Intra-national Trade Costs: 
Assaying Regional Frictions*†

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Abstract
The effects of intra-regional, inter-regional and international frictions on the trade flows of Canada’s provinces are disentangled by gravity model techniques. Unexplained Trade Barriers (UTBs) are the difference between inter-provincial trade barriers inferred from pair fixed effects and from bilateral distance and contiguity. The estimates reveal large intra-national trade costs and UTBs that vary significantly across Canada’s provinces. Decomposition of UTBs into relative border effects and a systematic residual UTB is based on a novel Cobb-Douglas aggregator of intra-provincial and pure inter-provincial trade costs. Variation of both components across provinces is big.

JEL Classification Codes: F13, F14, F16
Keywords: Intra-regional and Inter-regional Frictions, Border Frictions, Unexplained Trade Barriers, Canada

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“In an era of ongoing global economic uncertainty, an integrated, competitive and vibrant domestic economy is more important than ever. Enhanced internal trade helps businesses expand across regions, strengthens productivity, encourages greater labour mobility, lowers costs and attracts investment. As Canada considers new approaches for driving economic performance, we need to evaluate how trade across provinces and territories can become more efficient.”

Paul Ledwell, Executive Vice-President, Public Policy Forum Canada, October, 2013

1 Introduction

Intra-national trade barriers are large and present a substantial hurdle for domestic trade (Beaulieu et al., 2003). As such, internal distribution frictions have implications for gains from trade, economic development, and other economic outcomes, and their importance has been recognized both by the academic profession as well as by policy makers. From the perspective of the academic trade literature, intra-national trade frictions are crucial for proper quantification of the gains from trade, c.f., Arkolakis et al. (2012). In addition, Ramondo et al. (2016) demonstrate that the variation of internal trade costs helps resolve the puzzle in the open economy macro literature that larger countries should be richer than smaller countries. Furthermore, as evident from the opening quote of our study, policy makers also recognize the prominent role of intra-national trade frictions for strengthening national economies and for stimulating development within the world trading system.

Despite their importance not only for trade flows but also for economic development in general, intra-national obstacles to trade are less-studied and less-understood than international trade frictions. We make an effort to fill this gap by offering methods to simultaneously identify the effects of intra-regional, inter-regional and international frictions on the trade of Canada’s provinces. Capitalizing on the availability of excellent data, the focus

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1 “One of the most significant challenges [that] continue to restrict internal market is the inability of policymakers, economists and researchers to truly understand the economic impact of internal trade barriers, due to the lack of data and research” (p. 6, PPF Report, 2013). “The lack of current research on best practices has meant that [...] policymakers have often had to rely on anecdotal evidence that is often misinformed, biased and dated. As a result, it has been difficult to clearly identify solutions or accurately evaluate the impact that policies are having on internal trade flows. It has also meant that developing evidence-based policy solutions to address these issues has been made significantly more difficult.”

2 Consistent with our empirical focus on Canada, the reader should think of ‘intra-regional’ trade costs as ‘intra-provincial’ trade barriers and of ‘inter-regional’ trade costs as ‘inter-provincial’ trade barriers.
of our analysis is on intra-national (intra-provincial and inter-provincial) trade in Canada. However, our methods are readily extendable subject to data availability. The decomposition methods that we propose enable us to make an additional contribution by quantifying *Unexplained Trade Barriers* (UTBs) for inter-provincial trade in Canada.

We develop our methods in two stages. In the first stage, we infer bilateral trade costs from two alternative specifications; one with pair fixed effects and one with standard gravity variables. Both estimators employ the latest developments for estimations of structural gravity models. The bilateral fixed effects specification enables us to comprehensively account for all time-invariant bilateral trade costs, including inter-provincial trade costs, and to measure them as conditional expectation indexes that are free of the random errors due to mis-measured bilateral trade flow data. The specification with observable gravity variables serves two purposes. First, it delivers an alternative measure of inter-provincial trade costs that is based on standard bilaterally varying variables (e.g., distance and contiguity) and, as such, it is representative of the common approach to measure trade costs in the gravity literature. Second, and more important for our analysis, the specification with standard gravity variables allows for identification of province-specific (relative) intra-provincial trade costs, which we view as one of our main contributions.

In the second stage, we define Unexplained Trade Barriers as the difference between the bilateral trade cost estimates that are obtained from the pair fixed effects estimator and their fitted counterparts from the standard specification with gravity variables. A naive regression of the estimated bilateral fixed effects on the volume effects of the fitted bilateral gravity variables points to the presence of systematic UTBs. With no internal

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Our Unexplained Trade Barriers indexes are related to two contemporary papers. Caliendo et al. (2016) isolate the effects of distance vs. “other” trade costs that apply to U.S. inter-state trade. Our paper differs from Caliendo et al. (2016) methodologically, because we use estimation methods while they rely on ratio methods. In addition, our focus is on the decomposition of international vs. inter-regional vs. intra-regional trade costs. Egger and Nigai (2015) find that the pair fixed effects from structural gravity estimations carry additional information about international trade costs that is not captured by standard gravity covariates. We expand their analysis to demonstrate that *intra-national* trade costs are also subject to significant “unexplained” barriers to trade. “Unexplained” here applies Head and Mayer’s (2013a) cosmological metaphor: gravity trade costs are dark. This paper moves the darkness one step by identifying systematic effects of border costs relative to internal costs, but shadow covers what these costs may be.
border barriers, theory predicts that UTBs should be random and small, hence the naive regression of inferred pair fixed effects on the combined fitted effects of bilateral distance and contiguity should exhibit a slope equal to one and a very good fit. Instead, the UTBs implied by this naive regression are systematic and large. To extract information from the UTBs, we structure the components of the full bilateral trade costs with a Cobb-Douglas aggregator. The added structure permits a second-stage decomposition of UTBs into the systematic effects of regional relative border barriers in both origin and destination, and a systematic residual component. This procedure solves the inference problem posed by identification of inter-regional border barriers in the presence of heterogeneous intra-regional trade costs and pure inter-regional costs associated with distance and contiguity.

The assay uses a dataset of Canadian provincial trade flows in manufacturing from 1997-2007. The empirical focus is on Canada due to this country’s heterogeneous geographical and economic structure, significant policy interest in understanding intra-national trade barriers, and availability of detailed and carefully constructed data. The main advantage of our dataset is that it covers intra-provincial, inter-provincial, and international trade flows for each of Canada’s provinces and territories, and Statistics Canada has made every effort to ensure consistency between the three types of trade flows, c.f., Genereux and Langen (2002).

The most important “takeaway” from our paper, is that the (relative) intra-provincial frictions for each Canadian province are large and substantially heterogeneous across Canada’s provinces. The wide heterogeneity of intra-regional trade frictions across Canada’s provinces suggests that the common approach in the literature that treats regions (provinces and/or countries) as point masses is substantially at odds with reasonable inference from the data. Despite the limited number of estimates, we make an attempt to explain the large variation of relative intra-provincial frictions by provincial variation in economic activity and geographic size. The results indicate that distant and less-developed regions tend to ex-
hibit relatively low internal frictions and large border effects. On the other hand, central and economically-advanced regions show relatively low border barriers. Correlation analysis points to economic activity, development, and geography as potentially significant determinants of intra-regional trade costs. However, inference is hampered by the small number of observations and by the prominent presence of outliers. Thus, we leave a more rigorous analysis of the determinants of intra-regional trade costs as a fruitful direction for future research.

A second “takeaway” is that systematic residual Unexplained Trade Barriers induce significant systematic distortions of inter-provincial trade. The more remote and smaller regions (e.g., Yukon, Prince Edward Island, and the Northwest Territories) are subject to the largest systematic residual UTBs, while economically developed and central regions (e.g., Ontario, Alberta, and British Columbia) enjoy relative stimuli to trade from UTBs. The details of variation across provinces and provincial pairs may indicate where policy intervention is needed most and where it will be most efficient. Disentangling internal from border cost variation is an important but difficult task for future work. We expect the magnitude and heterogeneity of UTBs to be even larger in a cross-country study with international data.

Our paper is related to a small but vibrant and fast-growing literature concerned with the proper measurement of intra-national trade costs and their implications for various economic outcomes. Ramondo et al. (2016) demonstrate that the common findings that larger countries should be richer than smaller countries (from the macro literature) and that real income per capita increases too steeply with country size (from the trade literature), disappear when the standard, but unrealistic, assumption of frictionless domestic trade is relaxed. Donaldson (2016) extends a multi-country and multi-sector Ricardian model of trade to accommodate intra-national trade costs and examines the implications of the railroad network in India for productivity and welfare. Cosar and Demir (2016) and Cosar and Fajgelbaum (2016) study the implications of enhanced transportation infrastructure and internal geography by recognizing that international trade flows must pass through gateway locations,
e.g. seaports and airports. Our main contribution to this literature is that we propose new methods and capitalize on a unique data set in order to simultaneously identify international vs. inter-regional vs. intra-regional trade costs, and to decompose them into observable components and unexplained trade barriers. We find that inter-regional and intra-regional trade costs are quite heterogeneous, thus reinforcing the main arguments from the aforementioned papers that allowing for variation in intra-national trade costs has important implications for regional policy and for general equilibrium comparative statics.

