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ABSTRACT

We propose a novel approach to estimate the trade elasticity at various horizons. When large countries change Most Favored Nation (MFN) tariffs, small trading partners that are not in a preferential trade agreement experience plausibly exogenous tariff changes. The differential growth rates of imports from these countries relative to a control group — countries not subject to the MFN tariff scheme —can be used to identify the trade elasticity. We build a panel dataset combining information on product-level tariffs and trade flows covering 1995-2017, and estimate the trade elasticity at short and long horizons using local projections (Jordà, 2005). Our main findings are that the elasticity of tariff-exclusive trade flows in the year following the exogenous tariff change is about –0.7, and the long-run elasticity ranges from –1.5 to –2. The welfare-relevant long-run trade elasticity is about –0.6. Our long-run estimates are smaller than typical in the literature, and it takes 7-10 years to converge to the long run, implying that (i) the welfare gains from trade are high and (ii) there are substantial market penetration costs to accessing new customers.

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1 Introduction

The elasticity of trade flows to trade barriers – the "trade elasticity" – is the central parameter in international economics. Quantifications of the impact of shocks or trade policies on trade flows, GDP, and welfare hinge on its magnitude. However, there is currently no consensus on the value of this parameter, with a variety of empirical strategies delivering a broad range of estimates.[1]

This paper develops and implements a novel approach to estimating trade elasticities. Our principal contributions are to simultaneously address (i) endogeneity due to possible reverse causality and omitted variables, and (ii) variation across time horizons. The main results can be summarized as follows. First, our estimate of the long-run elasticity of trade values exclusive of tariff payments is -1.5 to -2, smaller than even the lower end of the range of existing estimates. This implies that the welfare-relevant (i.e., tariff-inclusive) long-run elasticity is less than 1 in absolute value, and thus the gains from trade are large. Second, the trade elasticity in the year following the initial tariff change is -0.7, and it takes several years for it to converge to the long-run value. The trade elasticity point estimate stabilizes between years 7 and 10, though the standard errors also widen. Third, there is substantial sectoral heterogeneity in trade elasticities. Across 10 broad HS sections, the long-run values range from -0.5 to -4.

To obtain these estimates, our first contribution is to address the reverse causality between trade flows and tariffs. The identification strategy relies on the key institutional feature of the WTO system: the MFN principle. Under this principle, a country must apply the same tariffs to all its WTO member trade partners. We estimate the trade elasticity based on the response of small exporters to an importer's MFN tariff change. The identifying assumption is that developments in the small exporters do not affect a country's decision to change its MFN import tariffs. Our estimation procedure then compares the small exporters' trade flows to a control group of exporters to the same country to whom MFN tariffs do not apply. These are countries in preferential trade agreements with the importer.

Our second contribution is to highlight the role of omitted variables. The theoretical foundations of the gravity equation emphasize the need to control for exporter and importer multilateral resistance terms, structurally (Anderson, 1979; Anderson and van Wincoop, 2003) or with appropriate fixed effects (e.g. Redding and Venables, 2004; Baldwin and Taglioni, 2006). We show that the traditional log-levels gravity specification with multilateral resistance fixed effects yields the conventional wisdom elasticities of -3 to -10. However, multilateral resistance terms do not absorb aggregate or product-specific bilateral taste shocks or other unobserved bilateral gravity variables. Omitting these unobservables can lead to large elasticity estimates – for instance if tariffs are low when the taste shocks are high. Once we augment the traditional specification with a richer set of fixed effects

[1] Anderson and van Wincoop (2004) and Head and Mayer (2015) review available estimates.

to soak up bilateral unobserved gravity variables and taste shocks, the OLS log-levels estimates fall sharply to below 1 in absolute value. We then show in stages how we arrive at our final estimate.

Our third contribution is to provide estimates over several time horizons, ranging from impact to 10 years. Because tariff changes can be autocorrelated, to estimate the impact of a tariff change at longer horizons we use time series methods, namely local projections (Jordà, 2005). This approach takes into account the fact that tariffs themselves may have a dynamic impulse response structure, implying the elasticities of trade flows at different horizons might depend on the pattern of autocorrelation of tariffs. One useful outcome of this exercise is that we can compare short- and long-run elasticities obtained within the same estimation framework. It is well-known that trade elasticities estimated from cross-sectional variation in tariffs tend to be much higher than the short-run elasticities needed to fit international business cycle moments. Normally, this divergence is rationalized by assuming that the elasticities estimated from the cross-section essentially reflect the long run. However, existing estimates either use purely cross-sectional variation (e.g. Caliendo and Parro, 2015), or a time difference over only one horizon (e.g. Head and Ries, 2001; Romalis, 2007). In both cases it is unclear whether what is being estimated is a long-run elasticity, an elasticity over a fixed time horizon, or a mix of short- and long-run elasticities. Our exercise provides mutually consistent estimates of the short- and the long-run elasticities, as well as the full path of the trade responses over time.

Our analysis uses data on global international trade flows from BACI, and tariffs from UN TRAINS. The sample covers 183 economies, over 5,000 HS 6-digit categories, and the time period 1995-2017.

Having established how our elasticity estimates improve on existing ones in several dimensions, we undertake two exercises that connect our empirical analysis to theory and quantification. First, we provide a formula to convert our point estimates to the long-run elasticity used in static trade models for steady state comparisons, such as the welfare gains from trade. We also account for the fact that our left-hand side variable is trade values exclusive of tariff payments, whereas the most commonly defined elasticity in the trade models is that of tariff-inclusive spending. After these adjustments, the elasticity relevant for computing the welfare gains from trade is about -0.6. Applying it in the well-known formula of Arkolakis, Costinot, and Rodríguez-Clare (2012), the gains from trade are about 10 times larger than under the commonly used elasticity of -5.

Second, we calibrate a simple dynamic model that delivers a slowly building time-path of elasticities. The model is a dynamic extension of the Arkolakis (2010) market penetration framework, where the number of customers of a firm plays the role of the firm's capital stock.[2] The sluggish response of trade is rationalized by a combination of convex adjustment costs and slow customer base depreciation.

[2] The notion of customers as capital has been explored by Drozd and Nosal (2012), Gourio and Rudanko (2014), and Fitzgerald, Haller, and Yedid-Levi (2017).

Alternative mechanisms leading to a difference between the short and long-run elasticities, such as the extensive margin, exporter learning, or investment to lower future costs of exporting have been explored in an active recent literature (see, among many others, Costantini and Melitz, 2007; Ruhl, 2008; Burstein and Melitz, 2013; Alessandria and Choi, 2014; Alessandria, Choi, and Ruhl, 2014; Ruhl and Willis, 2017). The goal of our exercise is not to revisit all of the proposed microfoundations for gradual adjustment of trade to trade cost shocks. Rather, we set up the simplest possible dynamic model, to illustrate the basic mechanics and quantify the parameters governing it.

Related Literature Anderson and van Wincoop (2004) and Head and Mayer (2015) review existing trade elasticity estimates. One common approach is to use tariff variation to estimate this elasticity (e.g. Caliendo and Parro, 2015; Head and Ries, 2001; Romalis, 2007). Other methods exploit differences in prices across locations (Eaton and Kortum, 2002; Simonovska and Waugh, 2014; Giri, Yi, and Yilmazkuday, 2020). Existing estimates do not attempt to address the reverse causality of tariffs with respect to trade flows, and do not distinguish different time horizons. An alternative is to estimate an elasticity of substitution structurally (e.g. Feenstra, 1994; Broda and Weinstein, 2006; Feenstra et al., 2018). In some environments the substitution elasticity governs the trade elasticity, but in others it does not. Our empirical strategy is not confined to environments in which the trade elasticity coincides with the elasticity of substitution.

An important recent strand of the literature uses customs data to estimate firm-level elasticities of exports to tariffs, and aggregates firm-level responses to recover macro elasticities (see, among others, Bas, Mayer, and Thoenig, 2017; Fitzgerald and Haller, 2018; Fontagné, Martin, and Orefice, 2018). Often, similar to our strategy, the identifying variation comes from comparisons of MFN and non-MFN destinations. Our approach complements these firm-level analyses. The customs data have the clear advantage of the forensic precision with which different dimensions of firm-level responses to tariffs can be pinned down. On the other hand, this approach normally uses data for a limited set of countries (most often 1) and years, making it challenging to control for multilateral resistance terms and/or exploit time series variation in tariffs for identification.[3]

Bown and Crowley (2016) describe the empirical features of tariff policy in general, and the MFN system in particular. A feature of MFN tariffs important for our purposes is that countries negotiate upper bounds on MFN tariffs, and are then free to set actual MFN tariffs anywhere below those bounds. In the data, a significant fraction of MFN tariffs is actually below the bounds, and thus countries can vary them without violating their WTO commitments. There is a voluminous theoretical and empirical literature on trade policy, both unilateral and within the framework of trade

[3] An exception to the common finding of high long-run trade elasticities is Sequeira (2016), who estimates a virtually zero elasticity of trade flows to tariffs for the Mozambique-South Africa preferential trade agreement. The proposed explanation for this result is that high levels of corruption in Mozambique imply that firms rarely pay the tariffs in the first place. This mechanism is unlikely to account for the comparatively low elasticities we find in worldwide data.

agreements, synthesized most recently in Bagwell and Staiger (2016). This literature emphasizes endogeneity of tariffs to a variety of factors, and thus calls for an effort to overcome that endogeneity in estimation.

A more recent literature has focused on the impact of the 2017-2019 US-China trade war. Closely related to our paper is Fajgelbaum et al. (2020), who use the trade war as a shock to simultaneously estimate demand and supply elasticities. Our approach in contrast isolates variation coming from the responses of third countries to incidents like the trade war. Our estimates are complementary in that we provide both short-run and steady-state estimates, which at the current moment is naturally impossible in the context of the trade war.

The rest of the paper is organized as follows. Section 2 lays out the econometric framework and the identification strategy. Section 3 describes the data, and Section 4 the main results. Section 5 connects the estimates to theory. Section 6 concludes.

2 Estimation Framework

2.1 Definition

As the objective of this paper is to estimate elasticities of trade volumes to trade cost shocks at different time horizons, we start with a definition of a horizon-specific trade elasticity. Let i and j index countries, p products, and t time. Let $X_{i,j,p,t}$ be the exports of p from j to i, and $\phi_{i,j,p,t}$ the "iceberg" trade cost. Denote by Δ_h a time difference in a variable between periods $t-1$ and $t+h$: $\Delta_h x_t \equiv x_{t+h} - x_{t-1}$.

Definition. The *horizon-h trade elasticity* ε^h is defined as

$$\varepsilon^h = \frac{\Delta_h \ln X_{i,j,p,t}}{\Delta_h \ln \phi_{i,j,p,t}}. \tag{2.1}$$

Note that the long-run trade elasticity is obtained as $h \to \infty$. It measures the permanent change in trade flows that accompanies a permanent change in trade costs.

2.2 Estimation

In practice, we will be using tariff variation to estimate ε^h. Let the total trade costs be multiplicative in ad valorem tariffs $\tau_{i,j,p,t}$ and non-tariff costs $\kappa_{i,j,p,t}$:

$$\phi_{i,j,p,t} = \kappa_{i,j,p,t} \cdot (1 + \tau_{i,j,p,t}).$$

Then $\varepsilon^h \approx \Delta_h \ln X_{i,j,p,t} / \Delta_h \tau_{i,j,p,t}$.

Consider a change in tariffs $\Delta_0 \tau_{i,j,p,t}$ between $t-1$ and t. We estimate the following equation using local projections (Jordà, 2005):

$$\Delta_h \ln X_{i,j,p,t} = \beta_X^h \Delta_0 \tau_{i,j,p,t} + \delta_{i,p,t} + \delta_{j,p,t} + \delta_{i,j,p} + u_{i,j,p,t}^X, \tag{2.2}$$

where the δ's are fixed effects. This equation will give us an estimate β_X^h of the impact of a single-period change in tariffs from $t-1$ to t on change in trade flows between $t-1$ and $t+h$. If $\Delta_0 \tau_{i,j,p,t}$ was a one-time change in tariffs (that is, $\Delta_h \tau_{i,j,p,t} = \Delta_0 \tau_{i,j,p,t}$), the coefficient β_X^h is an estimate of ε^h for each h.

One potential problem with this interpretation that in the data, tariffs themselves may change between t and $t+h$ following an initial shock $\Delta_0 \tau_{i,j,p,t}$. If we do not take into account that the tariff changes might be staggered over time, we could either over- or under-estimate the trade elasticity. For instance, if a tariff reduction in the initial year tends to be followed by further tariff reductions, we would attribute a large change in trade flows to a small initial tariff change not taking into account subsequent, dependent, tariff decreases. The opposite would happen if tariffs were mean-reverting, such that initial reductions tend to be followed by increases.[4] To account for this, we estimate a local projection of the h-period tariff change on the initial shock in tariffs:

$$\Delta_h \tau_{i,j,p,t} = \beta_\tau^h \Delta_0 \tau_{i,j,p,t} + \delta_{i,p,t} + \delta_{j,p,t} + \delta_{i,j,p} + u_{i,j,p,t}^\tau, \tag{2.3}$$

where the impact effect of tariffs on tariffs is $\beta_\tau^0 = 1$ by definition.

The horizon h trade elasticity can then be recovered as $\varepsilon^h = \frac{\beta_X^h}{\beta_\tau^h}$. This estimation can be carried out at different horizons $h = 0, ..., H$, to trace the full profile of ε^h over h. In practice we use a maximum horizon of $H = 10$, as discussed in Section 3.

2.3 Identification

Estimating (2.2) by OLS would be similar to the common approach in the literature that treats all tariff variation as exogenous, except that we would explicitly highlight differences in impacts across time horizons. In practice tariffs are set by governments which, in turn, are influenced by lobbyists, and subject to the WTO policy framework. There are three concerns with viewing applied tariff changes as exogenous. First, it is possible that a third factor drives both tariff changes and changes in trade flows. A newly elected government, for instance, could change not only tariffs but also other policies that affect import demand. In a similar spirit, business cycle fluctuations could induce governments to change tariffs (Bown and Crowley, 2013). Again, imports would change in part because of the tariff change, and in part due to the changes in economic conditions. Further, a taste

[4]This is a problem similar to that faced by the empirical fiscal multiplier literature.

shock for a product from a specific source country could trigger both larger imports of the product and lower tariffs on that product due to lobbying. Second, there could be reverse causality, whereby governments change tariffs because of observed or anticipated changes in trade patterns. Third, it could be that foreign governments influence a country's government to change tariffs, either through the WTO body, or through other channels.

An instrument for tariff changes is difficult to find, as tariff changes (and more broadly, changes in trade policy) are unlikely to ever be unanticipated or orthogonal to economic activity. We turn to the WTO's MFN tariff system to construct a plausibly exogenous instrument. All WTO member countries are bound by treaty to apply tariffs uniformly to all other WTO countries. Exceptions to this principle are countries that are in preferential trade agreements (PTA) such as NAFTA. Tariffs between countries in PTAs may be lower than the MFN tariff rate.

When a country changes its MFN rate on a product, it might do so due to concerns about imports from an important partner country, or lobbying by an important partner country. The baseline instrument uses the insight that third countries are also affected by this tariff change if they are MFN partners. From the point of view of these third countries, the tariff change is plausibly exogenous. The response of imports from these third countries can then identify the trade elasticity. Further, to eliminate concerns that trade flows at the country-product level might be trending over time, we use as a control group countries unaffected by the MFN tariff change because they are in a PTA.

Of course, while we provide some narrative examples of why MFN tariffs change in Section 2.4, it is not possible to pinpoint the rationale behind every product-level MFN tariff change. We presume that reverse causality concerns will mostly apply to large trading partners. Our identification strategy therefore treats MFN tariff changes as possibly endogenous to imports from large trading partners, and thus these trade flows are not part of the baseline treatment or control groups.

