Gains from Trade Liberalization with Flexible Extensive Margin Adjustment*

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September 13, 2022

Abstract

We propose a sufficient statistic to measure the ex-post welfare gains from trade in CES models featuring any productivity distribution and any pattern of selection into production and exporting. This statistic is based on a single data moment, the change in the market share of continuing domestic producers, and a single structural parameter, the elasticity of substitution between products. We apply our statistic to measure Canada's gains from the Canada-US Free Trade Agreement using data on observed firm selection. We find that welfare gains can substantially deviate from welfare estimates implied by formulas that assume a constant extensive margin trade elasticity.

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1 Introduction

Seminal papers by Krugman (1980) and Melitz (2003) show that changes in trade costs can have important effects on welfare by changing the set of firms serving domestic and foreign markets. A large empirical literature has attempted to quantify the "extensive" margin of adjustment to changes in trade costs. For example, Broda and Weinstein (2006) measure the welfare gains from increases in US import variety and Pavcnik (2002) and Melitz and Trefler (2012) measure the effect of trade liberalization on the exit of less productive domestic firms.

However, Arkolakis et al. (2012) (henceforth ACR) show that when import demand is iso-elastic, the welfare gains from trade can be calculated from two statistics: the aggregate trade share and trade elasticity. Conditional on these two statistics, it is not necessary to know the magnitude of the extensive margin adjustment to trade, even in models where the extensive margin adjustment is crucial to the welfare effect of trade.

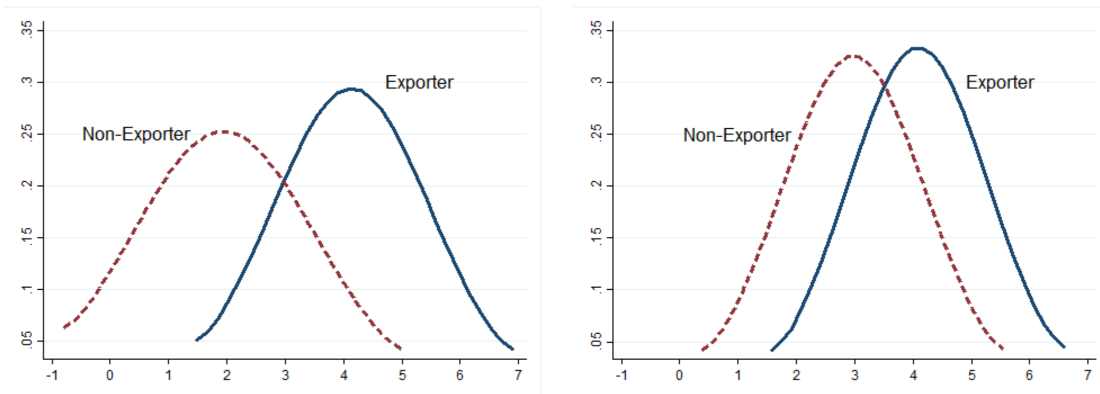
The assumptions necessary to deliver an iso-elastic import demand are quite stringent, particularly in models that allow for an extensive margin response to trade. Specifically, in such models, the extensive margin trade elasticity has to be constant. In a Melitz (2003) model this is the case when the distribution of firm productivity is Pareto and there is strict sorting into domestic production and exporting. Recent papers by Melitz and Redding (2015) and Head et al. (2014) consider alternative (non-Pareto) distributions of firm productivity that lead to departures from iso-elastic import demand, but maintain the assumption of strict sorting into exports and production.[1]

There is, however, abundant evidence that selection into export markets and exit does not follow strict sorting. Eaton et al. (2011) and Armenter and Koren (2015) document substantial overlap in the size distribution of exporters and non-exporters in France and the US. Figure 1 replicates this evidence for US and Canadian manufacturing for exporters vs. non-exporters (top panel) and for surviving vs. exiting firms (bottom panel). Many exporters are smaller (as measured by employment) than non-exporters, and many non-exporters are larger than exporters. Likewise, there is a substantial overlap in the size distribution of surviving vs. exiting firms in the two countries.

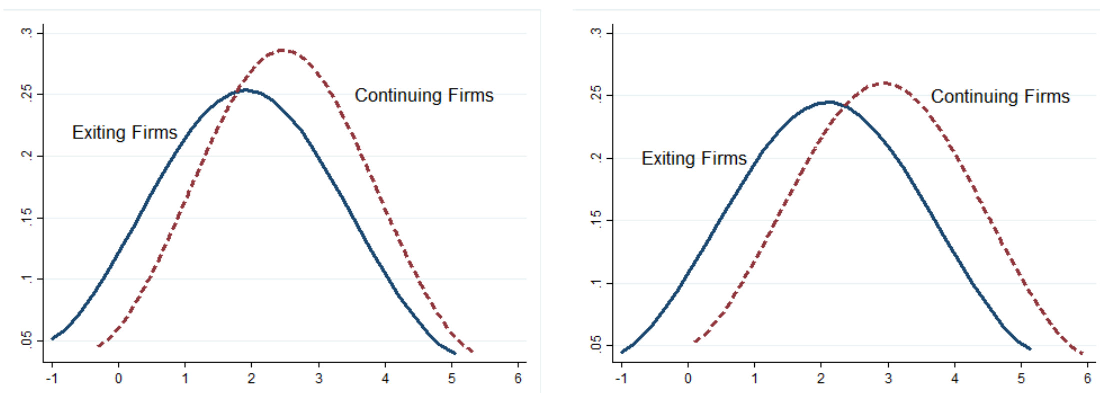
[1] Melitz and Redding (2015) calibrate the gains from trade in a Melitz model where the distribution of firm productivity follows a truncated Pareto; Head et al. (2014) do the same assuming a log-normal distribution.

Figure 1: Distribution of Employment

US | Canada



Exporters vs. Non-Exporters



Exiting vs. Continuing Establishments

Note: Top panel shows the distribution of log employment of exporting and non-exporting establishments in Canada in 1996 and the US in 1997. Bottom panel shows distribution of log employment of exiting and continuing establishments in Canada in 1988 and US in 1987. Exiting plants leave the data between 1988 and 1996 (Canada) or between 1987 and 1997 (US). Continuing plants are in the data in the initial and final years. Figures are based on fitting a normal distribution to the 20th, 50th, and 80th percentiles of the relevant statistics calculated from the Canadian and US manufacturing censuses.

This paper introduces a method to measure the gains from trade that is robust to any distribution of firm productivity and any pattern of selection into exporting and domestic production. Our proposed formula is based on one data moment, the domestic market share of continuing domestic producers, and one parameter, the elasticity of substitution between producers. This formula is essentially an application of the well-known Feenstra (1994) formula, albeit one that is very different from what is typically done in the trade literature. The standard application of Feenstra (1994)'s formula is to calculate *import variety* gains from trade using the expenditure share on continuing imported varieties in all imported varieties as the data moment (e.g., Broda and Weinstein (2006)). Instead, we apply the formula to calculate *overall* gains from trade using the expenditure share on continuing domestic varieties in all varieties as the data moment.

We illustrate our procedure by using Canadian data to measure the welfare effect on Canada of the Canada-US Free Trade Agreement (CUSFTA). We show that our estimate of the Canadian gains from this trade agreement can deviate substantially from the ACR statistic, depending on the values of the elasticity of substitution and the aggregate trade elasticity. We do not know for sure the values of these parameters, but both statistics imply similar welfare gains for the mean parameter values of the elasticity of substitution and the trade elasticity reported in the literature.

Our paper further relates to three sets of papers. First, compared to Melitz and Redding (2015) and Head et al. (2014), our proposed summary statistic works for any distribution of firm productivity and for any pattern of firm entry and exit into exports and production. Second, relative to Hsieh et al. (2020), our focus in this paper is on the overall gains from trade rather than on a decomposition of the foreign and domestic extensive margin responses to trade. Third, Fernandes et al. (2022) and Adao et al. (2020) use firm level data to estimate trade models that allow for flexible extensive margin responses consistent with deviations from iso-elastic import demand. Ours is an ex-post measure of the gains from trade and is silent on the structural parameters of the underlying trade model. In contrast, Fernandes et al. (2022) and Adao et al. (2020)'s method yields valuable structural parameters that can be used to conduct ex-ante evaluations.