Inference of border frictions from trade flows using gravity models feature in a prominent literature mostly focused on international borders, but studies in this vein usually suppress variation in distribution costs internal to the origin and destination areas of observation (regions or countries). The previous literature using gravity to infer internal trade frictions from trade flows 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. We generalize this treatment to allow for non-uniform intra-regional trade costs, in addition to non-uniform inter-regional, and non-uniform international barriers. Non-uniformity of intra-regional border frictions is both consequential and substantial, as we show. We are not aware of existing comparable estimates at the intra-regional level.

International border barriers are not our focus, but our estimation utilizes international as well as inter-regional trade flows. Thus, it relates somewhat to the literature on the international border barrier to Canada’s trade, e.g., McCallum (1995), Anderson and van Wincoop (2003). A more distantly related literature infers trade costs from price differences, 5 For US see Wolf (2000), Hillberry and Hummels (2003), Millimet and Osang (2007), Head and Mayer (2002, 2010), Coughlin and Novy (2012), Yilmazkuday (2012)); for EU see Nitsch (2000), Chen (2004), and Head and Mayer (2000, 2010); for Canada see Tombe and Winter (2014) and Albrecht and Tombe (2016); for OECD see 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).

6 Hillberry and Hummels (2008) is a notable exception that shows that manufacturing shipments between establishments within the same zip-code are three times larger than between establishments in different zip codes in the U.S. While, our data do not allow such a fine treatment, we complement Hillberry and Hummels (2008) by offering a unified framework to treat intra-regional, inter-regional, and international trade costs.
e.g., Engel and Rogers (1996) and Atkin and Donaldson (2013). The price comparison method is informative but it is limited in coverage due to data limitations. Thus, our inference from trade flows provides complementary evidence. A number of case studies have examined the economic costs of internal trade barriers in Canada, e.g., Beaulieu et al. (2003) and Grady and Macmillan (2007). We see a combination of our “top-down” estimation methods with the “bottom-up” approach in the case studies as a fruitful direction for future research. Finally, we note that methods should be applicable widely to inference of intranational trade costs and UTBs in multi-country and multi-regional studies, and can also be applied to quantify barriers to immigration and FDI, about which we know much less.

The remainder of the paper is organized as follows. Section 2 sets out the theoretical foundation. Section 3 presents the econometric specifications and discusses our identification strategies. Section 4 describes our data. Section 5 presents our main findings and sensitivity experiments. Section 6 concludes. Detailed data description and sensitivity estimates are included in supplementary online appendixes.

2 Theoretical Foundation

A brief review of gravity theory sets the stage for modeling and estimation of bilateral trade costs as a combination of intra-regional, inter-regional, and international costs.

2.1 The Structural Gravity Model of Trade: A Brief Review

Assume 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.\footnote{As demonstrated by Arkolakis et al. (2012), the structural gravity model that we review here is representative of a wide class of alternative theoretical foundations. See Anderson (2011), Head and Mayer (2014), Costinot and Rodriguez-Clare (2014), and Larch and Yotov (2016) for informative gravity surveys.} The demand system derived from cost minimizing behavior yields a system of final or intermediate demands represented by equation (1) below. Use of the market clearing condition for each origin region’s shipments and each destination region’s budget constraint
yields equations (2) and (3) below:

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

(1)

\[
(\Pi_i^k)^{1-\sigma_k} = \sum_j \left( \frac{t_{ij}^k}{P_j^k} \right)^{1-\sigma_k} \frac{E_j^k}{\bar{Y}^k}
\]  

(2)

\[
(P_j^k)^{1-\sigma_k} = \sum_i \left( \frac{\Pi_i^k}{\Pi_i^k} \right)^{1-\sigma_k} \frac{Y_i^k}{\bar{Y}^k}
\]  

(3)

The left hand side of (1) is size-adjusted trade, the actual distribution of goods and services relative to a frictionless benchmark distribution given aggregate sales and aggregate expenditures at each origin and destination, respectively. \(X_{ij}^k\) denotes the value of shipments at destination prices from origin \(i\) to destination \(j\) in goods or services of class \(k\); \(E_j^k\) denotes the expenditure at destination \(j\) on goods or services in \(k\) from all origins; and \(Y_i^k\) denotes the sales of goods or services \(k\) at destination prices from \(i\) to all destinations. \(Y^k\) is the total output, at delivered prices, of goods or services \(k\).

On the right hand side of (1), \(t_{ij}^k \geq 1\) denotes the variable trade cost factor on shipments of goods or services from \(i\) to \(j\) in class \(k\), and \(\sigma_k\) is the elasticity of substitution across goods or services of class \(k\). As coined by Anderson and van Wincoop (2003), \(P_j^k\) is the inward multilateral resistance (IMR), which consistently aggregates the incidence of trade costs on the consumers in importer \(j\), and \(\Pi_i^k\) is the outward multilateral resistance (OMR), which consistently aggregates \(i\)'s outward trade costs relative to destination price indexes. We refer the reader to Anderson and Yotov (2010) and Yotov et al. (2016) for a detailed discussion of the properties of the multilateral resistances, while here we concentrate on the modeling of the direct bilateral trade cost frictions, \(t_{ij}^k\). Furthermore, since the empirical analysis is performed with data on aggregate manufacturing, we suppress the sectoral subscript \(k\). 

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\[8\] The inference of trade costs from aggregate manufacturing has the disadvantage of a potential bias from composition effects within manufacturing (see Anderson and van Wincoop, 2004). Aggregation bias of the \(\text{cet. par.}\) trade cost is due to composition variation due to location of activity responding to trade costs. Yi (2010) emphasizes this force and calculates a general equilibrium response of trade to trade costs that differs from the partial equilibrium effect estimated from gravity equation (1).
2.2 A Full Bilateral Cost Model

The regional composition of full bilateral costs has usually been submerged in the gravity literature. The implicit justification of this practice is that origin and destination region fixed effects absorb any effects of local distribution frictions on full inter-regional trade frictions. Hence, bilateral costs, modeled as iceberg log linear functions of geographic proxies, reflect the pure inter-regional or international frictions of primary interest. In contrast, intranational costs are consequential for comparative statics and regional policy analysis. In particular, regional border barriers are a key concern of this paper. Moreover, the implicit justification turns out to be valid only under restrictions revealed by a formal treatment.

Full inter-regional trade costs are modeled as a degree-one homogeneous, increasing, and concave function \( t_{ij} = g(r_{ij}, r_{ii}, r_{jj}) \) of three components, the resource costs \((r_{hl}, \forall h, l)\) of delivering one unit of distribution activity within the origin, destination and transit between them respectively. (In the Ricardian case \( r_{ij} = w_i a_{ij} \) where \( w_i \) is the wage and \( a_{ij} \) is the unit labor requirement in activity \( ij \).) Concavity is implied by cost-minimizing behavior. Following the cost/production function literature of the past 50 years, the ‘true’ cost function is approximated parametrically as a Taylor series in logs. The base case series is to the first order, i.e., Cobb-Douglas:

\[
t_{ij} = r_{ij}^{\rho_1} r_{ii}^{\rho_2} r_{jj}^{\rho_3},
\]

where \( \rho_1 + \rho_2 + \rho_3 = 1 \). For \( i = j \), the specification implies \( t_{ii} = r_{ii} \). Border barriers, \( b_{ij}^{1-\delta_{ij}} \), where \( \delta_{ij} \) is the Kronecker delta, are a component of \( r_{ij} \). Directional variation takes the form of \( b_{ij} = b_i^{\zeta_O} b_j^{\zeta_D} \), where \( \zeta_O \) and \( \zeta_D \) are the Cobb-Douglas weights in the bilateral border component. Our methods identify systematic regional variation of border effects \( b_i \geq 1 \). Thus, \( r_{ij} = \bar{r}_{ij}(b_i^{\zeta_O} b_j^{\zeta_D})^{1-\delta_{ij}} \) and the full cost is

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9. Homogeneity of degree one is consistent with iceberg trade costs with no indivisibilities. Indivisibilities are treated by Helpman, Melitz and Rubinstein (2008), who include fixed export cost component. Their identification strategy to distinguish variable from fixed cost uses common religion to determine fixed but not variable cost, controversial in any case but unavailable for Canada’s provinces.

10. The alternative approximation is the second order series, i.e., Translog. We experiment with it in the sensitivity analysis, where we also employ a flexible specification with exporter and importer fixed effects.
Equation (4) is the structural foundation for the empirical decomposition of trade costs. The Cobb-Douglas restriction implies a useful theoretical property: system (1)-(3) is invariant to intra-regional trade costs. Invariance follows because \( r_{ii} \) and \( r_{jj} \) are part of the composite multilateral resistances \( r^{-\rho_2}_{ii} \Pi_i, r^{-\rho_3}_{jj} P_j \) that solve (2)-(3). Hence, the composite multilateral resistances are invariant to the level of intra-regional trade costs. In the econometric specification of bilateral trade costs, we control for the composite multilateral resistance terms with origin and destination fixed effects and identify the pure inter-regional cost. Comparative static effects of intra-regional trade costs in the Cobb-Douglas case are confined to upper level inter-sectoral allocation due to invariance of (2)-(3) for given \( E_s \) and \( Y_s \).

