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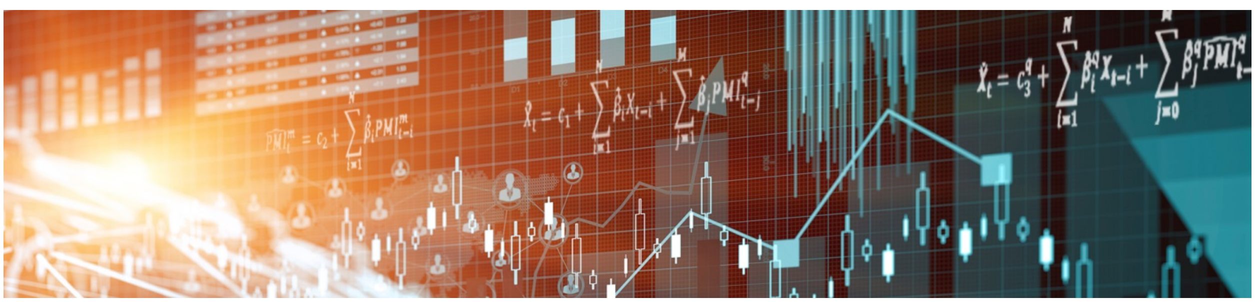
Estimating the Impacts of Tariff Changes: Two Illustrative Scenarios



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Abstract

We build upon new developments in the international trade literature to construct a quantitative Ricardian framework similar to Caliendo and Parro (2015) to isolate and estimate the long-run economic impacts of tariff changes. Our framework incorporates the most recent data and shows that the trade elasticities have changed considerably since the 1990s—highlighting the need to use recent data to quantitatively evaluate newly imposed and proposed tariff schedules. We apply our model and use our estimated elasticities to measure the long-run economic impact of the recently announced US tariffs on steel and aluminum and the first round of additional tariffs between the United States and China. Our results suggest that modifying the current global tariff schedules would imply considerable changes in trade flows and sectoral reallocations, but modest impacts on long-run output levels.

Bank topics: Recent economic and financial developments; Trade integration
JEL codes: F11, F13, F14, F15, F50, F62, F68

Résumé

Nous nous appuyons sur les travaux récents de la littérature sur le commerce international pour construire un modèle quantitatif semblable au modèle ricardien de Caliendo et Parro (2015). Ainsi, nous pouvons isoler et estimer les effets économiques à long terme des modifications apportées aux droits de douane. Notre cadre, qui intègre les données les plus récentes, indique que l'élasticité du commerce a largement changé depuis les années 1990. C'est pourquoi il est important d'utiliser des données récentes pour quantifier l'effet des droits de douane nouvellement imposés et proposés. À l'aide de notre modèle et de nos estimations de l'élasticité, nous calculons l'incidence économique à long terme des droits de douane sur l'acier et l'aluminium récemment annoncés par l'administration américaine et de la première série de droits de douane supplémentaires appliqués entre les États-Unis et la Chine. Les résultats obtenus donnent à croire que la modification des droits de douane internationaux actuels aurait des répercussions considérables sur les flux commerciaux et la réallocation entre les secteurs. Toutefois, les conséquences seraient modestes sur les niveaux de production à long terme.

Sujets : Évolution économique et financière récente; Intégration des échanges
Codes JEL : F11, F13, F14, F15, F50, F62, F68

1 Introduction

Quantifying the impact of tariff changes has become a priority for many policy institutions given the recent rising trade tensions. In this paper, we build upon new developments in the international trade literature to isolate and quantify the long-run economic impacts of tariff changes on the Canadian and global economies. In particular, we applied the most recent data and trade elasticity estimates on the Ricardian model of Caliendo and Parro (2015) to quantify the long-run impacts of tariff changes under the following two scenarios:

Scenario #1: The United States imposes import tariffs on steel and aluminum.

Scenario #2: The United States and China each impose tariffs on a series of goods worth $50 billion.

We use the Caliendo and Parro (2015) model in our benchmark analysis because of its many attractive features that allow us to precisely isolate and quantify the long-run impacts of tariff changes. First, it is a Ricardian trade model (e.g., Eaton and Kortum (2002)). This implies that differences in technology, across sectors and countries, drive comparative advantage and trade.[1] Second, the model has multiple countries and sectors, with interactions across tradable and non-tradable sectors observed in the input-output tables. Therefore, it allows for trade between countries that are different in terms of resources or technology, including different stages of development. In addition, the model explicitly incorporates trade in intermediate goods, which allows us to capture global value chains and to understand the impact of tariff changes on key systemic sectors of the economy. Third, the model's solution allows us to specifically isolate the long-run impacts of tariff changes from other economic developments. Finally, the multi-sector aspect of the model with input-output linkages allows us to run counterfactual scenarios on tariffs targeted to particular sectors or goods, and to understand how these targeted tariffs ripple through the economy.

