Trade Restrictiveness Indexes and Welfare: A Structural Approach

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Abstract

Trade restrictiveness indexes (TRI) have become a staple for practitioners and policy makers to summarize international trade barriers. TRIs theoretically found a measure of trade restrictiveness by calculating the uniform tariff that is welfare equivalent to the observed distribution of applied tariffs within a country. This paper is the first to incorporate importer market power and exporter heterogeneity into calculations of TRIs and welfare globally. To do so we structurally estimate a quantitative model of international trade. The structure of the model allows tractable estimation of importer and exporter welfare and TRIs for every country in the world from 1990-2007. Canonical estimates, which ignore exporter heterogeneity and importer market power, are shown to overstate efficiency losses from tariffs by a factor of 5 for the average importer. Additionally, by not accounting for importer market power previous studies failed to measure substantial welfare losses to exporters that are captured by importers through tariffs. These channels are shown to significantly impact the measurement and interpretation of TRIs. To conclude, we employ the methodology to evaluate China's WTO accession and a counterfactual renegotiation of the NAFTA.

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1 Introduction

An importer's trade restrictiveness index is calculated by asking what is the uniform tariff that if applied to imports would yield the same welfare as the current structure of actual tariffs. This methodology provides a way of evaluating importers' trade policy that is theoretically founded. These indexes therefore do not suffer from the critiques levied against weighted average tariff measures, and allows for meaningful cross country comparisons. Trade restrictiveness indexes (TRI) have consequently become a staple of policy analysis around the globe.

While there have been a wide range of theoretical contributions on TRIs under various assumptions of importer and exporter characteristics (c.f., Anderson and Neary (2005) for a survey), empirical work has remained relatively stagnant. Empirically, the industry standard to calculate TRIs is drawn from Feenstra (1995), and take similar forms as Kee et al. (2009).[1] This methodology relies on linear approximations of supply and demand, exporter homogeneity, and small country assumptions. In this paper, we extend the welfare analysis to accept curvature in supply and demand, exporter heterogeneity, and large country assumptions in ways that are commonplace in the theoretical literature.[2]

The impact on calculations of welfare and TRIs from extending the model is substantial. Canonical empirical results are shown to load all of the distortions to the economy from a tariff on importer efficiency losses. This is a direct result of small country (i.e., perfectly elastic export supply) assumptions. Relaxing these assumptions, our extended model highlights the importance of terms of trade effects resulting from tariffs. When export supply is not perfectly elastic, exporters pass-through a portion of the tariff to their shipped prices. These so called terms of trade effects are shown to be a significant portion of importer wel-

[1] In speaking of these industry standards, Irwin (2010) explains, "On the other hand, the estimates here do not account for any improvement in the terms of trade as a result of import tariffs (Broda et al. (2008)). Still, with these caveats in mind, such welfare calculations are still routinely made and it should be interesting to see how historical estimates of these costs compare with more recent estimates."

[2] Chen et al. (2014) claim to extend the empirical literature on TRIs to account for terms of trade effects. However, they make an incorrect assumption regarding the pass-through of the tariff to shipped prices. By association, their welfare and TRI calculations are misspecified given their model.

fare. Given our estimates, we show the canonical model over estimates importer deadweight (efficiency) losses from tariffs by a factor of five. Additionally, the average importer is shown to extract significant welfare gains at the expense of exporters due to terms of trade effects. For the average importer, we estimate nearly a 50% pass-through of the tariff to exporter prices, which results in a net welfare gain from applied tariffs of around $2 billion or 0.4% of the value of imports.

Introducing these new channels into importer and exporter welfare also impacts TRIs. Our model has a wealth of mechanisms impacting importer welfare absent from previous studies. We show how to decompose these channels in our welfare calculations. Through these decompositions, we demonstrate how to calculate a number of TRIs. The canonical estimates of TRIs only consider the uniform tariff that yields identical importer efficiency losses as the vector of applied tariffs in the data. In our model this accounts for only one portion of welfare. Yet we can still calculate these efficiency TRIs. Our estimates of importer efficiency TRIs are roughly in line with the existing empirical literature. However, the departures from applying our model are informative. For example, canonical methods overestimate the efficiency TRI for the US by around 50%. Our method describes how these differences are closely related to importer terms of trade gains. The US is particularly apt to influence terms of trade with its policies. We highlight this fact by decomposing TRIs into their contribution to terms of trade gains and efficiency losses. For the US, the terms of trade and foreign efficiency loss TRIs are relatively large. By ignoring these channels, the canonical TRI overstates US efficiency losses as it lumps these channels into one metric.

Lastly, we introduce a net TRI that simultaneously accounts for the efficiency and terms of trade effects from importer policy. We argue that this net TRI is best thought of as the importer's ability to extract welfare from exporters via terms of trade effects using tariffs. Our net TRI consolidates these channels. We document that the US, for example, has one of the largest estimated net TRIs in the data. We describe how our estimates indicate a strong tendency for US trade policy to target industries with large terms of trade effects and small efficiency losses (i.e., inelastically supplied exports).

One difficulty of extending our empirical TRI models along the proposed dimensions is credibly estimating the underlying import demand and export supply elasticities for every importer-exporter-good in the entire world. Overcoming this hurdle in practice requires placing structure on importers' markets and welfare. We do so by adopting the quantitative model of trade as proposed in Soderbery (2016). This model has the benefit of fitting many prevailing assumptions in the trade literature (e.g., CES import demand, exporter heterogeneity and importer market power) while remaining flexible enough to structurally estimate. The model's flexibility lends itself to our empirical extension of TRIs and welfare calculations globally.

The closest analysis to ours is Costinot and Rodríguez-Clare (2014), who examine the move from Armington (1969) to Melitz (2003) models of international trade and evaluate the predicted effects of trade and trade policy (including an application to TRIs). Since their focus is on exposing the evolution of the microeconomic and macroeconomic channels between the models, their policy evaluations are designed for illustration rather than quantification. Here we are focused on quantifying welfare and policy in a parsimonious way so that our methodology can be readily applied across the universe of trading countries. Fundamentally, Costinot and Rodríguez-Clare (2014) is an exercise in letting models speak to the impact of trade and policy on welfare, while ours is aimed at relaxing some of the constraints of the model to put the onus on the data. In this way our study is more closely related to Kee et al. (2009) who analyze TRIs across many countries. However, we will demonstrate that their assumptions are overly restrictive and ignore important channels impacting welfare.

Broadly, this paper can be thought of as bridging the gap between new trade theory with heterogeneity (e.g., the analysis of Costinot and Rodríguez-Clare (2014)) and reduced form empirical studies of welfare and trade policy (e.g., Kee et al. (2009)). We do so by incorporating exporter heterogeneity and by extension importer market power into our calculations of the impact of trade policy on welfare and our resulting measures of trade restrictiveness. We conclude by demonstrating the tractability of the model and its predictions by examining the effect on TRIs and welfare from China's WTO accession and a hypothetical renegotiation of the North American free trade agreement (NAFTA).

We proceed as follows. Section 2 presents our quantitative trade model. Section 3 demonstrates how to calculate welfare and TRIs in our model with importer market power and exporter heterogeneity. Section 4 presents our estimates of welfare and TRIs, and Section 4.1 analyzes the impact of China's accession to the WTO contrasting our results with the canonical estimates and Section 4.2 examines the counterfactual effects of a hypothetical renegotiation of the NAFTA. Section 5 concludes.

2 Welfare and Trade Restrictiveness Indexes

A daunting number of channels and decompositions have been explored by the theoretical literature on computable welfare and trade restrictiveness measures. However, the empirical literature has focused on a narrower range. The result has been widespread estimates of TRIs drawing from Feenstra (1995) which focuses the welfare analysis by invoking on small country assumptions, linear approximations of supply and demand, and exporter homogeneity in order to tractably calculate welfare and TRIs. Here we extend the methodology to a richer framework in order to systematically examine the role of linear approximations, then small countries, and finally exporter heterogeneity on our estimates.