Internal cost variation induces trade cost asymmetry unless \( \zeta_O = \zeta_D \). Estimates below indicate \( \zeta_O \neq \zeta_D \). Asymmetry also arises if \( \bar{r}_{ij} \neq \bar{r}_{ji} \), the case examined by Waugh (2010). In our notation, Waugh (2010) assumes \( r_{ii} = r_{jj} = 1 \) and introduces asymmetry to \( t_{ij} = r_{ij} b_i \) with exporter-specific \( b_i \) and symmetric \( r_{ij} \). Variation in \( b_i \) is used to explain asymmetry in trade patterns between high income and developing countries. Our focus on Canadian provincial trade reveals no significant effects of allowing for asymmetric \( \bar{r}_{ij} \) in the robustness checks reported below. Under the Cobb-Douglas invariance property, our allowance for internal cost variation makes no difference. Thus, (4) differs from Waugh’s specification by allowing for destination border effect variation. Invariance to internal cost variation is violated by general cost function specifications \( g(\cdot) \). For example, in the translog case \( \ln(t_{ij}/\Pi_i P_j) \) decomposes into the Cobb-Douglas invariance term analyzed above plus a second order effect term that contains the intra-regional trade cost. Non-invariance implies that intra-regional trade cost changes affect all bilateral trade patterns by changing all the multilateral resistances. Evidence below is weakly consistent with rejecting non-invariance.
3 Empirical Foundation

This section details the econometric specification and procedures used to infer inter-provincial trade costs, intra-provincial trade costs, and unexplained trade barriers in Canada. We proceed in three steps. First, in Section 3.1 we employ a flexible specification with pair fixed effects, which allows us to construct a comprehensive measure of inter-provincial trade costs. Then, in Section 3.2 we obtain an alternative measure of trade costs, which is based on observable gravity variables. The advantage of the econometric specification with gravity variables is that it also identifies (relative) intra-provincial trade costs. Finally, in Section 3.3 we construct a measure of potential unobservable barriers at provincial borders.

3.1 Pair Fixed Effects Estimator

The objective of this section is to describe methods to obtain a comprehensive (and free of measurement error) index of inter-provincial trade costs. To that end, we employ a flexible econometric approach with bilateral fixed effects and rely on the latest econometric techniques to estimate the following empirical structural gravity model:

\[
\frac{X_{ij,t}Y_t}{Y_{i,t}E_{j,t}} = \exp[\alpha_1 \text{INTERPR}_t T_{ij,t} + \alpha_2 \text{INTRAPR}_t T_{ij,t} + \gamma_{ij} + \eta_{i,t} + \theta_{j,t}] + \epsilon_{ij,t}. \tag{5}
\]

As defined earlier, the dependent variable is size-adjusted trade and, following the recommendations of Santos Silva and Tenreyro (2006), we employ the Poisson Pseudo-Maximum Likelihood (PPML) estimator to account for heteroskedasticity in trade data and to take advantage of the information that is contained in the zero trade flows in our sample. The first two terms under the exponentiation operator of (5) are designed to capture the evolution of internal trade costs in Canada over time. Given the specifics of internal trade costs, we cannot employ any of the standard time-varying gravity covariates (e.g., tariffs, trade agreements,}

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11 Our sample consists of a total of 14 regions including 12 Canadian provinces and territories, the U.S., and the rest of the world (ROW). Accordingly, the bilateral fixed effects that we employ in the estimations are based on this set of regions.

12 We refer the reader to Head and Mayer (2014) and Piermartini and Yotov (2016) for detailed discussions of the latest developments in the empirical structural gravity literature.
Therefore, we rely on time-varying indicator variables to pick up any unobservable time-varying effects. Specifically, $\text{INTERPR}_{ij,t} = \text{INTERPR}_{ij} \times T_t$ is the interaction of $\text{INTERPR}_{ij}$, a dummy variable for inter-provincial trade with a time trend $T_t$, and its estimate is intended to capture any changes in inter-provincial trade costs over the period of investigation. Similarly, $\text{INTRAPR}_{ij,t} = \text{INTRAPR}_{ij} \times T_t$ is the interaction between a dummy variable for intra-provincial trade and a time trend, and its estimated coefficient has a similar interpretation. By construction, the estimated coefficients of $\text{INTERPR}_{ij,t}$ and $\text{INTRAPR}_{ij,t}$ should be interpreted as deviations of inter-provincial or intra-provincial Canadian trade costs from the changes in international trade costs over time.

The third term under the exponentiation operator of (5), $\gamma_{ij}$, denotes the pair fixed effects in our specification, which should account for all observable and unobservable time-invariant bilateral trade costs. We restrict the pair fixed effects for inter-provincial trade in Canada to symmetry, i.e., $\gamma_{ij} = \gamma_{ji}; \forall i,j \in \text{CA}$ \footnote{We impose symmetry for two reasons. First, for comparability with the necessarily symmetric gravity variables from the standard gravity specification that we describe in the next section. Second, because if we employ asymmetric pair fixed effects, then two normalizations are required for each region to avoid perfect collinearity. This causes significant complications in the interpretation of the time-invariant bilateral trade costs. In the sensitivity analysis, we allow for asymmetric pair fixed effects and discuss the implications.} In contrast, throughout the analysis, we do not impose any restrictions on international trade costs, i.e., between the Canadian regions, the U.S., and the rest of the world (ROW) \footnote{We recognize that the treatment of international trade costs with asymmetric pair fixed effects is inconsistent with the symmetric treatment of inter-provincial trade costs. However, we prefer this approach for the following reasons. First, the specification with asymmetric pair fixed effects offers the most flexible and comprehensive account of time-invariant bilateral international trade costs. Second, while we have no prior reasons to believe that inter-provincial trade costs are asymmetric, there is significant anecdotal evidence that some international trade costs are asymmetric indeed, e.g., the trade costs between Canada and the U.S. Third, measurement and interpretation of international trade costs is beyond the scope of this paper. Fourth, consistent treatment of international and inter-provincial trade costs in the specification with gravity variables would require the creation of observable proxies with questionable meaning, e.g., bilateral distance between each of Canada’s provinces and ROW. Fifth, and probably most important given our focus on intra-national trade costs, while our treatment of international trade costs is not consistent with the treatment of inter-provincial trade costs within each specification, it is consistent across the two specifications, which we believe is crucial for the comparison between the inter-provincial trade costs in the two cases. In the Supplementary Appendix, we demonstrate that our results are robust to the treatment of international trade costs with symmetric pair fixed effects as well as to the exclusion of the U.S. and ROW from our sample.}. With symmetric inter-provincial pair fixed effects, due to perfect collinearity, we need to drop as many provincial pair fixed effects as there are provinces in our sample. We choose to drop the fixed effects that correspond to
intra-provincial trade, as we find this normalization most natural and intuitive. As a result, all estimates of the inter-provincial fixed effects that we identify are interpreted relative to the intra-provincial fixed effects, and the theoretical full trade cost (4) is reduced to its pure inter-provincial cost component: \( \gamma_{ij} = (1 - \sigma)\rho_1 \ln \bar{r}_{ij} \) in our structural interpretation. The estimated time-invariant trade costs for inter-provincial trade volumes are thus defined as:

\[
(t_{ij}^{FE})^{1-\sigma} \equiv \exp(\gamma_{ij}) = \exp[(1 - \sigma)\rho_1 \ln \bar{r}_{ij}],
\]

where, the superscript ‘\( FE \)’ stands for fixed effects.

The last two terms under the exponentiation operator of (5) account for the multilateral resistances. \( \eta_{i,t} \) 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 time-varying destination country factors. The use of exporter-time and importer-time fixed effects causes another perfect collinearity problem, which requires dropping one of the directional fixed effects in each year and an additional fixed effect if the estimations are performed with a constant term. Finally, we treat \( \epsilon_{ij,t} \) as a stochastic error term, which, as noted by Santos Silva and Tenreyro (2006), does not need to follow Poisson distribution despite the use of the PPML estimator.

### 3.2 Gravity Variables Estimator

This section presents a gravity counterpart to econometric specification (5), where the inter-provincial pair fixed effects from (5) are replaced by observable gravity variables. Specifically, we set the following empirical gravity model:

\[
\frac{X_{ij,t}Y_t}{Y_{i,t}E_{j,t}} = \exp[\alpha_1INTERPR_{Tij,t} + \alpha_2INTRAPR_{Tij,t} + \eta_{i,t} + \theta_{j,t}] \times \\
\exp[GRAV_{ij}(1 - \delta_{ij})\beta' + \delta_{ij}\psi_{ii}] + \epsilon_{ij,t}.
\]

(7)
Here, \( \text{GRAV}_{ij} \) is a vector of time-invariant covariates that replace the vector of pair-fixed effects \( \gamma_{ij} \) from specification (5) for \( i \neq j \) and \( \delta_{ij} \) is the Kronecker delta. We present and discuss the explanatory variables in \( \text{GRAV}_{ij} \) at the end of this section. An important feature of specification (7) for our analysis is that, when the inter-provincial pair fixed effects are replaced with observable gravity variables whose estimates are constrained to be common across the provinces in our sample, the gravity model (7) allows for the inclusion and identification of intra-provincial fixed effects \( \psi_{ii} \), which flexibly and comprehensively capture the impact of any observable and unobservable determinants of intra-regional trade (e.g., intra-national distance, national institutions, home bias). The economic interpretation of \( \psi_{ii} \) is a provincial border (or home bias) effect that is measured relative to all bilateral trade after controlling for distance and contiguity, hence it is implicitly normalized by an economy-wide average border effect.\(^{15}\) In structural terms:

\[
\psi_{ii} = \ln \left( \frac{\bar{b}_i / r_{ii}}{\bar{b} / \bar{r}} \right)^{(\sigma-1)\rho_1},
\]

where \( r_{ii} \) denotes the true intra-provincial trade cost and \( \bar{b}_i \) is the provincial border cost \( b_i \) plus the national average effect of provincial border effects facing exporter province \( i \).

