

# Import Liberalization as Export Destruction?

## Evidence from the United States\*

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### Abstract

How does import protection affect export performance? In trade models with scale economies, import liberalization can reduce industry-level exports by cutting domestic production. We show that this export destruction mechanism reduced US export growth following the permanent normalization of trade relations with China (PNTR). But there was also an offsetting boost to exports from lower input costs. We use our empirical results to calibrate the strength of scale economies in a quantitative trade model. Counterfactual analysis implies that while PNTR increased aggregate US exports relative to GDP, exports declined in the most exposed industries because of the export destruction effect. On aggregate, the US and China both gain from PNTR, but the gains are larger for China.

**Keywords:** Trade policy, Import liberalization, Comparative advantage, Scale economies, China shock.

**JEL Classification:** F12, F13, F15.

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*“The idea that a protected domestic market gives firms a base for successful exporting is one of those heterodox arguments, common in discussions of international trade, which are incomprehensible in terms of standard models yet seem persuasive to practical men.”*

Paul Krugman (1984, p. 191)

## 1 Introduction

The role of import protection in industrial policy has long been a subject of contentious debate. From Alexander Hamilton (1791) to Donald Trump, US leaders have argued that American manufacturing should be protected from foreign competition. Today at least, economists tend to be sceptical of such ideas, pointing to the advantages trade liberalization brings by reducing import costs and exposing domestic firms to the rigors of international competition.

Yet economic theory also formalizes conditions, often linked to the existence of scale economies, under which import protection may support industrial development. Graham (1923) and Ethier (1982) use scale economies to rationalize the infant industry argument for protection. Venables (1987) and Kucheryavyy et al. (2020) show that import liberalization can be welfare reducing if it leads to specialization in sectors with weak scale economies. And Krugman (1984) develops a model where import protection is export promoting at the industry level because the protected industry becomes more productive as it expands and exploits scale economies. Conversely, import liberalization is export destroying. A common criticism of protectionist arguments is that successful economies should be export oriented.<sup>1</sup> Krugman’s model suggests that import protection can be complementary to export success.

This paper studies the effect of import protection on exports and welfare. Our analysis exploits the permanent normalization of US trade relations with China (PNTR) as a policy liberalization that increased US openness to Chinese imports (Pierce and Schott 2016, Handley and Limão 2017). We use PNTR to address three questions raised by Krugman’s argument for import protection.

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<sup>1</sup>For example, Harrison and Rodríguez-Clare (2010) suggest that “any successful [industrial policy] strategy must ultimately increase the share of international trade in GDP”.

First, all else equal, does import liberalization destroy exports within industries? Second, what is the net effect of import liberalization on industry exports in equilibrium? Third, how did import liberalization resulting from PNTR affect welfare?

To motivate our estimation strategy, Section 2 develops a general equilibrium trade model featuring scale economies as in Krugman (1980) and input-output linkages as in Caliendo and Parro (2015). The model builds upon recent work by Grossman and Rossi-Hansberg (2010) and Kucheryavyy et al. (2020) studying conditions under which external economies trade models are well-behaved. Although Krugman (1984) presented his argument in a partial equilibrium, oligopoly model, we show that the mechanism he identified connecting import protection to exports also exists in the class of quantitative trade models with scale economies characterized by Kucheryavyy et al. (2020).<sup>2</sup> In particular, an increase in import competition resulting from liberalization reduces domestic real market potential causing a fall in domestic output. With scale economies, lower output reduces industry-level productivity making the industry less competitive in global markets and causing a decline in exports.

The model also highlights two additional channels by which import liberalization affects exports. There is an input cost effect through which a fall in the cost of imported intermediate inputs boosts exports by reducing production costs. And exports depend upon general equilibrium changes in domestic and foreign demand. We account for these channels in our empirical and quantitative analysis.

We estimate the impact of PNTR on US exports in Section 3. Following Pierce and Schott (2016) we measure industry-level exposure to PNTR by the *NTR gap*, defined as the tariff increase Chinese imports would have faced if the US had revoked China’s most favored nation trading status. Figure 1 plots the change in US export growth following PNTR against the NTR gap for NAICS goods industries.<sup>3</sup> The figure shows that export growth declined following PNTR in