2.1 A Quantitative Trade Model

We begin by adopting the generic welfare function from Feenstra (1995). Our focus, as is customary, is on the effect on the sum of importer welfare good by good through the efficiency and terms of trade effects generated by the tariff. Under common assumptions of the market conduct of domestic firms and separability of welfare across goods, Feenstra (1995) shows the marginal effect on welfare from a change in tariffs is generically,

$$\frac{\partial W^I}{\partial \tau^I_{gv}} = \tau^I_{gv} p^*_{gv} \frac{\partial x^I_{gv}}{\partial \tau^I_{gv}} - x^I_{gv} \frac{\partial p^*_{gv}}{\partial \tau^I_{gv}}, \tag{1}$$

where τ^I_{gv} is the tariff set by importer I on the variety v of good g, x^I_{gv} is the imported quantity and p^*_{gv} is the exporter (at the origin) price. In practice, it is convenient to recast Equation (1) in terms of values and trade elasticities.[3] Such that,

$$\frac{\partial W^I}{\partial \tau^I_{gv}} = \tau^I_{gv} p^*_{gv} x^I_{gv} \frac{\partial log(x^I_{gv})}{\partial log(p^I_{gv})} \frac{\partial log(p^I_{gv})}{\partial \tau^I_{gv}} - p^*_{gv} x^I_{gv} \frac{\partial log(p^*_{gv})}{\partial \tau^I_{gv}}, \tag{2}$$

The first term in (2) represents the total efficiency (deadweight) losses associated with higher delivered prices (p^I_{gv}) increasing the tariff applied to good g. The second term are terms of trade gains to importers as exporters may partially absorb some of the tariff in delivered prices. Specifically, if export supply is upward sloping, exporters will lower their shipped price (p^*_{gv}) leading to welfare gains through tariff revenues for the importer. Historically, the literature has ignored these terms of trade effects on welfare and TRIs by applications of small country assumptions (i.e., perfectly elastic export supply implies $\frac{\partial log(p^*_{gv})}{\partial \tau^I_{gv}} = 0$). Additionally, the literature has simplified welfare calculations through first order approximations of supply and demand. Here, we will allow for upward sloping export supply and focus on CES preferences for the importer, which are both commonplace in the theoretical literature. That is to say, we apply standard structure from new trade theory to calculate welfare and investigate the extent to which the prevailing assumptions from the empirical literature overlook important channels determining welfare and TRIs.

In order to estimate the welfare effects of a tariff using Equation (2) we need to specify import demand and export supply. Our goal is to stay true to key assumptions from new trade theory while maintaining the ability to estimate the key parameters of the model. We thus adopt the quantitative model of trade developed in Soderbery (2016). Import demand will be CES and export supply curves are heterogenous across exporters and potentially upward sloping. These features of the model capture the specific channels of interest in this paper, and make it amenable to structural estimation as described in Soderbery (2016). It is however worth noting that the model is quantitative by nature and focused on describing aggregate changes in the flows of goods between countries. This implies that we are foregoing

[3] While not made explicit in Feenstra (1995), this transformation underlies his discussion on pg. 1560.

deep analysis of the microeconomic origins (e.g., firm entry and exit or factor reallocation) of changes in welfare. While the microeconomic channels are potentially interesting, our goal is to make meaningful decompositions of aggregate importer and exporter surpluses in a way that is directly tied to the model and is computationally feasible on a large scale (i.e., every importer-exporter-product triplet in the world).

Explicitly, consumers nest their consumption of domestic and imported goods via Cobb-Douglas and face CES preferences across imported varieties, which yields demand for each imported variety v of good g,

$$x^I_{gv} = \xi^I_X \phi^I_g b^I_{gv} (p^I_{gv})^{-\sigma^I_g} (\mathcal{P}^I_g)^{\sigma^I_g - 1}, \tag{3}$$

where $\mathcal{P}^I_g = \left(\sum_v b^I_{gv} (p^I_{gv})^{1-\sigma^I_g} \right)^{\frac{1}{1-\sigma^I_g}}$ is the standard CES price index over the delivered prices p^I_{gv}, ξ^I_X and ϕ^I_g are the fractions of consumer income spent on imported good and on imported varieties of a good, respectively. A random taste shock b^I_{gv} will facilitate the estimation of the import demand elasticity σ^I_g. Import demand combines with export supply of the form,

$$p^*_{gv} = exp(\eta^I_{gv})(x^I_{gv})^{\omega^I_{gv}}. \tag{4}$$

Exporters thus have unique supply curves for their variety both within and across countries. The destination-variety-specific inverse export supply elasticity is ω^I_{gv}. We also allow for unobservable variety specific supply shocks η^I_{gv} to facilitate estimation.

Calculating welfare in this model requires solving for the trade equilibrium where import demand equals export supply taking into account competitive equilibrium effects (e.g., changes in the price index) of tariffs. Clearing the import and export market implies the equilibrium shipped price of variety v:[4]

$$p^*_{gv} = \left(\varphi_{gv}(1+\tau^I_{gv})^{-\sigma^I_g}\mathcal{P}_g^{\sigma^I_g-1}\right)^{\frac{\omega^I_{gv}}{1+\omega^I_{gv}\sigma^I_g}}. \tag{5}$$

The term $\varphi_{gv} \equiv \frac{\xi^I_X\phi^I_g b_{gv}}{exp(-\eta_{gv}/\omega^I_{gv})}$ is an unobservable variety-specific shock that is independent of the tariff. Solving for the aggregate price level allows us to represent each exported variety's price as a function of tariffs. To do so, we aggregate the individual variety prices given by the market clearing condition in (5) to match the CES price index.[5] This aggregation yields,

$$\mathcal{P}_g = (1+\tau^I_{gv})^{\frac{1}{1+\overline{\omega}^I_{go}}}\Phi_g. \tag{6}$$

In order to aggregate prices, we must define an "average" variety that charges a price equal to the price index.[6] Denote this average variety with subscript o, and let it be produced with technology denoted $\overline{\omega}^I_{go}$.[7] The term Φ_g is an index of variety taste and technology parameters, which is unaffected by the tariff.[8]

Fundamentally, our goal is to calculate the elasticity of imports, shipped and delivered prices with respect to the tariff. To do so, combine the price index with the market clearing price in (5), which yields the shipped price solely as a function of the tariff and unobservable shocks (unaffected by the tariff),

$$p^*_{gv} = (1+\tau^I_{gv})^{\frac{-\omega^I_{gv}(1+\overline{\omega}^I_{go}\sigma^I_g)}{(1+\overline{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)}}\left(\varphi_{gv}\Phi_g^{\sigma^I_g-1}\right)^{\frac{\omega^I_{gv}}{1+\omega^I_{gv}\sigma^I_g}}.$$

[4]The market clearing condition equates import demand with export supply curves and is given by $\xi^I_X\phi^I_g b_{gv}p_{gv}^{-\sigma^I_g}\mathcal{P}_g^{\sigma^I_g-1} = (exp(-\eta_{gv})p^*_{gv})^{1/\omega^I_{gv}}$.

[5]Given that each variety responds differently to the tariff as dictated by their supply elasticity, this is not a superficial task. It is, however, key to the calculation of the optimal tariff. The details of the aggregation are relegated to the appendix.

[6]This derivation is detailed in Soderbery (2016).

[7]In practice, $\overline{\omega}^I_{go}$ will be calculated as the within good import weighted geometric mean of the export supply elasticities. Specifically, $\overline{\omega}^I_{go} \equiv \frac{\sum_v p^I_{gv}x^I_{gv}\omega^I_{gv}}{\sum_v p^I_{gv}x^I_{gv}}$.