The paper proceeds as follows. We first derive a sufficient statistic for the gains from trade that holds for all trade models with CES preferences, including those where the import demand elasticity is not constant and firms do not sort into markets based on productivity only. We then use micro-data from Canadian manufacturing to calculate Canada's welfare gains for the 1988 to 1996 period after CUSFTA was signed.

2 Measuring the Gains from Trade

This section derives our sufficient statistic for the gains from trade liberalization and compares it with other formulas used to quantify welfare in trade settings with CES preferences and an extensive margin response to trade liberalization. We derive this statistic in the context of a generalized Melitz (2003) model where import demand is not necessarily iso-elastic. We do this by allowing the productivity distribution to take any form and by not imposing any restriction on selection into production and exporting.

2.1 Model assumptions and derivation

We assume a representative consumer with CES preferences over differentiated varieties. The production technology of each variety is linear in labor $y(\varphi) = \varphi l(\varphi)$, where φ is the productivity of the firm producing the particular variety. Trade frictions between firms producing in country i and shipping to country j are denoted by $\tau_{ij} > 1$ (we assume $\tau_{jj} = 1$ henceforth). Importantly, we make no assumptions about the entry process and instead just denote by M_{ij} the number of firms from country i that offer goods in country j.[2]

CES utility implies that demand from country j consumers for products offered by firms from country i with productivity φ is given by $q_{ij}\left(\varphi\right) = \frac{p_{ij}(\varphi)^{-\sigma}}{P_j^{1-\sigma}} Y_j$ where p_{ij} the delivered price in country j, P_j and Y_j are price index and nominal income in country j, and $\sigma > 1$ is the elasticity of substitution. We assume monopolistic competition so the profit maximizing price is a constant markup over the marginal cost: $p_{ij}\left(\varphi\right) = \frac{\sigma}{\sigma-1}\frac{w_i \tau_{ij}}{\varphi}$, where w_i is the wage in the producer's country.

Bilateral trade flows can therefore be expressed as a function of average prices, $X_{ij} = M_{ij}\left(\frac{\tilde{p}_{ij}}{P_j}\right)^{1-\sigma} Y_j$, where average prices are in turn a function of average productivities, $\tilde{p}_{ij} = \frac{\sigma}{\sigma-1}\frac{w_i \tau_{ij}}{\tilde{\varphi}_{ij}}$, where $\tilde{\varphi}_{ij}$ is a weighted harmonic mean of productivity.[3]

Consider now a shock to the economy, which causes some firms to exit and others to enter. We focus on trade liberalization in our application but our method really applies to

[2] In Appendix A, we extend the model to allow for intermediate goods, non-traded goods, and heterogeneous elasticities of substitution across industries.

[3] Specifically, $\tilde{\varphi}_{ij} \equiv \left(\int_{\varphi \in \Phi_{ij}} \varphi^{\sigma-1} dG_i\left(\varphi | \varphi \in \Phi_{ij}\right)\right)^{\frac{1}{\sigma-1}}$, where Φ_{ij} is the set of productivities corresponding to all country i firms serving country j and $G_i\left(\varphi | \varphi \in \Phi_{ij}\right)$ is their cumulative distribution.

any shock. We denote by M^c_{ij} the subset of *continuing* firms, defined as firms which are active both before and after the shock. Bilateral trade flows associated with continuing firms can be written as $X^c_{ij} = M^c_{ij}\left(\frac{\tilde{p}^c_{ij}}{P_j}\right)^{1-\sigma} Y_j$, where average prices and average productivity are defined only over this subset of firms, $\tilde{p}^c_{ij} = \frac{\sigma}{\sigma-1}\frac{w_i \tau_{ij}}{\tilde{\varphi}^c_{ij}}$. By definition, there are no changes in the set of continuing firms so that M^c_{ij} remains unchanged and $\tilde{\varphi}^c_{ij}$ changes only if there are within-firm productivity effects (i.e. there are no Melitz-type selection or re-allocation effects on $\tilde{\varphi}^c_{ij}$).

We derive our sufficient statistic by focusing on the domestic market share of *continuing domestic firms*, $\lambda^c_{jj} \equiv \frac{X^c_{jj}}{Y_j}$. Using our expression for X^c_{ij} above, we can express price index changes as $\Delta \ln P_j = \Delta \ln \tilde{p}^c_{jj} + \frac{1}{\sigma-1}\Delta \ln \lambda^c_{jj}$. From our expression for $\tilde{p}^c_{ij}$ above, we know that $\Delta \ln \tilde{p}^c_{jj} = \Delta \ln w_j - \Delta \ln \tilde{\varphi}^c_{jj}$ so that we can write changes in the domestic real wage as $\Delta \ln \frac{w_j}{P_j} - \Delta \ln \tilde{\varphi}^c_{jj} = -\frac{1}{\sigma-1}\Delta \ln \lambda^c_{jj}$. Changes in the domestic real wage are equal to changes in per-capita welfare if labor income is proportional to total income since then $\Delta \ln \frac{w_j}{P_j} = \Delta \ln \frac{Y_j/L_j}{P_j} \equiv \Delta \ln W_j$. This holds, for example, under free entry and we impose this assumption henceforth. We can thus write:

$$\Delta \ln W_j - \Delta \ln \tilde{\varphi}^c_{jj} = -\frac{1}{\sigma-1}\Delta \ln \lambda^c_{jj} \tag{1}$$

We will sometimes refer to (1) as the HLOY welfare statistic. This equation says that anything that affects welfare, other than the productivity of continuing domestic firms, shows up as changes in λ^c_{jj}. One implication of this is that the effect of changes in trade costs on welfare, including the effect of any reallocation and entry and exit induced by the change in trade costs, can be measured by one simple statistic, the change in the domestic market share of continuing domestic firms $\Delta \ln \lambda^c_{jj}$, and one parameter, the elasticity of substitution σ.

We want to make clear three points about our proposed statistic for the gains from trade in equation (1). First, while it captures all welfare effects from domestic net entry and changes in the price or variety of foreign imports when comparing two equilibria, interpreting it as the welfare gains from trade assumes that all of these changes are brought about by trade. This may not be true. For example, in a closed economy our sufficient statistic boils down to $\frac{1}{\sigma-1}\Delta \ln \lambda^c_{jj} = \frac{1}{\sigma-1}\Delta \ln M_{jj} + \Delta \ln \frac{\tilde{\varphi}_{jj}}{\tilde{\varphi}^c_{jj}}$, which is simply the gains from entry of new domestic varieties net of the losses from domestic exit.

Second, even if the changes underlying computation of equation 1 are driven by trade shocks, we do not know whether they are due to changes in *trade costs*, e.g. import tariff cuts negotiated under CUSFTA. For example, differential productivity growth (domestic vs. foreign) or changes in the fixed cost of exporting can also affect welfare through domestic net entry and changes in the price and variety of foreign imports. Thus while we apply our formula to data on observed trade flows and domestic firm selection during the CUSFTA period in section 3, we acknowledge that these data potentially reflect factors other than reductions in bilateral Canada-US trade costs. These points apply to any welfare comparison across observed equilibria, and highlight that our main contribution is towards measurement of welfare changes in trade models with selection rather than toward identification of trade or trade cost shocks.

Third, while we derived our sufficient statistic in a generalized Melitz (2003) model, it should be clear from our derivations that it holds in all models satisfying $X_{ij} \propto M_{ij} \left(\frac{\tilde{p}_{ij}}{P_j}\right)^{1-\sigma} Y_j$, $\tilde{p}_{ij} \propto \frac{w_i \tau_{ij}}{\tilde{\varphi}_{ij}}$, and $w_j L_j \propto Y_j$. For example, where the formula by ACR holds for an Eaton and Kortum (2002) model with Frechet productivity, our formula holds in a generalized Ricardian model with an arbitrary productivity distribution if M_{ij} is reinterpreted as the number of goods shipped from country i to country j.

2.2 Comparison to other welfare sufficient statistics

2.2.1 Relation to Feenstra (1994)

The formula in equation (1) is essentially an application of Feenstra (1994), albeit one that is very different from what is typically done in the literature. While prior papers such as Broda and Weinstein (2006) use Feenstra (1994) to measure the *import variety* gains from trade, we apply it to measure the *overall* gains from trade. Feenstra (1994) decomposes price index changes ($\Delta \ln P$) into a term capturing changes in the prices of continuing goods ($\sum_{i \in I^c} \bar{\mu}_i^c \Delta \ln p_i$, where I^c is a subset of continuing goods and $\bar{\mu}_i^c$ are Sato-Vartia weights) and a residual commonly thought of as capturing changes in the set of available goods (the "Feenstra ratio" $\frac{1}{\sigma-1} \Delta \ln \lambda^c$). However, the set I^c can be defined to include any subset of goods available in both periods in which case the Feenstra ratio term *also* captures the welfare effects of changes in the prices of any continuing goods excluded from the chosen set of continuing goods I^c. This includes, for example, changes in the prices of continuing imported goods that result from changes in iceberg trade costs or terms of trade.