Our baseline instrument is:

$$\begin{aligned}
\Delta_0 \tau^{instr}_{i,j,p,t} \quad = \quad & \mathbf{1}\left(\tau_{i,j,p,t} = \tau^{\text{applied MFN}}_{i,j,p,t}\right) \times \mathbf{1}\left(\tau_{i,j,p,t-1} = \tau^{\text{applied MFN}}_{i,j,p,t-1}\right) \\
& \times \mathbf{1}\,(\text{not a major trading partner in } t-1 \text{ in aggregate}) \\
& \times \mathbf{1}\,(\text{not a major trading partner in } t-1 \text{ at product level}) \\
& \times \mathbf{1}\,(\text{not a major trading partner in } t \text{ in aggregate}) \\
& \times \mathbf{1}\,(\text{not a major trading partner in } t \text{ at product level}) \\
& \times \left[\tau^{\text{applied MFN}}_{i,j,p,t} - \tau^{\text{applied MFN}}_{i,j,p,t-1}\right].
\end{aligned}$$

These terms can be understood as follows. The first two indicators simply say that the applied MFN tariff is binding for the countries and product in question both in the initial $t-1$ and final period t. The next four indicators relate to whether or not the exporter is a major trading partner in $t-1$ or t, either in terms of aggregate trade, or in terms of trade in product p. At both the aggregate and the product levels, a trading partner is coded as major if it is in the top 10.[5] Finally $\tau_{i,j,p,t}^{\text{applied MFN}} - \tau_{i,j,p,t-1}^{\text{applied MFN}}$ is simply the change in the tariff from $t-1$ to t. Note that this baseline instrument conditions on minor trading partners, which means that the major partners are excluded from the analysis: the value of $\Delta_0 \tau_{i,j,p,t}^{instr}$ is set to missing for these trade partners.

Then, we estimate equations (2.2) and (2.3) using $\Delta_0 \tau_{i,j,p,t}^{instr}$ as the instrument for the one year endogenous tariff change $\Delta_0 \tau_{i,j,p,t}$. Further, we can directly estimate the horizon h trade elasticity, using:

$$\Delta_h \ln X_{i,j,p,t} = \beta^h \Delta_h \tau_{i,j,p,t} + \delta_{i,p,t} + \delta_{j,p,t} + \delta_{i,j,p} + u_{i,j,p,t} \tag{2.4}$$

instrumenting $\Delta_h \tau_{i,j,p,t}$ with $\Delta_0 \tau_{i,j,p,t}^{instr}$. Note that this specification simply combines the two instrumented local projections (2.2)-(2.3) and directly identifies the trade elasticity at horizon h: $\widehat{\beta}^h$ is an estimate of ε^h. Estimating (2.4) directly has the advantage that we can obtain standard errors for the elasticity estimates.

While our baseline estimates treat the trade elasticity as invariant across product categories, below we also estimate these specifications for broad product groups to obtain a distribution of β_p^h's.

Discussion To succinctly state the source of the identifying variation: we compare the changes in imports from countries hit by a plausibly exogenous tariff change to the changes in imports from countries to whom those tariff changes did not apply. The "treatment" countries experienced tariff changes because they are part of the MFN system. The "control" countries did not experience the MFN tariff changes because they trade on different terms.

This "instrumented diff-in-diffs" setup sets a high bar for identification in the following sense. First, the instrument and our estimating equation are differenced, eliminating all time-invariant factors. Second, the estimating equations include importer-product-time and exporter-product-time fixed effects, as well as a time-invariant source-destination-product fixed effects. The former are the changes in multilateral resistance terms, that absorb time-varying importer- or exporter-product-specific supply or demand shocks, as well as broad tariff changes by a country across a number of products simultaneously. The source-destination-product fixed effects absorb trends in product-specific impacts of bilateral resistance forces like distance, addressing concerns about any gravity variables that survive time differencing. These fixed effects also soak up bilateral taste shocks for a product (in levels or trends), that could be correlated with tariffs applied on the product.[6]

[5] We also carried out the analysis considering the top 5 partners as major. The results were very similar.

[6] We vary the level of the product for the fixed effects between HS4 and HS6 to balance the tradeoff between absorbing more confounding variation but leaving less variation for estimation.

The identification problem then arises entirely from time-varying, bilateral, non-tariff barriers $\Delta_h \ln \kappa_{i,j,p,t}$, or other time-varying, bilateral product-specific supply or demand shocks. The residual tariff changes may still be the result of deliberate actions aimed at a specific partner in a specific product. After eliminating the trade partners that are the likely targets of these tariffs, the instrument isolates plausibly exogenous variation in tariff changes. Finally, by only identifying the elasticity from the differential growth rate of the "treatment" group exports relative to a "control" group of countries in PTAs, we leverage the time-series dimension of the data. Relying on the time series variation also makes it straightforward to estimate how the trade response varies over different horizons.

Section 4.3 contains further discussion of threats to identification, alternative instruments, as well as extensive robustness checks.

2.4 Narrative Examples of MFN Tariff Changes

To understand why countries change MFN tariffs, we provide some institutional background and discuss some examples.[7] When countries join the WTO, their accession treaty sets maximum MFN tariff rates ("bounds") that they can apply to WTO member countries. These MFN bounds are country- and product- specific, and vary from very low rates for developed countries and large economies to much higher rates for developing countries. For instance, the average bound rate is 3.5% in the US, 10.0% in China, and 48.6% in India. The number of products covered by the bounds is also negotiated and varies by country. In many countries, including the US and China, 100% of products are covered by the bounds. By contrast, 74% of products are subject to MFN bounds in India, and 50% in Turkey. The bounds themselves vary substantially across products. In the US in 2015, about 40% of products had a bound of 0, while about one-tenth of products had bounds above 10%. Once these MFN bounds are set, they rarely change, except in subsequent rounds of WTO negotiations. As such, changes in MFN bounds do not provide sufficient variation for an instrument.

In practice, actual applied MFN tariffs are frequently far below the bounds. Thus, countries can and do legally vary their applied tariffs below the bounds. Some motives are business-cycle related. For instance Turkey raised a number of MFN tariffs temporarily around its financial crisis. The tariffs were lowered again post-crisis. Similar patterns were observed in Argentina. Sometimes the rationale for changing the MFN rates is less clear – India raises and lowers tariffs on varied products year-to-year. Finally, MFN rates might also be changed while countries are engaged in a trade war. China lowered MFN rates on 1449 consumer goods and 1585 industrial products while raising tariffs on the US as part of the US-China trade war in 2018. As a result, China's average tariffs on the US were 20.7% in late 2018, while those faced by other exporters to China were only 6.7%, on average. Since the US was the motivation for these MFN tariff changes, they are plausibly exogenous from

[7] Further details can be found in Bown and Crowley (2016). We are grateful to Chad Bown for useful suggestions and examples.

the perspective of small exporters to China.[8]

This discussion makes clear the endogeneity of most tariff changes, and the rationale for the inclusion of a rich set of fixed effects (to remove business cycles and broad partner-specific variation). Further, the US-China trade war example illustrates the need to eliminate major partners from the instrument, in order to isolate the exogenous component of MFN tariff changes for third countries.

3 Data and Basic Patterns

Our trade dataset is the BACI version of UN-COMTRADE, covering years 1995-2017. The data contain information on the trade partners, years, and product codes at the HS 6-digit level of disaggregation, as well as the value and quantity traded. We link these data to information on tariffs from the TRAINS dataset, also covering 1995-2017. This dataset includes information on the applied and the MFN tariffs. The applied tariffs can differ from MFN tariffs for country pairs that are part of a PTA. Unfortunately, for many countries comprehensive information on tariff rates is not available before they join the WTO. The sample covers 183 economies and over 5,000 HS6 categories.[9]

The most detailed product classification available in the trade data is at the HS6 level. However, we face the constraint that the data are provided in several different revisions of HS codes. Further, even within the same year, countries sometimes report trade flows in different vintages of HS codes.[10] While some concordances of HS6 codes over time are available, we do not implement these fully as they necessitate splitting values of trade across product codes in different revisions or aggregating product codes. As we do not observe transaction-level trade, any such split will introduce composition effects into our tariff measures. In particular, we could have spurious tariff changes coming from averaging tariffs when product codes are combined over time. Instead, our definition of a product is an HS6 code of a specific revision, tracked over time. We link product codes across revisions *only* when there is a one-to-one mapping between the codes across revisions. This approach is conservative, but it does reduce the effective sample size – and hence widens the standard errors – for any very long run elasticity estimates, as over a longer horizon there will be fewer product codes that map uniquely across revisions. Hence, the maximum horizon over which we estimate the trade elasticity in the baseline analysis is ten years, which typically corresponds to only one change in HS revisions. Appendix Table A1 provides the fraction of codes that map uniquely across revisions. In a single revision transition, on average 89% of product codes have a unique mapping.[11]

[8] See the blogpost by Bown, Jung and Zhang in June 2019 for a discussion. This particular instance is not part of our sample, which ends in 2017, but serves as a useful illustration.

[9] The TRAINS database reports tariffs in ad valorem form. The large majority of MFN tariffs are ad valorem. Among the 148 WTO members in 2013, the median fraction of HS6 products covered by non-ad valorem (per-unit, or specific) tariffs is 0.01%, and the mean fraction is 1.76% (World Trade Organization, 2014). Unfortunately, comprehensive information on which MFN and preferential tariffs are non-ad valorem is not available in TRAINS.

[10] As far as we are aware, there is no double counting of trade flows reported under different HS revisions.

[11] Naturally, alternative specifications that include several lags of tariff changes require longer horizons than ten years,

The values of trade flows reported in these data are not inclusive of tariffs. Thus, the elasticities estimated by our procedure are tariff-exclusive, and must be appropriately adjusted to obtain the elasticity relevant from the consumer's perspective.[12]

Patterns in tariff changes Figure 1 plots the histograms of tariff changes. The left panels plot all data, while the right panels plot the data conditioning on observing a tariff change. While more than half the mass is below zero, tariff increases comprise a substantial share of tariff changes. The bottom two panels separate treatment (red) and control (green) groups. Both experience a range of tariff changes. Note that our identification strategy does not rely on the control group tariff changes being zero. Our specifications include importer-product-time fixed effects, which means that we are exploiting differential changes in MFN and non-MFN tariffs for identification. Below we check robustness by removing from the control group observations in which non-MFN tariffs change. Figure 2 plots the autocorrelation functions for tariffs. The impact change is normalized to 1. The 1-period negative autocorrelation is evident for the tariffs in our data. This pattern motivates the use of time-series methods that explicitly account for the fact that impact tariff changes are not fully permanent.

Examples of the treatment/control assignments Appendix Table A2 provides an illustration of how the instrument is implemented. As our instrument is defined at the product level, we illustrate it for a 4-digit HS code 6403, "Footwear; with outer soles of rubber, plastics, leather or composition leather and uppers of leather." For three large importers (the USA, Japan, and Germany) in 2006, we list partner countries that fall in each of the indicator categories in our instrument. We then list the source countries that are either in the treatment, control, or excluded groups for this product for these 3 large importers in 2006.

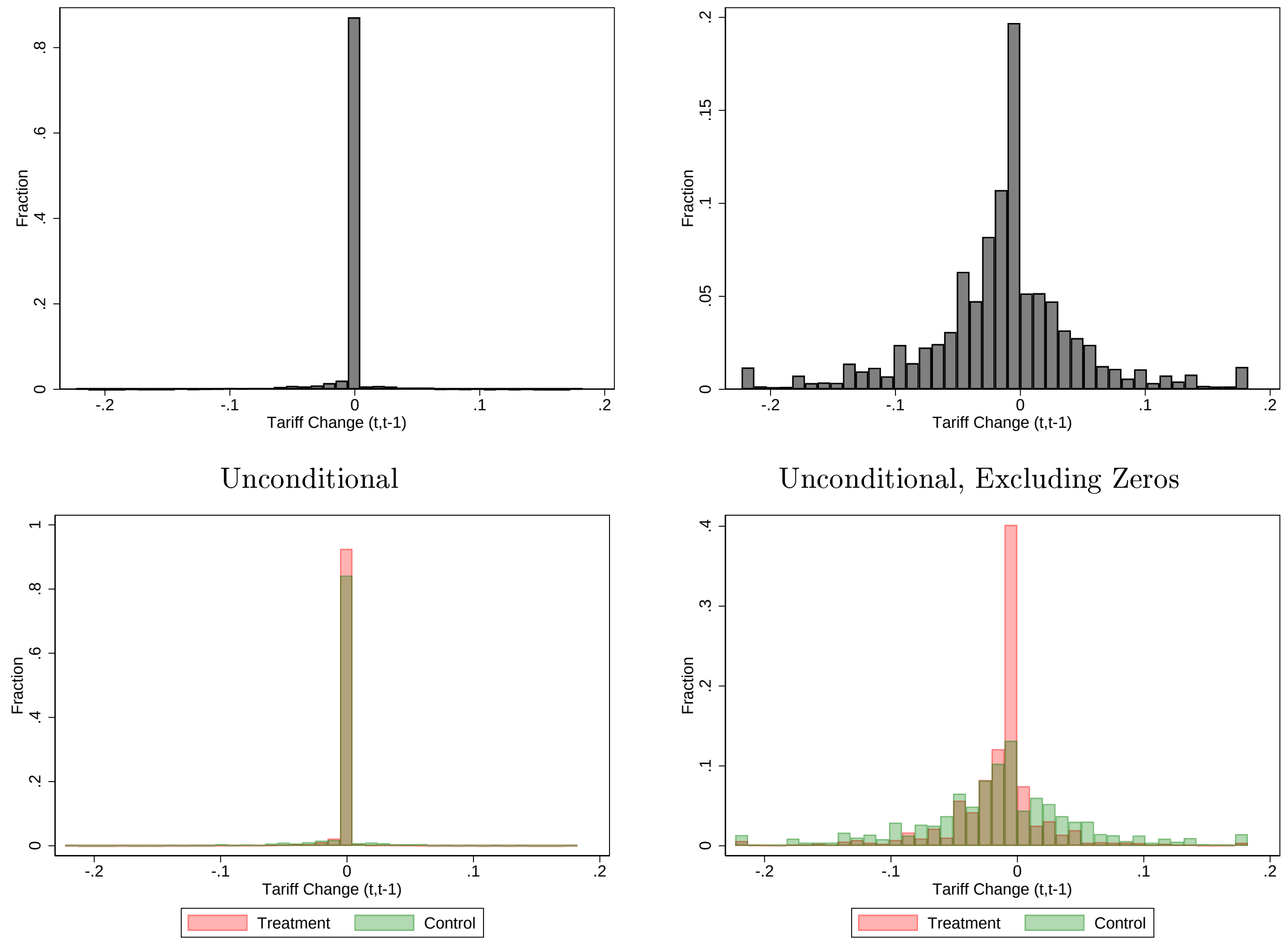
Columns 1-2 list the 10 largest MFN trading partners at $t-1$ and t. Trading on MFN terms is the first criterion for being selected into the treatment group. (Of course, there are many more than 10 countries in this category). Columns 3-4 list the 10 major trade partners in aggregate. These countries are disqualified from the treatment group. Columns 5-6 list the 10 major trading partners in HS 6403 specifically. These are also disqualified from the treatment group. As expected, there is imperfect overlap between the set of major partners overall and in a specific HS code.

After these countries are dropped, columns 7-9 list the treatment, control, and excluded groups. As the table highlights, for the US NAFTA countries such as Canada and Mexico are important in

reducing the sample size and increasing the standard errors of the estimates.

[12] Section 5 contains the complete discussion. As an example, if the underlying model Armington, our long-run estimates would correspond to the elasticity in the CES aggregator $-\sigma$, while the trade elasticity inclusive of tariffs would be $1-\sigma$.

Figure 1: Patterns in Tariffs: Frequency of Changes



Unconditional

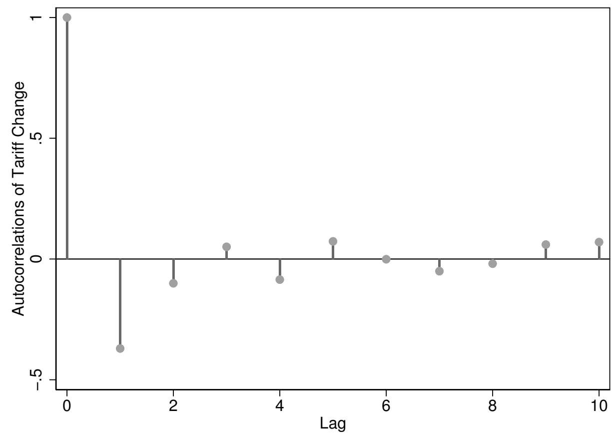
Unconditional, Excluding Zeros

Treatment and Control

Treatment and Control, Excluding Zeros

Notes: These figures display the frequency of tariff changes in our data. The top two panels display the unconditional frequency of all tariff changes (top left) and frequency excluding zeros (top right). The bottom panel displays the overlap in the frequency of changes in the treatment and control groups, including zero changes (left panel) and removing zero changes (right panel).