[8]Explicitly, $\Phi_g \equiv \varphi_{go}^{\overline{\omega}^I_{go}/1+\overline{\omega}^I_{go}}$

Heterogeneity in export supply elasticities drive differential price responses to the tariff across the imported varieties.[9] Additionally, we can write imports as a function of the tariff and variety-specific shocks,

$$x_{gv} = (1+\tau^I_{gv})^{\frac{-(1+\overline{\omega}^I_{go}\sigma^I_g)}{(1+\overline{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)}} exp(-\eta_{gv}) \left(\varphi_{gv}\Phi_g^{\sigma^I_g-1}\right)^{\frac{1}{1+\omega^I_{gv}\sigma^I_g}}.$$

This system of import demand and export supply has the desirable feature of nesting the canonical derivations of Feenstra (1995) and Kee et al. (2009). Applying their small country assumptions rules out exporter heterogeneity as $\omega^I_{gv} = 0 \ \forall \ v$, and results in $\frac{\partial W^I}{\partial \tau^I_{gv}} = \tau^I_{gv}p^*_{gv}x^I_{gv}\sigma^I_g$.[10] The small country assumption thus rules out terms of trade effects, leaving welfare calculation simply as a function of how much delivered prices ($\tau^I_{gv}p^*_{gv}$) and the change in imports ($x^I_{gv}\sigma^I_g$) are affected by the tariff . In familiar terms, the change in welfare is the Harberger (1964) triangle below the import demand curve above the exported price that emerges with the tariff.

As we relax the small country assumption, the slope of the export supply curve begins to affect welfare. Define $\Lambda^I_{gv} \equiv \frac{\omega^I_{gv}(1+\bar{\omega}^I_{go}\sigma^I_g)}{(1+\bar{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)} \in [0,1]$, which measures the pass-through of the tariff for each exported variety's shipped price.[11] The full model then implies,

$$\frac{\partial W^I}{\partial \tau^I_{gv}} = -\tau^I_{gv}p^*_{gv}x^I_{gv}\sigma^I_g(1-\Lambda^I_{gv}) + p^*_{gv}x^I_{gv}\Lambda^I_{gv}. \tag{7}$$

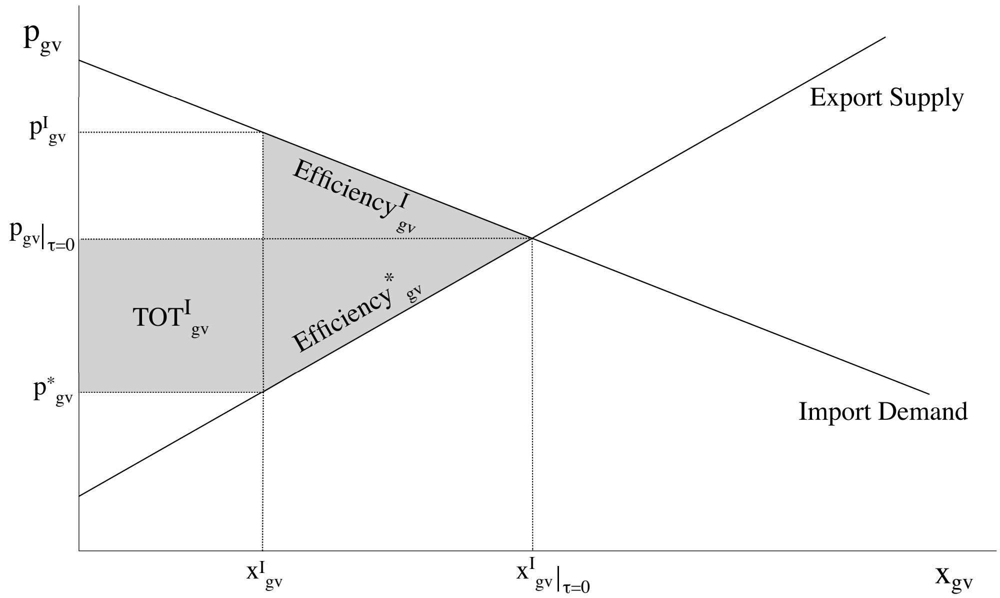
The following will consider a number of decompositions of this welfare function, which warrants some visualization of the problem. Figure 1 presents the welfare problem graphically. Application of the tariff τ^I_{gv} raises the price in country I to p^I_{gv}. The increase in price is strictly less than the amount of the tariff since export supply is upward sloping and the

[9]The elasticity of a variety's price with respect to the tariff is thus, $\frac{\partial log(p^*_{gv})}{\partial \tau^I_g}\Big|_{\tau^I_{gv}=0} = \frac{-\omega^I_{gv}(1+\overline{\omega}^I_{go}\sigma^I_g)}{(1+\overline{\omega}^I_{go})(1+\omega^I_{gv}\sigma^I_g)}$.

[10]As, $\frac{\partial log(p^*_{gv})}{\partial \tau^I_g}\big|_{\tau^I_{gv}=0} = 0$, $\frac{\partial log(p^I_{gv})}{\partial \tau^I_g}\big|_{\tau^I_{gv}=0} = 1$ and $\frac{\partial log(x^I_{gv})}{\partial log(p^I_{gv})} = \sigma^I_g$.

[11]At this point we can see where the analysis of Chen et al. (2014) introduces an unfounded assumption regarding pass-through of a tariff when export supply is upward sloping. Specifically, they assume $\Lambda^I = \frac{\sigma_g}{\omega_g+\sigma_g}$. In our model if we assumed as they do that export supply elasticities are homogenous, pass-through is $\Lambda^I = \frac{\omega_g}{\omega_g+1}$. While their assumption is convenient, it is unclear what model of export supply they have in mind, as it does not adhere to the export supply curves they estimate.

Figure 1: Import Market for Variety v of Good g



exporter lowers the shipped price of its variety to p^*_{gv}. This generates efficiency losses for the importer and exporter. Explicitly, integrating the first term of Equation (7) will yield the negative of the sum of the deadweight losses to the importer (Efficiency$^I_{gv}$) and the exporter (Efficiency$^*_{gv}$). Integrating the second term of Equation (7) produces the sum of the importer terms of trade gains (TOT$^I_{gv}$) and foreign efficiency losses. Empirically, we are interested in decomposing welfare and TRIs across these terms of trade and efficiency channels as well as their combined effects. Our model is by construction amenable to such decompositions. Next we will show how to calculate welfare and TRIs given the model.

3 Calculating Welfare and TRIs

The total change to importer welfare associated with moving from free trade to a positive tariff is acquired by integrating the partial derivative of the welfare function. Explicitly, we integrate Equation (1) from zero to the applied tariff τ^I_{gv} and add up the changes in welfare for each variety and good imported by I.

$$\begin{aligned}\Delta W^I &\equiv \sum_g \sum_v \int_0^{\tau^I_{gv}} \frac{\partial W^I}{\partial \tau^I_{gv}} \\ &= \sum_g \sum_v \left(-\int_0^{\tau^I_{gv}} p^*_{gv} x^I_{gv} \sigma^I_g (1-\Lambda^I_{gv}) \tau d\tau + \int_0^{\tau^I_{gv}} p^*_{gv} x^I_{gv} \Lambda^I_{gv} d\tau \right).\end{aligned}$$

Since the welfare function is additively separable, we can evaluate these integrals variety by variety and decompose the efficiency and terms of trade effects. The solution to the aggregate change in importer welfare from all applied tariffs is thus,

$$\Delta W^I = -\frac{1}{2} \sum_g \sum_v p^*_{gv} x^I_{gv} \sigma^I_g (1-\Lambda^I_{gv})(\tau^I_{gv})^2 + \sum_g \sum_v p^*_{gv} x^I_{gv} \Lambda^I_{gv} \tau^I_{gv}. \tag{8}$$

To reiterate, welfare nests the canonical results from Feenstra (1995). This is evident as when $\Lambda = 0$ welfare is only the efficiency losses to the importer from higher prices as tariffs increase. As Λ increases exporters pass-through more of the tariff to shipped prices, efficiency losses fall and terms of trade gains rise. Decomposing the welfare function across efficiency and terms of trade effects will lend insight into the channels through which tariffs are affecting importer welfare, and allow for comparisons to previous empirical studies.