Our statistic essentially boils down to choosing the subset of continuing goods that are produced in the home country and recognizing that in many trade models the domestic real wage is fixed in terms of these goods, making additional micro data on prices and domestic wages (or calculation of Sato-Vartia weights) unnecessary to calculate welfare changes. Intuitively, the market share of continuing domestic goods measures the net effect of all the margins of adjustment triggered by a change in trade costs. In a model with only adjustment on the intensive margin, the share of continuing domestic goods falls when a reduction in trade costs lowers the prices of foreign goods. In models that also have adjustment on the extensive margin, the share of continuing domestic goods also falls with more and better entering foreign varieties and rises with more and better exiting domestic varieties.

Note that in principle our approach allows a researcher to choose *any* set of continuing goods for which the domestic real wage can be directly measured, or for which changes are expected to be zero. The "Feenstra ratio" in our statistic then captures all welfare relevant changes in variety and/or prices for other goods, including those related to within-firm productivity changes, within-firm product variety changes, changes in quality/taste, and markup changes. For example, if one specifies the set of firms in I^c to include only continuing firms in industries that are not expected to be affected by tariff cuts under CUSFTA, any welfare-relevant changes affecting continuing firms in industries with high tariff cuts will be captured by changes in their market share relative to the firms in I^c (see Hsieh et al. (2020) for some examples). The available CUSFTA data will also allow us to implement this variant of our formula in the next section.

More generally, the appropriate choice when defining the set of continuing varieties for implementing our welfare statistic will depend on (a) the nature of the data on prices and quantities that is available, particularly the level of aggregation, (b) which continuing products, plants or firms have domestic real wage changes that are expected to be invariant to a trade shock or that can be quantified directly, and (c) the desirability of choosing a larger set of continuing varieties to minimize the effect of measurement error and idiosyncratic firm outcomes on the measurement of aggregate welfare.[4] Our benchmark implementation of equation (1) in the CUSFTA setting reflects the availability of plant-level data on sales in Canada, the implications of many common trade models that the domestic real wage in terms of continuing domestic producers is invariant to trade shocks, and the large share of domestic consumption that comes from continuing domestic plants.

2.2.2 Relation to Gains from Trade formulas

Our statistic can also be seen as a generalization of other formulas previously proposed in the literature to quantify the total gains from trade such as those used in Arkolakis et al. (2012), Melitz and Redding (2015) and Head et al. (2014). While we derive our formula based on bilateral trade flows associated with continuing domestic firms, $X_{jj}^c = M_{jj}^c \left(\frac{\tilde{p}_{jj}^c}{P_j}\right)^{1-\sigma} Y_j$, the formulas in Arkolakis et al. (2012), Melitz and Redding (2015) and Head et al. (2014) start from bilateral trade flows associated with *all* domestic firms, $X_{jj} = M_{jj} \left(\frac{\tilde{p}_{jj}}{P_j}\right)^{1-\sigma} Y_j$. Following the same steps we used to derive our formula yields the following expression:

$$\Delta \ln W_j - \Delta \ln \tilde{\varphi}_{jj} = -\frac{1}{\sigma - 1} \left(\Delta \ln \lambda_{jj} - \Delta \ln M_{jj}\right)$$

This formula is not immediately implementable since $\Delta \ln \tilde{\varphi}_{jj}$ includes selection effects and $\Delta \ln M_{jj} \neq 0$. In contrast, the productivity term in the HLOY welfare statistic $\Delta \ln \tilde{\varphi}_{jj}^c$ includes only within-firm productivity changes, and the number of continuing domestic firms M_{jj}^c in the HLOY statistic is obviously constant.

Melitz and Redding (2015) make progress by imposing the additional assumption that there is a unique domestic productivity cutoff φ_j^d below which domestic firms exit the domestic market. Recalling the definition of $\tilde{\varphi}_{jj}$ and using the relationship $M_{jj} = M_j^e \left[1 - G_j\left(\varphi_j^d\right)\right]$, where M_j^e is the number of entrants paying a fixed cost to draw a productivity from the cumulative distribution $G_j(\varphi)$, the above formula can be expressed as in equation (32) of

[4] For example, while our statistic could theoretically be applied at the level of individual firms, changes in the overall market share of individual firms are much more likely to be driven by firm-specific demand or productivity shocks than differential trade shocks for one firm versus all of the others.

Melitz and Redding (2015):

$$\Delta \ln W_j = -\frac{1}{\sigma-1}\Delta \ln \lambda_{jj} + \frac{1}{\sigma-1}\Delta \ln M_j^e + \frac{1}{\sigma-1}\Delta \ln \left[\int_{\varphi_j^d}^{\varphi_j^{max}} \varphi^{\sigma-1} dG_j(\varphi)\right] \tag{2}$$

The challenge in implementing equation (2) is that it requires that we measure changes in M_j^e, φ_j^d, and the shape of the cumulative distribution $G_j(\varphi)$. Melitz and Redding (2015) and Head et al. (2014) both implement versions of this global welfare statistic for truncated Pareto and log-normal productivity respectively but do so by first estimating and calibrating the parameters of the full structural model, which obviates the need for a sufficient statistic for welfare.

For small trade shocks, a local approximation of equation (2) can be derived using the properties $\Delta \ln W_j = \Delta \ln \varphi_j^d$ and $\Delta \ln \int_{\varphi_j^d}^{\varphi_j^{max}} \varphi^{\sigma-1} dG_j(\varphi) = -\gamma(\varphi_j^d)\Delta \ln \varphi_j^d$, where $\gamma(\varphi_j^d)$ is the hazard function of log firm size for the cumulative distribution $G_j(\varphi)$ evaluated at φ_j^d.[5] Substituting these into equation (2) for small changes and re-arranging yields:

$$\Delta \ln W_j = -\frac{1}{\sigma - 1 + \gamma(\varphi_j^d)}\left(\Delta \ln \lambda_{jj} - \Delta \ln M_j^e\right) \tag{3}$$

This local approximation of welfare changes, which applies for any distribution of firm productivity, appears in Arkolakis et al. (2009) and was also used by Melitz and Redding (2015) and Head et al. (2014). With an estimate of σ and a local estimate of $\gamma(\varphi_j^d)$, one could use equation (3) to approximate welfare gains from a small trade shock without knowledge of the full cumulative distribution $G_j(\varphi)$. Alternatively, Melitz and Redding (2015) show that the term $\sigma - 1 + \gamma(\varphi_d)$ is equal to the difference between a "partial" trade elasticity and the hazard differential between the domestic and foreign export productivity cutoffs.[6]

Note that regardless of the data and methods used to estimate $\sigma - 1 + \gamma(\varphi_j^d)$, the effects of changes in λ_{jj} on welfare can only be estimated locally unless $\gamma(\varphi_j^d)$ is constant. Furthermore,

[5] Although the local welfare gain is directly given by $\Delta \ln W_j = \Delta \ln \varphi_j^d$, which is much simpler than the local welfare formula in equation (3), we are not aware of any attempts to implement this with data, perhaps because the theoretical notion of a domestic productivity cutoff is less clear cut in real world applications.

[6] A partial trade elasticity is one that reflects both intensive margin $(\sigma - 1)$ and extensive margin responses to a change in trade costs but holds the relative wage and price index fixed; this is precisely the elasticity that is estimated in gravity equations with location and destination fixed effects. Bas et al. (2017) propose an alternative to gravity estimation for this parameter based on micro-data leveraging the link between the hazard function and the mean-to-min ratio of sales in each market.

an estimate of $\Delta \ln M_j^e$ is still needed to implement equation 3. Arkolakis et al. (2012) show that $\Delta \ln M_j^e = 0$ and $\gamma(\varphi_j^d) = \theta - \sigma - 1$ when firm productivity has a Pareto distribution with shape parameter θ. This greatly simplifies the welfare formula in equation (3) and allows integration of local changes up to global changes, yielding their global welfare formula:

$$\Delta \ln W_j = -\frac{1}{\epsilon} \Delta \ln \lambda_{jj} \tag{4}$$

where ϵ is an estimate of the partial trade elasticity and can alternatively be derived from the shape of the firm productivity distribution. This formula has the advantage of being easy to implement given observed changes in λ_{jj}, requiring only one parameter that can be estimated or calibrated in several ways. It also has the advantage of being a global formula that can be applied to estimate counter-factual welfare gains from a specific scenario, autarky, which sets $\lambda_{jj} = 1$.