We would like to emphasize that the results presented in this paper are long-run economic impacts from changes in tariff schedules predicted by our model. These are the impacts on trade flows and output levels once a new steady state has been reached by all countries and sectors, conditional on the current economic structure and state of technology. Our model does not address the transition to such an equilibrium, and the short-run impacts could be very different from those in the long run. In fact, such transitions are typically costly as companies have to turn to higher cost suppliers and workers in negatively affected sectors are laid off, while new opportunities in expanding sectors may take longer to be fully realized. In addition, our model does not include any real or nominal rigidities, or exchange rate movements, that would dictate the short-run model dynamics.[2] Finally, our model does not address the impact of other potential economic developments, such as advances in technology that affect growth (e.g., Cavallo and Landry (2018)), uncertainty and confidence effects, or government interventions to mitigate the negative impacts of tariff changes.

First, we look at the impact of the recently imposed tariffs on US imports of steel and aluminum. These intermediate metals are important inputs in many sectors of the economy. Therefore, tariffs levied on this sector tend to have larger effects on trade and output. The model suggests that the recently imposed tariffs on US imports of steel and aluminum affects Canadian, Mexican and US long-run output more than any other country's. In this scenario, Canadian exports of steel and aluminum fall significantly, but the impact

[1] Comparative advantage is a country's ability to produce a good at a lower cost relative to other goods and other countries, based on technology, and taking into account geography, tariffs and other trade barriers.

[2] To be precise, there is no explicit exchange rate in our model. The exchange rate, however, can be thought as the bilateral ratio of the consumption price index presented in Section 2.

on total Canadian exports is mitigated by a change in its sectoral composition: In response to the new tariffs, the model suggests that Canada increases its exports of raw materials and fabricated metals.

Second, we consider the impact of rising tensions in the US-China trade relationship. Such trade tensions can have direct consequences on these two large economies, but could also have indirect consequences for Canada and the rest of the world by disrupting global value chains. Specifically, we look at the trade and output impacts from the first round of tariffs on $50 billion worth of goods imports announced by both countries. The model suggests that the effects of increased tariffs on real GDP are larger for China than for the United States, both with and without China's reciprocal action. In particular, trade between China and the United States falls significantly following the imposition of these tariffs. For instance, Chinese exports to the United States fall by about 14 per cent. Interestingly, the model suggests that Mexico would make large market-share gains, suggesting that its goods are effective substitutes for Chinese exports. Overall, raising import tariffs between the United States and China would have a minimal impact on Canadian long-run output. The model also suggests that a reciprocal action is not beneficial for China's long-run output.

Overall, these results suggest that modifying the current global tariff schedules would imply considerable changes in trade flows and sectoral reallocations, but modest impacts on long-run output levels. The rest of the paper proceeds as follows. In section 2, we present the main equations of the Caliendo and Parro (2015) model, which we use as the backbone to run our tariff changes scenarios. In section 3, we describe the data and show our recent sectoral trade-elasticity estimates. The reader most interested in the results can move directly to section 4, in which we present our simulated results. Finally, section 5 concludes.

2 The Economic Environment

Our economic environment builds on the Eaton and Kortum (2002) Ricardian model of trade and is similar to Caliendo and Parro (2015). The model features multiple regions, sectoral linkages and heterogeneity in production structures. Households receive income from labour income and tariff revenues. Labour is the only factor of production, which is perfectly mobile across sectors but not across countries. The production technology displays constant returns to scale, and all markets are perfectly competitive. Finally, international trade in goods is costly because of transportation costs and tariffs. Below, we present the main equations of the Caliendo and Parro (2015) model, which we use as the backbone to run our tariff changes scenarios, and discuss its equilibrium equations.[3]

The Caliendo-Parro model

Households

In each country, representative households maximize utility by consuming a plethora of final goods C_n^j according to Cobb-Douglas preferences:

$$u(C_n) = \prod_{j=1}^{J} {C_n^j}^{\alpha_n^j}, \text{ where } \sum_{j=1}^{J} \alpha_n^j = 1. \tag{1}$$

Households receive income I_n from tariff revenues and labour income $w_n L_n$, where w_n represents country n's wage and L_n represents country n's labour supply.

[3] A more detailed version of the model and its solution are available in Caliendo and Parro (2015).

Intermediate goods

A continuum of intermediate goods ω^j is produced in each sector j. To capture the sectoral linkages, intermediate goods ω^j are produced from labour and a composite of intermediate goods from all other sectors—thereafter materials. To capture heterogeneity in production structures, we assume that producers of intermediate goods differ in production efficiency $z_n^j(\omega^j)$ and in their materials input. The production technology of an intermediate good ω^j in country n is

$$q_n^j(\omega^j) = z_n^j(\omega^j) \cdot l_n^j(\omega^j)^{\gamma_n^j} \cdot \prod_{k=1}^{J} m_n^{k,j}(\omega^j)^{\gamma_n^{k,j}} \text{ , where } \omega^j \in [0,1], \gamma_n^{k,j} \geq 0. \tag{2}$$

In equation (2), $l_n^j(\omega^j)$ represents labour, while $m_n^{k,j}(\omega^j)$ represents materials from sector k used in the production of intermediate goods ω^j. The parameter $\gamma_n^{k,j}$ is the share of materials from sector k used in the production of intermediate goods ω^j, with $\sum_{k=1}^{J} \gamma_n^{k,j} = 1 - \gamma_n^j$ and where $\gamma_n^j \geq 0$ is the share of value added. Constant returns to scale in the production of intermediate goods imply that existing technology can be scaled to meet changing demand (e.g., following a change in trade flows).