Finally, we can define inter-provincial bilateral trade costs based on the specification with gravity variables as:

\[
\left( r_{ij}^{\text{GRAV}} \right)^{1-\sigma} \equiv \exp[\text{GRAV}_{ij}(1-\delta_{ij})\beta'] = (\bar{r}_{ij} b_i^{\text{co}} b_j^{\text{co}})^{(1-\sigma)\rho_1},
\]

where the rightmost equality is in terms of theoretical specification (4).

The final step needed to implement the gravity variables estimator (7) is to define the observable proxies for inter-provincial trade costs that enter the vector of time-invariant covariates \( \text{GRAV}_{ij} \). To that end, we follow the developments in the related empirical gravity

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\(^{15}\)This combined effect arises because the indicator variable for \( i \)'s internal trade measures internal relative to inter-provincial trade, all else equal. Specification (7) is constructed without regional border indicator variables due to collinearity.
literature under the constraints of our sample. Some gravity studies allow for non-linear distance effects by decomposing the distance effects into intervals. Eaton and Kortum (2002), for instance, use aggregate world data and find that the estimate of the distance coefficient for shorter distances is larger (in absolute value) than for longer distances. Anderson and Yotov (2010) 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.

Another variable, which consistently delivers (positive) statistically significant estimates in gravity regressions that employ international trade flows data is ‘Contiguity’. Following the literature, we also define $\text{CONTIG}_{PR,PR_{ij}}$ as an indicator variable that takes the value of one when two regions share a common border, and it is equal to zero otherwise. While we can successfully control for the influence of bilateral distance and contiguity, as two of the most widely used gravity variables, our focus on trade within the same country does not allow us to include two other covariates that are standardly used in the related literature; the indicators for common language and for colonial relationships.

Finally, we note that, for consistency with the pair fixed effects specification and for a most comprehensive account of the international trade costs in our analysis, the specification with gravity variables continues to use directional pair fixed effects for international trade flows. Substituting the trade cost proxies that we just described into specification obtains our estimating equation with gravity variables:

As described in detail in the Supplementary Data Appendix, we follow the methods of Mayer and Zignago (2006) and Head and Mayer (2000) to construct population-weighted distances, which take into account the distances between multiple agglomerations within each region. An appealing argument for the use of this particular approach for our analysis is that the same procedure obtains consistent measures of internal distances and bilateral distances for any pair of regions. In our case, we construct consistent and comparable measures of inter-provincial and intra-provincial distance. Thanks to an excellent comment by an anonymous referee, we also experimented with the ‘network distance’ measure from Bemrose et al. (2017), who use transaction-level shipment data to measure provincial distance based on more fine-grained points. We are very grateful to Mark Brown (Statistics Canada) for providing these data and for offering helpful insights on its construction. As demonstrated in our sensitivity analysis, the two alternative distance measures deliver estimation results that are not statistically different from each other. We decided to use the population-weighted distances because the ‘network distance’ variable did not include NT and YT.

The only significant variation in colonial relationships within Canada is identical with linguistic variation and it is restricted to the case of Quebec. Thus, the potential effects of linguistic and colonial heritage differences between Quebec and the rest of the Canadian provinces and territories are controlled by the directional QC fixed effects, $\eta_{QC,t}$ and $\theta_{QC,t}$, in our econometric model.
Along with estimates of inter-provincial and international trade costs, equation (10) delivers province-specific estimates of intra-provincial trade costs ($\hat{\psi}_{ii}$). We view our specification and the corresponding estimates of intra-provincial trade costs as an important empirical contribution that complements some recent and influential studies that recognize the importance of heterogeneous intra-national trade costs, e.g., Ramondo et al. (2016). Our estimates of the intra-provincial fixed effects below demonstrate that the traditional assumption in the literature to treat countries as point masses is clearly rejected by the data, even for regions within the same country.

### 3.3 Quantifying Unexplained Trade Barriers

This section presents methods to identify potential unexplained barriers to inter-provincial Canadian trade. UTBs are defined as the difference (in logarithms) between the inter-provincial trade costs from the pair fixed effect estimator and the corresponding trade cost indexes that we obtain with the gravity variables estimator:

$$\ln UTB_{ij} \equiv \ln (\hat{t}_{ij}^{FE})^{1-\sigma} - \ln (\hat{t}_{ij}^{GRAV})^{1-\sigma}. \quad (11)$$

The difference at the right hand side of (11) should be random under the Cobb-Douglas (neutrality) assumption if there are no border barriers. Systematic UTBs are analyzed and decomposed by making use of the Cobb-Douglas structure. First, rearrange (11) as:

$$\ln (\hat{t}_{ij}^{FE})^{1-\sigma} = \ln(\hat{t}_{ij}^{GRAV})^{1-\sigma} + \ln UTB_{ij}. \quad (12)$$
Next, allow for the systematic influence of relative border barriers in origin and destination provinces as captured by the estimates of the intra-provincial fixed effects ($\hat{\psi}_{ii}^{GRAV}$ and $\hat{\psi}_{jj}^{GRAV}$, respectively), on the pair fixed effects estimates and translate (12) into an econometric specification:

$$\ln\left(\hat{t}_{ij}^{FE}\right)^{1-\sigma} = \omega_0 + \omega_1 \ln\left(\hat{t}_{ij}^{GRAV}\right)^{1-\sigma} + \omega_2 \hat{\psi}_{ii}^{GRAV} + \omega_3 \hat{\psi}_{jj}^{GRAV} + \nu_{ij}, \quad \forall i \neq j. \quad (13)$$

With no border barriers under the Cobb-Douglas cost assumption, $\ln UTB_{ij}$, captured by $\nu_{ij}$, is random and theory predicts $\omega_1 = 1$ and $\omega_0 = \omega_2 = \omega_3 = 0$. That is because in the no-border-barriers case $\psi_{ii}$ reflects only variation of intra-regional trade costs $r_{ii}$, by equation (8), and this has no influence on inter-provincial trade costs under the Cobb-Douglas assumption.

Non-uniform border effects are indicated by significant coefficients on the estimated $\hat{\psi}_{ii}$ in (13). If, furthermore, there is no correlation of internal costs $r_{ii}$ with border frictions $b_{i}$, the systematic difference in (11) is equal to the border frictions only (up to a normalization), so

$$\ln\left(\hat{t}_{ij}^{FE}\right)^{1-\sigma} = \ln\left(\hat{t}_{ij}^{GRAV}\right)^{1-\sigma} - [\hat{\zeta}_O \hat{\psi}_{ii} + \hat{\zeta}_D \hat{\psi}_{jj}],$$

where $\hat{\zeta}_O = \hat{\omega}_2$ and $\hat{\zeta}_D = \hat{\omega}_3$. This is because both the fixed effect bilateral estimates and the gravity variables bilateral estimates are invariant to internal costs – the former by construction and the latter because $r_{ii}$ and $r_{jj}$ are absorbed by the multilateral resistances.

This list of assumptions suggests that they are overly restrictive. (For example, a correlation between $r_{ii}$ and $b_{i}$ is plausible.) For these reasons, we develop the empirical analysis to look for systematic UTBs from the agnostic approach (13) with unrestricted coefficients. Due to the independent draws of the resampled residuals in the two first-stage estimators, the error term $\nu_{ij}$ in (13) is plausibly independent of the regressors. (13) is estimated using OLS with bootstrapping by resampling $\nu_{ij}$s with replacement. At a minimum, analysis of variance based on (13) gives a measure of how well the gravity treatment of trade costs performs.

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18Henderson 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 speci-
Applying the Cobb-Douglas cost structure to equation (13), the Cobb-Douglas weights, \( \zeta_O \) and \( \zeta_D \) are estimated from the results of (13) as \( \hat{\omega}_2/(\hat{\omega}_2 + \hat{\omega}_3) = \hat{\zeta}_O \) and \( \hat{\omega}_3/(\hat{\omega}_2 + \hat{\omega}_3) = \hat{\zeta}_D \). \( \hat{\zeta}_O \) and \( \hat{\zeta}_D \) are used with the estimates of \( \hat{\psi}_{ii} \) and \( \hat{\psi}_{jj} \) to construct the normalized relative border effects. The theory suggests that the systematic relative border effects \( \hat{\zeta}_O \hat{\psi}_{ii} + \hat{\zeta}_D \hat{\psi}_{jj} \) should be removed from the UTB in (11) along with the predicted effect of the gravity variables (with unit elasticity). This procedure yields estimates of systematic residual Unexplained Trade Barriers, denoted \( \text{UTB}^\ast \), which can be calculated in log form as:

\[
\ln \hat{\text{UTB}}^\ast_{ij} = \hat{\omega}_0 + (\hat{\omega}_1 - 1) \ln \left( \tilde{i}_{ij}^{\text{GRAV}} \right)^{1-\sigma} + [\hat{\omega}_2 + \hat{\omega}_2/(\hat{\omega}_2 + \hat{\omega}_3)] \hat{\psi}_{ii} + [\hat{\omega}_3 + \hat{\omega}_3/(\hat{\omega}_2 + \hat{\omega}_3)] \hat{\psi}_{jj}. \tag{14}
\]

By construction, \( \ln \hat{\text{UTB}}_{ij} = \ln \hat{\text{UTB}}^\ast_{ij} - [\hat{\zeta}_O \hat{\psi}_{ii} + \hat{\zeta}_D \hat{\psi}_{jj}] \). Including the random component, \( \ln \text{UTB}_{ij} = \ln \hat{\text{UTB}}_{ij} + \nu_{ij} \).