Our sufficient statistic in equation (1) can be viewed as a generalization of the formula by ACR. Recall that ACR require four "model primitives" - (i) Dixit-Stiglitz preferences, (ii) one factor of production, (iii) linear cost functions, and (iv) perfect or monopolistic competition - and three "macro-level restrictions" - (i) trade is balanced, (ii) aggregate profits are a constant share of aggregate revenues, and (iii) the import demand system is iso-elastic (with constant trade elasticity ϵ). Their model primitive (i) immediately implies our first key equation $X_{ij} \propto M_{ij} \left(\frac{\tilde{p}_{ij}}{P_j}\right)^{1-\sigma} Y_j$, while their model primitives (i)-(iv) together yield our second key equation $\tilde{p}_{ij} \propto \frac{w_i \tau_{ij}}{\tilde{\varphi}_{ij}}$. Our third key equation $w_j L_j \propto Y_j$ follows from their macro-level restrictions (i) and (ii) so that we effectively relax their macro-level restriction (iii).

To see the connection between the ACR and HLOY formulas, note that our formula (abstracting from within-firm productivity changes) can be written as follows:

$$\Delta \ln W_j = -\frac{1}{\sigma - 1} \Delta \ln \lambda_{jj} - \frac{1}{\sigma - 1} \Delta \ln \frac{X_{jj}^c}{X_{jj}} \tag{5}$$

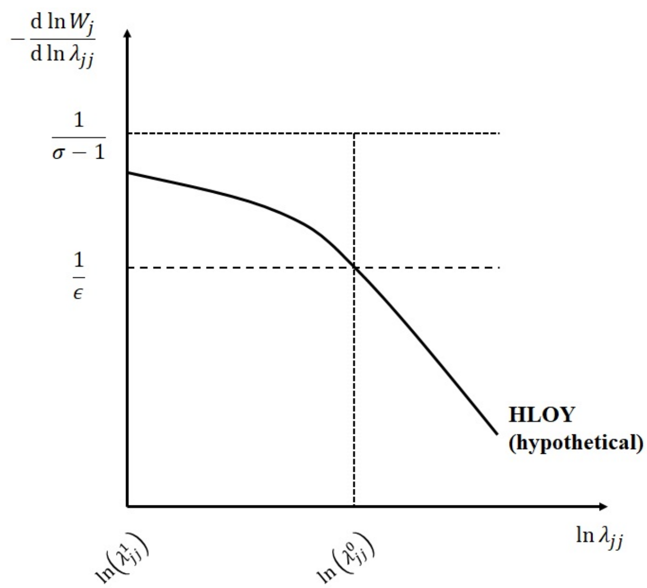
This version of the formula highlights that without changes in the share of continuing domestic products in total domestic sales (the second term on the right hand side), our formula is identical to the ACR formula in the no extensive margin Armington case where $\epsilon = \sigma - 1$.

We can also use this expression to show the conditions under which our formula and the ACR formula yield identical welfare gains when there is an extensive margin. Setting equations 4 and 5 equal and re-arranging yields the condition:

$$\frac{1}{\sigma-1}-\frac{1}{\epsilon}=-\frac{1}{\sigma-1}\frac{\Delta\ln\frac{X_{jj}^{c}}{X_{jj}}}{\Delta\ln\lambda_{jj}}$$

When import demand is iso-elastic (e.g. Melitz-Pareto), both our formula and the ACR formula yield identical results for the change in welfare, which implies strict global proportionality between (negative) percent changes in the share of continuing domestic firms in total domestic firm sales and percent changes in the domestic expenditure share. The ratio of these changes depends only on the difference between the constant trade elasticity and the intensive margin elasticity.

Figure 2: Variation in elasticities and welfare



Note: Figure plots the elasticity of welfare with respect to the domestic expenditure share for cases where this elasticity is constant (e.g. Armington with $1/(\sigma-1)$ and Melitz-Pareto with $1/\epsilon$) and for a hypothetical economy that satisfies the HLOY conditions but does not feature iso-elastic import demand.

When import demand is not iso-elastic but the conditions for our formula are satisfied, the bias in the ACR statistic depends on the relationship between the parameters σ and ϵ and the data moments in the equation above. Figure 2 illustrates one scenario for a hypothetical economy (labeled HLOY) that does not feature iso-elastic import demand. The figure plots the local elasticity of welfare with respect to the domestic expenditure share against the log domestic expenditure share for this economy. Welfare gains can be derived as the area under the curve.

The welfare elasticity is constant under the iso-elastic import demand assumption and equal to $\frac{1}{\sigma-1}$ in the no extensive margin case and $\frac{1}{\epsilon}$ with an extensive margin. As constant local welfare elasticities are effectively global elasticities, global welfare gains can be computed as the area of the rectangle between any two values of λ_{jj}. For our hypothetical HLOY economy, the local elasticity of welfare is identical to $\frac{1}{\epsilon}$ in the vicinity of λ^0_{jj}, implying that our formula and ACR deliver identical local welfare gains because $\frac{1}{\sigma-1} - \frac{1}{\epsilon} = \frac{1}{\sigma-1}\frac{d\ln\frac{X^{c0}_{jj}}{X_{jj}}}{d\ln\lambda^0_{jj}}$. However, welfare gains calculated using the ACR formula will be biased down (up) when evaluating global welfare changes with domestic expenditures below (above) λ^0_{jj}.[7]

To recap, the ACR formula, given that it does not need data on continuing/exiting varieties, is likely to be useful when either (a) there are small changes in λ_{jj} and the local import elasticity is known or (b) there are large (or hypothetically large, e.g. autarky) changes in λ_{jj} and we are confident that import demand is iso-elastic with a known elasticity. However, when $\frac{X^c_{jj}}{X_{jj}}$ is observed and there is confidence in the estimate of σ, our formula works for global changes in λ_{jj} under weaker assumptions and could imply welfare gains below or above those implied by the ACR formula for particular values of ϵ and σ (as depicted in Figure 2).

3 Application to the Canada-US Free Trade Agreement

3.1 Data

The Canada-US Free Trade Agreement (CUSFTA) was signed on January 2, 1988 and mandated the elimination of bilateral import tariffs in manufacturing, phased-in over a ten-year period starting on January 1, 1989. By 1996, Canadian tariffs on US imports had fallen

[7] Note that even when demand is not iso-elastic, there is some "average" ϵ between any two given values of λ_{jj} that could be plugged into the ACR formula such that it would deliver the same unbiased estimate of welfare gains as our formula. However, the appropriate value of ϵ would be different for each scenario and may not correspond to an estimate from a gravity equation. One would instead have to rely on either parametric assumptions about productivity (as in Melitz and Redding (2015), Head et al. (2014), and Fernandes et al. (2022)) or non-parametric estimation (as in Adao et al. (2020)).

from an average of 8% (equivalent to a 16% effective tariff rate) to about 1%. US tariffs on Canadian imports fell from about 4% in 1988 to below 1% during this period. Bilateral manufacturing trade almost doubled during this period and the agreement represents a large shock for Canada's manufacturing sector as about 70% of its trade is conducted with the US. Given the size of the CUSFTA shock, this period is likely to be informative about the size and nature of domestic and foreign extensive margin effects induced by trade liberalization and the consequent welfare gain.

To implement our formula we need information on domestic sales of continuing firms in Canada before and after CUSFTA came into force. We use the micro-data from Canada's Annual Survey of Manufacturing Establishments, so what we call "firms" going forward are really manufacturing plants and we are less concerned with how mergers might affect our estimates of exit.[8] This survey covers all but the very smallest Canadian manufacturing establishments with sales below $30,000 Canadian dollars. Our analysis focuses on the 1978-1988 and 1988-1996 time periods. We consider 1978-1988 as the "pre-CUSFTA" period and 1988-1996 as the "post-CUSFTA" period.[9] The information we use from these data include establishment id, exports, and sales. In each of the two time periods, we use the establishment id to identify firms as entrants, exiters, and continuing firms. We define an *entrant* as an establishment not in the data at the *beginning* of the time period, an *exiter* as an establishment not in the data at the *end* of the time period, and a *continuing* establishment as one that was present in the data at the beginning and at the end of a time period.