Since production of intermediate goods is constant returns to scale and markets are perfectly competitive, firms price at unit cost, $c_n^j / z_n^j(\omega^j)$, where the cost c_n^j of an input bundle is

$$c_n^j = \Psi_n^j \cdot w_n^{\gamma_n^j} \cdot \prod_{k=1}^{J} P_n^{k^{\gamma_n^{k,j}}} \text{, where } \Psi_n^j = \prod_{k=1}^{J} (\gamma_n^{k,j})^{-\gamma_n^{k,j}} (\gamma_n^j)^{-\gamma_n^j}. \tag{3}$$

In equation (3), P_n^k is the cost of materials from sector k, and Ψ_n^j is a constant, reflecting sectoral productivity differences across countries. Equation (3) captures a key difference relative to the one-sector model, as the cost of the input bundle depends on wages and on the price of all the composite intermediate goods in the economy. A change in policy that affects the price in any single sector will indirectly affect all the sectors in the economy via the wage and materials input.

Retailers

Retailers supply composite intermediate goods to households and firms. They supply Q_n^j at minimum cost by purchasing intermediate goods ω^j from the lowest-cost suppliers across countries.[4] The quantity of materials Q_n^j follows a Dixit and Stiglitz (1977) aggregate such that

$$Q_n^j = \left(\int r_n^j(\omega^j)^{1-1/\sigma^j} d\omega^j \right)^{\sigma^j/(\sigma^j - 1)}, \tag{4}$$

where $\sigma_j > 0$ is the elasticity of substitution across intermediate goods within sector j, and $r_n^j(\omega^j)$ is the demand of intermediate goods ω^j from the lowest cost supplier. The solution to the problem of the composite intermediate good producer gives the following demand for good ω^j:

[4] Allowing for producers of composite intermediate goods to search for the lowest-cost supplier is a key distinction from models with Armington-type assumptions such as the Global Trade Analysis Project (Corong et al. (2017)). In Ricardian models based on Eaton and Kortum (2002), the source from which goods are purchased is endogenously determined and can change as a consequence of tariff reductions. This is an adjustment along the extensive margin of trade.

$$r_n^j(\omega^j) = \left(\frac{p_n^j(\omega^j)}{P_n^j} \right)^{-\sigma^j} Q_n^j, \tag{5}$$

where P_n^j is the unit price of materials such that

$$P_n^j = \left(\int p_n^j(\omega^j)^{1-\sigma^j} d\omega^j \right)^{1/(1-\sigma^j)}, \tag{6}$$

and where $p_n^j(\omega^j)$ denotes the lowest price of intermediate good ω^j across all locations n where it can be delivered. In turn, composite intermediate goods from sector j are used as materials for the production of intermediate good ω^k in the amount $m_n^{j,k}(\omega^k)$ in all sectors k, and as final goods in consumption C_n^j. As such, the market clearing condition for the intermediate and final goods sector j is

$$Q_n^j = C_n^j + \sum_{k=1}^{J} \int m_n^{j,k}(\omega^k) d\omega^k. \tag{7}$$

Trade costs and prices

We consider two types of trade costs. First, a transportation cost or iceberg cost is defined in physical units as in Samuelson (1954), where one unit of a tradable intermediate good in sector j shipped from country i to country n requires producing $d_{ni}^j \geq 1$ units in i, with $d_{nn}^j = 1$. Second, an ad-valorem flat-rate tariff τ_{ni}^j applicable over unit prices. Combining both trade costs leads to the following:

$$\kappa_{ni}^j = (1 + \tau_{ni}^j) \cdot d_{ni}^j. \tag{8}$$

After taking into account trade costs, a unit of a tradable intermediate good ω^k produced in country i is available in country n at unit prices $c_i^j \kappa_{ni}^j / z_i^j(\omega^j)$. Therefore, the price of intermediate good ω^k in country n is given by

$$p_n^j(\omega^j) = \min_i \left(\frac{c_i^j \kappa_{ni}^j}{z_i^j(\omega^j)} \right). \tag{9}$$

The tradable and the non-tradable sectors are identical, except that $\kappa_{ni}^j = \infty$ in the non-tradable sector. Thus, it is always cheaper to buy goods from local suppliers in the non-tradable sector.