Four key channels are evident from Figure 1; 1) Deadweight losses to the importer (Efficiency^I), 2) deadweight losses to the exporter (Efficiency^*), 3) global deadweight losses ($\text{AggEff}^I = \text{Efficiency}^I + \text{Efficiency}^*$) and 4) the total terms of trade distortion (AggTOT^I

$= \text{TOT}^{I} + \text{Efficiency}^{*}$). From our model these regions are,

$$\Delta\text{Efficiency}^{I} = -\frac{1}{2}\sum_{g}\sum_{v} p^{*}_{gv} x^{I}_{gv} \sigma^{I}_{g} (1-\Lambda^{I}_{gv})^{2} (\tau^{I}_{gv})^{2} \tag{9}$$

$$\Delta\text{Efficiency}^{*} = -\frac{1}{2}\sum_{g}\sum_{v} p^{*}_{gv} x^{I}_{gv} \sigma^{I}_{g} (1-\Lambda^{I}_{gv})(\Lambda^{I}_{gv})(\tau^{I}_{gv})^{2} \tag{10}$$

$$\Delta\text{AggEff}^{I} = -\frac{1}{2}\sum_{g}\sum_{v} p^{*}_{gv} x^{I}_{gv} \sigma^{I}_{g} (1-\Lambda^{I}_{gv})(\tau^{I}_{gv})^{2} \tag{11}$$

$$\Delta\text{AggTOT}^{I} = \sum_{g}\sum_{v} p^{*}_{gv} x^{I}_{gv} \Lambda^{I}_{gv} \tau^{I}_{gv}. \tag{12}$$

In terms of evaluating trade policy, each of these measures is of individual interest. For those interested in assessing the economic efficiency for importers (i.e., the effects on domestic consumers) evaluating Efficiency^{I} is the key metric. Additionally, this deadweight loss measure is essentially the metric presented by the empirical literature as the costs of protectionism (c.f., Irwin (2010) and Kee et al. (2009)).

Allowing for export supply heterogeneity generates deadweight losses for the exporter. Evaluating Efficiency^{*} may not be of interest to truly protectionist policy makers, but for those evaluating a bargaining process between countries where importers internalize their distortions abroad from policy, this new metric should be valuable. Even more to this point, our ability to calculate the gains accrued by importers (AggTOT^{I}) at the cost of exporters should be of central importance to policy makers. Finally, while we are interested in aggregate (i.e., adding up welfare across all imported varieties and goods) welfare effects, the model is notably flexible enough to calculate each imported variety's contribution to efficiency and terms of trade in the economy.

With our welfare decompositions in hand, we now turn to TRIs. Generically, a TRI measures a uniform policy that is welfare equivalent to the vector of tariffs in the data. Put plainly, if an importer were to apply a uniform tariff across all goods and varieties how large would it have to be to yield the same welfare as the vector of applied tariffs which varies across goods and varieties. Since TRIs are theoretically founded, and calculated in welfare equivalence, they make cross country comparisons of trade restrictiveness possible. Here we take the intuition of TRIs a step further with our decompositions. We will ask such things as what is the uniform policy that leads to the same importer efficiency losses as applied tariffs. This will allow us to understand channels such as which countries' applied tariffs lead to the largest domestic distortions. That is to say, we will be able to evaluate and compare countries' trade policy in terms of domestic and foreign distortions (i.e., efficiency and terms of trade).

We begin by constructing TRIs for each of our decompositions. For example, we define the uniform tariff that yields to the same importer deadweight losses as applied tariffs, and denote it as $\text{TRI}_{\text{Efficiency}^I}$. Our decomposed TRIs are:

$$
\begin{aligned}
TRI_{\text{Efficiency}^I} &= \left(\frac{\sum_g \sum_v p^*_{gv} x^I_{gv} \sigma^I_g (1-\Lambda^I_{gv})^2 (\tau^I_{gv})^2}{\sum_g \sum_v p^*_{gv} x^I_{gv} \sigma^I_g (1-\Lambda^I_{gv})^2}\right)^{\frac{1}{2}} \\
TRI_{\text{Efficiency}^*} &= \left(\frac{\sum_g \sum_v p^*_{gv} x^I_{gv} \sigma^I_g (1-\Lambda^I_{gv})(\Lambda^I_{gv})(\tau^I_{gv})^2}{\sum_g \sum_v p^*_{gv} x^I_{gv} \sigma^I_g (1-\Lambda^I_{gv})(\Lambda^I_{gv})}\right)^{\frac{1}{2}} \\
TRI_{\text{AggEff}^I} &= \left(\frac{\sum_g \sum_v p^*_{gv} x^I_{gv} \sigma^I_g (1-\Lambda^I_{gv})(\tau^I_{gv})^2}{\sum_g \sum_v p^*_{gv} x^I_{gv} \sigma^I_g (1-\Lambda^I_{gv})}\right)^{\frac{1}{2}} \\
TRI_{\text{AggTOT}^I} &= \frac{\sum_g \sum_v p^*_{gv} x^I_{gv} \Lambda^I_{gv} \tau^I_{gv}}{\sum_g \sum_v p^*_{gv} x^I_{gv} \Lambda^I_{gv}}.
\end{aligned}
$$

As with our welfare calculations, depending on perspective each of these measures will shed light on where a country's policies are the most distortionary and restrictive. For instance, countries with high tariffs disproportionately in relatively elastically demanded industries will generate greater efficiency losses for the importer and yield large estimates of $\text{TRI}_{\text{Efficiency}^I}$. Similarly, high tariffs in inelastically supplied industries will increase $\text{TRI}_{\text{AggTOT}^I}$ as importers realize terms of trade gains.

Jointly, these decompositions interact through policy to yield the net TRI. Let $\Psi \equiv \frac{\sum_g \sum_v p^*_{gv} x^I_{gv} \Lambda^I_{gv}}{\sum_g \sum_v p^*_{gv} x^I_{gv} \sigma^I_g (1-\Lambda^I_{gv})}$, be our measure of the marginal aggregated terms of trade gains relative to efficiency losses from tariffs. Solving for the uniform tariff(s) that provides the same welfare for the importer (net of exporter deadweight losses) as the vector of applied tariffs yields,

$$TRI_{\text{Net}^I} = \Psi \pm \sqrt{\Psi^2 + (TRI_{\text{Efficiency}^*})^2 - 2\Psi TRI_{\text{AggTOT}^I}} \tag{13}$$

The first thing to notice is that the overall TRI takes on two values. With the introduction of upward sloping export supply curves (i.e., importer gains from terms of trade), welfare is no longer strictly decreasing with the tariff. This outcome is expected. Dakhlia and Temimi (2006) argue that with large countries (i.e., upward sloping export supply), the definition of the TRI should be modified to acknowledge importer terms of trade gains. In context, Anderson and Neary (1996) originally define the TRI against free trade (as we are doing here). No issues arise with this definition when export supply is perfectly elastic since welfare is monotonically decreasing with positive tariffs. As we see here, welfare is no longer monotonic, giving rise to multiple TRIs. Dakhlia and Temimi (2006) thus propose a modified TRI that measures deviations from optimal tariffs. We do not pursue that logic here, as our decompositions provide insight into the meaning of our multiple TRIs. We can see that adding the term under the radical, which we will denote as $\text{TRI}^+_{\text{Net}^I}$, measures the maximum distortion caused by the vector of tariffs. Conversely, subtracting this term, which we will denote as $\text{TRI}^-_{\text{Net}^I}$, yields the same welfare but measures the minimum of the distortions from applied tariffs to reach this welfare level.