We supplement these data on domestic sales by Canadian manufacturing establishments with data on US manufacturing exports to Canada, which allow us to construct λ^c_{jj}. In Appendix Table C1 we also report results that assume manufacturing imports are equal to Canadian manufacturing exports (measured using the same Canadian establishment data mentioned above). The results are quite similar which suggests that while neither balanced trade nor exclusive trade with the US hold exactly in the data, they are reasonable approximations.[10] Note that our analysis uses data for the manufacturing sector and ignores

[8]This survey was initially called the Census of Manufactures and is now known as Annual Survey of Manufactures.

[9]We also chose these time periods because Statistics Canada officials indicated to us that the years with the best sampling frame are 1978, 1988, and 1996.

[10]Canada had a trade surplus with the US during this period but it was fairly stable. The ratio of Canadian

non-manufacturing trade both because this was excluded from CUSFTA liberalization and because panel establishment data are not available for raw material industries.[11]

3.2 Application to Canada's welfare gains during CUSFTA period

We now apply our sufficient statistic (1) to measure Canadian welfare gains with a flexible extensive margin during the 1988-1996 post-CUSFTA period. The key parameter is the elasticity of substitution across varieties σ. Based on several empirical estimates, we pick $\sigma = 3.72$ as our baseline.[12] We also present data on the pre-CUSFTA period (1978-1988) and the differenced data for comparison, as these may be informative about trends or firm dynamics in Canada given that the earlier period did not feature major trade shocks.[13] Given the size of the CUSFTA shock we view this simple before-after analysis as informative about the welfare effects of CUSFTA, but will also present results comparing more and less liberalized industries that are similar to the industry difference-in-difference approach to identifying causal effects of trade liberalization.

Table 1 presents the key data moments that inform our welfare statistic and their magnitudes during the pre- and post-CUSFTA periods. Row 1 in Table 1 shows the change in the share of continuing domestic firms as a share of all domestic firms. This increased from 2.97% before CUSFTA (1978-1988) to 12.03% after CUSFTA (1988-1996). Equation (1) says that the key statistic is the change in domestic sales of continuing domestic firms as a share of *total* sales in the domestic market. This is simply the sum of the change in sales of continuing domestic firms as a share of all domestic firms shown in row 1 and the share of domestic firms in total sales. The latter, shown in Row 2, indicates that the market share of domestic firms fell massively – almost 26% – in the eight years after CUSFTA went into effect. This decrease is particularly notable relative to the very small (0.69%) increase in the market share of domestic firms in the period prior to CUSFTA. The last row in Table 1 shows $\Delta \ln \lambda_{jj}^{c}$ as

goods exports to the US over goods imports from the US rose from 1.14 to 1.16 between 1988 and 1996, see https://www.census.gov/foreign-trade/balance/c1220.html#1988.

[11]Raw materials (based on the WITS classification) made up 15.4% of Canada's imports and 8.5% of its exports in 1989, declining to 12.7% and 8.0% respectively by 1996, so excluding these has only minor effects on welfare gains.

[12]See Appendix B for more details.

[13]As the pre-period is 10 years and the CUSFTA period is 8 years, we multiply pre-period changes by 8/10 to make them more comparable.

the sum of rows 1 and 2. The share of continuing domestic firms in total sales in the Canadian market fell by 13.88% in 1988-1996, which can be compared to an increase of 3.66% in the period prior to CUSFTA.

The next to last row presents estimates of our welfare statistic using our baseline value of $\sigma = 3.72$ in Table B1. For comparison, the last row shows the ACR welfare statistic, where we assume $\epsilon = 4.71$.[14] In column 2 we report the welfare gains during the post-CUSFTA period, which are 5.10% using our statistic and 5.50% using the ACR statistic. In column 3 we report the difference between welfare gains during the post-CUSFTA period and the pre-CUSFTA period, based on the idea that this may control for pre-existing trends in import and domestic exit dynamics. The magnitude of welfare gains are only slightly larger given the limited changes in λ_{jj}^c and λ_{jj} during the pre-period, but now the ACR statistic is slightly lower (5.65%) than our statistic (6.45%).

In online Appendix A, we show how our welfare formula can be extended to the existence of non-tradables as well as intermediate goods. To implement this, we only need data on the expenditure share on manufacturing and the intermediate input share. Canada's manufacturing expenditure share during this period was about 0.32 and the share of value added in gross production was about 0.5, which suggests that the overall welfare gains are only 64% as large as this ($0.32/0.5 = 0.64$) using both of the adjustments discussed earlier but about twice as large for the manufacturing sector in isolation. Also note that the negative welfare value reported for the pre-period only implies negative welfare for the HLOY statistic under the assumption that there is no increase in the domestic real wage in terms of the output of continuing domestic firms; in reality this could be changing for reasons related and unrelated to CUSFTA, an issue we revisit in the next section.

Overall, the welfare gains are remarkably similar using either formula for the elasticity estimates we used, but of course the deviation between the welfare changes implied by the formulas depends importantly on the elasticities used. In Figure 3 we plot the welfare gains based on the HLOY and ACR statistics for different values of $\sigma - 1$ and ϵ. As can be seen, welfare gains are quite similar for either statistic when using the central elasticity estimates from the literature but could be quite different depending on one's preferred elasticity. In

[14] See Appendix B for a discussion of the empirical studies behind our choice of the baseline value of ϵ.

Table 1: Revenue Shares of Canadian firms and Implied Welfare Changes

	1978–1988	1988–1996	Difference
$\Delta \ln X^c_{jj}/X_{jj}$ [1]	2.97%	12.03%	9.06%
$\Delta \ln \lambda_{jj}$ [2]	0.69%	-25.91%	-26.61%
$\Delta \ln \lambda^c_{jj}$ [3]	3.66%	-13.88%	-17.55%
HLOY Welfare Gains $\sigma = 3.72$	-1.35%	5.10%	6.45%
ACR Welfare Gains $\epsilon = 4.71$	-0.15%	5.50%	5.65%

[1] Change in domestic revenues of *continuing* Canadian firms/all Canadian firms.
[2] Change in total domestic sales of *all* Canadian firms/total sales in Canadian market using US export data.
[3] Change in total domestic revenues of *continuing* Canadian firms/total sales in Canadian market.

Note: Column 1 (1978-1988) imputes the share or changes over 8 years based on the change over 10 years. Calculated from micro-data of Canada's Annual Survey of Manufacturing. See text for details.

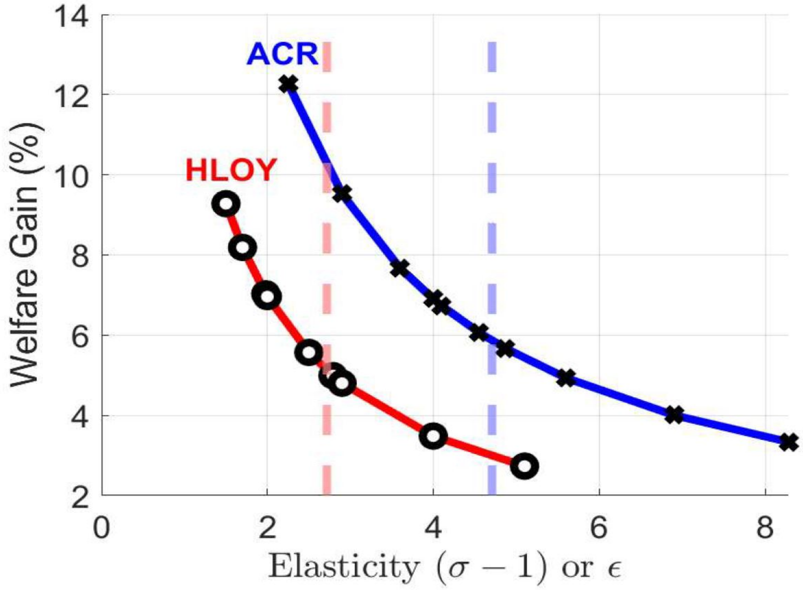
particular, elasticities chosen to match the firm size/productivity distribution under Zipf's law (which implies $\epsilon/(\sigma-1)$ close to 1 and hence $\epsilon \approx \sigma - 1$) would imply a substantially larger upward bias of the ACR statistic relative to the HLOY statistic given the size of the $\Delta \ln X^c_{jj}/X_{jj}$ term in our data.[15] However, moments of the firm size distribution that do not account for substantial overlap in the size/productivity distributions of exporters and non-exporters seem unlikely to be informative about the magnitude of firm selection effects under a trade shock; an advantage of our statistic in this respect is that it uses a data moment ($\Delta \ln X^c_{jj}/X_{jj}$) that accounts for arbitrary patterns of firm entry and exit.