Ricardian motives to trade are introduced following the Eaton and Kortum (2002) probabilistic representation of technologies allowing productivities to differ by country and sector. As such, we assume that the efficiency of producing a good ω^j in country n is the realization of a Fréchet distribution with a location parameter that varies by country and sector $\lambda_n^j \geq 0$ and shape parameter that varies by sector θ^j. In the context of this model, a higher $\lambda_n^j \geq 0$ implies higher average sectoral productivity—a notion of absolute advantage—whereas a smaller value of θ^j implies higher dispersion of productivity across goods ω^j—a notion of comparative advantage. We assume that the distributions of productivities are independent across goods, sectors and countries, and that $1 + \theta^j > \sigma^j$. With these assumptions, the price of the composite intermediate good is given by

$$P_n^j = A^j \left(\sum_{i=1}^{N} \lambda_i^j (c_i^j \kappa_{ni}^j)^{-\theta^j} \right)^{-1/\theta^j}, \tag{10}$$

for all sectors j and countries n.

Finally, with Cobb-Douglas preferences, the consumption price index is given by

$$P_n = \prod_{j=1}^{J} \left(\frac{P_n^j}{\alpha_n^j} \right)^{\alpha_n^j}. \tag{11}$$

Expenditure shares

Total expenditure on sector j goods in country n is given by

$$X_n^j = P_n^j Q_n^j. \tag{12}$$

Denote X_{ni}^j to be the expenditure in country n of sector j goods from country i. It follows that country n's share of expenditure on goods j from i is given by

$$\pi_{ni}^j = \frac{X_{ni}^j}{X_n^j}, \tag{13}$$

which is also the probability that country i provides goods at the lowest cost to country n. Using the properties of the Fréchet distribution, we can derive expenditure shares as a function of technologies, prices and trade costs:

$$\pi_{ni}^j = \frac{\lambda_i^j (c_i^j \kappa_{ni}^j)^{-\theta^j}}{\sum_{h=1}^{N} \lambda_h^j (c_h^j \kappa_{nh}^j)^{-\theta^j}}. \tag{14}$$

Notice that changes in tariffs have a direct effect on trade shares via the trade cost κ_{ni}^j, and an indirect effect through the input bundles cost c_n^j—since it incorporates all the information contained in input-output linkages.

Total expenditure and trade balance

Total expenditure on sector j is the sum of the expenditure on composite intermediate goods by firms and expenditure by households. Then, X_n^j is given by

$$X_n^j = \sum_{k=1}^{J} \gamma_n^{jk} \cdot \sum_{i=1}^{N} \frac{\pi_{in}^k}{1+\tau_{in}^k} X_i^k + \alpha_n^j I_n, \tag{15}$$

where

$$I_n = w_n L_n + R_n + D_n. \tag{16}$$

In this equation, I_n represents final absorption as the sum of labour income $w_n L_n$, tariff revenues R_n, and D_n the trade deficit. Specifically,

$$R_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{ni}^j M_{ni}^j, \text{ where } M_{ni}^j = X_n^j \frac{\pi_{ni}^j}{1+\tau_{ni}^j} \text{ represents imports,} \tag{17}$$

and

$$D_n = \sum_{k=1}^{J} D_n^k, \text{ and } D_n^j = \sum_{i=1}^{N} M_{ni}^j - \sum_{i=1}^{N} E_{ni}^j, \text{ where} E_{ni}^j = X_i^j \frac{\pi_{in}^j}{1+\tau_{in}^j} \text{ represents exports.} \tag{18}$$

Aggregate trade deficits in each country are exogenous in the model, while sectoral trade deficits are endogenously determined.[5]

Finally, using the definition of expenditure and trade deficit we have that

$$\sum_{j=1}^{J}\sum_{i=1}^{N} \frac{\pi_{ni}^j}{1+\tau_{ni}^j} X_n^j - D_n = \sum_{j=1}^{J}\sum_{i=1}^{N} \frac{\pi_{in}^j}{1+\tau_{in}^j} X_i^j. \tag{19}$$

This condition reflects the fact that total expenditure, excluding tariff payments, in country n minus trade deficits equals the sum of each country's total expenditure, excluding tariff payments, on tradable goods from country n. In this environment, the equilibrium of the model can be described as follows:

Model's equilibrium: Given L_n, D_n, λ_n^j and d_{ni}^j, an equilibrium under policy τ is a wage vector $w \in R_{++}^N$ and prices $\{P_n^j\}_{j=1,n=1}^{J,N}$ that satisfy equilibrium condition (3), (10), (14), (15) and (19) for all j, n.

Equilibrium in relative changes

As in Caliendo and Parro (2015), we solve for changes in prices and wages after changing from tariff schedules τ to τ', instead of solving for an equilibrium under tariff schedules τ. First, this allows us to condition the model on the state of the world in a base year. Second, this allows us to identify the effect on equilibrium outcomes from a pure change in tariff schedules—which is what we are after in this paper. Finally, we can solve for the general equilibrium of the model without needing to estimate parameters that are difficult to identify in the data, as productivity parameters and iceberg cost vanish in differences. The equilibrium of the model in relative changes, that is under tariff schedule τ' relative to a tariff schedule τ, can be described as follows:

Equilibrium in relative changes: Let (w, P) be an equilibrium under policy τ and let (w', P') be an equilibrium under tariff schedule τ'. Define $(\hat{w}, \hat{P})$ as an equilibrium under τ' relative to τ, where a variable with a hat "$\hat{x}$" represents the relative change of the variable, namely $\hat{x} = x'/x$. Using equations (3), (10), (14), (15) and (19), the equilibrium conditions in relative changes satisfy the following conditions:

1. Cost of the input bundles:

$$\hat{c}_n^j = \hat{w}_n^{\gamma_n^j} \cdot \prod_{k=1}^{J} \hat{P}_n^{k\gamma_n^{k,j}}. \tag{20}$$

2. Price index:

$$\hat{P}_n^j = \left(\sum_{i=1}^{N} \pi_{ni}^j (\hat{c}_i^j \hat{\kappa}_{ni}^j)^{-\theta^j}\right)^{-1/\theta^j}. \tag{21}$$

[5]The quantitative results are robust to whether we exogenously impose current aggregate trade surplus/deficits or aggregate balanced trade for each region.

3. Bilateral trade shares:

$$\hat{\pi}^j_{ni} = \left(\frac{\hat{c}^j_i \hat{\kappa}^j_{ni}}{\hat{P}^j_n}\right)^{-\theta^j}. \tag{22}$$

4. Total expenditure in each country n and sector j:

$$X^{j\prime}_n = \sum_{k=1}^{J} \gamma^{jk}_n \cdot \sum_{i=1}^{N} \frac{\pi^{k\ \prime}_{in}}{1+\tau^{k}_{in\prime}} X^{k\prime}_i + \alpha^j_n I^{\prime}_n. \tag{23}$$

5. Trade balance:

$$\sum_{j=1}^{J}\sum_{i=1}^{N} \frac{\pi^{j\ \prime}_{ni}}{1+\tau^{j\ \prime}_{ni}} X^{j\prime}_n - D_n = \sum_{j=1}^{J}\sum_{i=1}^{N} \frac{\pi^{j\ \prime}_{in}}{1+\tau^{j\ \prime}_{in}} X^{j\prime}_i, \tag{24}$$

where

$$\hat{\kappa}^j_{ni} = \frac{1+\tau^{j\ \prime}_{ni}}{1+\tau^{j}_{ni}}, \text{ and } I^{\prime}_n = w^{\prime}_n L_n + \sum_{j=1}^{J}\sum_{i=1}^{N} \tau^{j\ \prime}_{ni} \frac{\pi^{j\ \prime}_{ni}}{1+\tau^{j\ \prime}_{ni}} X^{j\prime}_n + D_n. \tag{25}$$

From inspecting equilibrium conditions 20-23, we can observe that the focus on relative changes allows us to perform policy experiments without relying on estimates of total factor productivity or transport costs. We need only two sets of tariff structures (τ and τ'), data on bilateral trade shares (π^j_{ni}), the share of value added in production (γ^j_n), value added ($w_n L_n$), the share of intermediate consumption ($\gamma^{k,j}_n$) and sectoral dispersion of productivity (θ^j). The share of each sector in final demand (α^j_n) is obtained from these data. In the next section, we briefly describe the data and the estimation of sectoral productivity dispersion (θ^j)—which is the only set of parameters to estimate.

3 Data and Estimation

Matching the model with the data

Our quantitative analysis includes 44 sectors and 16 regions. The sectors are divided into 24 tradable and 20 non-tradable sectors, which are enumerated in Appendix A. We group sectors by commodities defined using the Harmonized Commodity Description and Coding System (HS) 2012 at the six-digit level of aggregation and concorded to two digits ISIC Revision 3. The regions include Canada, its main trading partners, and a catch-all region named rest of world—which is especially important to understand global trade flows. Canada's main trading partners are Australia, Brazil, China, the European Union, India, Japan, Malaysia, Mexico, Norway, Peru, South Korea, Switzerland, Thailand and the United States.[6]

We use the most recent available data to get an up-to-date picture of the global economy. Data on bilateral trade flows are from the United Nations Statistical Division (UNSD) Commodity Trade (COMTRADE) database. We use an average of 2014 and 2015 bilateral trade flows data because some sectoral trade flows are lumpy even at annual frequency (e.g., aircraft).[7] Data on sectoral value added, gross production and

[6]Canada's main trading partners are defined in the Canadian Effective Exchange Rate published on the Bank of Canada's website.

[7]We choose to not incorporate the 2016 bilateral trade flow data because the recent oil price shock affected trade flows significantly in 2016.

input-output tables are from the 2011 OECD Input-Output Database.[8] We obtain measures of π_{ni}^{j}, γ_{n}^{j}, $\gamma_{n}^{j,k}$ and α_{n}^{j} using data on bilateral trade flows, value added, gross production and input-output tables.

Finally, bilateral tariffs data are from the WTO Tariffs Database for the year 2016 at the HS 2012 six-digit level. They are aggregated into our 24 tradable sectors using the average of 2014 and 2015 bilateral trade flow data. We use trade agreement tariffs (e.g., NAFTA) when lower than most-favoured-nation (MFN) tariffs, and apply symmetric tariff schedules in cases where a trade agreement between two countries was not available for one of the countries in the WTO Tariffs Database.