Figure 2: Patterns in Tariffs: Autocorrelation



Notes: This figure displays the unconditional autocorrelation of tariff changes for the sample.

the control group. The excluded group comprises large trading partners like Germany, China, and France, but also smaller economies such as Vietnam that are important exporters of footwear to the US. The treatment group includes smaller trading partners in footwear who trade at MFN rates, such as Portugal, Poland, Slovakia, and Hungary. While we do not incorporate explicit data on regional trade agreements, the instrument design appropriately assigns countries in customs unions or PTAs to control or excluded groups.[13] For Germany, for instance, EU member countries do not appear in the treatment groups, and are only part of the control groups.

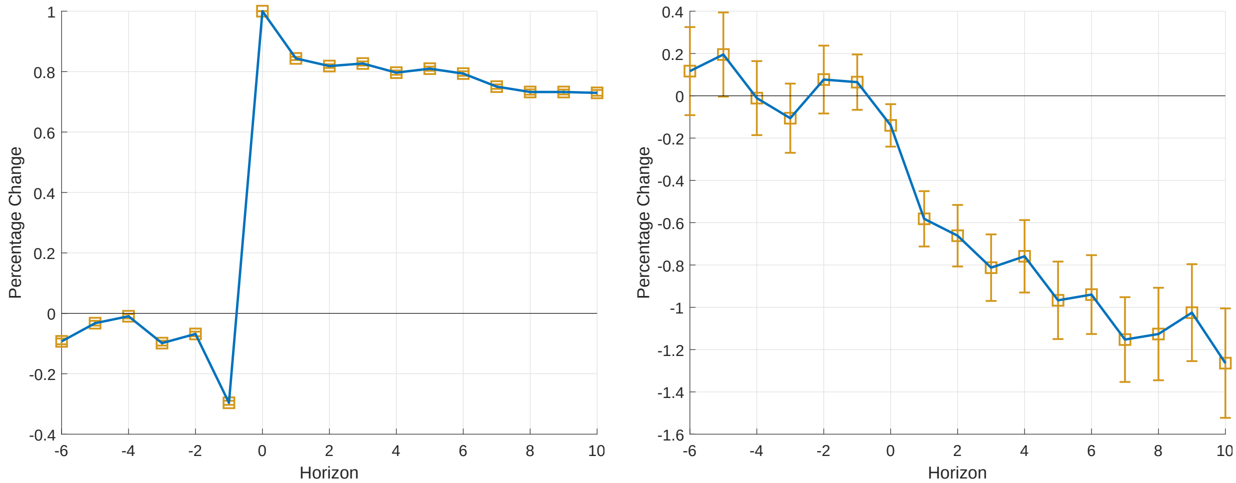
Appendix A presents additional summary statistics about our sample, including information on the average share of imports by destination and the incidence of MFN and non-MFN trade in the data.

4 Results

We begin by estimating the impact effects of a one-time tariff change on h-periods ahead trade flows and tariffs, as in equations (2.2)-(2.3), using our instrumental variables approach. For the baseline estimation, the product disaggregation for the fixed effects is at the HS4-level. We also exclude major trading partners at the HS4-level in the baseline instrument. The left panel of Figure 3 reports the time path of tariff changes h periods after the initial 1-unit change. Thus, by construction the $h = 0$

[13]The instrument might be improved if we could additionally incorporate information on PTAs. This would help in particular in assigning observations to the control group instead of the excluded group in some instances where the PTA rate is the same as the MFN rate and the country is a large trading partner. Currently, these observations have to be excluded. Unfortunately, while aggregate datasets on PTAs are available, these are typically not product-level. Many free trade agreements exclude certain products, and applying them to all products is problematic for our estimation. Assigning observations to the excluded group increases our standard errors but is the conservative option.

FIGURE 3: Local Projections: Tariffs and Trade



Tariffs | Trade

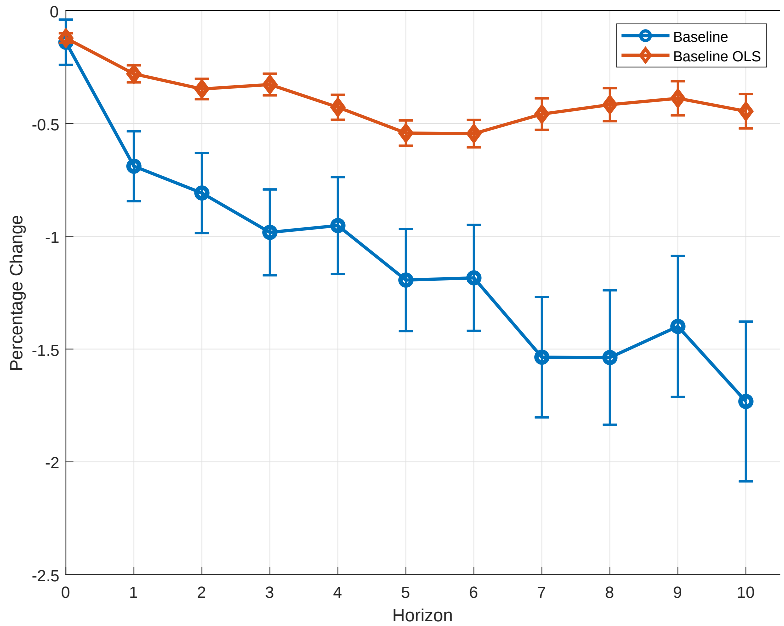
Notes: This figure displays the results from estimating equations (2.2) and (2.3) – the local projection of tariff growth (left panel) and imports (right panel) on one period tariff growth instrumented at various horizons. The equation is estimated with no pre-trend controls. The bars display 95% confidence intervals. Standard errors are clustered at the country-pair-product level.

coefficient is 1. The mean reversion in tariff levels is evident: following the initial impulse, only about 0.8% of the change remains after 5 years. At the same time, the figure indicates the existence of pre-trend. A tariff increase of one percent is preceded by a reduction of approximately 0.3 in the pre-period, reflecting the negative first order autocorrelation highlighted above. We will control for this pre-trend by including lags of tariff changes in our robustness checks.

The right panel of Figure 3 displays the estimates of the impact of an initial tariff change on trade flows. Here, there is no evident pre-trend. Trade flows have an elasticity to tariff changes of -0.14 on impact, converging to -1.26 in the long run. Columns 1 and 4 of Table A4 report the coefficient estimates and the standard errors for the tariff and trade local projections, respectively.

Figure 4 reports the baseline estimates of the trade elasticity ε^h across horizons. The impact ($h = 0$) elasticity is -0.14. Our data are annual, and it is unlikely that all tariff changes go into effect on January 1. Thus, we do not focus attention on the impact elasticity as it can be low due to partial-year effects. The point estimate in the year following the tariff change is probably a better indicator of the short-run elasticity. At $h = 1$, the elasticity is around -0.7. The 10-year elasticity is -1.73. Over the first 7 years, the elasticity converges smoothly to the long-run value. The red line reports the OLS estimates. Notice that OLS – which uses all tariff variation – actually produces a smaller trade elasticity than IV at all horizons > 0, a fact we will return to in Section 4.2. The time pattern

Figure 4: Trade Elasticity: OLS vs IV



Notes: This figure displays the trade elasticity estimated using the baseline instrumented specification in (2.4) (blue), and the OLS estimates of the same equation (red). The equations are estimated with no pre-trend controls. The bars display 95% confidence intervals. Standard errors are clustered at the bilateral country-pair-product level.

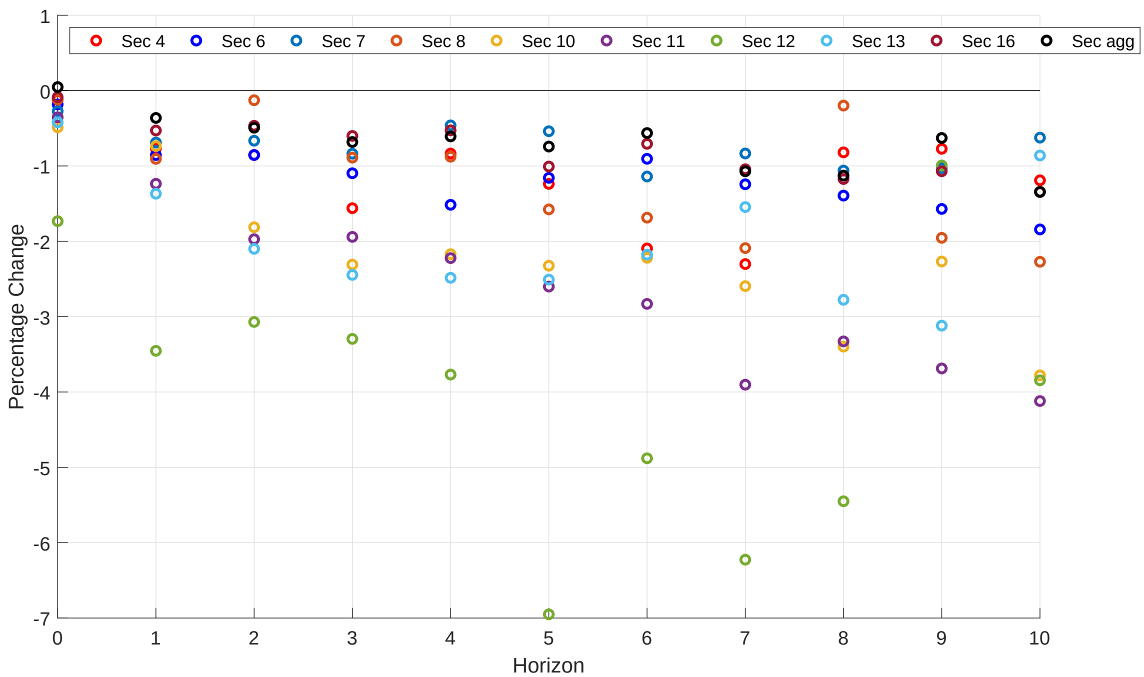
is roughly similar for OLS and IV.

4.1 Sectoral Heterogeneity

We next estimate the trade elasticities by sector. HS codes are organized into 21 sections that are consistent across countries. These sections describe broad categories of goods, such as "Live Animals, Animal Products" (Section 1). In practice, there is insufficient tariff variation in some of these sections to obtain precise estimates of the elasticity at all horizons. Thus, we combine a few of the sections together, leaving us with 10 sections. Table A3 describes the sections and lists the sections that are aggregated.

Figure 5 plots the point estimates of the trade elasticities over h for the 10 HS "Sections." The long-run elasticities range from -0.5 to -4 even in this coarse sectoral breakdown. In addition, the elasticities fan out over time. The range at $h = 1$ is from -0.3 to -1.4 (setting aside the outlier Section 12), much narrower than the long-run range. Table A5 presents the summary statistics for the trade elasticities at the 10-Section level, by horizon. The time path of the mean and median elasticities is similar to the aggregate elasticity.

Figure 5: Trade Elasticity: Sectoral Heterogeneity



Notes: This figure displays the trade elasticity estimated for HS Sections using the baseline instrumented specification in (2.4). Some HS Sections are grouped into a single aggregate section "Sec agg" as described in the text.

4.2 Relationship to Other Estimates

Our preferred IV estimates of the trade elasticity are -0.7 in the short run, rising to about -1.75 in the long run. These are substantially smaller than the conventional wisdom range of -5 to -10 (see for instance the review in Anderson and van Wincoop, 2004). Interestingly, even our OLS estimates, which treat all tariff variation as exogenous as typical in the literature, are much smaller than the values commonly estimated in other studies. Table 1 investigates the source of these differences.

Panel A of the table estimates the elasticity using a log-levels OLS specification, assuming all tariff variation is exogenous. This specification, both without fixed effects and with the most commonly used fixed effects to account for multilateral resistance (importer-product-time and exporter-product-time), yields values between -3.1 and -6.6, which are similar to previous estimates. We then add country-pair-product fixed effects to the same specification. The elasticity estimates fall sharply to about -0.9 with multilateral resistance terms (column 5), close to our baseline OLS estimates. Making the product dimension of the fixed effects finer in column 6 does not substantively change the estimates. The country-pair-product fixed effects soak up any confounders in the gravity equation that are country-pair-product specific (for instance, different, but constant, shipping costs between a pair of countries for steel and agricultural product groups). Clearly, including them is important for the estimation.

Panel B of the table then presents the results of a 5 year differenced OLS specification. The estimates fall sharply across all combinations of fixed effects, and are often below 1 in absolute terms. Differencing removes additional confounders, as discussed in Section 2.

Panel C then implements a specification in which the five-year differenced tariff change on the right-hand-side is instrumented by the actual one year tariff change at the start of the 5-year period. This is an intermediate step between running simple differenced OLS and our full instrumentation strategy. Here, the estimation is by 2SLS, but we do not claim it is an IV since we are using all initial-year tariff changes, rather than the exogenous subset. When our baseline fixed effects are included (Column 5), this amounts to the estimation of (2.4) by "OLS" for $h = 5$.

The rationale for using only the initial 1-year tariff change is that relying on high-frequency variation minimizes the impact of other confounding factors. In addition, using just the initial year tariff change to identify the coefficient implies that we are closer to picking up a 5-year impact of a tariff change, rather than the impact of tariff changes that occurred late in the 5-year period. This is an object closer to the 5-year elasticity. Again, across all versions of the fixed effects estimates are much smaller and below than 1 in absolute value, except when no fixed effects are included at all (column 1). In our preferred specification in Column 5, which is the same as our baseline OLS estimation of

Table 1: Elasticity Estimates: Alternative Approaches

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Log-levels, OLS						
$\tau_{i,j,p,t}$	-3.111***	-4.413***	-6.626***	-2.562***	-0.920***	-0.898***
	(0.019)	(0.018)	(0.043)	(0.013)	(0.022)	(0.022)
R^2	0.009	0.334	0.349	0.504	0.526	0.774
Obs	104.35	104.32	103.52	102.95	102.15	95.94
Panel B: 5-year log-differences, OLS						
$\Delta_5\tau_{i,j,p,t}$	-1.857***	-1.486***	-0.693***	-1.587***	-0.572***	-0.485***
	(0.015)	(0.014)	(0.020)	(0.015)	(0.021)	(0.028)
R^2	0.002	0.062	0.179	0.109	0.174	0.498
Obs	37.09	37.07	36.71	36.76	36.38	34.27
Panel C: 5-year log-differences, 2SLS, tariffs instrumented by actual 1-year tariff change						
$\Delta_5\tau_{i,j,p,t}$	-1.215***	-0.812***	-0.536***	-0.860***	-0.543***	-0.474***
	(0.017)	(0.018)	(0.027)	(0.019)	(0.029)	(0.035)
Obs	37.09	37.07	36.71	36.76	36.38	34.27
Panel D: 5-year log-differences, 2SLS, baseline instrument						
$\Delta_5\tau_{i,j,p,t}$	-3.256***	-2.062***	-1.302***	-1.894***	-1.194***	-1.478***
	(0.050)	(0.059)	(0.106)	(0.063)	(0.115)	(0.181)
Obs	20.29	20.27	19.94	20.03	19.71	17.94
Panel E: 5-year log-differences, 2SLS, all partners instrument						
$\Delta_5\tau_{i,j,p,t}$	-1.844***	-1.284***	-0.682***	-1.431***	-0.811***	-1.089***
	(0.023)	(0.026)	(0.051)	(0.027)	(0.052)	(0.093)
Obs	37.09	37.07	36.71	36.76	36.38	34.19
Fixed effects						
importer x hs4	no	yes	no	no	no	no
exporter x hs4	no	yes	no	no	no	no
importer x hs4 x year	no	no	yes	no	yes	no
exporter x hs4 x year	no	no	yes	no	yes	no
importer x exporter x hs4	no	no	no	yes	yes	no
imp x hs6 x year, exp x hs6 x year, imp x exp x h6	no	no	no	no	no	yes

Notes: This table presents the results of estimating the trade elasticity at a single horizon. The dependent variable is log of trade value, in levels (Panel A), or 5-year differences (Panels B-E). Panels C, D, and E differ in instruments used for the tariff change. Column 1 reports the results with no fixed effects. Column 2 adds importer-product and exporter-product fixed effects, column 3 interacts these fixed effects with years, column 4 includes country-pair-product fixed effects, column 5 includes our baseline fixed effects and column 6 uses the fixed effects in column 5 but defines the product at the HS6 level. Standard errors clustered by country-pair-product are in parentheses. ***, ** and * denote significance at the 99, 95 and 90% levels. Numbers of observations are reported in millions. All first-stage F-statistics are greater than 10000.

equation (2.4), the estimate is -0.543.

