the YT and NT are the two territories with the lowest CTB indexes as exporters (see Panel A), these are two regions that face the largest relative resistance to inter-provincial trade.

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 6 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 is normalized to 1, the difference between the two is due entirely to the difference in the multilateral resistances in the two specifications.[45] 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 6 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

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

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

in Table 7.[46] First, 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 intra-provincial CTBs is largest for the remote regions YT (79%) and NT (62%). Second, the changes in inter-provincial CTBs off the diagonal in Table 7 are mixed, but with some consistent patterns. First, the 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. These remote regions thus have become less integrated with the rest of the Canadian provinces over 1997-2007. Subtracting the diagonal terms gives the percentage change in CIBs, offsetting most of the fall for YT but not for NT. ON and MB are other provinces that experience lower CTBs for their exports to most provinces and territories, but in their cases the fall in intra-regional CTB implies a rise in CIBs. CTB changes at the province level are summarized in the last column in Table 7, where we report consistently aggregated provincial numbers. YT, NT, ON and MB are the four regions where CTB fell over the period 1997-2007. The rest of the Canadian provinces and territories register an increase in CTB.

The overall rise in CTBs in the last column (supplemented by subtracting the diagonal terms to obtain CIBs) suggests that most of the Canadian provinces and territories have become more integrated in manufacturing trade over the period 1997-2007 (extending a result reported by Anderson and Yotov (2010)). NT is the big exception. This result is driven by changes in the provincial output and expenditure shares in manufacturing, because, as discussed earlier, there is little evidence of time variation in the bilateral trade costs.

4.4 Analysis of Residuals and Sensitivity Experiments

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 (26) as the difference between the actual data and

[46] 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.

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 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 (15). 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. (The data set of residuals is available by request.) 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 (17) 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.

A full cross section display of residuals for 2002 (the mid-year of the sample) is expressed in percentage terms for comparability in Table 8. 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

[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.

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 (15). 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 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 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.

4.5 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

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

[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).

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 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.

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

5 Conclusion

A novel econometric method is applied to flexibly estimate bilateral intra-national trade costs. The results imply that bilateral trade flows are not invariant to intra-regional costs (neutrality is rejected). The results suggest there is much to be learned from drilling deeper into inter- and intra-regional trade costs and their relationship.

We estimate large Canadian interprovincial trade costs. On average for manufacturing, interprovincial trade in Canada is subject to frictions from all sources, including the effects of distance, that are equivalent to a tax of 109%. After accounting for the role of distance and contiguity, the interprovincial border is equivalent to a border tax of 5.6% for manufacturing, an average which varies considerably by province.

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

	(1) Pair Fixed Effects	(2) Gravity Variables
INTRAPR_T	-0.025	-0.023
	(0.097)	(0.132)
INTERPR_T	-0.001	-0.000
	(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)
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 (17). The estimates in column (2) are obtained from specification (28), 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 (17), 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
	(0.017)**	(0.038)**	(0.046)**	(0.034)**	(0.050)**	(0.024)**
cons	0.178	0.242	0.175	0.321	0.253	0.375
	(0.049)**	(0.108)*	(0.126)	(0.096)**	(0.147)+	(0.069)**
N	1140	96	102	104	102	106
R^2	0.9547	0.958	0.947	0.969	0.947	0.972
p-value($a_1 = 1$)	0.2461	0.1483	0.6653	0.0582	0.0649	0.0006
p-value($a_0 = a_1 - 1 = 0$)	0.0000	0.0001	0.0000	0.0000	0.0939	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
	(0.023)**	(0.030)**	(0.030)**	(0.041)**	(0.054)**	(0.025)**
cons	0.257	0.153	0.092	0.139	0.083	-0.083
	(0.070)**	(0.087)+	(0.094)	(0.117)	(0.156)	(0.081)
N	108	108	104	102	106	102
R^2	0.966	0.969	0.971	0.946	0.931	0.974
p-value($a_1 = 1$)	0.0293	0.9443	0.3803	0.6170	0.9526	0.0002
p-value($a_0 = a_1 - 1 = 0$)	0.0000	0.0000	0.0000	0.0096	0.0089	0.0000