Trade elasticity estimates

The remaining parameters to measure are the trade elasticities. In the model, trade elasticities govern the extent of comparative advantage and are key parameters for our quantitative scenarios analysis. For example, a low trade elasticity implies a high productivity dispersion across countries. This means that a retailer's current supplier is likely to remain its lowest-cost supplier when trade costs increase. As such, an increase in tariffs or other trade costs has a small impact on trade flows.

We estimate trade elasticities using tariff schedules and bilateral trade flow data following Caliendo and Parro (2015). Specifically, our estimating equation is

$$\ln\left(\frac{X_{ni}^{j}X_{ih}^{j}X_{hn}^{j}}{X_{in}^{j}X_{hi}^{j}X_{nh}^{j}}\right) = -\theta^{j}\ln\left(\frac{\tilde{\tau}_{ni}^{j}\tilde{\tau}_{ih}^{j}\tilde{\tau}_{hn}^{j}}{\tilde{\tau}_{in}^{j}\tilde{\tau}_{hi}^{j}\tilde{\tau}_{nh}^{j}}\right) + \epsilon^{j}, \tag{26}$$

where $\tilde{\tau}_{ni} = (1 + \tau_{ni})$ for all n, h, i.

Our trade elasticity estimates and their standard errors are presented in **Table 1**. The elasticity estimates range from a high degree of substitutability of 69.1 in the other energy sector (e.g., coal) to a low of 1.1 in the farm sector. For example, the intermediate metals sector (e.g., steel and aluminum) elasticity estimate is in the mid-range of 6.2. From (22), this implies that a 10 per cent increase in tariffs reduces the sectoral imports shares by 45 per cent—keeping everything else constant. These estimates are in the range of the trade elasticity estimates in the literature.[9]

The dispersion in trade elasticity shown in **Table 1** highlights differences in sectoral sensitivity to tariff changes. The equality of parameter estimates across sectors is strongly rejected by an F-test. Although the focus of this paper is on sectoral trade elasticities and input-output linkages, we nevertheless estimated an aggregate trade elasticity by running (26) on all sectoral data. For example, this is the trade elasticity that would be used in a one-sector model such as Eaton and Kortum (2002). On aggregate, our trade elasticity estimate is 2.7, which is in the range of the estimates in the literature. Notice, however, that this aggregate elasticity estimate is much lower than the sectoral average of 12.0. See Imbs and Mejean (2015) and Simonovska and Waugh (2014) for a discussion on this issue and other recent advances.

Table 1 also shows the trade elasticity reported in Caliendo and Parro (2015). These are based on 1993 data, the year before NAFTA came into force. These trade elasticity movements highlight the importance of using recent estimates when quantifying the impact of tariff changes on the global economy.

[8] At the time of publication, the 2011 OECD Input-Output Database was the most up-to-date database that ensured consistency across countries.

[9] These estimates are robust to the removal of different types of outliers.

Table 1: Trade elasticity estimates

Sector	θ_{2016}	s.e.	θ_{1993}	s.e.
Other energy	69.1	(5.6)	51.1	(18.1)
Ores	43.0	(9.4)	15.7	(2.8)
Pharmacy	29.4	(4.4)	4.8	(1.8)
Oil and gas	18.2	(2.1)	51.1	(18.1)
Wood	15.8	(1.0)	10.8	(2.5)
Machinery, n.e.c	13.0	(2.5)	1.5	(1.8)
Electrical machinery	12.3	(3.5)	10.6	(1.4)
Medical and communication	9.8	(4.4)	7.1	(1.7)
Metals (fabricated)	9.6	(2.2)	4.3	(2.2)
Paper	9.1	(1.8)	9.1	(1.7)
Other transportation	8.7	(0.6)	0.4	(1.1)
Printing	8.3	(2.2)	9.1	(1.7)
Recyclable	7.6	(1.4)	5.0	(0.9)
Metals (intermediate)	6.2	(1.9)	8.0	(2.5)
Rubber	5.0	(2.2)	1.7	(1.4)
Auto	4.5	(2.3)	1.0	(0.8)
Aircraft	3.5	(3.1)	0.4	(1.1)
Non-metal products	3.0	(1.4)	2.8	(1.4)
Other manufacturing, n.e.c	2.9	(1.9)	5.0	(0.9)
Chemicals	2.2	(1.8)	4.8	(1.8)
Non-metals	1.9	(1.7)	15.7	(2.8)
Clothing	1.7	(1.0)	5.6	(1.1)
Food	1.5	(0.4)	2.6	(0.6)
Farm	1.1	(0.2)	8.1	(1.9)
Aggregate	2.7	(0.1)	4.5	(0.4)

Note: θ_{1993} are from Caliendo and Parro (2015). Some of these estimates have been split across sectors due to the smaller number of sectors in Caliendo and Parro (2015).

4 Two Illustrative Scenarios

In this section, we measure the long-run economic impacts of two tariff scenarios: (1) the United States imposes tariffs on aluminum and steel and (2) the United States and China each impose tariffs on a series of goods worth $50 billion. In particular, we present goods trade (i.e., merchandise trade) and real GDP effects. Since this is a one-factor model, the latter correspond to the real wage impact. Furthermore, we focus on trade flow impacts from tariff changes—and not on the growth or decline of the respective domestic sectors.