4 Data

This research capitalizes on significant efforts of the Canadian government and Statistics Canada, in particular, to construct a detailed, comprehensive, and internally consistent dataset that covers production, expenditure, and intra-provincial, inter-provincial, and international trade flows for each of Canada’s provinces and territories at the sectoral level over the period 1997-2007. Specifically, the original dataset covers most of Canada’s economy at the sectoral level for a total of 28 industries including agriculture, 18 manufacturing sectors, aggregate manufacturing, and 9 service categories for the period 1997-2007. We aggregate the Northwest Territories and Nunavut in one unit, even though they are separate since April 1, 1999. Thus, our sample consists of a total of 14 regions including 12 Canadian provinces and territories, the U.S., and the rest of the world (ROW). Furthermore, in order to emphasize our methodological contributions and to simplify the presentation of our results, we perform the analysis with data on ‘Total Manufacturing’.

As described in Genereux and Langen (2002), the objectives of the Canadian govern-

ification is a hybrid of parametric and non-parametric approaches that allows for heterogeneity of intra- and inter-regional border effects.
ment to construct such data were channeled under the Project to Improve Provincial Economic Statistics (PIPS): “Three fundamental developments [under PIPS] contributed to strengthen considerably the inter-provincial and international trade flows from 1997 onwards. The three areas are: (i) The various surveys that collect data on provincial trade are more comprehensive and robust from 1997 onwards than in previous years; (ii) Trade information is analyzed, reconciled and integrated in a detailed set of official provincial/territorial Input-Output (IO) tables from 1997 onwards; Furthermore, the survey information that buttresses these provincial IO tables has also been expanded and/or strengthened considerably, contributing not only to the overall quality of the provincial IO tables but also to the overall quality of the provincial trade flows program; (iii) Finally, trade flow information is reconciled with other System of National Accounts relevant variables such as the provincial/territorial Gross Domestic Product Expenditures-based and its components and the provincial/territorial GDP by Industry, thus improving overall data consistency.” (p.6).

In addition, every effort has been made by the developers of the dataset to ensure that the missing and zero values in the data are indeed missing or zeros, respectively.\textsuperscript{19}

While Statistics Canada has made every effort to ensure completeness and internal consistency of their data, there are some caveats that should be kept in mind when interpreting our results. For example, the primary source of data for inter-provincial trade flows of manufactured goods is the Canadian Annual Survey of Manufacturers (ASM), which comes with some limitations. For instance, the ASM does not collect destination information for small manufacturing establishments, which account for close to 8\% of all Canadian manufacturing shipments and vary by province. Instead, ASM records these shipments as purchased by consumers within the province of the establishment. This implies that our sample may overstate the importance of intra-provincial trade. Also, sometimes the destinations of shipments identified in ASM are not necessarily the final destination of the shipments. To alleviate this issue, in the Total Manufacturing data that we employ for our analysis, there are only 62 zero trade values and 38 missing trade values. The vast majority of missing values are for remote provinces and territories (i.e., NT and YT), whose share in economic activity is relatively small. Thus, our main results are robust to replacing all missing values with zeros and to the removal of YT and NT.

\textsuperscript{19}For instance, in the Total Manufacturing data that we employ for our analysis, there are only 62 zero trade values and 38 missing trade values. The vast majority of missing values are for remote provinces and territories (i.e., NT and YT), whose share in economic activity is relatively small. Thus, our main results are robust to replacing all missing values with zeros and to the removal of YT and NT.
issue, Statistics Canada utilized the Wholesale Trade Commodity Survey by Origin and Destination, which provides information on origin of purchases and destination of sales of wholesalers. Despite such limitations, we view this dataset as a significant improvement beyond any existing dataset and as the best suited data to perform our analysis.\(^{20}\)

Table 1 offers the summary statistics for the key variables that we use to obtain our main results for Total Manufacturing. Consistent with our focus on intra-national trade in Canada, the statistics in Table 1 are based only on provincial data, including intra-national as well as international provincial trade, but excluding trade and distance between the U.S. and ROW as well as output and expenditure for the U.S. and for the rest of the world. The numbers in Table 1 reveal significant disproportions in provincial trade. Specifically, the mean values of intra-provincial and international trade for Canada’s regions are large but comparable to each other with slightly higher intra-provincial trade. However, both intra-provincial trade and international trade for Canada’s regions are significantly larger (more than 10 times) as compared to the average inter-provincial trade.

Figures 1 and 2 complement the numbers in Table 1 by offering a visual analysis of the relationship between inter-provincial, intra-provincial, and international trade over time and across Canada’s provinces. Figure 1 plots the evolution of the shares of inter-provincial, intra-provincial, and international trade within the total Canadian trade over the period between 1997 and 2007. Two main findings stand out from the figure. First, the fact that Canadian provinces engage much more in international and intra-provincial trade than in inter-provincial trade remains consistent over time. As captured by Figure 1 throughout the period of investigation, intra-provincial trade accounts for about 32% of the total Canadian trade while inter-provincial trade comprises only about 17% of the total Canadian trade.

\(^{20}\)For instance, we believe that our Canadian dataset has several advantages over the U.S. Commodity Flow Survey (CFS). First, the CFS data are not comprehensive as they are based only on a representative sample of business establishments. Second, the CFS data do not contain information on expenditure at the state level and do not allow for the calculation of intra-state trade flows. Third, international imports at the state level are also not reported in the CFS data. Fourth, as compared to the original Canadian data, the CFS data exclude certain notable sectors such as agriculture, transportation, retail and services. For a detailed description of the challenges, advantages, and caveats with the construction of the Canadian data set, we refer the reader to Genereux and Langen (2002).
International trade accounts for the largest share of provincial trade (about 51%). Second, we see that the proportions of inter-provincial vs. intra-provincial vs. international trade for the Canadian provinces remain relatively constant over time. This result is reinforced by the structural gravity estimates in the next section, where we obtain insignificant estimates of the time-varying intra-national trade costs within Canada.

Figure 2 complements Table 1 and Figure 1 by plotting the relationship between inter-provincial, intra-provincial, and international trade for each of Canada’s provinces in 2002, which is the middle (and representative) year in our sample. While the figure supports the conclusions so far, on average, it also reveals some interesting and significant patterns of variation across provinces. For example, Figure 2 shows that, by a discrete margin, YT and NT are the regions with the largest shares of intra-provincial trade and the smallest fractions of international trade. Together with NL and ON, YT and NT are also the regions with the smallest inter-provincial trade shares. However, unlike YT and NT, NL and ON are actually the two provinces with the largest share of international trade in the sample. This analysis points to large ‘home bias’ effects and significant borders to inter-provincial and international trade for YT and NT, which are confirmed by our econometric results.

Finally, in addition to the key Canadian trade data, we also employ a series of other variables, e.g., proxies for geography (distance and contiguity), production and expenditure data for U.S. and ROW. For brevity, and since the sources and methods to construct these variables are more standard and/or of less interest, we discuss them explicitly when the variables are introduced in the analysis and we offer detailed descriptions of these variables and the sources and methods that we use to obtain them in the Supplementary Data Appendix.

5 Estimation Results

This section follows the structure of Section 3, ‘Empirical Foundation’, to present and analyze our main results. Specifically, in Subsection 5.1 we summarize the results from the pair fixed effects econometric model. Then, in Subsection 5.2 we discuss the estimates of
inter-provincial and relative intra-provincial trade costs that are obtained from the econometric specification with gravity variables. Subsection 5.3 reports UTBs and analyzes their systematic component. The section concludes with a list of robustness experiments.

5.1 Inter-provincial Trade Costs: A Pair Fixed Effects Approach

We start with analysis of the estimation results from the pair fixed effects specification (5). Due to the large number of estimates that we need to present, we report them in two separate tables. The estimates of the coefficients on the time-varying covariates (INTERPR\_T and INTRAPR\_T) appear in column (1) of Table 2, while the estimates of the inter-provincial fixed effects are reported in Table 3. The coefficient estimates on INTERPR\_T and INTRAPR\_T indicate no significant intertemporal change on trade with international partners, so static results are presented. Specifically, the economically small and statistically insignificant estimates on INTERPR\_T and INTRAPR\_T suggest that there has not been any significant change in the inter-provincial and intra-provincial bilateral trade frictions during the eleven-year period (1997-2007) of our investigation.

The estimates of the inter-provincial fixed effects \( \hat{\gamma}_{ij} \) from specification (5) are reported in Panel A of Table 3. The first column in Table 3 lists each region as an exporter, while the label of each column stands for each region as an importer. The last column of Table 3, labeled CA, reports aggregate inter-provincial log volume reduction estimates for each province, obtained using the consistent aggregation procedure that we present in the Supplementary Appendix. The diagonal elements are all zeros, reflecting the fact that the intra-provincial fixed effects are used as a reference group. In addition, due to our symmetry assumption, we only report the inter-provincial \( \hat{\gamma}_{ij} \)'s above the diagonal. The latter should be interpreted relative to the geometric mean of the omitted intra-provincial fixed effects, as explained above. The off-diagonal \( \hat{\gamma}_{ij} \)'s in Panel A are all negative, large in absolute value,

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21 As noted earlier, we obtain our main estimates with the PPML estimator. OLS estimates, which are reported in the Supplementary Appendix, confirm our main findings.