3.3 Welfare changes from continuing domestic firms

So far we computed welfare gains during the post-CUSFTA period using changes in the revenue share of domestic continuing establishments, which provides a valid measure of overall welfare gains holding the value of these establishments (i.e. the real wage of workers defined in terms of their output) constant. While the original Melitz model and the models analyzed in Arkolakis et al. (2012) have this feature, there are two distinct reasons why there could be

[15] Di Giovanni and Levchenko (2013) make a related point in the context of comparing welfare gains from an Armington model versus a Melitz-Pareto model with an extensive margin and Zipf's law.

Figure 3: Welfare gains from CUSFTA



Note: Figure shows welfare change estimates for the cumulative 8-year period after CUSFTA, relative to the 8-years before CUSFTA. Estimated based on our sufficient statistic are displayed in red with circle markers and estimates from the ACR are displayed in blue with a cross as marker. The x-axis measures the elasticity used, which is $\sigma - 1$ for our welfare statistic and ϵ for ACR. See text for details. Each marker is the value of the sufficient welfare statistics with an elasticity from a different empirical study. The list of empirical studies used for these elasticities can be found in Appendix Tables B1 for σ and Table B2 for ϵ.

welfare changes related to within-firm effects. First, models with exogenous firm productivity could still feature changes in domestic markups or product variety/quality for these firms. Second, endogenous firm productivity could also change the real wage of workers defined in terms of the output of continuing firms.

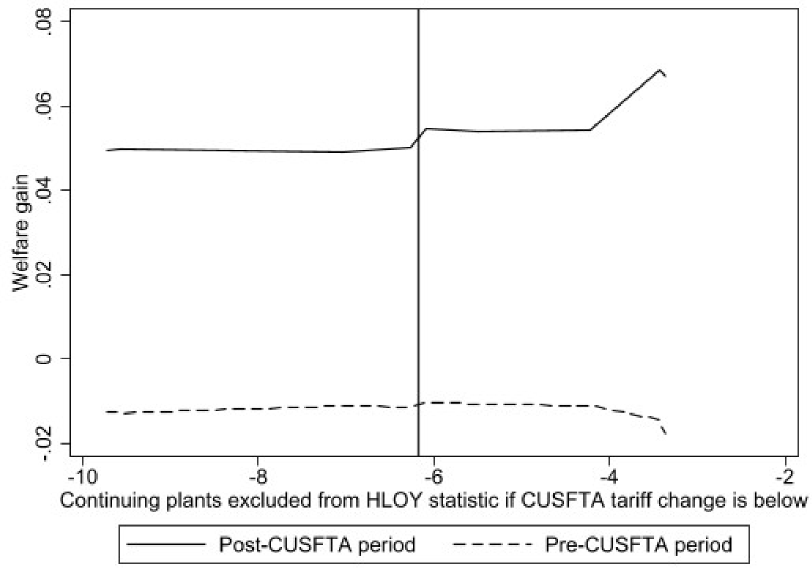
While our formula in equation (1) already accounts for these issues when it comes to continuing foreign firms, they are difficult to address directly for the continuing domestic firms without more detailed data on individual products and prices to measure $\tilde{p}^c_{jj}$ (or $\tilde{\varphi}^c_{jj}$ when only within-firm productivity is allowed to vary). We can partly address this by noting that our formula can capture welfare gains associated with changes in the value to consumers of *some* continuing domestic establishments, provided one specifies a restricted set of continuing domestic establishments that have a constant real wage defined in terms of their output. By re-calculating equation (1) using the domestic revenue share of this restricted set, any increase in the value of the *other* continuing domestic establishments will be captured by the formula. Intuitively, if we observe a larger fall in λ^c_{jj} for the restricted set of continuing firms than the full set of continuing firms, the increase in relative domestic revenues for the *other* continuing firms captures any additional welfare effects from changes in their productivity, markups, quality, or product variety relative to the restricted set of continuing firms.

In our setting, a natural way to specify this restriction is to use only domestic continuing establishments in sectors that had low initial tariffs in 1988 (and hence minimal tariff reductions due to CUSFTA). Figure 4 presents results from an analysis along these lines. When we split our 22 two-digit industries by above and below median import tariff cuts (represented by the vertical line) and define our continuing firm share using only continuing firms in industries where tariff cuts were below the median tariff cut, we find that welfare gains in the post-CUSFTA period are slightly larger but close to our estimates reported in Table 1. The gains get slightly larger moving to the right as we further restrict continuing firms to the industries with only the smallest tariff cuts, and slightly smaller as we expand the set of continuing firms to include industries with all but the largest tariff cuts. When all continuing domestic firms are included welfare gains converge to our estimate in Table 1. Overall, this analysis suggests that the magnitude of within-domestic firm welfare gains attributable to CUSFTA tariff cuts – the additional welfare gains over this period above and beyond those identified in Table 1 – are plausibly in the range of 0-2% when focusing on the post-CUSFTA period and 0-3% when accounting for pre-CUSFTA trends.

Note that in principle this approach could be extended along dimensions other than the size of industry tariff cuts. For example, if one believed that the productivity of exporting firms rises due to trade liberalization, one could restrict the sample to continuing establishments that do not export, thereby capturing any additional welfare gains arising from an increase in the value of continuing exporting firms relative to continuing non-exporters. If there is a specific set of continuing establishments for which changes in the relevant factors – markups, productivity, product variety, quality – could be measured directly, this would be a natural choice for the restricted set of establishments. The only caveat is that, as mentioned in section 2.2.1, looking at changes in the revenue share for too small of a set of firms is likely to confound the aggregate effects of trade liberalization on prices and variety that our statistic is aimed at capturing with idiosyncratic firm-level shocks to productivity and demand.

Our results here can be compared to several estimates of changes in within-firm produc-

Figure 4: Welfare gains including (some) within-plant gains



Note: Figure shows welfare change estimates for the cumulative 8-year period after CUSFTA (solid line) and 10-year period before CUSFTA (dashed line, converted to 8-year basis). Estimates are based on our sufficient statistic with $\sigma = 3.72$ but with different restrictions on the set of continuing firms. From left to right, we shrink the set of continuing firms to only include those firms in industries with tariff cuts smaller than the number on the x-axis (percentage point tariff reductions). Vertical line represents the CUSFTA import tariff cut for the median 2-digit Canadian industry.

tivity during this period. An important caveat is that changes in the value of continuing domestic firms in terms of domestic wages may be distinct from typical measures of firm productivity in the literature. Firm productivity is often measured using revenue or value added per worker but in a canonical Melitz model revenue and value added per worker are equalized across firms in equilibrium. These measures also potentially confound export participation effects (e.g. a firm can increase its value added per worker by selling higher prices or quantity abroad) with increases in the value of the firm to domestic consumers. Deflating by an aggregate or industry-level output price index may also fail to resolve this issue depending on the type of adjustments that are accounted for by statistical authorities. Beyond productivity, changes in within-firm domestic markups, product variety, and product quality may or may not be adequately captured by these real revenue per worker or value added per worker measures.

With these caveats, our data can be used to directly estimate changes in revenue or value added per worker during the 1978-1988 and 1988-1996 periods for continuing domestic firms.