Panels D and E implement two versions of our IV specification. Panel D has the conservative baseline instrument, excluding major trading partners, and Panel E has the IV including all trading partners with pure diff-in-diff identification. Relative to the OLS estimates in Panel C, both instruments push estimates back further away from 0. The conservative instrument increases estimates the most relative to OLS, as expected, but has larger standard errors. This instrument brings the estimates closer to -1.2 at the five year horizon in the specifications with the country-pair-product fixed effects and multilateral resistance fixed effects.

Appendix B provides two more tables that support these conclusions. Table A6 contrasts the traditional gravity specification in Panel A of Table 1 to the results from a balanced panel. While the conventional approach with the balanced panel delivers even higher elasticities (as high as 8-10), the insight that the importer-exporter-HS4 fixed effect decreases the estimate substantially remains the same in the balanced panel. Table A7 presents results for specifications in differences with alternative time horizons (3 or 7 years) as well as a balanced panel. When differencing, the importer-exporter-HS4 fixed effect in levels which is critical in the log-levels traditional gravity specification is removed. The estimates in differences decrease across all panels when the traditional multilateral resistance terms are interacted with years, which eliminates cyclical variation. The importer-exporter-HS4 fixed effect in the differenced specification (taking out trends in taste shocks) does not affect the results substantively.

4.3 Robustness

Pre-trends and anticipation effects Tariff decreases often follow a tariff increase (tariffs are autocorrelated), as shown above. Indeed, the left panel of Figure 3 reveals some evidence of a pre-trend in tariffs. We can account for differential pre-trends in tariffs using the standard approach of controlling for lagged tariff and trade changes. Columns 2-3 of Table 2 add 2 and 5 lags, respectively, to compare the results to the baseline in column 1. The point estimates change very little when adding lags, although at times the standard errors rise substantially. Columns 2-3 and 5-6 of Table A4 reports the results of local projections of tariffs and trade flows directly on the initial tariff change, as in (2.2)-(2.3), while allowing for 2 and 5 lags. Once again, the point estimates change little when adding lags.

A distinct concern is anticipation effects. Even if pre-treatment tariffs are constant, countries might already adjust their exports in response to an expected future MFN tariff change by the importer. Note that for these anticipation effects to pose a problem for us, they would need to occur differentially in the treatment and control countries. It is unclear in our context that the control group would not exhibit anticipation effects. The PTA trading partner might also adjust its exports upwards in

TABLE 2: Trade Elasticity, Robustness: Pre-Trends, Alternative Clustering, Alternative Samples

	Baseline	Two Lags	Five Lags	FE50	Two-way Clustering	Balanced Panel	Alternative Control Group
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
t	-0.140***	-0.178**	0.191	-0.174**	-0.140*	-0.359**	-0.144***
	(0.051)	(0.086)	(0.133)	(0.073)	(0.078)	(0.143)	(0.055)
obs	39.22	23.64	13.50	20.16	39.22	7.10	34.56
$t+1$	-0.689***	-0.655***	-0.130	-0.572***	-0.689***	-0.758***	-0.535***
	(0.079)	(0.127)	(0.195)	(0.106)	(0.149	(0.199)	(0.083)
obs	30.95	19.92	11.58	17.07	30.95	7.10	27.28
$t+3$	-0.983***	-0.482***	-0.222	-0.777***	-0.983***	-1.142***	-0.581***
	(0.097)	(0.173)	(0.287)	(0.123)	(0.250)	(0.185)	(0.105)
obs	24.51	15.81	8.93	14.08	24.51	7.10	21.42
$t+5$	-1.194***	-0.893***	-0.661*	-1.050***	-1.194***	-1.201***	-0.864***
	(0.115)	(0.218)	(0.375)	(0.143)	(0.291)	(0.193)	(0.126)
obs	19.71	12.46	6.69	11.60	19.71	7.10	17.08
$t+7$	-1.536***	-1.582***	-1.603***	-1.229***	-1.536***	-1.294***	-1.048***
	(0.136)	(0.285)	(0 .538)	(0.169)	(0.348)	(0.207)	(0.149)
obs	15.60	9.46	4.84	9.35	15.6	7.10	13.38
$t+10$	-1.732***	-1.852***	-1.933**	-1.512***	-1.732***	-2.513***	-1.057***
	(0.181)	(0.420)	(0.818)	(0.219)	(0.505)	(0.233)	(0.200)
obs	10.22	5.87	2.82	6.28	10.22	7.10	8.53

Notes: This table presents robustness exercises for the results from estimating equation (2.4). All specifications include importer-HS4-year, exporter-HS4-year and importer-exporter-HS4 fixed effects. Columns 2 and 3 vary the pretrend controls (including alternatively two lags or five lags of import growth and tariff changes). Column 4 reports the results when the sample is restricted to fixed-effects clusters with a minimum of 50 observations. Standard errors are clustered at the importer-exporter-HS4 level, except in Column 5 where they are additionally clustered by year. Column 6 restricts the sample to a balanced panel. Column 7 reports results where the control group only contains observations with zero tariff changes. ***, ** and * indicate significance at the 99, 95 and 90 percent level respectively. Observations are reported in millions.

response to a future MFN tariff decrease against a large MFN partner, for instance.[14]

We check for the presence of such anticipation effects by examining pre-trends in the trade volume equation estimates. Figure 3 shows no evidence of pre-trends in trade values even without controlling for tariff pre-trends.

[14] If anything, differential anticipation effects would bias the trade elasticity estimates upwards. As an example, suppose a to-be treated country expects tariffs to increase in the future, and responds by exporting more today. Then, in the periods after the tariffs actually rise, trade falls, but from a higher level than without this type of anticipatory behavior. Thus, the recorded change in trade is larger, implying a higher estimated trade elasticity.

Alternative controls, standard errors, and samples Column 4 of Table 2 restricts the estimation sample to fixed-effect groups that have at least 50 observations. Column 5 two-way clusters the standard errors by importer-exporter-HS4 and year. In both cases the estimates and their precision change little. Column 6 reports a balanced panel. While the point estimate at year 10 is slightly higher, the difference from the other specifications is not significant, in particular we cannot reject an elasticity at year 9-10 of -2. The estimates in years 7-8 are similar to the other specifications. This is reassuring as the balanced panel conditions on a sample that has positive trade flows in every year. This sample might have different characteristics than the full sample, but similarity in point estimates suggests that sample selection is not a big concern. Finally column 7 reports the results from an estimation where we drop observations in the control group that experience tariff changes. The estimates are similar to the baseline in the short run, and somewhat lower in the long run.

Alternative instruments, outcome variables, and fixed effects The baseline instrument excludes large trading partners from both treatment and the control groups. Column 2 of Table 3 reports the results when admitting these countries into the treatment group. In this case the instrument is simply the change in the MFN tariff rate for all countries subject to the MFN tariff rate. The point estimates fall to about -1 for the long-run elasticity. Column 3 reports the results of using fixed effects at the finest level of product classification, HS 6-digit. The point estimates are slightly larger at the 10-year horizon, but the standard errors also rise. Columns 4 and 5 report results for quantities and unit values, respectively. For interpreting the unit values coefficients, it is important to keep in mind that these are unit values exclusive of tariffs. It turns out that the impact in the long run is mostly on quantities. Unit values fall at short to medium horizons, suggesting imperfect pass-through of tariffs to consumer prices. In the long run there is no significant effect on unit values, consistent with the long-run response being primarily in quantities. Section 5.2 returns to the implications of these quantity and unit value estimates.

Extensive margin Our baseline specifications use log differences and by implication produce estimates of the trade elasticity for the intensive margin alone. Our data permit estimation of a bilateral product-level extensive margin.[15] To implement the specifications that include the extensive margin, we use the differenced inverse hyperbolic sine transformation instead of log differences for trade flows as suggested by Burbidge, Magee, and Robb (1988). This transformation allows us to include zero or missing trade flows, while approximating logs for larger values of the data.[16] The

[15] As highlighted by Ruhl (2008), among others, the long-run elasticity may be even higher when the extensive margin is taken into account.

[16] Tariff data are typically not missing and we can always construct $\ln(1+\tau_{i,j,p,t})$, so we do not need the inverse hyperbolic transformation for tariffs. Bellemare and Wichman (2020) highlight that caution must be used in interpreting the estimated coefficient as an elasticity, but in our case the estimated β^h can be interpreted as an elasticity. The estimated coefficient converges to an elasticity as the underlying variable being transformed (trade values in our case) takes on large enough values on average. This is the case in the trade data.

resulting estimates in column 6 of Table 3 can be interpreted as the "total" elasticity, inclusive of both the intensive and product-level extensive margins. The point estimates are similar to the baseline initially, but slightly smaller in the long run. We conjecture that this is because the estimation sample now includes many instances of trade being zero at both $t-1$ and $t+h$. Since these appear as zero changes in the sample, they drive down the point estimate.

Additional results, diagnostics, and robustness Column 7 of Table 3 estimates a distributed-lag model as an alternative to the local projection specification. This approach has two disadvantages relative to the baseline: (i) it requires a panel of non-missing log growth rates for trade, tariffs, and the instrument for every lag, reducing the estimation sample greatly even relative to the balanced panel exercise; and (ii) it imposes linearity on the estimates. Caveats aside, the distributed lag specification with 10 lags yields a long-run trade elasticity of 1.58 with a standard error of 1.02, while the number of observations falls to just around 5.5 million. This point estimate is statistically indistinguishable from our baseline estimates.[17]

Appendix B presents the results for all the specifications at every horizon. This appendix also reports the first stage F-statistics for the baseline instrument and the all partners instrument for every horizon. In all cases, the first stage F-statistics are much higher than 10.

Other candidates for instruments One downside of our instrument is that we cannot be certain which partner countries primarily motivated each MFN tariff change. Without specific knowledge of the reasons behind each MFN tariff change, our instrument will always be subject to this concern. There are other candidate instruments that could in principle be considered under the WTO framework. Here, we discuss these potential instruments and issues with each of them.

A natural candidate instrument is WTO accession. When a country such as China joins the WTO, the negotiations are protracted, and there are substantial anticipation effects (see for instance Pierce and Schott, 2016). However, once China joins the WTO and sets its MFN tariffs, small third countries in the WTO are also affected by these MFN tariffs. These countries are plausibly facing an exogenous change, conditional on the anticipation effects, as they were likely not key players in the negotiations. While there are a few WTO accessions in our data, a key problem with implementing

[17]Formally, we estimate the equation $\Delta_0 \ln X_{i,j,p,t} = \sum_{k=0}^{10} \gamma^k \Delta_0 \tau_{i,j,p,t-k} + \delta_{i,p,t} + \delta_{j,p,t} + \delta_{i,j,p} + u_{i,j,p,t}$ instrumenting $\Delta_0 \tau_{i,j,p,t-k},\ k \in [0,10]$ with $\Delta_0 \tau^{instr}_{i,j,p,t-k},\ k \in [0,10]$. The trade elasticity at horizon h reported in Table 3 is then $\sum_{k=0}^{h} \gamma^k$. As this estimation requires 11 instruments for 11 endogenous variables, we report the Sanderson-Windmeijer F-statistic for weak instruments in Appendix Table A10. Conceptually, there is a subtle difference between the object estimated by local projections and the distributed lag approach. Whereas the local projections take into account the time series behavior of the tariff variable, the distributed lag coefficients cumulated up to horizon h are estimates of the response of trade to a permanent once-and-for-all change in tariffs that happened at horizon 0. Section 5 lays out the details. In the notation of that section, the sum of the distributed lag coefficients $\sum_{k=0}^{h} \gamma^k$ corresponds to θ^h, whereas the local projection model estimates ε^h. We show that in practice ε^h is close to θ^h.

TABLE 3: Trade Elasticity, Robustness: Alternative Instruments, Outcomes, Fixed Effects, Samples and Models

	Baseline (1)	All Partners (2)	HS6 (3)	Quantities (4)	Unit Values (5)	Extensive (6)	Distributed Lag (7)
t	-0.140***	-0.302***	-0.167**	-0.019	-0.070*	-0.118***	0.239
	(0.051)	(0.025)	(0.080)	(0.064)	(0.039)	(0.041)	(0.294)
obs	39.22	70.41	36.1	38.82	38.73	48.93	5.56
$t+1$	-0.689***	-0.620***	-0.913***	-0.551***	-0.109*	-0.681***	0.168
	(0.079)	(0.037)	(0.119)	(0.096)	(0.056)	(0.067)	(0.402)
obs	30.95	55.77	28.57	30.65	30.55	37.52	5.56
$t+3$	-0.983***	-0.754***	-1.418***	-0.684***	-0.224***	-0.840***	-0.502
	(0.097)	(0.044)	(0.146)	(0.119)	(0.069)	(0.084)	(0.571)
obs	24.51	44.82	22.49	24.25	24.17	29.49	5.56
$t+5$	-1.194***	-0.822***	-1.570***	-0.849***	-0.241***	-1.114***	-0.263
	(0.115)	(0.052)	(0.171)	(0.142)	(0.080)	(0.102)	(0.716)
obs	19.71	36.42	18.01	19.48	19.45	23.48	5.56
$t+7$	-1.536***	-0.848***	-2.343***	-1.385***	-0.042	-1.369***	-0.770
	(0.136)	(0.061)	(0.200)	(0.165)	(0.092)	(0.118)	(0.853)
obs	15.6	28.95	14.16	15.4	15.37	18.39	5.56
$t+10$	-1.732***	-0.972***	-2.704***	-1.591***	-0.032	-1.327***	-1.584
	(0.181)	(0.077)	(0.254)	(0.219)	(0.123)	(0.154)	(1.028)
obs	10.22	19.33	9.18	10.05	10.04	11.77	5.56

Notes: This table presents alternative estimates for the results from estimating equation (2.4), varying the instrument or outcome variable. Column 2 uses an alternative definition of the instrument where all trade partners subject to the MFN regime are included. Column 4 reports results for quantities, and Column 5 the results for unit values. Column 6 presents results for the intensive and extensive margin combined using the inverse hyperbolic sine transformation for trade flows with the baseline instrument. Column 7 presents results from a distributed lag model. All specifications include importer-HS4-year, exporter-HS4-year and importer-exporter-HS4 fixed effects, except Column 3 where the product dimension of fixed effects is at the HS6 level. Standard errors are clustered at the importer-exporter-HS4 level. ***, ** and * indicate significance at the 99, 95 and 90 percent level respectively. Observations are reported in millions.

this instrument is that product-level tariff data are typically not available in standard datasets for countries *before* they join the WTO. It is therefore not possible to construct the exogenous tariff change (the change from the pre-WTO rate to the MFN rate).[18]

A second instrument would be a change in the MFN bound, which is the maximum tariff a country in the WTO can apply against other countries. While these are likely less discretionary, the MFN bounds are set in the WTO accession treaty and very hard to change ex-post. The lack of instances of changes in the bounds implies there is insufficient variation in this instrument to estimate the elasticity.

5 Applications

We stress that equations (2.2), (2.3), and (2.4) are "model free," and under our identification assumptions will produce estimates of ε^h by definition. The mapping between these estimates and parameters in theoretical models then depends on model structure. This section has two parts. The first maps our estimates to the long-run elasticity applicable in static trade models, and performs welfare gains from trade calculations. The second develops a simple dynamic framework of sluggish adjustment to trade cost shocks, and explores what the time path of our estimates implies for the parameters governing adjustment.

5.1 The Long-Run Trade Elasticity and Welfare

This section presents a mapping from the estimated ε^h to the long-run (steady state) trade elasticity, the key parameter in static international trade models. We clarify two points. First, the estimation of ε^h takes into account the time series behavior of tariffs as well as trade flows. If in the data tariffs exhibit any autocorrelation behavior after the initial impulse, the estimated ε^h will reflect the dynamic behavior of both trade flows and tariffs. Thus, the ε^h itself does not answer the question of what happens following a one-time permanent change in trade costs. However, we can use the components of ε^h to recover the steady-state elasticity that applies in static (long-run) models. Second, how the long-run estimated elasticity relates to structural model parameters depends on whether the trade data used in estimation include tariff payments.