22 The order of the Canadian provinces and territories in our tables follows the preamble of the Agreement on Internal Trade: Newfoundland and Labrador, Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, the Northwest Territories and Yukon.
and statistically significant. The estimates are quite precise but to avoid clutter, the standard errors are suppressed. The estimates vary widely across provincial partners. Plausibly, some of the differences across provincial pairs reflect the influence of geography. However, as we demonstrate in Section 5.3 below, we also identify significant unexplained borders.

In order to facilitate interpretation, in Panel B of Table 3 we present the estimated inter-provincial fixed effects as percentage trade volume effects. All off-diagonal elements in Panel B of Table 3 are less than 100 – after controlling for origin and destination province-specific characteristics, inter-provincial trade is significantly smaller than intra-provincial trade. The vast majority of the volume effect estimates are considerably small (smaller than 10 percent), implying that trade between provinces is much lower than trade within provinces. 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, all else equal, while the estimate of 0.02 for pair NL-YT suggests that inter-provincial trade between these regions is about 0.02 percent of their average intra-provincial trade. Panel B also reveals significant heterogeneity in the percentage volume reductions across different pairs. Aggregating each province’s volume reductions across its partners, column CA reveals that YT, NT, PE, and NL are the regions with the largest deflection of inter-provincial into intra-provincial trade, while ON, AB, and QC are the regions with the smallest corresponding deflection. The bottom right element of Panel B summarizes that overall inter-provincial manufacturing trade in Canada is about 5.2 percent of the intra-provincial trade.

5.2 Intra-national Trade Costs: A Gravity Variables Approach

Estimates from specification (10) are reported in column (2) of Table 2. Our results show that, similar to its strong negative impact on international trade, distance also impedes inter-provincial trade within Canada: all of the four distance estimates are sizable, negative, and statistically significant at any conventional level. Overall, the effects of distance on inter-provincial trade in Canada across different distance intervals are similar, with some variation. The smallest estimate (in absolute value) is for the smallest distance interval
(\textit{DISTANCE}_{-1}), and the largest estimate is for the largest interval (\textit{DISTANCE}_{4}), but there is some evidence of non-monotonicity, since the estimate on \textit{DISTANCE}_{3} is smaller than the estimate on \textit{DISTANCE}_{2}. The estimate on \textit{CONTIG.PR.PR}_{ij} is positive and statistically insignificant but very small in magnitude, \( \beta_{\text{contig}} = 0.055 \). This result contrasts with the large estimates from the international gravity literature. A natural explanation for the difference is that we are estimating the effects of contiguity between regions within the same country. Interestingly, our estimates are also in contrast with the very large and significant estimates of adjacency from Wolf (2000), who obtains estimates of the effects of contiguity between states that vary between 0.94 and 1.02 from alternative specifications.23

Column (2) of Table 2 also reports estimates of the volume effects of the log of provincial relative border costs, i.e., the ratio of border friction to the internal friction. To aid intuition, recall from (8) that the volume effect in levels corresponds to the theoretical concept

\[
\frac{\bar{b}_{ij}/\bar{r}_{ii}}{b/r} (\sigma-1) p_1.
\]

Thus, we can only identify relative border barriers and, therefore, the variation across the estimates of the province fixed effects in column (2) has meaning but the level of the \( \psi_{ii} \) estimates cannot be interpreted meaningfully. By construction, larger \( \psi_{ii} \)’s imply large interprovincial borders relative to intra-provincial trade costs. Thus, strictly speaking, one cannot interpret the larger values of \( \psi_{ii} \) simply as larger ‘home bias’ effects, even though ‘home bias’ may be part of the story. Importantly, the relative border estimates from column (2) of Table 2 exhibit wide variation that is visualized in the heat map of Figure 3, where darker colors indicate larger relative borders. The largest value that we obtain is for Yukon Territory, followed by Prince Edward Island and Northwest Territories. These are the regions that face the largest difficulties to sell to other Canadian regions relative to intra-regional trade. The

23 Contiguity may matter differently for trade between the large contiguous provinces, e.g., ON and QC, than it does for trade between small and remote contiguous provinces, e.g., NT and YT. This hypothesis could 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 bilateral fixed effects and obviates the difference between pairwise fixed effects and the gravity variables estimator.
smallest values are for Ontario, British Columbia and Alberta, suggesting that these are the three provinces that face the lowest relative borders for inter-provincial trade.

Despite the small number of observations and the prominent presence of outliers, we try to look for some systematic determinants of the variance across our estimates of $\psi_{ii}$ in Figure 4. Specifically, the figure offers correlation analysis between our relative border estimates and population as a proxy for economic size (Panel A), intra-provincial distance as a proxy for transportation costs (Panel B), and GDP per capita and road conditions as proxies for economic development (Panel C and Panel D, respectively). To diminish the influence of outliers, we drop NT, PE, and YT from the analysis. NT has the highest GDP per capita in Canada due to its natural resources. PE has the smallest internal distance and YT has the smallest population, of which about 75% is concentrated in Whitehorse, the capital. In addition, similar to PE, YT also has a very small internal distance.

Panel A of Figure 4 depicts an inverse relationship between population and the influence of relative borders. This relationship is robust to the inclusion of the three outliers and implies that larger provinces are more open to inter-provincial trade relative to intra-provincial trade. Panel B captures a weak positive relationship between internal distance and relative borders. This relationship is not robust. On the one hand, the figure suggests that the positive relationship will be very strong if ON, BC and AB were not included in the sample. At the same time, however, once we add NT, PE, and YT to the current sample, the relationship becomes negative. Finally, the inverse relationships that are captured in the bottom panels of Figure 4 suggest a positive correlation between economic development, proxied by GDP per capita and road conditions, and openness to inter-provincial relative to intra-provincial trade. Overall, the analysis in Figure 4 points to some provincial charac-

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24 Data on population for each Canadian province and territory for 2002 are available from the Canadian Council on Social Development using data from Statistic Canada’s CANSIM, Table 051-0001. Data on Gross Domestic Product per capita in current dollars for 2002/2003 for each Canadian region are provided by Statistics Canada’s Table A.33. Data on road conditions in Canada are from the Fraser Institute’s report on “Transportation Performance of the Canadian Provinces.” The variable that we adopt reflects the percent of highways in “fair” or “poor” condition.

25 The clear relationship between development, as measured by GDP per capita, and the relative borders that we capture in Panel C of Figure 4 disappears once we introduce NT in our sample. The reason is
teristics as significant determinants of relative international borders. However, as cautioned earlier, the very small number of observations and the presence of outliers do not allow for rigorous econometric analysis of the determinants of relative provincial borders. We leave this interesting task for future research.

The section concludes with a preliminary evaluation of the relative performance of the gravity variables and pairwise fixed effects estimator, which will extend naturally to the UTB analysis in the next subsection. The Akaike Information Criterion (AIC), which we report in row AIC of Table 2 gives a rough comparison of these non-nested 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 the usual rule of thumb suggests, which provides ‘substantial’ support for the gravity estimator relative to the fixed effects estimator (Burnham and Anderson, 2002). This suggests that distance is a powerful predictor of bilateral trade costs within Canada, since contiguity effects are insignificant. Nevertheless, as demonstrated in the next section, a systematic pattern in the difference between fixed effects and gravity variables estimators emerges from a more rigorous regression analysis.

5.3 Unexplained Inter-provincial Trade Barriers

We start the UTB analysis with a motivational graph, Figure 5, which plots our estimates of inter-provincial trade costs from the specification with pair fixed effects, ln \((\hat{t}_{ij}^{\text{FE}})^{1-\sigma}\), against the corresponding trade cost estimates from the estimator with the gravity variables, ln \((\hat{t}_{ij}^{\text{GRAV}})^{1-\sigma}\). With no border barriers under the Cobb-Douglas cost assumption, ln \(UTB_{ij}\), defined as the difference between the two trade cost measures, is random and the plot of ln \((\hat{t}_{ij}^{\text{FE}})^{1-\sigma}\) against ln \((\hat{t}_{ij}^{\text{GRAV}})^{1-\sigma}\) should be clustered around the 45-degree line. Three main findings stand out from Figure 5. First, the two sets of inter-provincial trade cost measures are highly but not perfectly correlated. The correlation is \(\rho = 0.69\). Second, for many pairs that NT has the highest GDP per capita in Canada due to its natural resources. However, the negative relationship between road conditions and relative borders is present and remains strong with and without the outliers in our sample.

\(25\) AIC is theoretically founded for maximum likelihood estimators, so for PPML it is a rough guide only.
the estimates are significantly off the 45-degree line on Figure 5. This points to non-random UTBs. Third, we find some pairs below and some pairs above the 45-degree line. This suggests that the standard gravity variables may under-predict inter-provincial trade costs in some cases and over-predict them in others.

Motivated by this preliminary evidence for non-random differences between $\ln \left( \hat{t}_{ij}^{FE} \right)^{1-\sigma}$ and $\ln \left( \hat{t}_{ij}^{GRAV} \right)^{1-\sigma}$, we proceed with a more formal quest for the systematic presence of unexplained trade barriers that is based on specifications (13) and (14) from Section 3.3. We begin with the estimation of several versions of equation (13), which will enable us to test the homogeneity restriction, i.e., $\omega_0 = 0$, $\omega_1 + \omega_2 + \omega_3 = 0$, and the Cobb-Douglas assumption, $\omega_2 + \omega_3 + 1 = 0$. Rejection of the null hypothesis indicates the presence of systematic UTBs, which we will then calculate using (14). An initial benchmark estimates (13) subject to $\omega_2 = \omega_3 = 0$. The results reported in column (1) of Table 4 reveal that the coefficient estimate on $\ln \left( \hat{t}_{ij}^{GRAV} \right)$ is not significantly different from 1; the $R^2 = .48$; and the estimate of the constant term is statistically significant and very large.