We deflate these changes using the July Industrial Product Price Index (which measures producer prices in Canada). Converted to a similar 8 year basis, real revenue per worker rose 12.0% in the pre-CUSFTA period versus 15.4% in the post-CUSFTA period, while real value added per worker rose 14.7% in the pre-CUSFTA period and 13.6% in the post-CUSFTA period. These changes are similar in magnitude to those calculated by Lileeva (2008) for the set of firms common to 1980 and 1996 using 4-digit industry price deflators; Lileeva finds a 14.5% increase in real value added per worker during the pre-CUSFTA period and 10.8% increase during the post-CUSFTA period. Changes in real value added per worker imply some deceleration in continuing firm productivity growth during the CUSFTA period, while changes in revenue per worker are more consistent with an acceleration of productivity growth. Lileeva (2008) and Melitz and Trefler (2012) use cross-sectional variation in tariff cuts across industries and firms to provide a causal measure of changes in within-firm productivity due to CUSFTA tariff cuts. Both papers conclude that most of the growth in within-firm productivity is driven by continuing and new Canadian exporters, with the increase caused by CUSFTA tariff cuts ranging between 4% and 5.4%. Altogether, these studies and our own analysis suggest that within-firm productivity growth could be about as important as the other sources of gains from trade during this period.

3.4 Were these welfare gains caused by CUSFTA tariff cuts?

Our statistic measures welfare gains from changes in the set of domestic and foreign varieties and changes in the prices of foreign varieties, relative to continuing domestic varieties. We applied our statistic to the post-CUSFTA period and found large welfare gains during this period, substantially larger than during the pre-CUSFTA period. However, we acknowledge that other shocks, both domestic and foreign, could have driven the changes in our statistic, particularly if they varied substantially between the pre- and post-CUSFTA period. One way we can assess the extent to which movements in our statistic are being driven by tariff cuts under CUSFTA is to compare changes for more and less liberalized industries, in the spirit of Trefler (2004) and other papers, with less liberalized industries serving as a "control" group or counter-factual.

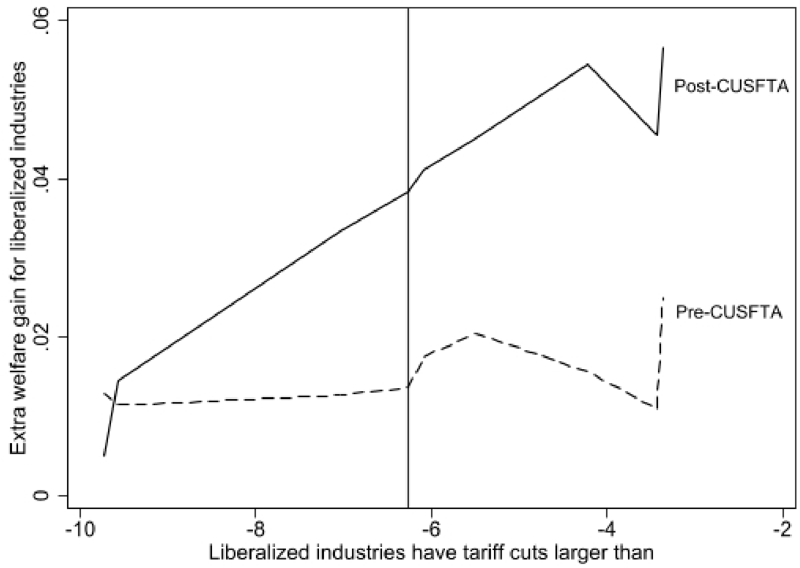
We explore this in Figure 5, where we plot the difference in welfare gains for liberalized (high tariff cut) industries versus control (low tariff cut) industries for the post-CUSFTA and pre-CUSFTA period using our welfare statistic.[16] The vertical line coincides with splitting the 2-digit industries based on the median tariff cuts, and moving from left to right we add industries with smaller tariff cuts to the liberalized group and remove them from the control group. The graph reveals two key points. First, our welfare statistic does not display any notable pre-trends when comparing industries with larger and smaller tariff cuts under CUSFTA. Second, industries with higher tariff cuts have substantially higher welfare gains than those with lower tariff cuts, suggesting that most of the changes in welfare we measure with our statistic during the post-CUSFTA period are in fact driven by the CUSFTA tariff cuts themselves rather than other foreign shocks or macroeconomic forces that would have similar effects on industries with high versus low tariff cuts.

4 Conclusion

We propose a new sufficient statistic to measure ex-post welfare gains in trade models for which the import demand system is not necessarily iso-elastic. This includes a Ricardian model of trade with an arbitrary distribution of productivity and a Melitz model with any pattern of selection into exporting and production as well as any distribution of productivity. The statistic is simple to calculate, as it is just a function of one data moment, the market share of continuing domestic firms, and one parameter, the elasticity of substitution across varieties. When applied to the CUSFTA liberalization period, our statistic indicates an approximately 5.1% increase in Canadian welfare due to the combination of net domestic exit, net foreign entry and cheaper foreign varieties. These gains are only slightly lower than those implied using the ACR statistic when both statistics are implemented using typical elasticity estimates from the literature, which suggests that despite substantial deviations between a textbook Melitz-Pareto model and the firm selection resulting from a large intra-industry trade shock, the bias from applying the ACR statistic can be small for reasonable parameter values.

[16]For this exercise we remove the auto industry (Canadian SIC 32) from the sample as it is difficult to quantify the relevant tariff cut. Under the Autopact agreement that existed for decades prior to CUSFTA, Detroit automakers received tariff free access to the Canadian market subject to local content requirements. CUSFTA expanded this tariff-free access to non-Detroit automakers subject to similar local content requirements, representing a large tariff cut for many European and Asian automakers producing in the United States but a zero tariff cut for Detroit automakers.

Figure 5: Extra welfare gains for liberalized industries



Note: Figure shows the difference in welfare gains for liberalized industries versus others for the cumulative 8-year period after CUSFTA (solid line) and 10-year period before CUSFTA (dashed line, converted to 8-year basis). Estimates are based on our sufficient statistic with $\sigma = 3.72$ but with different thresholds for defining "liberalized" industries. From left to right, we add industries with smaller tariff cuts to the group of "liberalized" industries (and remove them from the control group). The vertical line represents the CUSFTA import tariff cut for the median 2-digit Canadian industry.

While our proposed statistic provides a more robust way to measure welfare gains in trade models with an extensive margin, there are at least three limitations. First, it does not measure the potential effect of trade liberalization on productivity growth among incumbent domestic firms, except when applied to a restricted set of firms that can be viewed as largely exempt from trade liberalization. Second, the statistic by itself does not tell us what fraction of the implied welfare change is due to changes in trade costs. These limitations are common to other approaches that have been proposed in the literature and highlight the challenge of applying statistics derived from models assuming fixed productivity distributions and well-identified trade cost comparative statics to real world data from trade liberalization episodes. However, we find some support for a causal interpretation based on a comparison of more to less liberalized industries. A third limitation of our statistic is that it can only be applied to measure ex-post welfare gains, and cannot tell us the gains from counter-factual changes in trade costs such as a hypothetical liberalization scenario or a hypothetical return to autarky. This is because our approach leverages data on observed entry and exit, rather than predicting extensive margin changes using stronger assumptions about the distribution of firm productivity and nature of selection or more detailed modeling that could allow for extrapolation outside of observed firm selection.

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Online Appendix

(Not for publication)

A Model Extensions

Similar to the analysis in Arkolakis et al. (2012) and Hsieh et al. (2020), the Melitz framework analyzed here can be generalized along certain dimensions with only small intuitive changes in the welfare formula. For example, suppose consumers spend a share $1-\mu_j$ of their income on non-traded goods produced under perfect competition, constant returns, and constant productivity. Suppose further that firms spend a fraction $1-\eta_j$ of their costs on intermediates using the same variety aggregator as consumers. It is easy to verify using a similar logic as in Hsieh et al. (2020) that our welfare formula then becomes $\Delta \ln W_j - \frac{\mu_j}{\eta_j}\Delta \ln \tilde{\varphi}^c_{jj} = -\frac{\mu_j}{\eta_j}\frac{1}{\sigma-1}\Delta \ln \lambda^c_{jj}$, where $\tilde{\varphi}^c_{jj}$ and λ^c_{jj} are calculated just as before considering only traded goods. Hence, we can correct our baseline estimate of the gains from trade liberalization for non-traded and intermediate goods by multiplying it by $\frac{\mu_j}{\eta_j}$. Intuitively, intermediate goods amplify the gains from trade and non-traded goods dampen the gains from trade. For Canada, $\frac{\mu_j}{\eta_j} \approx \frac{2}{3}$ so that the welfare gains get dampened by approximately $\frac{1}{3}$.