Dynamic and static gravity We suppress the product dimension in the exposition to economize on notation. Let the trade flows follow the gravity relationship:

$$X_{i,j,t} \propto \prod_{k=0}^{\infty} \phi_{i,j,t-k}^{\theta_k} \cdot S_{i,t} \cdot D_{j,t} \tag{5.1}$$

[18] We have contacted the national statistical agencies of countries that joined the WTO in our sample. Most agencies do not have these data.

where $S_{i,t}$ and $D_{j,t}$ are the multilateral resistance terms, that vary by importer and exporter respectively, but not country pair. The non-standard feature of (5.1) is that time-t trade flows are allowed to depend on past values of iceberg trade costs $\phi_{i,j,t-k}$ with a horizon-dependent elasticity θ_k. This would be the case if, for example, adjustment of trade is sluggish, and conditions in the past affect the trading relationships that exist in the present. Of course, this specification nests the traditional contemporaneous gravity equation, which obtains when $\theta_k = 0\ \forall k > 0$. The assumption of dependence of current trade on past trade costs is falsifiable, and our empirical work can be viewed as an econometric test of this assumption.

One can view the static gravity relationship as a steady-state version of (5.1). Suppose that all the $\phi_{i,j,t}$'s and multilateral resistance terms are constant over time. In steady state:

$$X_{i,j} \propto \phi_{i,j}^{\sum_{k=0}^{\infty} \theta_k} \cdot S_i \cdot D_j, \tag{5.2}$$

which is the textbook gravity relationship. Equation (5.2) shows that the object of interest for static international trade models is the long-run trade elasticity $\theta \equiv \sum_{k=0}^{\infty} \theta_k$. We assume that the structure of θ_k's is such that the long-run trade elasticity is finite. This would be the case, for instance, if $\theta_k = 0\ \forall k > K < \infty$.

Mapping back to empirical estimates Plugging in the form of iceberg trade costs into (5.1) and taking logs:

$$\ln X_{i,j,t} \propto \sum_{k=0}^{\infty} (\theta_k \ln \kappa_{i,j,t-k} + \theta_k \tau_{i,j,t-k}) + \ln S_{i,t} + \ln D_{j,t}.$$

The impact of a single-period change in tariffs at t on trade at $t+k$ is:

$$\frac{\partial \ln X_{i,j,t+k}}{\partial \tau_{i,j,t}} \approx \theta_k.$$

However, in the data tariff changes are persistent. The impact of a one-time permanent change in tariffs that occurs between $t-1$ and t on trade at $t+h$ is

$$\frac{\partial \ln X_{i,j,t+h}}{\partial \tau_{i,j,t}} = \sum_{k=0}^{h} \theta_k \equiv \theta^h. \tag{5.3}$$

Note the switch from a subscript on θ_k to a superscript on θ^h, to denote the cumulative nature of the latter. As $h \to \infty$, $\theta^h \to \theta$, the long-run trade elasticity. As a practical matter, we can only estimate parameters up to the horizon $h = 10$ years, and will by necessity treat the 10-year estimates as reflecting the long run. The time series behavior of point estimates suggests that this may be a fair approximation.

We now turn to the question of how to recover θ^h from our estimates. The h-year difference in trade flows is:

$$\Delta_h \ln X_{i,j,t} \approx \sum_{k=0}^{\infty} \theta_k \Delta_h \tau_{i,j,t-k} + \Delta_h \ln S_{i,t} + \Delta_h \ln D_{j,t} + u_{i,j,t}, \tag{5.4}$$

where the error term corresponds to the change in non-tariff bilateral trade costs, $u_{i,j,t} = \sum_{k=0}^{\infty} \Delta_h \theta_k \ln \kappa_{i,j,t-k}$.

If there was a permanent shock $\Delta_0 \tau_{i,j,t}$ to tariffs at a specific calendar t, then the h-period change is simply equal to the initial change: $\Delta_h \tau_{i,j,t} = \Delta_0 \tau_{i,j,t}$. In that case it is easy to verify from the definition (2.1) that $\varepsilon^h = \theta^h$, and it could just be estimated by regressing $\Delta_h \ln X_{i,j,t}$ on that tariff change for each h, which corresponds exactly to equation (2.2).

However, the tariff changes may be autocorrelated, and so a time-t innovation $\Delta_0 \tau_{i,j,t}$ may be followed by further changes later. Equation (2.3) flexibly captures the autocorrelation in tariffs by relating the h-period change back to the initial impulse. Indeed, Figure 3 reports the estimates of this equation and shows a moderate degree of mean-reversion in tariffs. Combining (2.3) and (5.4), the h-period change in trade flows has the following relationship to a time-t impulse in tariffs (dropping κ's, S's and D's):

$$\Delta_h \ln X_{i,j,t} \propto \left(\theta_0 \beta_\tau^h + \theta_1 \beta_\tau^{h-1} + \theta_2 \beta_\tau^{h-2} + \theta_3 \beta_\tau^{h-3} + ... + \theta_h\right) \Delta_0 \tau_{i,j,t}.$$

Intuitively, the h-period-ahead response of trade flows to a one-unit initial change in tariffs is a combination of the elasticities of trade changes to lagged trade costs θ_k and the best predictions of what tariffs themselves will be k periods ahead following a time-t innovation in tariffs, β_τ^k. Combining this relationship with (2.2), we can recover the elasticities to permanent trade cost changes θ^h from our estimates of trade elasticities ε^h and the time series behavior of tariffs themselves β_τ^h:

$$\varepsilon^h = \theta^h + \theta_1 \frac{\beta_\tau^{h-1} - \beta_\tau^h}{\beta_\tau^h} + \theta_2 \frac{\beta_\tau^{h-2} - \beta_\tau^h}{\beta_\tau^h} + \theta_3 \frac{\beta_\tau^{h-3} - \beta_\tau^h}{\beta_\tau^h} + ... + \theta_h \frac{1 - \beta_\tau^h}{\beta_\tau^h}. \tag{5.5}$$

Thus, the elasticity to the permanent shock θ^h is a transformation of the ε^h and the β_τ^h estimates reported above. Since this expression holds also for $h = 0$, (5.5) can be used to recover each θ^h recursively. Once we have done that, we will treat the 10-year horizon θ^{10} as an estimate of the long-run elasticity θ.

Trade flows net and gross of tariffs The second important aspect of the interpretation of our coefficient estimates is whether the elasticity is defined with respect to spending inclusive or exclusive of tariffs. Most theoretical gravity relationships relate spending by domestic agents to trade costs, with the trade elasticity defined correspondingly. On the other hand, the data on our outcome variable $X_{i,j,t}$ does not include tariff payments.

To see the consequences of this disparity, denote by $\widetilde{X}_{i,j}$ the steady state spending by consumers in economy i on goods from j, and by $\widetilde{\theta}$ the elasticity of this consumer spending to trade costs:

$$\widetilde{X}_{i,j} \propto \phi_{i,j}^{\widetilde{\theta}} \cdot S_i \cdot D_j. \tag{5.6}$$

The elasticity $\widetilde{\theta}$ is relevant for the welfare gains from trade calculations, for example. Since $\widetilde{X}_{i,j} = (1+\tau_{i,j})X_{i,j}$ and $\phi_{i,j} = \kappa_{i,j} \cdot (1+\tau_{i,j})$, we can rewrite (5.6) in terms of trade flows exclusive of tariff payments $X_{i,j}$, which are reported in our data:[19]

$$X_{i,j} \propto \kappa_{i,j}^{\widetilde{\theta}} \left(1+\tau_{i,j}\right)^{\widetilde{\theta}-1} \cdot S_i \cdot D_j. \tag{5.7}$$

Comparing (5.7) to (5.2), the two elasticities have the following relationship: $\widetilde{\theta} = \theta + 1$. As an example, in an Armington setting $\widetilde{\theta}$ corresponds to $1-\sigma$, where σ is the elasticity of substitution between goods coming from different origins. In that case, $\theta = -\sigma$. In an Eaton-Kortum setting, $\widetilde{\theta}$ is the Frechet dispersion parameter. In that case, it can be recovered by adding 1 to our θ estimates.

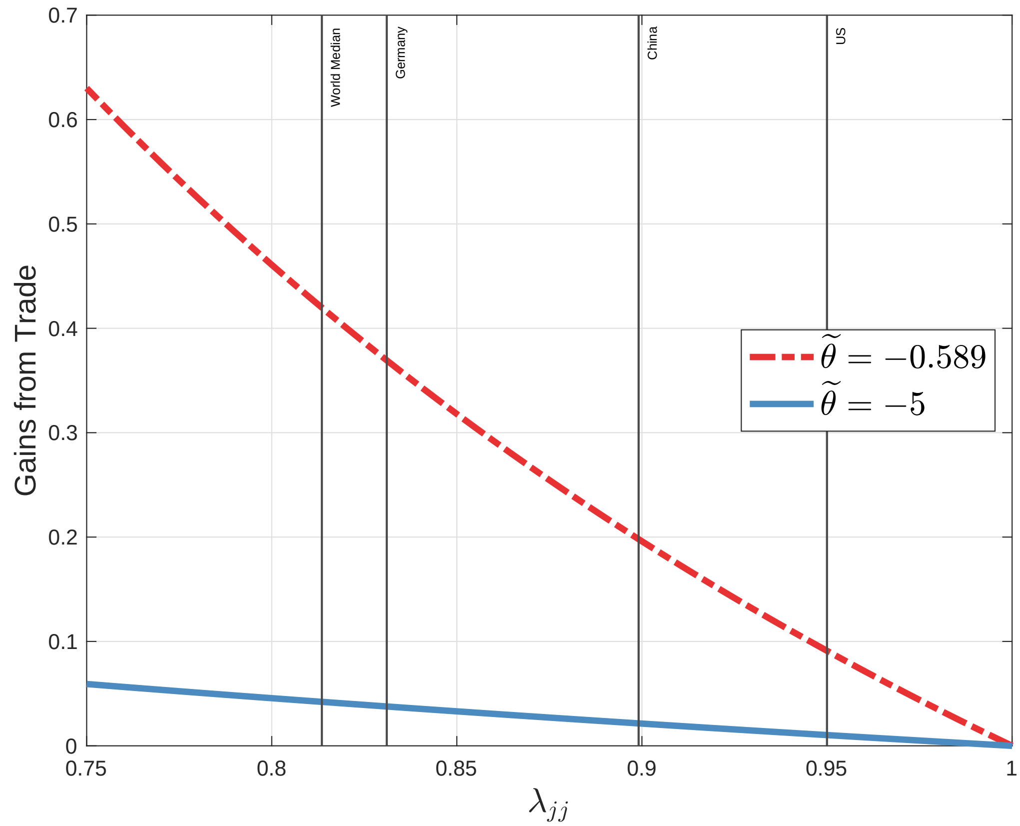
Welfare gains from trade As is well known from Arkolakis, Costinot, and Rodríguez-Clare (2012), the gains from trade relative to autarky in many quantitative trade models can be expressed as a function of the trade elasticity and the domestic absorption share: $1 - \lambda_{jj}^{1/\widetilde{\theta}}$, with λ_{jj} the share of spending on domestically-produced goods in total spending. As detailed above, we can obtain $\widetilde{\theta}$ from our estimates by first computing θ^h from the ε^h and β_τ^h's as in (5.5). This calculation gives us $\theta^{10} = -1.589$. Treating this as our best estimate of the long-run tariff-exclusive trade elasticity θ, we conclude that the welfare-relevant elasticity $\widetilde{\theta}$ is -0.589.

Figure 6 displays the gains from trade as a function of λ_{jj}, under our value of $\widetilde{\theta}$ and under an elasticity of -5 considered by Arkolakis, Costinot, and Rodríguez-Clare (2012). As expected, the gains from trade are substantially larger with our elasticity. For the US, gains from trade are 9.1% for $\widetilde{\theta} = -0.589$, compared to 1.0% for $\widetilde{\theta} = -5$. The median welfare gain is 42% in the sample 64 countries, compared to 4.2% implied by $\widetilde{\theta} = -5$.[20] Table A11 reports the gains from trade under $\widetilde{\theta} = -0.589$, -5, and -10 for selected countries in the sample.

[19] This calculation assumes that $X_{i,j}$ is recorded as c.i.f. The relationship between $\widetilde{\theta}$ and θ is the same if $X_{i,j}$ is f.o.b., since the iceberg costs $\kappa_{i,j}$ are log-additive and make up the error term in our estimation.

[20] We use data from the OECD IO tables for 64 countries for the year 2006, the midpoint of our trade and tariff sample. We compute import penetration by dividing imports by gross output as in Arkolakis, Costinot, and Rodríguez-Clare (2012).

Figure 6: Gains from Trade



Notes: This figure displays the gains from trade as a function of the domestic absorption ratio λ_{jj} under our baseline welfare-relevant elasticity of -0.598 (red dashed line) and a comparison elasticity of -5 (solid blue line). "World Median" denotes the median domestic absorption ratio of the 64 countries in the OECD world input-output tables in 2006.

5.2 Dynamics of Trade Elasticities

We next present a simple model that is qualitatively consistent with our estimated elasticities over different horizons. The recent literature on trade dynamics is rich in both substantive mechanisms and quantification (see, among many others, Costantini and Melitz, 2007; Ruhl, 2008; Burstein and Melitz, 2013; Drozd and Nosal, 2012; Alessandria and Choi, 2014; Alessandria, Choi, and Ruhl, 2014; Ruhl and Willis, 2017; Fitzgerald, Haller, and Yedid-Levi, 2017). The goal of this section is not to revisit all of the proposed mechanisms for gradual adjustment of trade to trade cost shocks. Rather, we set up the simplest possible model of sluggish adjustment, to illustrate the basic mechanics and quantify the parameters governing it. The model is a dynamic extension of the Arkolakis (2010) market penetration framework, where the number of customers of a firm adjusts gradually and plays the role similar to the firm's capital stock. The key difference to the capital stock is that the number of customers is specific to a foreign market.

Firm's problem Consider a representative firm with a constant marginal cost c, selling its good domestically and abroad. The firm's problem is separable by market, and thus without loss of generality we only model exports to a single foreign country. Since there is only one source and one destination, we drop the i, j subscripts to economize on notation. As in Burstein, Neves, and Rebelo (2003) and others, sales in a foreign country require local distribution services, that are combined in fixed proportions with the exported good.

The foreign consumer pays the price

$$p_t^c = p_t^x (1 + \tau_t) + d,$$

where p_t^x denotes the exporter's *fob* price, τ_t the ad-valorem tariff, and d the per unit cost of local distribution services.

The firm commands monopoly power, and foreign demand exhibits a constant elasticity σ. Normalizing the aggregate foreign demand shifters to unity, the firm faces the demand curve

$$q_t = n_t (p_t^c)^{-\sigma},$$

where n_t is the mass of foreign consumers the firm reaches. The firm's optimal price is

$$p_t^x = \frac{\sigma}{\sigma - 1} c + \frac{1}{\sigma - 1} \frac{d}{1 + \tau_t}. \tag{5.8}$$

The price received by the producer is decreasing in tariffs, because higher tariffs increase the costs of foregone sales at the margin. This feature of the model is consistent with the unit value response documented in Table 3, and implies that the tariff passthrough to the consumer is incomplete. The exporter price is also greater than the price in the absence of distribution costs, because the monopolist does not internalize foregone sales by the distribution sector. The firm's flow profits from exporting are $n_t \pi (\tau_t)$, where $\pi(.)$ is a decreasing function in tariffs.

As in Arkolakis (2010), the firm incurs costs to reach foreign consumers. The mass of foreign consumers available for the firm to sell to evolves according to the accumulation equation

$$n_{t+1} = n_t (1 - \delta) + a_t, \tag{5.9}$$

where a_t is the mass of newly added customers in the foreign country. We assume that adding a new customers requires a payment of $f(a)$, where $f' > 0$ and $f'' > 0$, and that the existing mass of consumers already reached by the firm depreciates at rate δ.

The firm discounts at interest rate r, correctly predicts the future path of tariffs, and maximizes the present discounted value of future profits

$$\max_{\{a_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^t \left[n_t \pi\left(\tau_t\right) - f\left(a_t\right)\right]$$

subject to the accumulation equation (5.9).

Letting λ_t be the multiplier on the accumulation equation, the firm's first-order conditions are

$$f'\left(a_t\right) = \lambda_t, \tag{5.10}$$

$$\lambda_t = \frac{1}{1+r}\left[\pi\left(\tau_{t+1}\right) + (1-\delta)\lambda_{t+1}\right].$$

The firm chooses its investment into accumulating new consumers such that the marginal benefit λ_t equals the marginal cost $f'\left(a_t\right)$. The shadow value λ_t, in turn, is the present discounted value of profits generated by each consumer reached in the foreign market.

Exports, as measured in the data, are $X_t = p_t^x q_t$. The framework is sufficiently simple to analytically characterize the trade elasticity for different time horizons and alternative assumptions on the evolution of tariffs.