Recall that all the effects discussed below are long-run impacts. That is, these are the impacts on trade flows and output levels after a new steady state has been reached by all countries and sectors conditional on

Table 2: US impact from the recent US tariffs on steel and aluminum
(25 per cent tariff on steel and 10 per cent tariff on aluminum, percentage change)

Metal intermediates		**Total**		**Real**
Imports	Exports	Imports	Exports	**GDP**
-43.5	-8.3	-1.2	-1.9	-0.04

the current economic structure and state of technology. This model does not address the transition to such an equilibrium, and the short-run impacts could be very different from those in the long run. Our model does not include any real or nominal rigidities, or short-run exchange rate movements, that would dictate the short-run model dynamics. In addition, our model does not address the impact of other potential economic developments, such as advances in technology that affect growth (e.g., Cavallo and Landry (2018)), uncertainty and confidence effects, or government interventions to mitigate the negative impacts of tariff changes.

Scenario #1: US tariffs on steel and aluminum

On March 1, 2018, President Trump announced his intention to impose a 25 per cent tariff on steel and a 10 per cent tariff on aluminum imports. On May 31, the US administration announced the end of tariff exemptions granted to Canada, Mexico and the European Union and on June 1, it began to levy the tariffs. We consider the impact of these tariffs on the United States and its trading partners.[10]

Intermediate metals are important intermediate goods in many other sectors. Therefore, tariffs on this sector tend to have larger effects due to the importance it holds in input-output linkages. The main results for the United States are presented in **Table 2** and the results for the other countries in **Table 3**.

Overall, the main takeaway is that the countries that see the largest impacts on their real GDP are Canada, the United States and Mexico—although small in relative terms. Moreover, trade in the sector sees a considerable change. Canadian exports of intermediate metals fall significantly. However, the impact on total Canadian exports is mitigated by a change in the sectoral composition. In response to the tariffs, the model suggests that Canada starts exporting less processed and more processed metal goods, particularly in the ores and fabricated metals sectors.

As mentioned in the previous section, this sector has a large trade elasticity and is therefore quite sensitive to tariff changes. Consequently, US imports of intermediate metals fall considerably. In fact, the model suggests an overshoot of the target identified in Department of Commerce documents (U.S. Department of Commerce (2018a), U.S. Department of Commerce (2018b)). US exports also fall in many sectors, partly reflecting the importance of intermediate metals as an input in their own exports, and further contributing to the fall in real GDP.

[10]The model uses aggregate sectors, and tariffs cannot be applied on individual goods. This scenario is therefore calculated with a trade-weighted average tariff on US imports of intermediate metals for each country. The weights are applied at the HS 2012 six-digit level on all aluminum and steel goods.

Table 3: Global impact from the recent US tariffs on steel and aluminum
(25 per cent tariff on steel and 10 per cent tariff on aluminum, percentage change)

	Exports of metal intermediates to		**Total exports to**		**Real GDP**
Source	United States	World	United States	World	
Australia	-32.4	-1.5	-2.4	-0.1	-0.01
Brazil	-68.5	-19.2	-9.9	-0.6	-0.01
Canada	-33.4	-18.2	-1.4	-0.8	-0.05
China	-58.6	-4.3	0.0	0.1	0.00
European Union	-56.5	-2.8	-1.3	0.0	0.00
India	-67.1	-5.8	-2.0	-0.2	-0.01
Japan	-63.1	-4.6	-0.8	0.0	0.00
Malaysia	-21.3	-1.2	0.4	0.1	-0.01
Mexico	-26.0	-18.9	-0.3	-0.2	-0.04
Norway	-13.9	-1.2	-1.2	-0.1	-0.01
Peru	26.5	3.9	6.8	0.2	0.00
South Korea	-66.5	-9.7	-4.3	-0.2	-0.02
Switzerland	8.6	0.0	0.6	0.0	-0.02
Thailand	-53.7	-2.4	0.1	0.0	0.00
United States	·	-8.3	·	-1.9	-0.04
RoW	-39.7	-2.8	-2.1	0.0	-0.01

Note: RoW refers to rest of the world, which is an aggregate of countries not listed in this table.

Scenario #2: The US-China trade relationship

Second, we consider the impact of the rising tension in the US-China trade relationship. Specifically, we look at the trade and real GDP impacts of the first round of tariffs announced by both countries on $50 billion worth of goods imports.[11]

The main impacts on trade and real GDP are presented in **Table 4**. We focus on exports to Canada, China and the United States as well as the real GDP impact. The model suggests that effects of this trade conflict on real GDP are larger for China than the United States, both with and without China's reciprocal action. In fact, the model suggests that a reciprocal action does not benefit China's long-run real GDP.