Comparisons across the two measures have little meaning (i.e., one interpretation of Dakhlia and Temimi (2006)), but we will demonstrate that comparisons within the measures across countries is a valuable tool for quantifying trade restrictiveness and its channels for policy analysis. In a related theoretical application of new trade theory, Costinot and Rodríguez-Clare (2014) find multiple TRIs. They claim "The non-uniqueness of the TRI reflects the importance of general equilibrium effects in gravity models," but do not expand on the finding. Here, we see that multiple TRIs arise as a consequence of importer terms of trade gains and provide insight into how importers are manipulating these gains with their policies.

4 Empirical Evaluation

Putting the analysis into motion requires estimates of import demand and export supply elasticities, trade flows and the universe of tariffs. The biggest challenge are reliable estimates of our elasticities for every traded good and country in the world. Here we have allowed for exporter heterogeneity in supply and assumed CES import demand. We thus borrow the structural estimator developed in Soderbery (2016), which yields consistent estimates of import demand and export supply elasticities for every HS4 product traded by every country. To be clear, the model requires importer-product specific import demand elasticities and importer-exporter-product specific export supply elasticities.[12] We combine these estimates with publicly available trade data from *ComTrade*. Finally, applied tariffs are importer by exporter by good specific and are extracted from a combination of *Trains*, the *International Customs Tariffs Bureau* and the WTO.[13] The intersection of our data leaves 182 countries trading 1087 HS4 products from 1990-2007.

Table 1 presents summary statistics for the top 25 importers in terms of GDP in 2006.[14] Higher GDP countries tend to be the biggest importers and exporters in the data. The US is the largest importer while China is the largest exporter in 2006. These large countries also tend to have the strongest importer market power, as indicated by high inverse export supply elasticities ω^I_{gv}. There is also a strong positive correlation between the median rate of pass-through and a country's imports relative to GDP. What these summary statistics do not fully capture is the significant variation in the amount of trade and elasticities across importer-exporter pairs and products. Additionally, there is substantial heterogeneity in the tariffs applied by importers. These dimensions of heterogeneity across importers, which depend on with whom and what goods are traded, is the motivation for compact aggregated statistics such as TRIs and aggregate welfare to evaluate trade and policy.

[12] As is customary in trade given our data, we will define a variety as a unique exporter-product pair following Armington (1969).

[13] Many thanks to Robert Feenstra and John Romalis for the tariff data. They are the same utilized by Feenstra and Romalis (2014), which provides a detailed description in their Appendix B.

[14] We will focus on the top 25 countries for the sake of brevity. However, in our online appendix we repeat each of our pertinent tables for every country in the world.

Table 1: Importer Characteristics in 2006

				Median Elasticities		
Country	GDP	Imports	Exports	Import Demand	Export Supply	Pass-through $(1-\Lambda)$
USA	13201.82	2622.06	1586.05	2.958	1.268	0.474
Japan	4340.13	732.28	1102.34	3.000	1.297	0.464
Germany	2906.68	1312.18	1772.61	3.030	1.276	0.467
China	2668.07	953.21	1902.92	2.898	1.302	0.459
UK	2345.01	760.11	579.16	2.989	0.906	0.576
France	2230.72	782.47	736.90	2.982	0.888	0.575
Italy	1844.75	612.35	689.93	3.018	0.862	0.583
Canada	1251.46	492.66	443.38	3.057	1.237	0.466
Spain	1223.99	443.41	293.75	2.842	0.645	0.623
Brazil	1067.96	125.64	139.39	2.851	0.779	0.614
Russia	986.94	177.31	229.06	2.981	0.869	0.587
India	906.27	182.74	154.01	2.997	0.790	0.617
Korea	888.02	460.65	461.17	2.791	0.508	0.670
Mexico	839.18	423.85	305.25	2.937	0.939	0.552
Australia	768.18	163.39	102.55	2.999	0.857	0.595
Netherlands	657.59	425.50	433.85	2.852	0.660	0.608
Turkey	402.71	172.95	114.27	2.847	0.481	0.697
Belgium	392.00	502.70	390.69	2.856	0.659	0.617
Sweden	384.93	175.98	202.45	2.843	0.719	0.583
Switzerland	379.76	247.29	287.35	2.852	0.723	0.585
Indonesia	364.46	63.82	139.16	2.813	0.518	0.675
Poland	338.73	186.51	124.85	2.849	0.686	0.594
Austria	322.44	196.15	186.48	2.846	0.700	0.581
Norway	310.96	93.70	100.15	2.823	0.740	0.580

Notes: GDP is total gross domestic product reported by *CEPII*, Imports and Exports are reported by *ComTrade*, and all are in billions of US dollars from 2006. Elasticities are the median across all varieties, where Import Demand is the CES elasticity σ_g^I, Export Supply is the inverse export supply elasticity ω_{gv}^I, Pass-through to importer prices is one minus Λ_{gv}^I.

Table 2 begins our analysis of trade restrictiveness. For brevity and comparisons to the existing empirical literature we will continue focusing on trade in 2006 and the top 25 largest countries.[15] To remind the reader, $\text{TRI}^-_{\text{Net}^I}$ is the minimum uniform tariff that would yield the same overall welfare as applied tariffs. We thus interpret $\text{TRI}^-_{\text{Net}^I}$ as a measure of the efficacy of the tariffs applied by the importer. That is to say, a high $\text{TRI}^-_{\text{Net}^I}$ corresponds with an importer setting tariffs that target industries and exporters with relatively high rates of tariff pass-through so that terms of trade gains compared to efficiency losses are high. Notably, the

[15]To be clear, our calculations have been made considering all countries and years in the data. The full estimates will be available at web.ics.purdue.edu/~asoderbe.

strongest positive correlate with $\text{TRI}^{-}_{\text{Net}^I}$ is the change in importer welfare from its applied tariffs relative to total imports.

Table 2: Trade Restrictiveness Indexes in 2006

Importer	Avg Tariff	$\text{TRI}_{\text{Canonical}}$	$\text{TRI}_{\text{Eff}^I}$	$\text{TRI}_{\text{AggEff}^I}$	$\text{TRI}_{\text{AggTOT}^I}$	$\text{TRI}^{-}_{\text{Net}^I}$	$\text{TRI}^{+}_{\text{Net}^I}$
USA	0.027	0.032	0.021	0.027	0.030	0.032	0.130
Japan	0.023	0.047	0.051	0.051	0.021	0.018	0.710
Germany	0.010	0.021	0.025	0.023	0.008	0.007	0.445
China	0.091	0.081	0.080	0.081	0.070	0.067	0.599
UK	0.011	0.011	0.020	0.021	0.011	0.008	0.123
France	0.010	0.024	0.021	0.023	0.009	0.008	0.433
Italy	0.010	0.022	0.019	0.021	0.008	0.007	0.401
Canada	0.033	0.033	0.032	0.034	0.013	0.011	0.607
Spain	0.010	0.018	0.022	0.023	0.008	0.007	0.459
Brazil	0.125	0.152	0.169	0.161	0.117	−0.040	0.196
Russia	0.101	0.055	0.101	0.102	0.093	0.087	0.393
India	0.276	0.267	0.303	0.298	0.257	−0.164	0.311
Korea	0.074	0.032	0.148	0.136	0.058	0.005	0.344
Mexico	0.100	0.055	0.055	0.053	0.037	0.009	0.091
Australia	0.045	0.049	0.041	0.045	0.051	0.055	0.190
Netherlands	0.010	0.024	0.024	0.024	0.008	0.007	0.501
Turkey	0.015	0.031	0.033	0.032	0.012	0.009	0.267
Belgium	0.009	0.022	0.022	0.022	0.007	0.006	0.543
Sweden	0.008	0.021	0.021	0.022	0.005	0.004	0.573
Switzerland	0.096	0.106	0.112	0.110	0.084	0.073	0.525
Indonesia	0.055	0.096	0.073	0.085	0.056	0.030	0.208
Poland	0.009	0.023	0.023	0.024	0.005	0.004	0.498
Austria	0.008	0.019	0.019	0.020	0.005	0.004	0.567
Norway	0.004	0.027	0.028	0.029	0.002	0.001	0.610

Notes: Avg Tariff is the simple average of all importer applied tariffs. $\text{TRI}_{\text{Canonical}}$ is calculated forcing pass-through to zero for all countries. $\text{TRI}_{\text{Net}^I}$ is missing for Mexico in 2006 as it is an imaginary number given our estimates.