The short-run trade elasticity The accumulation equation above assumes that investment into new customers is subject to a 1-period "time-to-build" common in the real business cycle literature since Kydland and Prescott (1982). This implies that the number of customers reachable in the foreign destination, n_t, is constant within the impact period. We thus think of the short-run trade elasticity as the trade elasticity for constant n_t:

$$\theta_{sr} := \left.\frac{d\ln X_t}{d\ln\left(1+\tau_t\right)}\right|_{n_t=n} = \underbrace{-\frac{1}{\sigma-1}\frac{s_d}{1-s_d}}_{\frac{d\ln p_t^x}{d\ln(1+\tau_t)}\text{ (producer price response)}} \underbrace{-\sigma\cdot \underbrace{\left(1-s_d\right)\left[1-\frac{1}{\sigma-1}\frac{s_d}{1-s_d}\right]}_{\frac{d\ln p_t^c}{d\ln(1+\tau_t)}\text{ (pass-through into consumer prices)}}}_{\left.\frac{d\ln q_t}{d\ln(1+\tau_t)}\right|_{n_t=n}\text{ (short-run quantity response)}}, \tag{5.11}$$

where $s_d \equiv \frac{d}{p_t^x(1+\tau_t)+d}$ is the share of local distribution costs in the consumption price.

Both prices and quantities respond to the tariff change. An increase in tariffs reduces the price producers charge (see 5.8), with elasticity $\frac{d\ln p_t^x}{d\ln(1+\tau_t)} = -\frac{1}{\sigma-1}\frac{s_d}{1-s_d}$. The (imperfect) passthrough rate into tariff-inclusive prices is thus $1+\frac{d\ln p_t^x}{d\ln(1+\tau_t)} = 1-\frac{1}{\sigma-1}\frac{s_d}{1-s_d}$. Since consumer prices include distribution costs, passthrough into consumer prices is further muted, $\frac{d\ln p_t^c}{d\ln(1+\tau_t)} = (1-s_d)\left(1+\frac{d\ln p_t^x}{d\ln(1+\tau_t)}\right)$. The quantity response to a tariff change is then multiplied by the demand elasticity σ.

The long-run trade elasticity In addition to the short-run changes discussed above, the firm's customer base n_t adjusts in the long run. We think of the long-run trade elasticity as the response of trade in steady state to a change in steady state tariffs. Dropping time subscripts to denote steady state values, the long-run elasticity is:

$$\theta_{lr} := \frac{d\ln X}{d\ln(1+\tau)} = \theta_{sr} + \underbrace{-\sigma(1-s_d)\left(\frac{f''(a)\,a}{f'(a)}\right)^{-1}}_{\frac{d\ln n}{d\ln(1+\tau)}\text{ (response of customer base)}}, \tag{5.12}$$

and thus adds the customer base response to the short-run elasticity. The customer base responds to the tariff change with the same elasticity as investment into new consumers ($\frac{d\ln n}{d\ln(1+\tau)} = \frac{d\ln a}{d\ln(1+\tau)}$). Investment into new consumers, in turn, is determined by the curvature of market penetration costs $f(a)$, and the shadow value λ (see equation 5.10). Since the shadow value is determined by the effect of tariffs on per-customer flow profits π, we have $\frac{d\ln a}{d\ln(1+\tau)} = \left(\frac{f''(a)a}{f'(a)}\right)^{-1}\frac{d\ln\lambda}{d\ln(1+\tau)} = \left(\frac{f''(a)a}{f'(a)}\right)^{-1}\frac{d\ln\pi}{d\ln(1+\tau)}$. The elasticity of per-customer flow profits to tariffs is $\frac{d\ln\pi}{d\ln(1+\tau)} = -\sigma(1-s_d)$. Putting these pieces together delivers (5.12).

Transitional dynamics Consider a tariff change at time t_0 and its effect on exports at time t_0+h. Before t_0, the dynamic system is assumed to be in steady state. For the dynamic response of trade flows to tariffs, both the history of tariffs between t_0 and t_0+h and expectations about tariffs beyond horizon t_0+h matter. More precisely, for an arbitrary sequence of tariff changes relative to the steady state $d\ln(1+\tau_{t_0})$, $d\ln(1+\tau_{t_0+1})$, $d\ln(1+\tau_{t_0+2})$, ..., the effect on exports at time t_0+h is

$$\begin{aligned} d\ln X_{t_0+h} \;=\; & -\frac{\sigma(\delta+r)(1-s_d)}{1+r}\delta\left(\frac{f''(a)\,a}{f'(a)}\right)^{-1}\sum_{\ell=0}^{h-1}(1-\delta)^{h-(\ell+1)}\sum_{k=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{k} d\ln(1+\tau_{t_0+\ell+k+1}) \\ & +\theta_{sr}\, d\ln(1+\tau_{t_0+h}). \end{aligned}$$

Since this expression is complicated, we next consider two simpler examples, both reasonably good descriptions of the observed tariff changes in our data.

Example 1: tariff constant after 1 period First, consider a surprise change in the tariff sequence of the form $d\ln(1+\tau_{t_0})$, $d\ln(1+\tau_{t_0+1}) = d\ln(1+\tau_{>t_0})$, $d\ln(1+\tau_{t_0+2}) = d\ln(1+\tau_{>t_0})$, $d\ln(1+\tau_{t_0+3}) = d\ln(1+\tau_{>t_0})$,..., all expressed relative to the initial steady state. That is, the tariff change takes one particular value, $d\ln(1+\tau_{t_0})$, in the impact period, and is subsequently constant at $d\ln(1+\tau_{>t_0})$. Note that this example nests a one-off permanent change in tariffs ($\tau_{t_0} = \tau_{>t_0}$), and is a good approximation of our estimated impulse response function in Figure 3.

The trade elasticity is θ_{sr} in the impact period. At horizon $h \geq 1$ the trade elasticity is

$$\frac{d\ln X_{t_0+h}}{d\ln\left(1+\tau_{t_0+h}\right)} = \frac{d\ln X_{t_0+h}}{d\ln\left(1+\tau_{>t_0}\right)} = \theta_{sr} - \sigma\left(1-s_d\right)\left(\frac{f''(a)\,a}{f'(a)}\right)^{-1}\left(1-(1-\delta)^h\right).$$

This expression makes clear that the trade elasticity geometrically approaches the new steady state. The rate of convergence is $(1-\delta)$. Convergence occurs in one period if $\delta = 1$ (full customer base depreciation), and becomes slower for smaller δ.

Example 2: AR(1) Second, consider a first order autoregressive process for tariffs so that $d\ln\left(1+\tau_{t+1}\right) = \rho \cdot d\ln\left(1+\tau_t\right)$. Then

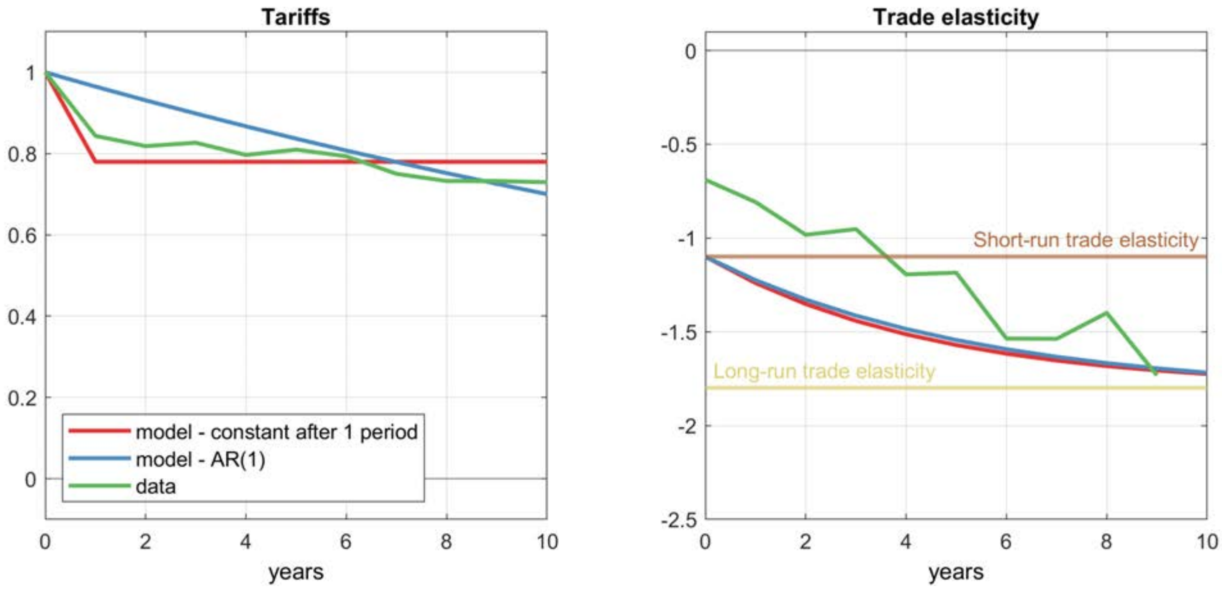
$$\frac{d\ln X_{t_0+h}}{d\ln\left(1+\tau_{t_0+h}\right)} = \theta_{sr} - \sigma\left(1-s_d\right)\left(\frac{f''(a)\,a}{f'(a)}\right)^{-1}\frac{(\delta+r)\,\delta}{\left[1+r-(1-\delta)\,\rho\right]\left(1-\frac{1-\delta}{\rho}\right)}\left(1-\left(\frac{1-\delta}{\rho}\right)^h\right).$$

Note the following. First, since the tariff change approaches zero, the elasticity is not well defined in the limit. Both the tariff change and exports will return to the initial steady state. Second, for finite h, the dynamics are governed by $1-\left(\frac{1-\delta}{\rho}\right)^h$, which is very similar to the above example, but now the AR(1) coefficient ρ plays a role. Third, the term $\frac{(\delta+r)\delta}{[1+r-(1-\delta)\rho]\left(1-\frac{1-\delta}{\rho}\right)}$ enters the expression, driving a wedge between the long-run trade elasticity and the horizon-invariant part the above expression. Depending on parameter values, this expression can be greater or smaller than one. A value of greater than one implies that the trade elasticity at long but finite horizons can exceed the long-run elasticity.

Quantification To illustrate the quantitative properties of the model, we subject it to the two tariff shocks in the examples above. We let the elasticity of demand be $\sigma = 1.5$, and the share of local distribution services $s_d = 0.2$. The latter is comparatively low by the standards of the literature, but these two values in combination deliver the unit value response reported in Table 3. These two parameters are all that is needed to pin down the short-run trade elasticity θ_{sr}. The curvature in the adjustment cost $\left(\frac{f''(a)a}{f'(a)}\right)^{-1} = 1.71$ is then entirely pinned down by the difference between the long- and short-run elasticities (5.12). The depreciation rate is set to $\delta = 0.2$ to roughly match the rate of convergence to the long run. These are all the parameters needed to implement Example 1. For Example 2, we also need the interest rate and the AR(1) coefficient. We set these to $r = 0.03$ and $\rho = 0.965$.

The left panel of Figure 7 plots the paths of tariffs. The red line is Example 1, where tariffs increase by one unit in the impact period, and then stay at 0.8 starting in period 1 onwards. The blue line is the AR(1) path of tariffs following an impulse of size 1. The green line plots the impulse response of tariffs estimated in the data, which is quite similar to the two model experiments.

Figure 7: Time Path of Elasticities in the Dynamic Model



Notes: This figure illustrates the trade elasticities as implied by the model.

The right panel of Figure 7 depicts the trade elasticities. The green line is the econometric estimates. Because the data are annual, and it is unlikely that all tariff changes went into effect on January 1, the year-zero trade elasticity is most likely subject to partial-year effects. Thus, for the purposes of comparing to the model, we consider the $h = 1$ empirical estimate to be the impact elasticity θ_{sr}. The red and blue lines depict the model trade elasticity in the two experiments. They are nearly indistinguishable from each other.

The model succeeds in delivering a smooth path of adjustment that lasts a decade. The key parameter for the speed of adjustment is the depreciation rate δ. The slow adjustment observed in the data implies that δ is substantially below 1. The main shortcoming of the model is its overshooting of the short-run elasticity, which in the data is about 0.7. The model short-run elasticity is governed by only two parameters, σ and s_d (see 5.11). The former has to be above 1 to be consistent with monopolistic competition; the latter has to lie between 0 and 1. It turns out that there exists no combination of σ and s_d satisfying these restrictions that delivers $\theta_{sr} < 1$.

6 Conclusion

We develop a novel method to estimate the trade elasticity, a key parameter in virtually all models in international economics. To tackle the endogeneity problem that tariffs might be lower in products where countries expect the largest trade flows, we develop an instrument that relies on the WTO's MFN principle. We estimate trade elasticities at different horizons, and find short-run values of about -0.7, and long-run values close to -1.75. Our estimates are robust to alternative specifications of the instrument and controls, and uniformly larger than OLS. Our estimates are also not specific to a particular model framework, and apply to all models that have a gravity specification for trade flows in the long run.

Our long-run estimates imply the welfare-relevant trade elasticity is below 1 in absolute value. This is significantly smaller than conventional wisdom in the literature, suggesting the welfare gains from trade are larger than previously thought. Our finding that the trade elasticity differs by horizon and only converges to the "long-run" after about 7-10 years implies substantial adjustment costs to changing trade volumes.

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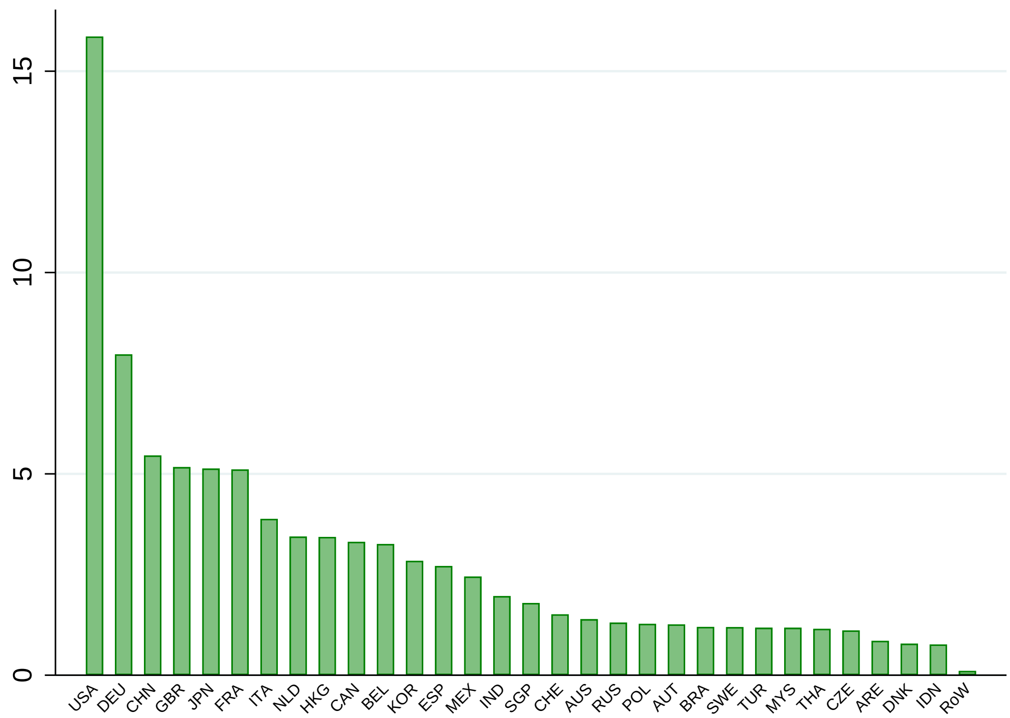
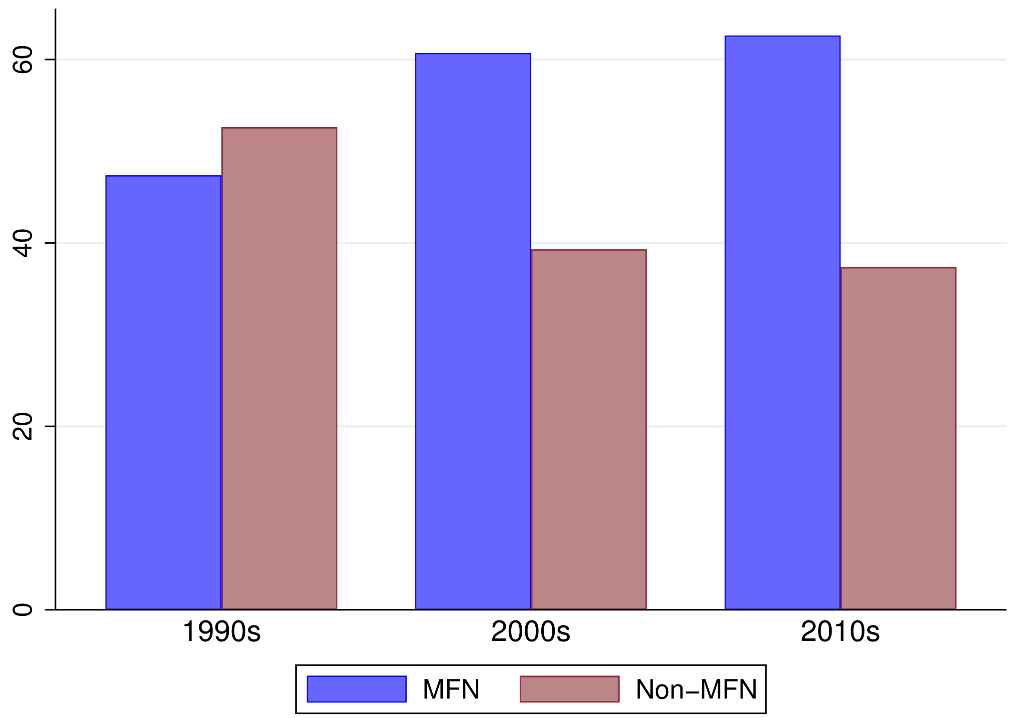
Appendix A Data