Trade between China and the United States falls significantly following the imposition of these tariffs. For instance, Chinese exports to the United States fall by about 14 per cent. Canada's exports to the United States rise as a consequence. There has been much discussion about the fall in Canada's market share of US imports and the model suggests that this trade conflict would result in Canada regaining some of the lost ground. Interestingly, however, the model suggests that Mexico would make larger export gains, suggesting that Canada's exports are not the best substitute for Chinese exports. Overall, this imposition of tariffs would

[11] We simulate this scenario with a 25 per cent tariff on US imports from China of the aircraft and printing sectors, a 10 per cent tariff on machinery, n.e.c., and a 3.75 per cent tariff on the medical and communication sector, reflecting tariffs of $50 billion on Chinese goods. We simulate the Chinese retaliation with a 25 per cent tariff on Chinese imports from the United States of the farm, chemicals, aircraft and auto sectors, summing to $50 billion.

Table 4: Global impact from the recent US tariffs on Chinese goods imports
(United States imposes tariffs on $50 billion of Chinese goods imports, percentage change)

	Total exports to			Real
Source	Canada	China	United States	**GDP**
Panel A: US tariffs only				
Australia	2.1	-3.9	3.0	-0.01
Brazil	1.0	-2.5	1.8	-0.00
Canada	·	-3.3	0.7	-0.00
China	2.1	·	-14.0	-0.06
European Union	1.0	-2.0	3.0	0.01
India	0.7	-1.2	1.2	0.00
Japan	1.0	-2.1	4.1	0.01
Malaysia	0.8	-2.3	7.6	0.02
Mexico	-0.3	-4.8	2.2	0.03
Norway	1.9	-1.7	2.2	0.00
Peru	1.5	-4.2	0.9	-0.01
South Korea	1.1	-1.9	4.4	0.00
Switzerland	1.0	-2.2	3.6	0.00
Thailand	0.6	-1.7	5.6	0.03
United States	-0.8	-3.2	·	-0.03
RoW	1.2	-2.1	2.1	0.00
Panel B: Reciprocal action by China with tariffs on $50 billion of US goods				
Australia	1.5	-3.2	2.3	-0.01
Brazil	0.6	-1.8	1.3	-0.00
Canada	·	-2.2	0.6	0.00
China	1.5	·	-14.6	-0.14
European Union	0.6	-0.8	2.6	0.01
India	0.5	-0.9	0.9	0.00
Japan	0.7	-1.8	3.6	0.01
Malaysia	0.6	-2.1	7.2	0.02
Mexico	-0.3	-4.1	2.1	0.04
Norway	1.0	-1.1	1.9	-0.00
Peru	1.2	-3.3	0.5	-0.01
South Korea	0.8	-1.7	4.0	0.00
Switzerland	0.4	-1.8	3.3	0.00
Thailand	0.4	-1.5	5.2	0.02
United States	-0.4	-15.2	·	-0.04
RoW	0.7	-1.8	1.8	-0.00

Note: RoW refers to rest of the world, which is an aggregate of countries not listed in this table.

have a minimal impact on Canadian real GDP.

5 Conclusion

In this paper, we build upon new developments in the international trade literature to identify and quantify the impact of tariff changes on the Canadian and global economies. In particular, we apply the most recent data and trade elasticity estimates using the Ricardian model of Caliendo and Parro (2015) to quantify the impact of recently applied and proposed tariff changes. Our results suggest that modifying the current global tariff schedules would imply massive changes in trade flows and sectoral reallocations, but modest impacts on long-run output levels. We can also apply our framework to look at the long-run economic impacts of Brexit, the proposed Trans-Pacific Partnership (TPP) or the Canada-European Union Comprehensive Economic and Trade Agreement (CETA), as well as other alternative tariff scenarios.

Once again, we would like to reiterate that the results presented in this paper are long-run economic impacts. That is, these are the impacts on trade flows and output levels once a new steady state has been reached by all countries and sectors conditional on the current economic structure and state of technology. Our analysis does not address the transition to such an equilibrium, and the short-run impacts could be very different from those in the long run.

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A Appendix

Table A-1: Sector decomposition and corresponding ISIC

Number	ISIC	Sector
1	01,05	Farm
2	02,20	Wood
3	10,12,23	Other energy
4	11	Oil and gas
5	13	Ores
6	14	Non-metals
7	15-16	Food
8	17-19	Textiles
9	21	Paper
10	22	Printing
11	24	Chemicals
12	2423	Pharmacy
13	25	Rubber
14	26	Non-metal products
15	27	Metals (intermediate)
16	28	Metals (fabricated)
17	29	Machinery
18	30-33	Medical and communication
19	31	Other electric
20	34	Auto
21	351,352,359	Other transport
22	353	Aircraft
23	36	Other manufacturing
24	37	Recyclable
25	40-41	Electricity
26	45	Construction
27	50-52	Retail
28	55	Hotels
29	60	Land transport
30	61	Water transport
31	62	Air transport
32	63	Aux transport
33	64	Post
34	65-67	Finance
35	70	Real estate
36	71	Renting machinery
37	72	Computer
38	73	Research and development
39	74	Other business
40	75	Public
41	80	Education
42	85	Health
43	90-93	Other services
44	95	Private