Notes: This table reports the results from the various tetrads experiments based on equation (27). 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	CA(FE)
A. Volume Effects, $100 \times \hat{t}_{ij}^{1-\sigma}/(\hat{t}_{ii}^{1-\sigma}\hat{t}_{ii}^{1-\sigma})^{1/2}$														
NL	1	8.11	3.42	6.57	2.95	3.43	2.22	.76	1.33	1.09	.66*	.11	2.58	2.53
NS		1	10.96	20.56	9.64	5.33	2.7	1.37	1.54	1.25	.7*	.12*	4.63	4.87
PE			1	9.65	4.05	2.18	1.13	.57	.64	.52	.29*	.05	2.24	2.46
NB				1	12.72	11.72	2.78	1.39	1.56	1.25	.69*	.12	7.11	6.8
QC					1	28.57	3.27	1.98	3.3	1.71	.89	.16	12.21	9.47
ON						1	6.85	2.91	5.98	4.72	1.44	.28	9.57	9.25
MB							1	13.31	14.56	4.64	1.27	.46	6.95	5.77
SK								1	16.18	7.94	.88	.27*	6.43	5.23
AB									1	25.55	1.93	.66	10.04	8.44
BC										1	1.45	.71	8.09	6.2
NT											1	.22	1.42	1.3
YT												1	.41	.37
CA													5.8	5.19
B. Tariff Equivalents, $\hat{\tau}_{ij}^{GRAV} = (\hat{t}_{ij}/(\hat{t}_{ii}\hat{t}_{jj})^{1/2} - 1) \times 100$														
NL	0	87	133	98	141	132	159	239	194	209	250*	445	149.5	150.81
NS		0	74	49	79	108	147	192	184	199	246*	433*	115.58	112.9
PE			0	79	123	160	207	263	253	272	329*	563	158.44	152.59
NB				0	67	71	145	191	183	199	246*	434	93.68	95.83
QC					0	37	135	166	135	177	225	399	69.17	80.25
ON						0	95	142	102	115	189	336	79.79	81.33
MB							0	66	62	115	198	283	94.77	104.03
SK								0	58	88	226	340*	98.55	109.11
AB									0	41	168	251	77.64	85.51
BC										0	188	244	87.53	100.41
NT											0	360	189.91	196.16
YT												0	294.86	305.31
CA													103.77	109.47
C. Unexplained Trade Barriers, $\hat{\tau}_{ij}^{UTB} = \hat{\tau}_{ij}^{FE} - \hat{\tau}_{ij}^{GRAV}$														
NL	0	-7	-10	-2	-7	5	35	9	16	4	87*	271	2.06	.75
NS		0	5	3	21	-13	8	4	-28	-35	-48*	83*	-2.55	.13
PE			0	-6	9	-5	6	0	0	-34	99*	64	-5.59	.26
NB				0	11	8	20	-1	-12	-13	53*	18	9.46	7.31
QC					0	10	-39	-36	-31	-60	-5	4	15.01	3.93
ON						0	-1	-38	-28	-20	65	18	1.83	.29
MB							0	-11	-1	-13	37	83	1.9	-7.36
SK								0	-6	13	80	153*	.85	-9.71
AB									0	14	17	45	6.09	-1.78
BC										0	33	-11	13.96	1.08
NT											0	-24	37.31	31.06
YT												0	24.14	13.69
CA													5.63	-.07

Notes: This table presents estimates based on specification (28), where trade costs are controlled for with the standard gravity covariates of distance and contiguity. Panel A and Panel B report the corresponding volume effects and tariff-equivalents, respectively. Panels C reports the Unexplained Trade Barriers (UTBs) as defined in equation (24). 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: Neutrality Test Results, CA Manufacturing, 2002.

	(1) BENCHMARK	(2) INTERNAL	(3) CONSTRAINT
$\ln\left(\hat{t}_{ij}^{GRAV}\right)$	1.141	0.965	0.997
	(0.108)**	(0.033)**	(0.044)**
$\ln\left(\hat{t}_{ii}^{GRAV}\right)$		-0.607	-0.487
		(0.033)**	(0.023)**
$\ln\left(\hat{t}_{jj}^{GRAV}\right)$		-0.621	-0.513
		(0.029)**	(0.023)**
_cons	3.302	-0.839	-0.074
	(0.636)**	(0.259)**	(0.260)
N	126	126	126
R^2	0.475	0.938	0.928

Notes: This table reports results from neutrality tests based on specification (30). 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 $\ln\left(\hat{t}_{jj}^{GRAV}\right)$. Lastly, 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. Bootstrapped standard errors in parentheses. See text for more details. + $p < 0.10$, * $p < .05$, ** $p < .01$

Table 6: 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. $CIB = (CTB_{ij}/CTB_{ii})^{1/(1-\sigma)}$, 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	.2
NS	3	-.7	-19.3	-15.3	-60.7	12.3	-42.3	-37	22.7	36.7	53	-44.6	-1
PE	10.1	-5.5	.1	14.2	-13	2.6	-26.2	-22.2	-9	32.8	-84.4	-10	0
NB	-2.2	-3.9	12.7	.3	-25.3	-29.1	-61.9	-20.5	8	17.3	-42.4	12.6	-2
QC	2.2	-53.1	-21.6	-32.4	-.3	-43.5	41.7	29.8	35.4	61.7	21.9	18.2	-1.5
ON	-8.7	31.5	14	-11.9	-17.8	.8	-7.6	43	43.5	37.5	-69	16.7	.6
MB	-50.3	8.3	8.2	-15.7	60.6	11.3	-.3	20.3	9.1	35.3	-10	-42.3	2.6
SK	3.3	18.6	18	20.5	56.2	56.7	26.5	-.1	23.3	-4.9	-58.1	-104.9	4
AB	-20.3	43.2	9.5	25	50.1	46.9	-3.8	5.1	.2	-31.3	6.3	-11.8	1.1
BC	-13	42.8	31.3	17	63.6	27.7	9.1	-59.7	-61.5	.9	-25.3	32.9	-.5
NT					-11.6	-194.3	-132.5	-262	-73.4	-88.4	0	23.6	-2.6
YT					-30.7	-62.1			-131.3	-12.9	14.6	0	-1.2

Notes: This table presents estimates of the Constructed Trade Bias index, as defined in specification (25). 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 (17), and the standard gravity variables approach, (28). See text for more details.

Table 7: 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 8: 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.