Another extension considers industries that are heterogeneous in terms of the intra-industry elasticity of substitution. Specifically, suppose that utility of the representative consumer is a CES aggregate of aggregate consumption of S industries, with an elasticity of substitution ε, and aggregate consumption of industry s is itself a CES aggregate of individual varieties, with elasticity of substitution σ_s. In this case, our sufficient statistic is simply a weighted average of the change in the domestic market share of continuing firms of each sector. Specifically, equation 1 becomes $\Delta \ln W_j - \sum_{s=1}^{S} \nu_{js}\Delta \ln \tilde{\varphi}^c_{jjs} = -\sum_{s=1}^{S} \frac{\nu_{js}}{\sigma_s-1}\Delta \ln \lambda^c_{jjs}$ where ν_{js} is the Sato-Vartia share of industry s, $\tilde{\varphi}^c_{jjs}$ is the weighted harmonic mean of productivity of continuing domestic firms in sector s, and λ^c_{jjs} is the domestic market share of continuing domestic firms of sector s.

Table A1 calculates the welfare gains to Canada from CUSFTA in the multi-industry model with heterogeneous elasticities of substitution using this formula. The table shows the welfare gains for each two digit industry using the elasticity of substitution for the industry calculated by Oberfield and Raval (2021). The next to last row aggregates the industry level estimates using the Sato-Vartia weights. For comparison, the last low replicates our baseline result where we treat all Canadian manufacturing as one industry with a common elasticity of substitution.

Table A1: Industry level welfare changes

CSIC	Post-CUSFTA	Pre-CUSFTA[1]	Difference
10	-5.13%	-4.53%	-0.60%
11	-11.51%	-2.41%	-9.10%
12	-1.16%	-11.84%	10.68%
15	6.85%	0.64%	6.20%
16	3.40%	2.80%	0.59%
17	-12.40%	-5.71%	-6.69%
18	5.09%	-3.32%	8.41%
19	2.90%	-0.67%	3.57%
24	-10.89%	-1.70%	-9.20%
25	-0.70%	0.26%	-0.96%
26	-2.15%	1.12%	-3.27%
27	6.63%	0.57%	6.06%
28	-3.00%	5.12%	-8.12%
29	2.80%	3.13%	-0.33%
30	6.55%	-2.32%	8.87%
31	8.15%	-6.33%	14.48%
32	23.27%	-1.96%	25.24%
33	21.49%	-0.51%	22.00%
35	2.20%	-0.28%	2.48%
36	-3.79%	-4.21%	0.41%
37	2.13%	0.54%	1.59%
39	4.79%	-0.63%	5.43%
Aggregate from industry data[2]	6.66%	-1.42%	8.08%
Aggregate data	5.10%	-1.35%	6.45%

Note: Welfare estimates are calculated using equation (1) from the main text for 2 digit Canadian SIC (CSIC) industries. Elasticities of substitution are based on Oberfield and Raval (2021), using an equally weighted concordance from US-SIC to CSIC. Calculated from micro-data of Canada's Annual Survey of Manufacturing.

[1] Imputed changed in the share over 8 years in the pre-CUSFTA period based on the change over 10 years (from 1978 to 1988).

[2] Sato-Vartia average of industry level welfare changes.

B Demand and Trade Elasticities

One of the two key inputs for our new sufficient statistic is an estimate of the parameter σ, which can be interpreted as the firm-level intensive margin elasticity with respect to tariffs. In this context, the proliferation of firm-level microdata during the last decade led to a variety of studies using micro-data to estimate the within-firm trade elasticity σ. Broadly, these studies can be classified as either using reduced-form regressions of firm-level export sales volume on tariff changes, or using other methods such as instrumental variables (IV) or structural estimation. An overview of studies and their econometric methodology can be found in Table B1.

Within the reduced form tariff regression studies, Buono and Lalanne (2012) and Fitzgerald and Haller (2018) using the Uruguay Round of GATT in 1994 as natural experiment to estimate the intensive margin trade elasticity at the firm level. Despite using different firm samples (French firms for Buono and Lalanne (2012); Irish firms for Fitzgerald and Haller (2018)), both papers find similar values for σ, around 2.5 to 3. Variation in estimates for σ vary somewhat more for studies using tariff regressions without a designated natural experiment, as Table B1 shows. On the other hand, there are also numerous studies using firm-level data without using tariff variation. For example, Fontagne et al. (2018) use electricity price shocks as supply shock instrument to estimate σ, while Hottman et al. (2016) use model-implied instruments to estimate the elasticity of substitution between firms. These IV methods result in estimates for σ ranging from 3.9 in Hottman et al. (2016) to 6.1 in Fontagne et al. (2018). Structural estimates of σ come from studies, such as Bernard et al. (2003) and Eaton et al. (2011), which use simulated moment matching to arrive at estimates for σ of 3.79 and 2.98. Overall, the average value for σ across the high quality firm-level studies we reviewed is 3.72.

To compare our sufficient welfare statistic with Arkolakis et al. (2012), we also need to calibrate the parameter ϵ, which can be measured using the aggregate trade elasticity. In Table B2, we collect a number of estimates of the trade elasticity based on a wide variety of empirical methods. These range from reduced-form tariff regressions, as in Boehm et al. (2022), to triple-difference gravity estimators, as in Caliendo and Parro (2015), to estimators using price data, as in Eaton and Kortum (2002), to Simulated Moment Matching, as in

Table B1: Firm-level Intensive Margin Elasticity Estimates

	Data	Method	Estimate
Buono and Lalanne (2012)	French firms	Reduced form regression of sales on tariff changes	2.50
Berthou and Fotagne (2015)	French firms	Reduced form regression of sales on tariff changes	3.50
Bas et al. (2017)	French/Chinese firms	Reduced form regression of sales on tariff changes	5.00
Fontagne et al. (2018)	French firms	Reduced form regression of sales on tariff changes	2.70
Fitzgerald and Haller (2018)	Irish firms	Reduced form regression of sales on tariff changes	2.70
Fontagne et al. (2018)	French firms	Electricity price IV	6.10
Bernard et al. (2003)	US mfg plants	Structural estimation (Sim. Moment Matching)	3.79
Eaton et al. (2011)	French firms	Structural estimation (Sim. Moment Matching)	2.98
Hottman et al. (2016)	US firms	Structural estimation (Model-based IV)	3.90

Eaton et al. (2011). We also add our own estimate, based on matching static and dynamic moments of our data.[17] The average value for the trade elasticity across these estimates is $\epsilon = 4.71$, which we use as a baseline value.

[17] See Hsieh et al. (2020) for details

Table B2: (Aggregate) Trade Elasticity Estimates

	Data	Method	Estimate
Head and Ries (2001)	US-CAN trade	Reduced form regression of border effects on tariffs	6.90
Caliendo and Parro (2015)	Sectoral trade and tariffs	Triple-differenced gravity	4.55
Boehm et al. (2021)	Trade and tariffs	Reduced form regression of trade on MFN tariff changes by trade partners	2.25
Eaton and Kortum (2002)	UN-ICP price data	Structural estimation	8.28
Simonovska and Waugh (2014)	UN-ICP price data	Structural estimation	4
Bernard et al. (2003)	US mfg plants	Structural estimation (Sim. Moment Matching)	3.6
Eaton et al. (2011)	French firms	Structural estimation (Sim. Moment Matching)	4.87
Imbs and Mejean (2015)	Sectoral trade and tariffs	Triple-differenced gravity	5.6
Imbs and Mejean (2015)	Product-level trade	Structural estimation	4.1
Hsieh et al. (2020)	US and CAN mfg plants	Structural Estimation (Moment Matching)	2.90

C Welfare estimates using alternative import data

The baseline results in the text used US imports to Canada to calculate the domestic spending share λ_{jj}. Alternatively, one could impose balanced trade and use the value of Canadian exports as measure of trade to calculate λ_{jj}. Table C1 compares our results from using US import data to the results using Canadian exports as proxy for trade. Broadly welfare estimates from CUSFTA are very similar.

Table C1: Welfare measurement using different measures of imports

Source of import data	Period: CUSFTA (1988-1996)
	Change in domestic share $\Delta\lambda_{jj}$
US imports	-25.91%
Canadian firm exports	-23.86%
	Welfare change under HLOY formula
US imports	5.10%
Canadian firm exports	4.35%
	Welfare change under ACR ($\epsilon = 4.71$)
US imports	5.50%
Canadian firm exports	5.07%