We see considerable variation across countries in $\text{TRI}^{-}_{\text{Net}^I}$. Our estimates highlight differences across even seemingly similar countries in how policies target terms of trade. Comparing our TRIs between the US and Japan is a useful example. These countries are both large importers and WTO members with similar average tariffs. Our estimate of $\text{TRI}^{-}_{\text{Net}^I}$ for the US is over double that for Japan. This suggests Japan's tariffs tend to target exporters and goods that generate large efficiency losses and relatively small terms of trade gains. The story is precisely the opposite for the US. This pattern is confirmed by decompositions of the effects of tariffs on efficiency ($\text{TRI}_{\text{Eff}^I}$) with the effects on terms of trade ($\text{TRI}_{\text{AggTOT}^I}$) across the two countries. We see that US tariffs generate large terms of trade gains relative to efficiency losses.

Conversely, $\text{TRI}^+_{\text{Net}^I}$ can be thought of as a measure of the inefficient use of tariffs by the importer. A high $\text{TRI}^+_{\text{Net}^I}$ corresponds with tariffs leading to large efficiency losses relative to terms of trade gains. We can see these differences clearly by contrasting the US and Norway. The US has the second lowest $\text{TRI}^+_{\text{Net}^I}$ while Norway has the second highest. The implication is that the US applies tariffs that target inelastically exported varieties (i.e., terms of trade gains), while Norway applies tariffs targeting elastically supplied varieties. Consequently our new TRIs quickly explain the large welfare gains to the US from its policies in comparison to the small welfare effects of tariffs in Norway. The following will present our full welfare estimates, and document that US tariffs increase welfare by 1.33% of its total imports, while Norwegian tariffs only increase welfare by 0.05% of its imports in 2006. In light of this discussion, labeling these overall indexes as trade restrictiveness should be done with care – a more appropriate characterization is in terms of the overall distortions to the import market caused by tariffs.

The more classic analogy equating trade restrictiveness and TRIs lies in $\text{TRI}_{\text{Eff}^I}$. This index simply measures the size of the deadweight losses to the importer due to its tariffs. It is therefore the most appropriate comparison to the canonical measure ($\text{TRI}_{Canonical}$) from the empirical literature where we force pass-through of the tariff to be zero (c.f., Feenstra (1995) and Kee et al. (2009)). By ignoring terms of trade effects, we see a strong correlation between all of the efficiency measures.

All of these efficiency measures notably follow more closely the simple average of applied tariffs. There are however some important departures between the canonical TRI and our efficiency TRIs. For the US, the canonical measure overstates the restrictiveness of applied tariffs in terms of their distortion to welfare. This is a result of the relatively high degree of tariff passthrough by exporters to the US (see Table 1). This is evident as the aggregate efficiency $\text{TRI}_{\text{AggEff}^I}$ is higher than the importer efficiency index, suggesting exporter deadweight losses are relatively high as a result of US tariffs. Our measures thus present a clear way to observe whether exporters or importers bear a relatively larger portion of the burden tariffs in terms of deadweight losses.

Additionally, the terms of trade index $\text{TRI}_{\text{AggTOT}^I}$ in the US is larger than the efficiency indexes, which shows how US policy extracts welfare at the expense of exporters. Conversely, the canonical TRI understates restrictiveness when importers' policies are relatively inefficient (i.e., terms of trade gains are achieved with large corresponding deadweight losses). India's policies highlight this point most clearly.

As an example, our indexes suggest Indian tariffs are the most inefficiently applied as they lead to substantial deadweight losses to both India and its trading partners with relatively small corresponding terms of trade gains. Explicitly, our measure of effectiveness $\text{TRI}^-_{overall}$ is the lowest of all importers and $\text{TRI}_{\text{AggEff}^I}$ is high relative to $\text{TRI}_{\text{AggTOT}^I}$ in India.

The patterns of the data embodied by TRIs are echoed by our welfare estimates. Table 3 presents welfare across our importers. Unambiguously, the canonical welfare estimates overstate the efficiency losses induced by tariffs. Without terms of trade gains, these estimates suggest welfare is decreasing substantially for all importers from applied tariffs. Our model tells a different story. While tariffs generate efficiency losses to the importer, we see that for all but two countries tariffs yield more welfare from terms of trade gains. The net effect for importers effectively applying tariffs to generate terms of trade gains is generally around a positive 1-3% of the total value of imports welfare gain (e.g., US, China, Russia). Relating these estimates back to our TRIs in Table 2, these countries also generate the largest $\text{TRI}^-_{\text{Net}^I}$.

While most importers capitalize on terms of trade gains with their tariffs, Brazil and India do not. We can conclude from our estimates that these countries inefficiently apply large tariffs to industries with elastic demand and low pass-through. This strategy does produce large terms of trade gains, but these gains are dwarfed by even larger efficiency losses. This observation also highlights a key inefficiency of the canonical model. Since every distortion is captured by importer efficiency losses in these models they drastically overstate importer efficiency losses. Specifically, canonical estimates overstate efficiency losses to importers by a factor of five, on average. For example, the canonical model estimates a welfare loss of 138% (or $252.3 billion) to India from its applied tariffs. Our estimates also suggest significant welfare losses to India, but accounting for terms of trade gains yield a more realistic 12.6% welfare loss. Generally, for countries that appear to be targeting terms of trade with their policies, this discrepancy between the canonical estimates of importer efficiency losses can be upward of ten fold (e.g., Russia). The data and our estimates thus suggest an important role for terms of trade when estimating importer welfare.

Table 3: The Effect of Applied Tariffs on Welfare in 2006

		$\frac{\Delta\text{Importer Welfare}}{\text{Imports}}$		Decomposing Importer Welfare			
Importer	Imports	Canonical	ΔW^I	ΔAggEff^I	$\Delta\text{Efficiency}^I$	$\Delta\text{Efficiency}^*$	ΔAggTOT^I
USA	2622.06	−0.54%	1.33%	−0.22%	−0.11%	−0.11%	1.55%
Japan	732.28	−0.46%	0.96%	−0.20%	−0.11%	−0.09%	1.16%
Germany	1312.18	−0.12%	0.38%	−0.06%	−0.04%	−0.02%	0.44%
China	953.21	−1.27%	3.31%	−0.54%	−0.30%	−0.24%	3.86%
UK	760.11	−0.78%	0.37%	−0.15%	−0.13%	−0.03%	0.52%
France	782.47	−0.11%	0.34%	−0.05%	−0.03%	−0.02%	0.39%
Italy	612.35	−0.10%	0.30%	−0.05%	−0.03%	−0.02%	0.35%
Canada	492.66	−0.32%	0.59%	−0.10%	−0.06%	−0.05%	0.69%
Spain	443.41	−0.09%	0.30%	−0.05%	−0.03%	−0.02%	0.35%
Brazil	125.64	−8.13%	−1.99%	−6.62%	−6.06%	−0.56%	4.64%
Russia	177.31	−7.29%	3.18%	−0.97%	−0.61%	−0.36%	4.15%
India	182.74	−138.06%	−12.61%	−21.92%	−19.27%	−2.65%	9.31%
Korea	460.65	−2.50%	0.17%	−1.99%	−1.81%	−0.18%	2.16%
Mexico	423.85	−2.67%	0.48%	−1.57%	−1.22%	−0.34%	2.04%
Australia	163.39	−1.00%	2.09%	−0.40%	−0.26%	−0.14%	2.50%
Netherlands	425.50	−0.09%	0.29%	−0.05%	−0.03%	−0.02%	0.34%
Turkey	172.95	−0.17%	0.28%	−0.13%	−0.10%	−0.02%	0.40%
Belgium	502.70	−0.08%	0.27%	−0.04%	−0.03%	−0.02%	0.31%
Sweden	175.98	−0.07%	0.20%	−0.04%	−0.02%	−0.02%	0.24%
Switzerland	247.29	−1.87%	3.10%	−0.99%	−0.64%	−0.35%	4.09%
Indonesia	63.82	−1.83%	0.84%	−0.96%	−0.58%	−0.38%	1.79%
Poland	186.51	−0.10%	0.16%	−0.05%	−0.03%	−0.02%	0.22%
Austria	196.15	−0.06%	0.19%	−0.03%	−0.02%	−0.01%	0.22%
Norway	93.70	−0.12%	0.05%	−0.07%	−0.04%	−0.03%	0.12%

Notes: Imports are in billions of US $ in 2006. All welfare measures are relative to total imports. Canonical welfare is calculated forcing pass-through to zero for all countries.