Figure A1: Fraction of World Imports (Average, %)



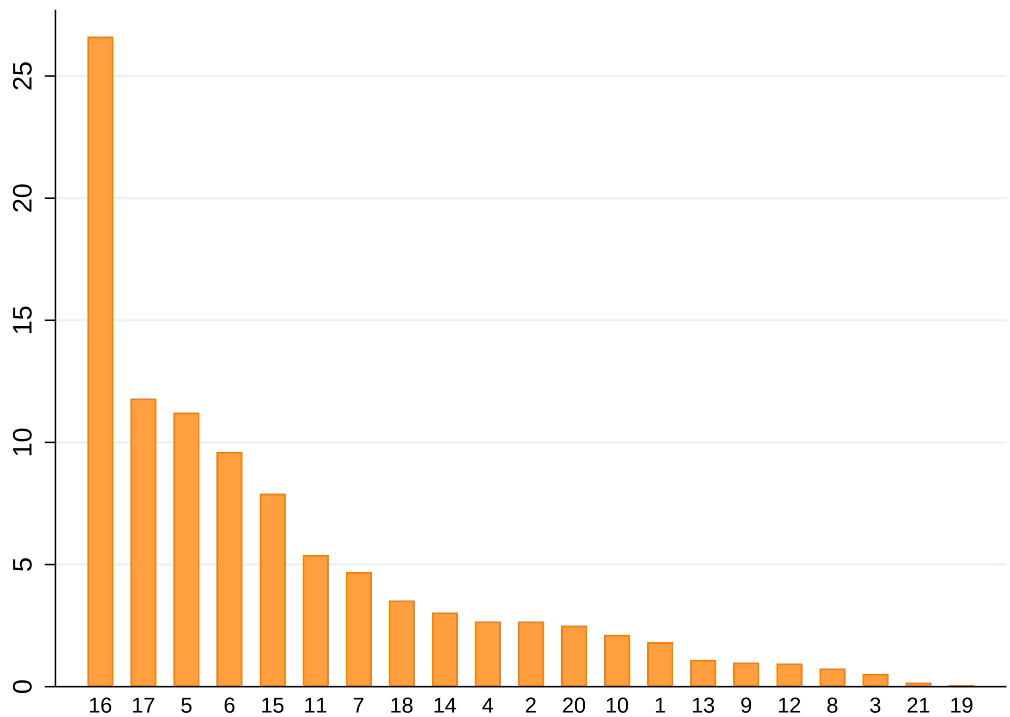
Notes: This figure shows the average fraction of world trade flows by importer in our sample.

Figure A2: Fraction of World Imports: MFN vs. non-MFN (%)



Notes: This figure shows the average fraction of world trade that is subject to MFN tariffs and non-MFN tariffs by decade in our sample.

Figure A3: Fraction of World Imports by HS Section (Average, %)



Notes: This figure shows the average fraction of trade that is in each HS Section in our sample.

Table A1: HS Codes Mapping Across Revisions

		Mapped to:				
		HS-92	HS-96	HS-02	HS-07	HS-12
Mapped from:	HS-96	89.38				
	HS-02	81.55	90.81			
	HS-07	73.34	80.74	88.48		
	HS-12	68.17	74.91	81.81	91.93	
	HS-17	61.85	67.92	73.62	81.99	88.05

Notes: This table presents the fraction of HS codes that can be mapped uniquely from as HS revision in the "Mapped from" row to an HS revision in a "Mapped to" column. All numbers are in percentages.

Table A2: Instrument – Illustration

Importer	MFN Trade Partners		Major Trade Partners Aggregate		Major Trade Partners HS 6403		Treatment	Control	Excluded
	2005	2006	2005	2006	2005	2006			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Germany									
	USA	USA	FRA	FRA	ITA	ITA	HKG	ITA	CHN
	CHN	CHN	CHN	CHN	CHN	CHN	KOR	VNM	IND
	JPN	JPN	NLD	NLD	VNM	VNM	SGP	PRT	USA
	KOR	KOR	ITA	ITA	PRT	PRT	NZL	AUT	JPN
	IND	IND	USA	USA	AUT	AUT	CAN	NLD	
	CAN	CAN	GBR	GBR	IND	IND	AUS	SVK	
	HKG	HKG	BEL	BEL	NLD	NLD	PRK	IDN	
	SGP	RUS	AUT	AUT	SVK	SVK		ESP	
	BRA	SGP	CHE	CHE	ESP	IDN		GBR	
	RUS	BRA	JPN	JPN	ROU	ROU		FRA	
Panel B: Japan									
	CHN	CHN	CHN	CHN	CHN	CHN	GBR	KHM	CHN
	USA	USA	USA	USA	ITA	ITA	PRT	MMR	ITA
	KOR	KOR	AUS	SAU	KHM	KHM	BRA	BGD	VNM
	AUS	AUS	IDN	ARE	VNM	VNM	MAR	MEX	IDN
	ITA	ITA	KOR	AUS	IDN	IDN	IND	LAO	ESP
	CAN	FRA	DEU	IDN	MMR	MMR	CHE	NPL	FRA
	DEU	CAN	THA	KOR	BGD	BGD	HUN	LBN	DEU
	FRA	DEU	MYS	QAT	ESP	ESP	SVK		THA
	VNM	VNM	ARE	DEU	FRA	FRA	LKA		USA
	DNK	DNK	SAU	THA	DEU	DEU	AUT		KOR
Panel C: USA									
	CHN	CHN	CAN	CAN	CHN	CHN	PRT	MEX	CHN
	JPN	JPN	CHN	CHN	ITA	ITA	SVK	CAN	ITA
	DEU	DEU	MEX	MEX	BRA	BRA	POL	DOM	BRA
	KOR	KOR	JPN	JPN	VNM	VNM	HKG	ISR	VNM
	ITA	ITA	DEU	DEU	IDN	IDN	HUN	MAR	IDN
	GBR	GBR	KOR	KOR	THA	THA	CHE	COL	THA
	FRA	FRA	GBR	VEN	MEX	MEX	ALB	SLV	ESP
	IND	IND	FRA	GBR	ESP	ESP	BGR	AUS	IND
	HKG	HKG	ITA	FRA	IND	IND	DNK	ZAF	FRA
	VNM	VNM	MYS	MYS	DOM	DOM	AUT	PER	DEU

Notes: This table illustrates the construction of our instrument, using as an example product code 6403 "Footwear; with outer soles of rubber, plastics, leather or composition leather and uppers of leather" in 2006. Columns 1-2 list the top exporters to three importing countries – USA, Germany and Japan – exporting under the MFN regime in periods $t = 2006$ and $t - 1 = 2005$. Columns 3-4 list the importing countries' major aggregate trading partners in these periods. Columns 5-6 list the major trading partners in product 6403. Columns 7-9 then list the main countries in the treatment, control and excluded group for imports of product 6403 to the three importing countries.

TABLE A3: HS Sections

Code	Name
4	PREPARED EDIBLE FATS;ANIMAL OR VEGETABLE WAXES
	PREPARED FOODSTUFFS;
	BEVERAGES, SPIRITS AND VINEGAR; TOBACCO AND MANUFACTURED TOBACCO SUBSTITUTES
6	PRODUCTS OF THE CHEMICAL OR ALLIED INDUSTRIES
7	PLASTICS AND ARTICLES THEREOF; RUBBER AND ARTICLES THEREOF
8	RAW HIDES AND SKINS, LEATHER, FURSKINS AND ARTICLES THEREOF;
	SADDLERY AND HARNESS; TRAVEL GOODS,
10	PULP OF WOOD OR OF OTHER FIBROUS CELLULOSIC MATERIAL;
	RECOVERED (WASTE AND SCRAP) PAPER OR PAPERBOARD;
	PAPER AND PAPERBOARD AND ARTICLES THEREOF
11	TEXTILES AND TEXTILE ARTICLES
12	FOOTWEAR, HEADGEAR, UMBRELLAS, SUN UMBRELLAS,
	WALKING-STICKS, SEAT-STICKS, WHIPS, RIDING-CROPS AND PARTS THEREOF;
	PREPARED FEATHERS AND ARTICLES MADE THEREWITH;
13	ARTICLES OF STONE, PLASTER, CEMENT, ASBESTOS, MICA OR SIMILAR MATERIALS;
16	MACHINERY AND MECHANICAL APPLIANCES;
	ELECTRICAL EQUIPMENT; PARTS THEREOF; SOUND RECORDERS AND REPRODUCERS,
	TELEVISION IMAGE AND SOUND RECORDERS AND
	REPRODUCERS, AND PARTS AND ACCESSORIES OF SUCH ARTICLES
	ARTIFICIAL FLOWERS; ARTICLES OF HUMAN HAIR
	Aggregated
1	LIVE ANIMALS; ANIMAL PRODUCTS
2	VEGETABLE PRODUCTS
3	ANIMAL OR VEGETABLE FATS AND OILS AND THEIR CLEAVAGE PRODUCTS
	HANDBAGS AND SIMILAR CONTAINERS; ARTICLES OF ANIMAL GUT (OTHER THAN SILK-WORM GUT)
5	MINERAL PRODUCTS
9	WOOD AND ARTICLES OF WOOD; WOOD CHARCOAL;
	CORK AND ARTICLES OF CORK; MANUFACTURES OF STRAW,
	OF ESPARTO OR OF OTHER PLAITING MATERIALS;
	BASKETWARE AND WICKERWORK
14	NATURAL OR CULTURED PEARLS, PRECIOUS OR SEMI-PRECIOUS
	STONES, PRECIOUS METALS, METALS CLAD WITH PRECIOUS METAL
	AND ARTICLES THEREOF; IMITATION JEWELLERY; COIN
15	BASE METALS AND ARTICLES OF BASE METAL
	CERAMIC PRODUCTS; GLASS AND GLASSWARE
17	VEHICLES, AIRCRAFT, VESSELS AND ASSOCIATED TRANSPORT EQUIPMENT
18	OPTICAL, PHOTOGRAPHIC, CINEMATOGRAPHIC, MEASURING,
	CHECKING, PRECISION, MEDICAL OR SURGICAL INSTRUMENTS AND APPARATUS;
	CLOCKS AND WATCHES; MUSICAL INSTRUMENTS; PARTS AND ACCESSORIES THEREOF
19	ARMS AND AMMUNITION; PARTS AND ACCESSORIES THEREOF
20	MISCELLANEOUS MANUFACTURED ARTICLES
21	WORKS OF ART, COLLECTORS' PIECES AND ANTIQUES

Notes: This table describes the 21 internationally compatible HS "Sections", which are groupings of HS product codes. We also list the 9 HS Sections that we aggregate in the main text into a Section 'aggregate', as there is insufficient variation in either tariffs or trade flows or both in these sections to estimate the elasticity. A5 summarizes the estimates for all sections without aggregation.

Appendix B Robustness

Table A4: Robustness: Local Projections

	Panel A: Tariffs			Panel B: Trade		
	Baseline	Two Lags	Five Lags	Baseline	Two Lags	Five Lags
	(1)	(2)	(3)	(4)	(5)	(6)
$t-6$	-0.093***	-0.062***	-0.110***	0.117	0.212	0.257*
	(0.005)	(0.006)	(0.007)	(0.106)	(0.137)	(0.156)
$t-5$	-0.033***	-0.034***	.	0.195*	-0.005	.
	(0.004)	(0.005)	.	(0.101)	(0.126)	.
$t-4$	-0.010***	-0.055***	.	-0.011	-0.021	.
	(0.004)	(0.005)	.	(0.089)	(0.117)	.
$t-3$	-0.099***	-0.111***	.	-0.106	0.148	.
	(0.004)	(0.004)	.	(0.083)	(0.100)	.
$t-2$	-0.068***	.	.	0.077	.	.
	(0.004)	.	.	(0.082)	.	.
$t-1$	-0.296***	.	.	0.065	.	.
	(0.003)	.	.	(0.067)	.	.
t	.	.	.	-0.140***	-0.178**	0.191
	.	.	.	(0.051	(0.086)	(0.133)
$t+1$	0.844***	0.890***	0.872***	-0.582***	-0.583***	-0.113
	(0.003)	(0.004)	(0.006)	(0.067)	(0.113)	(0.170)
$t+2$	0.818***	0.831***	0.816***	-0.662***	-0.511***	-0.203
	(0.003)	(0.005)	(0.007)	(0.074)	(0.128)	(0.199)
$t+3$	0.827***	0.822***	0.808***	-0.813***	-0.396***	-0.179
	(0.004)	(0.006)	(0.008)	(0.080)	(0.142)	(0.232)
$t+4$	0.797***	0.821***	0.816***	-0.759***	-0.475***	-0.385
	(0.004)	(0.006)	(0.009)	(0.087)	(0.161)	(0.274)
$t+5$	0.810***	0.818***	0.797***	-0.967***	-0.731***	-0.527*
	(0.003)	(0.006)	(0.010)	(0.093)	(0.178)	(0.299
$t+6$	0.794***	0.774***	0.734***	-0.940***	-0.773***	-0.390
	(0.004)	(0.007)	(0.011)	(0.095)	(0.184)	(0.306)
$t+7$	0.751***	0.683***	0.654***	-1.153***	-1.081***	-1.048***
	(0.004)	(0.007)	(0.011)	(0.102)	(0.194)	(0.350)
$t+8$	0.733***	0.693***	0.704***	-1.126***	-1.113***	-0.788*
	(0.005)	(0.008)	(0.014)	(0.112)	(0.227)	(0.454)
$t+9$	0.733***	0.698***	0.691***	-1.025***	-0.984***	-0.931*
	(0.004)	(0.009)	(0.016)	(0.117)	(0.258)	(0.506)
$t+10$	0.731***	0.706***	0.743***	-1.264***	-1.308***	-1.436**
	(0.005)	(0.011)	(0.019)	(0.132)	(0.297)	(0.606)

Notes: This table presents the results from estimating the local projections equations (2.3) (Panel A) and (2.2) (Panel B). The first column in each panel presents the baseline local projects results, while the second and third columns in each panel present results with 2 and 5 lags of tariffs and trade as pre-trend controls respectively. Standard errors clustered by country-pair-product are in parentheses. ***, ** and * denote significance at the 99, 95 and 90% levels.

Table A5: Trade Elasticity: Sectoral Heterogeneity

	Mean (1)	Median (2)	25 percentile (3)	75 percentile (4)
t	-0.373	-0.229	-0.422	-0.117
$t+1$	-1.091	-0.813	-1.236	-0.690
$t+2$	-1.242	-0.855	-1.972	-0.493
$t+3$	-1.566	-1.329	-2.309	-0.838
$t+4$	-1.547	-1.197	-2.223	-0.608
$t+5$	-2.065	-1.407	-2.508	-1.008
$t+6$	-1.92	-1.891	-2.219	-0.905
$t+7$	-2.286	-1.818	-2.595	-1.071
$t+8$	-2.073	-1.284	-3.329	-1.061
$t+9$	-1.710	-1.321	-2.269	-0.994
$t+10$	-2.123	-1.595	-3.779	-1.191

Notes: This table presents results from estimating equation (2.4) at the HS Section-level for every horizon. We include estimates for 10 HS Sections here, including one aggregated super-section as described in the text. All specifications include importer-HS4-year, exporter-HS4-year and importer-exporter-HS4 fixed effects.