Column (2) of Table 4 presents estimates of (13) with unrestricted $\omega$’s. We summarize the results in numbered points so as to facilitate their discussion thereafter. (i) $R^2 = .94$, a substantial increase. This result implies that intra-national relative trade cost variation picked up by the volume effect $\hat{\psi}_{ii}$ contributes significantly to the variation of bilateral fixed effects, doubling the variation explained by distance; (ii) $\hat{\omega}_1$ is closer to 1 and not statistically different from 1. Together, results (i) and (ii) indicate that intra-national cost variation is almost uncorrelated with bilateral distance and contiguity; (iii) $\hat{\omega}_2$ and $\hat{\omega}_3$ are each greater in absolute value than $-1/2$ and their sum is statistically smaller than $-1$, all at the 1% level of confidence. This result suggests that intra-national trade costs are correlated with an unobserved variable affecting inter-regional trade costs that is not neutralized by origin and destination fixed effects; (iv) $\hat{\omega}_0$ is smaller in absolute value, but statistically and quantitatively significantly less than 0; (v) $\hat{\omega}_1 + \hat{\omega}_2 + \hat{\omega}_3 < 0$. Results (iv) and (v) imply that homogeneity of degree zero is rejected: the chi-squared test for the combined restrictions
\( \omega_0 = 0, \omega_1 + \omega_2 + \omega_3 = 0 \) is rejected (p-value of 0.0001). Given the Cobb-Douglas structure, hypotheses tests (iii)-(v) imply the presence of systematic residual UTBs.

Column (3) of Table 4 reports estimates of (13) subject to the constraint \( \omega_2 + \omega_3 = -1 \). The results imply that, subject to the constraint, the values of \( \omega_1 = 1 \) and \( \omega_0 = 0 \) cannot be rejected. The homogeneity hypothesis in the constrained model is not rejected either: the chi-squared test for the combined restrictions \( \omega_0 = 0, \omega_1 + \omega_2 + \omega_3 = 0 \) has a p-value of 0.1389. The constrained values of \( \hat{\omega}_2 \) and \( \hat{\omega}_3 \) are pushed slightly toward 1/2 compared to the \( \hat{\omega}_2 / (\hat{\omega}_2 + \hat{\omega}_3) \) and \( \hat{\omega}_3 / (\hat{\omega}_2 + \hat{\omega}_3) \) values. The constrained model comes close in practice to the simple homogeneous Cobb-Douglas model. Nevertheless, columns (2) and (3) taken together imply non-random residuals of the constrained regression, with important information.

The UTBs generated by the estimated version of (14) using the coefficients in column (3) of Table 4 are given by (15) below. Standard errors are reported in parentheses.

\[
\ln\hat{UTB}_{ij}^* = -0.839 - 0.035 \ln(t_{ij}^{GRAV})^{1-\sigma} - 0.1123 \hat{\psi}_{ii} - 0.1149 \hat{\psi}_{jj} + \hat{\nu}_{ij}.
\] (15)

Equation (15) includes the adjustment term \( z_{ij} = (\hat{\omega}_1 - 1) \ln(t_{ij}^{GRAV})^{1-\sigma} \) due to the slight under-prediction of the gravity trade cost coefficient. The importance of variation in relative home bias \( \hat{\psi}_{ii} \) and \( z_{ij} \) in explaining \( \ln\hat{UTB}_{ij}^* \) is described by standardized (beta) coefficients of 0.583 (\( z_{ij} \)), -0.491 (\( \hat{\psi}_{ii} \)) and -0.534 (\( \hat{\psi}_{jj} \)). The systematic provincial border barrier effects in residual UTB (15) are inherently non-discriminatory, though producing systematic effects. Discriminatory border effects, if any, are part of the error term \( \nu_{ij} \). However, we note that the idiosyncratic border effects \( \nu_{ij} \) have relatively small influence, because the residual \( (\hat{\nu}_{ij}) \) variance is 6.2% of the variance of \( \hat{\gamma}_{ij}^{FE} \) based on the unconstrained regression (13)\(^{27}\).

Table 5 reports expected (fitted) systematic residual UTBs, \( E[\hat{UTB}_{ij}^*] \), the systematic portion of equation (15). The estimates reveal that there are some residual UTBs that are

\(^{27}\)In principle, groups of regions could form samples to pick up systematic discriminatory effects through different \( \hat{\omega}_k \) coefficients. With only 12 Canadian provinces this suggested technique has too few degrees of freedom to be useful. The discriminatory implications of the residuals \( \nu_{ij} \) of (14) may be informative in some cases where added information can be brought to bear on discriminatory provincial border effects.
greater than one and some that are less than one. For instance, YT, NT and PE exhibit a large number of UTBs that are smaller than one, while most of the UTBs for AB, BC and ON are greater than one. At one extreme, the UTB estimate of 0.55 for trade between NT and YT that we report in Table 5 suggests that trade flows between NT and YT are reduced 45% by their 2002 UTB in manufacturing. UTBs on trade between YT and PE are similar. At the other extreme, our estimates of 1.308 for trade between ON and AB and of 1.3 for trade between ON and BC suggest that trade flows between ON and BC and ON and AB are raised by about 30% due to UTBs. These patterns and the variation across provinces and provincial pairs may indicate where policy intervention has larger payoffs. Beaulieu et al. (2003) offer ample anecdotal evidence for the existence of significant inter-provincial barriers to trade within Canada including home-biased government procurement, province-specific occupational licenses, etc. We believe that some of these barriers are definitely captured by our UTB indexes and we view a formal study that connects our indexes with detailed data on inter-provincial barriers as a valuable direction for future work.

The interpretation here of systematic UTBs is tentative for two reasons. First, omitted bilateral effects could be components of the error term in (15) and hence (14). For example, if the set of gravity variables in (10) 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 inter-provincial trade. For example, contiguous provinces are more likely to cooperate with each other. Second, specification (15) assumes a Cobb-Douglas cost function. But the results of estimating (14) could be indicative of non-Cobb-Douglas cost structure for costs other than UTBs, with no UTBs. This implies omitted variables in the test based on equation (15). To address
this caveat, we experiment with two alternative specifications of equation (13): a translog model and a flexible specification with fixed effects.

The translog is natural to use as the alternative nesting the Cobb-Douglas. The translog adds 6 second order parameters to be estimated. (Using symmetry and the number of permutations of 3 activities: one for Origin, one for Destination, and one for the pure inter-regional. Special case restrictions can reduce this number.) The first order parameters are constrained to sum to one as in the Cobb-Douglas case; the second order parameters are constrained to sum to zero. For the Canadian case, with 12 provinces, the data are rather sparse (12 × 11 = 136 observations of inter-regional fixed effects under symmetry) to believably estimate so many parameters. On datasets with more observations, the translog gains traction. But collinearity is a well-known issue. A translog counterpart to (13) is

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

(16)

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

Column (4) of Table 4 reports the results from the translog specification in equation (16). None of the new terms is statistically different from zero and the joint test cannot reject the hypothesis that \(\omega_4 + \omega_5 + \omega_6 = 0\). The p-value for the corresponding chi-squared test is 0.6773. We also cannot reject the hypotheses that \(\omega_1 = 1\), \(\omega_0 = 0\), \(\omega_2 = -1/2\), \(\omega_3 = -1/2\), and \(\omega_2 + \omega_3 = -1\). Our findings do not reject the Cobb-Douglas functional form, while the multicollinearity of the translog form blows up the standard errors. Thus, while the estimates of the Cobb-Douglas terms from columns (2) and (4) may not be statistically different from each other, the relatively large differences in their magnitudes point to potential caveats in the Cobb-Douglas assumption to identify UTBs. Identifying non-Cobb-Douglas cost functions that obtain more accurate comparative statics (e.g., the effect of an intra-regional improvement on bilateral costs) is an important task for future research.

Equation (13) and its structural interpretation invite suspicion that an alternative origin and destination effects mechanism may be at work. A natural and flexible atheoretic “smell”
test replaces $\psi_{ii}$ and $\psi_{jj}$ with exporter and importer fixed effects. The results are reported in column (5) of Table 4. The coefficient of $\ln(\hat{P}^{GRAV}_{ij})^{1-\sigma}$ is insignificantly different from its theoretical counterparts in columns (2) and (3). In fact, the estimate in column (5) is further away from one. The $R^2$ in column (5) rises only slightly compared to columns (2) and (3). In combination, closeness of the coefficient estimates and goodness of fit suggest that the restrictions of theory are plausible.

### 5.4 Credibility Checks

We perform a series of robustness checks, which are described in detail in a Supplementary Appendix. We summarize the results in numbered points so as to facilitate exposition.