4.1 Application: China's WTO Accession

Here we use our estimates for more detailed analysis of importer policies. China's WTO accession in 2001 was a particularly interesting rearranging of trade policy by a country emerging as a leader in international trade. We will show how to use the more robust details of our model to dissect China's trade policy changes. Table 4 begins by decomposing China's welfare five years before and after 2001.

Table 4: Chinese Welfare and Restrictiveness Before and After WTO Accession

		Welfare ($Bill)				Trade Restrictiveness			
Year	Imports	Efficiency^I	AggTOT^I	Total	Canonical	Avg Tar	$\mathrm{TRI}_{\mathrm{Eff}^I}$	$\mathrm{TRI}^-_{\mathrm{Net}}$	$\mathrm{TRI}_{\mathrm{Canon}}$
1996	237.134	−8.613	35.401	19.663	−38.124	0.275	0.295	0.194	0.297
2006	953.212	−2.883	36.775	31.585	−12.130	0.090	0.080	0.067	0.081

Notes: Imports are in Billions of US $.

In 1996, China was a relatively large importer of foreign goods at nearly $240 billion. Their policies at the time were some of the most protectionist in the world with an average tariff around 30%. Their tariffs were relatively effectively applied as we see a large TRI^-_{Net}, and generated significant terms of trade gains ($35B or 15% of import value) with relatively small efficiency losses ($8.6B or 4% of import value). In the aggregate, Chinese policies in 1996 yielded a welfare gain of nearly $20B (8% of import value). The most striking difference comes from comparing the Canonical results (i.e., where all export supply is assumed to be perfectly elastic) to our estimates. Since Chinese tariffs are relatively large and distortionary and canonical estimates load all of the effects on importer efficiency losses, the empirical literature would estimate nearly $40B (16% of import value) of deadweight loss to China form its tariffs in 1996. Interestingly, even though the estimated deadweight loss from the canonical method is nearly five times larger than from our model, the TRIs are nearly identical.

A related discussion exists in Anderson and Neary (2003). There they argue that differences in elasticity estimates have a relatively small effect on TRI calculations, but model specification has a more significant impact.[16] Here we are using the same elasticities for each calculation – the canonical case simply forces all export supply elasticities to zero. We confirm that model specification does in fact have a significant impact on our welfare calculations. However, a valuable feature of our model is it seems to nest the canonical restrictiveness measure from our decompositions. In essence, canonical estimates focus solely on the relative importance of importer efficiency losses from tariffs. This channel is readily documented by our model through $\text{TRI}_{\text{Efficiency}^I}$

China's post WTO accession trade in 2006 is handily different from 1996. On average, tariffs were cut by two thirds, and imports nearly quadruple. The growth in imports along with tariff cuts could lead to an ambiguous effect on the scale of the welfare effects from tariffs. We see that even though imports rose, declining tariffs dominate the efficiency losses, which fall from $8.6B (4% of import value) to $2.9B (0.3% of import value). Conversely, the terms of trade effects are dominated by the scale of imports. While the rise in levels from $35.4B to $36.7B, they fall in percent of import value from 15% to 4%. Total welfare gains in China from tariffs nearly double in levels, but fall in percent of import value from 8% to 3%. As we should expect, the TRIs measuring the efficiency losses to China fall. As we have noted, the information contained in $\text{TRI}^-_{\text{Net}}$ is more intricate than simply trade restrictiveness. Since this TRI falls, we can conclude that Chinese policy is less predatory wpost WTO accession. This is not surprising, since the confines of the WTO have been shown to hinder the ability of member countries to take advantage of terms of trade gains through tariffs.[17]

Comparing a particular period of trade policy for a particular importer provides a setting

[16]From pg. 645 of Anderson and Neary (2003), "Of course, all our estimates of the TRI and the MTRI are dependent on the model used to calculate them. Anderson (1998) reports that results are not very sensitive to elasticity values, a finding that applies here as well since the same data and model are used. The insensitivity result is consistent with the folklore of CGE modelingÑelasticities do not matter much but specification of the model does matter. (For an illustration in the TRI context, see O'Rourke (1997).) It would be useful to have estimates based on different CGE models to understand better the effects of differences in specification. Despite these caveats, the case seems to be made that the standard measures are likely to be very seriously misleading in practice."

[17]This is very much in line with Soderbery (2016)), who shows that while WTO importers' tariffs do respond to terms of trade motives they are less responsive after accession.

to further decompose the effects of policy. Our model also allows for rich analysis of the effects of an importer's policy on its trading partners. By introducing terms of trade effects and heterogeneity across exporters, our model generates significant variation in the impact of policy changes on exporting countries ignored by canonical estimates. Table 5 presents the impact of China's WTO accession on its main trade partners.

Table 5: The Effects of Chinese Tariffs on Exporter Welfare

China Imports: 1996					
Exporter	Exports	Efficiency*	Efficiency* (% of Exports)	Avg Tariff	TRI_{Eff^*}
JPN	65.340	−1.756	−2.69%	0.293	0.298
USA	26.278	−0.731	−2.78%	0.289	0.305
KOR	23.829	−0.911	−3.82%	0.295	0.336
DEU	16.103	−0.267	−1.66%	0.296	0.247
ITA	7.248	−0.120	−1.65%	0.308	0.241
RUS	5.222	−0.052	−1.00%	0.208	0.165
FRA	3.653	−0.077	−2.11%	0.297	0.256
GBR	3.590	−0.097	−2.69%	0.283	0.307
AUS	3.002	−0.034	−1.15%	0.272	0.184
IDN	2.497	−0.044	−1.75%	0.301	0.159
CAN	2.078	−0.036	−1.73%	0.262	0.223
SWE	1.732	−0.038	−2.22%	0.256	0.247
CHE	1.731	−0.031	−1.77%	0.275	0.245
NLD	1.700	−0.034	−2.00%	0.266	0.245
BRA	1.126	−0.460	−40.87%	0.249	1.047
IND	0.922	−0.012	−1.32%	0.275	0.196
ESP	0.858	−0.020	−2.32%	0.293	0.280
AUT	0.510	−0.007	−1.46%	0.266	0.216
MEX	0.278	−0.004	−1.47%	0.265	0.257
NOR	0.181	−0.003	−1.44%	0.243	0.219
Total	237.134	−7.126	−3.00%	0.216	0.303
China Imports: 2006					
Exporter	Exports	Efficiency*	Efficiency* (% of Exports)	Avg Tariff	TRI_{Eff^*}
JPN	261.678	−0.547	−0.21%	0.096	0.083
KOR	158.047	−0.341	−0.22%	0.096	0.082
USA	108.473	−0.340	−0.31%	0.094	0.098
DEU	75.830	−0.199	−0.26%	0.096	0.095
AUS	18.905	−0.069	−0.37%	0.091	0.099
ITA	17.479	−0.041	−0.24%	0.099	0.088
FRA	16.062	−0.035	−0.22%	0.097	0.085
RUS	13.709	−0.006	−0.05%	0.071	0.024
GBR	12.181	−0.028	−0.23%	0.091	0.086
IDN	11.071	−0.052	−0.47%	0.095	0.100
BRA	10.312	−0.019	−0.19%	0.084	0.058
CAN	10.181	−0.011	−0.11%	0.087	0.057
IND	9.241	−0.064	−0.69%	0.091	0.141
CHE	9.012	−0.028	−0.32%	0.091	0.102
BEL	7.562	−0.016	−0.21%	0.083	0.077
NLD	6.950	−0.013	−0.18%	0.089	0.070
SWE	5.966	−0.016	−0.26%	0.087	0.090
ESP	5.425	−0.011	−0.20%	0.095	0.076
MEX	3.602	−0.008	−0.21%	0.083	0.091
AUT	3.210	−0.009	−0.30%	0.089	0.099
NOR	1.246	−0.002	−0.12%	0.079	0.052
Total	953.212	−2.307	−0.24%	0.077	0.082

Notes: Exports and exporter welfare (Efficiency*) are in billions of US $.