TABLE A6: Elasticity Estimates, "Traditional Gravity," Levels

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Log-levels, OLS						
$\tau_{i,j,p,t}$	-3.111***	-4.413***	-6.626***	-2.562***	-0.920***	-0.898***
	(0.019)	(0.018)	(0.043)	(0.013)	(0.022)	(0.022)
R^2	0.009	0.334	0.349	0.504	0.526	0.774
Obs	104.35	104.32	103.52	102.95	102.15	95.94
Panel B: Log-levels, OLS, Balanced Panel						
$\tau_{i,j,p,t}$	-5.806***	-7.939***	-10.331***	-2.988***	-0.686***	-1.111***
	(0.049)	(0.054)	(0.096)	(0.033)	(0.052)	(0.051)
R^2	0.016	0.363	0.420	0.547	0.591	0.880
Obs	19.68	19.68	19.68	19.68	19.68	17.94
Fixed effects						
importer x hs4	no	yes	no	no	no	no
exporter x hs4	no	yes	no	no	no	no
importer x hs4 x year	no	no	yes	no	yes	no
exporter x hs4 x year	no	no	yes	no	yes	no
importer x exporter x hs4	no	no	no	yes	yes	no
imp x hs6 x year, exp x hs6 x year, imp x exp x h6	no	no	no	no	no	yes

Notes: This table presents the results from estimating the trade elasticity at a single horizon. The dependent variable is the log of trade value. Panel A is the log-levels specification, and Panel B is a balanced panel log-levels specification. Column 1 reports the results with no fixed effects. Column 2 adds importer-product and exporter-product fixed effects, Column 3 interacts these fixed effects with years, column 4 includes country-pair-product fixed effects and column 5 includes our baseline fixed effects. Column 6 uses HS6 product level fixed effects. Robust standard errors are in parentheses. ***, ** and * denote significance at the 99, 95 and 90% levels. Number of observations reported in millions. For the balanced panel in Column 6, the number of reported observations is lower as HS6 fixed effects drop additional singleton clusters, but the underlying panel is the same.

Table A7: Elasticity Estimates, "Traditional Gravity," Differences

	OLS			2SLS using all 1 year Tariff Changes			Baseline IV		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: 3-year log-differences									
$\Delta_3\tau_{i,j,p,t}$	-1.017***	-0.485***	-0.414***	-0.690***	-0.371***	-0.327***	-1.875***	-1.034***	-0.983***
	(0.012)	(0.016)	(0.017)	(0.015)	(0.023)	(0.025)	(0.050)	(0.087)	(0.097)
R^2	0.034	0.097	0.117						
Observations	45.50	45.07	44.72	45.50	45.07	44.72	25.11	24.72	24.51
Panel B: 7-year log-differences									
$\Delta_7\tau_{i,j,p,t}$	-2.026***	-0.921***	-0.681***	-1.070***	-0.644***	-0.459***	-2.388***	-1.443***	-1.536***
	(0.017)	(0.025)	(0.026)	(0.022)	(0.034)	(0.036)	(0.073)	(0.124)	(0.136)
R^2	0.094	0.157	0.228						
Observations	29.54	29.24	28.92	29.54	29.24	28.92	16.09	15.82	15.6
Panel C: 5-year log-differences, Balanced Panel									
$\Delta_5\tau_{i,j,p,t}$	-1.625***	-0.865***	-0.700***	-0.645***	-0.458***	-0.490***	-2.116***	-1.316***	-1.173***
	(0.021)	(0.034)	(0.033)	(0.023)	(0.039)	(0.042)	(0.061)	(0.107)	(0.115)
R^2	0.001	0.076	0.278						
Observations	19.68	19.68	19.68	19.68	19.68	19.68	19.68	19.68	19.68
Fixed Effects									
Imp-HS4	Yes	No	No	Yes	No	No	Yes	No	No
Exp-HS4	Yes	No	No	Yes	No	No	Yes	No	No
Imp-HS4-Year	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Exp-HS4-Year	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Imp-Exp-HS4	No	No	Yes	No	No	Yes	No	No	Yes

Notes: This table presents the results from estimating the trade elasticity at a single horizon. The dependent variable is the log-difference in trade value, over 3 years (Panel A), 7 years (Panel B), and 5 years, balancing the panel (Panel C). Columns 1-3 report the OLS results, columns 4-6 2SLS instrumenting with the 1-year tariff changes, and columns 7-9 instrumenting with the baseline instrument. Robust standard errors are in parentheses. ***, ** and * denote significance at the 99, 95 and 90% levels. Number of observations reported in millions. All first-stage F statistics are greater than 10000.

Table A8: Trade Elasticity, Every Horizon:, Robustness: Pre-Trends, Alternative Clustering, Alternative Samples

	Baseline	Two Lags	Five Lags	FE50	Two-way Clustering	Balanced Panel	Alternative Control Group
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
t	-0.140***	-0.178**	0.191	-0.174**	-0.140*	-0.359**	-0.144***
	(0.051)	(0.086)	(0.133)	(0.073)	(0.078)	(0.143	(0.055)
obs	39.22	23.64	13.5	20.16	39.22	7.1	34.56
$t+1$	-0.689***	-0.655***	-0.130	-0.572***	-0.689***	-0.758***	-0.535***
	(0.079)	(0.127)	(0.195)	(0.106)	(0.149)	(0.199)	(0.083)
obs	30.95	19.92	11.58	17.07	30.95	7.1	27.28
$t+2$	-0.808***	-0.615***	-0.248	-0.656***	-0.808***	-0.991***	-0.487***
	(0.091)	(0.154)	(0.244)	(0.118)	(0.209)	(0.201)	(0.095)
obs	27.43	17.73	10.21	15.49	27.43	7.1	24
$t+3$	-0.983***	-0.482***	-0.222	-0.777***	-0.983***	-1.142***	-0.582***
	(0.097)	(0.173)	(0.287)	(0.123)	(0.250)	(0.185)	(0.105)
obs	24.51	15.81	8.93	14.08	24.51	7.1	21.42
$t+4$	-0.953***	-0.578***	-0.472	-0.776***	-0.953***	-1.044***	-0.493***
	(0.110)	(0.196)	(0.335)	(0.136)	(0.304)	(0.208)	(0.116v
obs	21.97	14.08	7.75	12.79	21.97	7.1	19.21
$t+5$	-1.194***	-0.893***	-0.661*	-1.050***	-1.194***	-1.201***	-0.864***
	(0.115)	(0.218)	(0.375)	(0.143)	(0.291)	(0.193)	(0.126)
obs	19.71	12.46	6.69	11.6	19.71	7.1	17.08
$t+6$	-1.18***5	-0.999***	-0.531	-1.010***	-1.185***	-1.052***	-0.781***
	(0.120)	(0.238)	(0.417)	(0.150)	(0.263)	(0.199)	(0.133)
obs	17.57	10.93	5.74	10.44	17.57	7.1	15.15
$t+7$	-1.536***	-1.58***2	-1.603***	-1.229***	-1.536***	-1.294***	-1.048***
	(0.136)	(0.285)	(0.538)	(0.169)	(0.348)	(0.207)	(0.149)
obs	15.6	9.46	4.84	9.35	15.6	7.1	13.38
$t+8$	-1.537***	-1.606***	-1.120*	-1.354***	-1.537***	-1.593***	-1.070***
	(0.152)	(0.327)	(0.646)	(0.186)	(0.353)	(0.211)	(0.164)
obs	13.68	8.15	4.03	8.25	13.68	7.1	11.68
$t+9$	-1.400***	-1.409***	-1.347*	-1.209***	-1.400***	-2.013***	-0.802***
	(0.159)	(0.369)	(0.733)	(0.195)	(0.515)	(0.225)	(0.180)
obs	11.83	6.96	3.38	7.2	11.83	7.1	9.99
$t+10$	-1.732***	-1.852***	-1.933**	-1.512***	-1.732***	-2.513***	-1.057***
	(0.181)	(0.420)	(0.818)	(0.219)	(0.505)	(0.233)	(0.200)
obs	10.22	5.87	2.82	6.28	10.22	7.1	8.53

Notes: This table presents robustness exercises for the results from estimating equation (2.4). All specifications include importer-HS4-year, exporter-HS4-year and importer-exporter-HS4 fixed effects. Columns 2 and 3 vary the pretrend controls (including alternatively two lags or five lags of import growth and tariff changes). Column 4 reports the results when the sample is restricted to fixed-effects clusters with a minimum of 50 observations. Standard errors are clustered at the importer-exporter-HS4 level, except in Column 5 where they are additionally clustered by year. Column 6 restricts the sample to a balanced panel. Column 7 reports results where the control group only contains observations with zero tariff changes. ***, ** and * indicate significance at the 99, 95 and 90 percent level respectively. Observations are reported in millions.

TABLE A9: Trade Elasticity, Every Horizon, Robustness: Alternative Instruments, Outcomes, Fixed Effects, and Samples

	Baseline (1)	All Partners (2)	HS6 (3)	Quantities (4)	Unit Values (5)	Extensive (6)	DL (7)
t	-0.140***	-0.302***	-0.167**	-0.019	-0.070*	-0.118***	0.239
	(0.051)	(0.025)	(0.080)	(0.064)	(0.039)	(0.041)	(0.294)
obs	39.22	70.41	36.1	38.82	38.73	48.93	5.56
$t+1$	-0.689***	-0.620***	-0.913***	-0.551***	-0.109*	-0.681***	0.168
	(0.079)	(0.037)	(0.119)	(0.096)	(0.056)	(0.067)	(0.402)
obs	30.95	55.77	28.57	30.65	30.55	37.52	5.56
$t+2$	-0.808***	-0.688***	-1.245***	-0.717***	-0.044	-0.695***	0.077
	(0.091)	(0.042)	(0.141)	(0.110)	(0.063)	(0.076)	(0.498)
obs	27.43	49.72	25.22	27.14	27.04	33.02	5.56
$t+3$	-0.983***	-0.754***	-1.418***	-0.684***	-0.224***	-0.840***	-0.502
	(0.097)	(0.044)	(0.146)	(0.119)	(0.069)	(0.084)	(0.571)
obs	24.51	44.82	22.49	24.25	24.17	29.49	5.56
$t+4$	-0.953***	-0.773***	-1.678***	-0.690***	-0.165**	-0.863***	-0.287
	(0.110)	(0.050)	(0.167)	(0.134)	(0.076)	(0.096)	(0.646)
obs	21.97	40.5	20.12	21.72	21.67	26.34	5.56
$t+5$	-1.194***	-0.822***	-1.570***	-0.849***	-0.241***	-1.114***	-0.263
	(0.115)	(0.052)	(0.171)	(0.142)	(0.080)	(0.102)	(0.716)
obs	19.71	36.42	18.01	19.48	19.45	23.48	5.56
$t+6$	-1.185***	-0.854***	-1.680***	-0.805***	-0.299***	-1.137***	-0.554
	(0.120)	(0.054)	(0.171)	(0.148)	(0.083)	(0.105)	(0.784)
obs	17.57	32.51	16.03	17.35	17.33	20.8	5.56
$t+7$	-1.536***	-0.848***	-2.343***	-1.385***	-0.042	-1.369***	-0.770
	(0.136)	(0.061)	(0.200)	(0.165)	(0.092)	(0.118)	(0.853)
obs	15.6	28.95	14.16	15.4	15.37	18.39	5.56
$t+8$	-1.537***	-0.934***	-2.159***	-1.488***	0.097	-1.470***	-0.727
	(0.152)	(0.067)	(0.221)	(0.186)	(0.103)	(0.130)	(0.914)
obs	13.68	25.56	12.34	13.49	13.47	16.05	5.56
$t+9$	-1.400***	-0.914***	-2.013***	-1.374***	0.083	-1.218***	-1.140
	(0.159)	(0.071)	(0.224)	(0.194)	(0.109)	(0.137)	(0.968)
obs	11.83	22.25	10.69	11.65	11.63	13.76	5.56
$t+10$	-1.732***	-0.972***	-2.704***	-1.591***	-0.032	-1.327***	-1.584
	(0.181)	(0.077)	(0.254)	(0.219)	(0.123)	(0.154)	(1.028)
obs	10.22	19.33	9.18	10.05	10.04	11.77	5.56

Notes: This table presents alternative estimates for the results from estimating equation (2.4), varying the instrument or outcome variable. Column 2 uses an alternative definition of the instrument where all trade partners subject to the MFN regime are included. Column 4 reports results for quantities, and Column 5 the results for unit values. Column 6 presents results for the intensive and extensive margin combined using the inverse hyperbolic sine transformation for trade flows with the baseline instrument. Column 7 presents results from a distributed lag model. All specifications include importer-HS4-year, exporter-HS4-year and importer-exporter-HS4 fixed effects, except Column 3 where the product dimension of fixed effects is at the HS6 level. Standard errors are clustered at the importer-exporter-HS4 level. ***, ** and * indicate significance at the 99, 95 and 90 percent level respectively. Observations are reported in millions.

Table A10: Trade Elasticity: Estimates and First Stage F-Statistics

	OLS	Baseline IV	F-stat	All Partners	F-stat	Distributed Lag	SW F-stat
t	-0.122***	-0.140***	116532	-0.302***	515754	0.239	7538
	(0.011)	(0.051)		(0.025)		(0.294)	
t+1	-0.280***	-0.689***	66993	-0.620***	220173	0.168	8543
	(0.019)	(0.079)		(0.037)		(0.402)	
t+2	-0.347***	-0.808***	64934	-0.688***	221260	0.077	8769
	(0.023)	(0.091)		(0.042)		(0.498)	
t+3	-0.327***	-0.983***	52129	-0.754***	194330	-0.502	10843
	(0.025)	(0.097)		(0.044)		(0.571)	
t+4	-0.428***	-0.953***	49223	-0.773***	168103	-0.287	18552
	(0.028)	(0.110)		(0.050)		(0.646)	
t+5	-0.543***	-1.194***	41666	-0.822***	157110	-0.263	16514
	(0.029)	(0.115)		(0.052)		(0.716)	
t+6	-0.545***	-1.185***	39965	-0.854***	124035	-0.554	13335
	(0.031)	(0.120)		(0.054)		(0.784)	
t+7	-0.459***	-1.536***	34892	-0.848***	116218	-0.770	15231
	(0.036)	(0.136)		(0.061)		(0.853)	
t+8	-0.417***	-1.537***	27453	-0.934***	96587	-0.727	13068
	(0.037)	(0.152)		(0.067)		(0.914)	
t+9	-0.389***	-1.400***	23430	-0.914***	82525	-1.14	14710
	(0.039)	(0.159)		(0.071)		(0.968)	
t+10	-0.446***	-1.732***	19927	-0.972***	74577	-1.584	14969
	(0.039)	(0.181)		(0.077)		(1.028)	

Notes: This table presents the first-stage F-statistics for the main estimates. For the Distributed Lag model we report the Sanderson-Windmeijer F-statistic to test for weak instruments as we have 11 instruments and 11 endogenous variables.

TABLE A11: Gains from Trade

Country	$\widetilde{\theta} = -0.589$	$\widetilde{\theta} = -5$	$\widetilde{\theta} = -10$
G7			
Canada	38.3%	3.9%	1.9%
France	28.0%	3.0%	1.5%
Germany	36.9%	3.8%	1.9%
Italy	24.8%	2.7%	1.3%
Japan	13.4%	1.5%	0.7%
UK	24.8%	2.6%	1.3%
US	9.1%	1.0%	0.5%
Major Emerging Markets			
Brazil	12.9%	1.4%	0.7%
China	19.8%	2.1%	1.1%
India	18.6%	2.0%	1.0%
Mexico	10.5%	1.2%	0.6%
Russia	35.3%	3.6%	1.8%
South Africa	25.1%	2.7%	1.3%
Median, 64 Countries	42.0%	4.2%	2.1%

Notes: Data are from the OECD IO tables for 64 countries in year 2006. Gains from trade relative to autarky are computed using the formula $\lambda_{jj}^{1/\widetilde{\theta}}$, where λ_{jj} is 1 minus the import share. The import share is calculated as imports divided by gross output. The numbers for China and Mexico include export-processing activities (China) and global manufacturing activities (Mexico).