(i) We allow for asymmetric bilateral fixed effects in equation (5). Differences are small, hence symmetry is consistent with the data. (ii) OLS estimations confirm the robustness of our PPML results. (iii) Suspicious of the role played by the large rest-of-the-world (ROW) aggregate and U.S. regions, we exclude them consecutively from our sample. The estimates of inter-provincial trade costs are unaffected. (iv) We replace all missing trade values in the data with zeros. The the inter-provincial trade costs and the UTB numbers remain qualitatively unchanged with only minor quantitative changes. (v) We drop YT and NT, which are the regions with the most missing and/or zero trade flow values in our sample. The results remain unchanged. (vi) We employ the ‘network distance’ measure of Bemrose et al. (2017) instead of the population-weighted distance index that we use for the main analysis. Once again, the results remain the same. (vii) Finally, we use only interval data for the years 1997, 1999, 2001, 2003, 2005, and 2007. There are no significant differences between the set of estimates with two-year lags and the main estimates.

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29 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).
6 Conclusion

A structural gravity econometric method is developed and applied to flexibly estimate bilateral intra-national trade costs from inter- and intra-regional trade flows. A key step is specifying a bilateral trade cost function that aggregates internal, border and pure inter-regional costs. Application to the bilateral trade of Canada’s provinces reveals that provincial trade is differentially affected by variation in relative border frictions that depress the trade of small remote provinces and favor trade of large central provinces. We call these Unexplained Trade Barriers to suggest there is much to be learned from attempting to explain the variation in inter- and intra-regional trade costs and border barriers.

Our findings for the Canadian provinces and territories surely hold much more widely. Even larger differences in intra-national trade costs are likely to be obtained in an international study at the cross-country level. There are at least three implications for future research. First, the standard approach in the trade literature that treats regions (e.g. provinces and/or countries) as point masses is substantially at variance with reasonable inference from the data. Allowing for the variation has important implications for regional policy and general equilibrium comparative statics. Second, we see significant potential benefits from applying our methods at the sectoral level of the rich Canadian data. As noted earlier, such analysis will enable us to offer more rigorous and informative UTB analysis. In addition, the richer database of sector-province relative inter-provincial borders that we can obtain will enable us to draw more solid inference about the influence of their determinants. Third, non-uniform border barriers within countries induce significant systematic distortions of inter-regional trade. We expect that the magnitude and heterogeneity of UTBs will be even larger in a cross-country study with international data. The flexible fixed effects treatment of trade costs can also be applied to quantify barriers to immigration and FDI, about which we know much less than about trade costs.
References


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Notes: This table presents the summary statistics for the key variables in our analysis. Trade and production stats are based on Total Manufacturing across Canada’s provinces. Data for US and ROW are only used for the construction of INTERNTNL_TRADE, which summarizes provincial exports to US and ROW. All other stats are based on provincial data only. INTERPROV_TRADE denotes inter-provincial trade. INTRAPROV_TRADE denotes intra-provincial trade. $Y_i$ and $E_j$, denote the values of provincial output and expenditure, respectively. DIST_INTER and DIST_INTRA denote inter-provincial and intra-provincial distance, respectively. Finally, CONTIG_PR_PR is an indicator for contiguous provinces. See text for more details.
Table 2: PPML Panel Gravity, Total Manufacturing, 1997-2007

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| N        | 2052 | 2052 |
| AIC      | 6.38 | 8.20 |

Notes: This table reports PPML panel gravity estimates for Total Manufacturing, 1997-2007. The dependent variable is size-adjusted trade. The estimates in column (1) are obtained from the fixed effects specification (5). The estimates in column (2) are obtained from specification (10), where the bilateral fixed effects are replaced with gravity variables. Column (2) also reports the bilateral time-invariant intra-provincial fixed effect estimates. All estimates are obtained with exporter-time and importer-time fixed effects. The estimates of the exporter-time and importer-time fixed effects, together with the estimate of the constant term, are omitted for brevity. Standard errors are clustered by country pair and are reported in parentheses. + p < 0.10, * p < 0.05, ** p < 0.01. See text for more details.
Table 3: PPML with Pair Fixed Effects, Total Manufacturing, 2002

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</tbody>
</table>

Notes: This table presents (symmetric) bilateral trade cost estimates based on specification (5), where trade costs are controlled for with bilateral fixed effects. Panel A reports estimates of the bilateral fixed effects $\gamma_{ij}$, which are obtained with a panel PPML estimator together with the estimates from column (1) of Table 2. All estimates are highly statistically significant. Standard errors (clustered by exporter-importer) are omitted for brevity. Panel B reports the corresponding volume effects, obtained by transforming the estimates from Panel A as follows: $\exp(\hat{\gamma}_{ij}) \times 100$. "*" is used to denote that only one-way trade flows are used to obtain the corresponding estimate due to the lack of trade data for some pairs in our sample. See text for more details.
### Table 4: Neutrality Tests and Alternative UTB Specifications, Total Manufacturing, 2002

<table>
<thead>
<tr>
<th></th>
<th>(1) BENCHMARK TEST</th>
<th>(2) CONSTRAINT</th>
<th>(3) TRANSLOG</th>
<th>(4) PROVINCE FEs</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ln(\hat{t}^{GRAV}_{ij}) )(^{1-\sigma} )</td>
<td>1.141 (0.090)**</td>
<td>0.965 (0.033)**</td>
<td>0.997 (0.035)**</td>
<td>0.959 (0.038)**</td>
</tr>
<tr>
<td>( \hat{\psi}_{ii} )</td>
<td>-0.607 (0.033)**</td>
<td>-0.487 (0.021)**</td>
<td>-0.507 (0.125)**</td>
<td>-0.560 (0.113)**</td>
</tr>
<tr>
<td>( \hat{\psi}_{jj} )</td>
<td>-0.621 (0.031)**</td>
<td>-0.513 (0.021)**</td>
<td>-0.560 (0.125)**</td>
<td></td>
</tr>
<tr>
<td>( \hat{\psi}<em>{ii} \times \hat{\psi}</em>{jj} )</td>
<td>0.003 (0.020)</td>
<td>-0.009 (0.022)</td>
<td>0.035 (0.023)</td>
<td></td>
</tr>
<tr>
<td>( \text{CONST} )</td>
<td>3.302 (0.546)**</td>
<td>-0.839 (0.253)**</td>
<td>-0.074 (0.205)</td>
<td>-0.641 (0.394)</td>
</tr>
<tr>
<td>( N )</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.475</td>
<td>0.938</td>
<td>0.939</td>
<td>0.951 **</td>
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</table>

**Notes:** This table reports results from the invariance tests and alternative econometric specifications based on equation (13), where we allow for the systematic influence of the relative border barriers in origin and destination provinces on the pair fixed effects \( \hat{\gamma}_{ij} \) from (5). The dependent variable is always \( \ln(\hat{t}^{FE}_{ij}) \), which is based on the pair fixed effects estimates from specification (5). The estimator is always OLS. Column (1) only includes as independent variable the predicted bilateral trade cost effects \( \ln(\hat{t}^{GRAV}_{ij}) \) from (10). Column (2) adds as covariates the estimates of the intra-provincial volume effects \( \hat{\psi}_{ii} \) and \( \hat{\psi}_{jj} \) (again based on specification (10)). Column (3) restricts the sum of the coefficients on \( \hat{\psi}_{ii} \) and \( \hat{\psi}_{jj} \) to be equal -1. Column (4) implements a translog specification by including the squared terms of \( \ln(\hat{t}^{GRAV}_{ii}) \) and \( \ln(\hat{t}^{GRAV}_{jj}) \) and their interaction. Finally, column (5) replaces \( \hat{\psi}_{ii} \) and \( \hat{\psi}_{jj} \) with exporter and importer fixed effects, whose estimates are omitted for brevity. Bootstrapped standard errors in parentheses. + \( p < 0.10 \), * \( p < 0.05 \), ** \( p < 0.01 \). See text for further details.
Table 5: UTB Estimates, Total Manufacturing, 2002

<table>
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<th>PE</th>
<th>NB</th>
<th>QC</th>
<th>ON</th>
<th>MB</th>
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<th>AB</th>
<th>BC</th>
<th>NT</th>
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</table>

Notes: This table reports UTB estimates, which are obtained as the expected (fitted) systematic residuals from specification (15). These UTBs are generated by the estimated version of (14) using the coefficients in column (3) of Table 4. Bootstrapped standard errors are not reported to avoid clutter. See text for more details.

Figure 1: Changes in Provincial Trade Shares Over Time

This figure offers a visual representation of the evolution of total international trade, total inter-provincial trade, and total intra-provincial trade as fractions of total Canadian trade over the period between 1997 and 2007.
This figure offers a visual representation of the variation of total international trade, total inter-provincial trade, and total intra-provincial trade as fractions of total Canadian trade across the Canadian provinces and territories in 2002.

This figure offers a visual presentation of the estimates of the relative border estimates, $\psi_{ij}$, from specification (10) for each of Canada’s regions. The interpretation of the estimates is as the ratio of border friction to the internal friction. Darker color suggests larger relative border to inter-regional trade relative to intra-regional trade. See text for more details.
Figure 4: On the Determinants of Relative Provincial Borders

This figure visualizes the correlations between the relative border estimates, \( \psi_{ij} \), from specification (10) and four province-specific variables including population (Panel A), intra-provincial distance (Panel B), provincial GDP per capita (Panel C), and road conditions (Panel D). As outliers, YT, NT and PE are not included in the analysis. See text for further details.

Figure 5: Inter-provincial Trade Costs: Pair Fixed Effects vs. Gravity Variables

This figure offers a visual representation of the relationship between the inter-provincial trade cost estimates that are obtained with the pair fixed effect estimator from specification (5) versus the corresponding trade cost estimates that are obtained from the specification with gravity variables (10) for each province pair. See main text for further details.