As Table 4 documented, China's tariffs before WTO accession were large and relatively distortionary. Unlike the canonical model, which has no clear predictions regarding exporter welfare from tariffs, our model precisely calculates the deadweight losses to exporters from Chinese tariffs (Efficiency*). Exporter losses vary across country as their mix of products and export supply elasticities are heterogeneous. The country most impacted by Chinese tariffs in 1996, as a percent of total exports, was Brazil. Brazilian exporters exported about $1B of goods to China, but the mix of tariffs it faced resulted in 40% of this value in deadweight loss. Conversely, Russia was most favorably taxed by China, losing only 1% of its export value relative to free trade. These differences are clearly reflected by the TRI faced by exporters. The uniform tariff that would lead to the same welfare losses as applied tariffs was over 100% for Brazil, and only 16.5% for Russia.

Notably, WTO members tended to face the most restrictive tariffs in 1996, as their TRIs were generally large and tend to be above the average tariff they face. This apparent discrimination by Chinese policy potentially motivates the push for China to join the WTO, as we see exporter efficiency TRIs fall even below average tariffs for most members.

After joining the WTO, Chinese tariffs fall rapidly with heterogeneous effects across its trade partners. Efficiency losses to exporters fall across the board, with the most significant decreases being accrued by WTO members. Interestingly, even though Russia was not a WTO member at the time (and therefore not subject to MFN tariffs), China appears to have restructured tariffs favorably for them as well, as their deadweight losses fall to nearly zero percent of exports. Uncovering these rich patterns of how an importer's policy differentially impacts exporters hinges on our model's ability to capture terms of trade effects and exporter heterogeneity. Overall, deadweight losses for all exports to China fell from 3% of total exports ($7.1 billion) in 1996 to only 0.24% ($2.3 billion) in 2006.

4.2 Application: A Renegotiation of the NAFTA

President Trump has vowed to renegotiate the NAFTA. While the details of this renegotiation are murky, our model provides us with a lightweight tool to examine some hypothetical restructuring of tariffs between the US, Canada and Mexico. As a first step, we consider the (unlikely) situation where the US backs out of NAFTA by applying MFN tariffs to Canada and Mexico with no retaliation by these countries. That is to say, the US increases tariffs against its neighbors and Canada and Mexico maintain zero tariffs on US exports. Next, we consider the (more likely) situation where all North American countries back out of the NAFTA by reverting to MFN tariffs for each good they trade.

Table 6: Welfare Effects of Renegotiating the NAFTA

			Importer Welfare ($Bill)				Exporter Welfare ($Bill)		
Scenario		Imports	Efficiency^I	AggTOT^I	Total	Exports	Efficiency$^*_{CAN}$	Efficiency$^*_{MEX}$	Efficiency$^*_{US}$
Baseline	Canada	305.941	0.299	3.347	2.809	383.836	·	0	0
	Mexico	253.967	5.371	8.633	1.830	266.854	0	·	0
	US	626.763	2.901	40.423	34.473	535.981	0	0	·
US Only	Canada	305.941	0.299	3.347	2.809	376.154	·	0	0.150
	Mexico	253.967	5.371	8.633	1.830	259.625	0	·	0.156
	US	611.852	3.350	47.584	40.880	535.981	0	0	·
All N.A.	Canada	297.611	0.470	8.295	7.381	376.154	·	0	0.150
	Mexico	219.881	10.862	26.717	12.543	259.625	0	·	0.156
	US	611.852	3.350	47.584	40.880	493.565	0.205	1.880	·

Notes: Imports and Exports are from the other North American countries in billions of US $. Baseline is calculated using actual data in 2006. US only is the counterfactual where the US exits the NAFTA and applies MFN tariffs, and All N.A. indicates all North American countries exit the NAFTA and apply MFN tariffs.

We can calculate the counterfactual changes in trade flows and welfare in each country by simulating the effects implied by our model given our estimated import demand and export supply elasticities. Table 6 presents these counterfactual scenarios. Comparing our estimates using actual data (Baseline) to the first scenario where the US raises tariffs agains Canada and Mexico (US Only), we see that the value of US imports from Canada and Mexico only modestly decreases by around 2%. This is for two reasons. First, reverting to MFN tariffs by the US implies increasing tariffs from zero to only around 2% on average. Second, the US has relatively strong importer market power, as the median export supply elasticity in the US is relatively large and pass-through of the tariff relatively weak (Table 1). These characteristics explain why the distortion to US imports from increasing North American tariffs is mild. A related result is that US efficiency losses from the full set of tariffs remain relatively low at around $3 billion. However, US terms of trade gains increase as raising tariffs on its North American trade partners allows the US to capitalize on its importer market power. Ultimately, the US can realize welfare gains from unilaterally increasing tariffs agains Canada and Mexico.

The right-hand pane of Table 6 presents total exports by each North American country to the other North American countries. Here we see the complement of the effect on imports. The increase in US tariffs has a fairly symmetric impact on both Canadian and Mexican exports, with each falling by around 2%. Additionally, we can calculate the welfare losses to exporters from the increased US tariffs, and estimate losses around $150 million for both countries.

Next, we examine the effects of Canada and Mexico responding to US tariff increasing by applying their MFN tariffs to US imports. The strongest effects are seen in Mexico. There US exports fall by around 5%, and US welfare from exports to Mexico falls by around $2 billion. This is driven by relatively large increases in tariffs by Mexico – from zero to around 10% on average. This leads to substantial efficiency losses to Mexican consumers at around $11 billion (nearly doubling from the baseline). These efficiency losses are however offset by an increase in Mexican terms of trade gains, as Mexico capitalizes on market power over US imports.

One caveat to this analysis is the time frame of welfare effects. Given the estimation, welfare in this model should be thought of as short-medium run gains and losses. This does not account for any long run adjustments by import markets to rising prices and falling quantities of imports that could lead to additional welfare losses for the importer. For instance, the US imports significant numbers of goods used as intermediates in production from Mexico. Increasing prices of these imported goods may lead to long-run welfare losses in downstream US industries not captured by our model. Lastly, we should also admit the possibility that in the long-run export supply and import demand elasticities may be lower than our estimates. The former drives terms of trade gains to importers, and the latter dictates importer efficiency losses. Our estimates of short run terms of trade gains may decline and efficiency losses may grow in the long-run.

5 Conclusion

Applying a quantitative model that accounts for importer market power and exporter heterogeneity highlighted the importance of terms of trade when evaluating import tariffs. We demonstrated that the current empirical literature overstates importer losses from tariffs and restrictiveness as it ignores the gains to importers from manipulating terms of trade. Broadly, we showed that acknowledging importer terms of trade motives when setting tariffs has significant implications for welfare and TRI estimates in the data.

Finally, through an application of China's WTO accession we further documented the benefits of our methodology. We were able to explicitly measure the effects of China's sweeping tariff reductions on importer and exporter welfare. Additionally, we showed how our model can be used to identify the efficacy of import tariffs through various TRIs. Ultimately, the rich detail provided by our methodology should be a valuable tool for practitioners and policy makers alike.

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