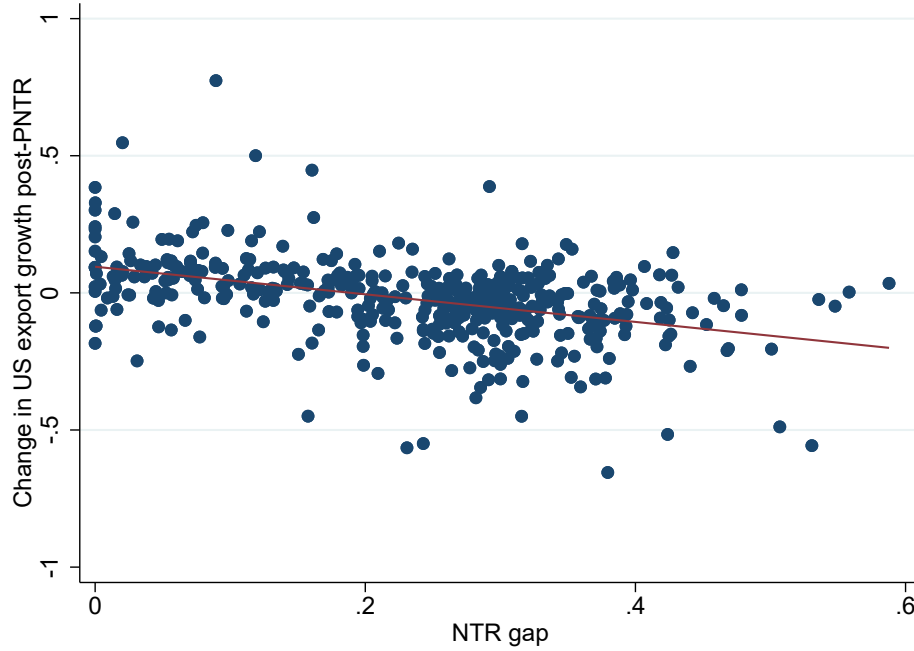
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<sup>2</sup>This class includes models where scale economies result from external economies of scale, from love of variety with homogeneous or heterogeneous firms (Krugman 1980, Melitz 2003), or from endogenous innovation (Somale 2021). Thus, contrary to Krugman’s claim quoted above, the idea that import protection can be export promoting is comprehensible in terms of today’s standard trade models.

<sup>3</sup>See Section 3.2 and Appendix B for details on the data.

industries with higher NTR gaps.

Figure 1: PNTR and US export growth



Notes: Change in US export growth post-PNTR defined as the annualized change in log total exports between 2000 and 2007 minus the annualized change between 1995 and 2000. Solid line shows fitted relationship from linear regression. The estimated slope coefficient is  $-0.51$  with robust standard error of  $0.057$ . NAICS goods industries.

Building on Figure 1, we estimate the model's bilateral export growth equation treating the NTR gap as a shock to import protection. We compare the change in US export growth for NAICS goods industries before and after Congress passed PNTR in 2000 to changes in the export growth of other OECD countries. Our empirical strategy uses fixed effects to absorb changes in importer demand, technology shocks that are common across exporters, and industry-level trends in export supply capacity and trade costs. In addition, we control for US export supply shocks that are correlated with industries' input, skill or capital intensity levels.

The reduced form estimation results support the existence of the Krugman (1984) mechanism. Export growth following PNTR was lower in industries with higher NTR gaps, i.e. industries more exposed to increased Chinese import competition. We also estimate the model structurally using the NTR gap as an instrument that shifts output growth. The estimated elasticity of exports to

output is positive, consistent with the reduced form evidence of scale economies in US production.

Our estimates imply that import liberalization led to export destruction, all else equal. However, we find that PNTR did not leave all else equal. It also had an export promotion effect by reducing input costs. We estimate that US export growth following PNTR was greater in industries more reliant on inputs from industries with higher NTR gaps.<sup>4</sup> This input cost channel offset the export decline caused by greater Chinese import competition and the two effects have comparable magnitudes. We find that PNTR reduced exports in 2007 by 13 percent more for an industry at the 75th percentile of the NTR gap distribution than for an industry at the 25th percentile. Performing the same comparison for the input cost shock distribution implies a 14 percent increase in exports. The combined impact of the two channels varies substantially by industry and is negative for 41 percent of industries.

To evaluate the net effect of PNTR on US exports we must also account for general equilibrium changes that are absorbed by the fixed effects in the estimating equation. Consequently, in Section 4 we calibrate our trade model and use it to quantify the impact of PNTR on trade and welfare. We use the World Input-Output Tables in 2000 and calibrate the PNTR shock by estimating its impact on US imports from China.

Conditional on the trade elasticity, the strength of scale economies is determined by the elasticity of exports to output. We calibrate this output elasticity for goods sectors so that the simulated effect of the NTR gap on US exports matches the equivalent moment in our empirical estimates. This yields an output elasticity of 0.835, below the value of one implicitly assumed by Krugman (1980) or Melitz (2003), but large enough to generate substantial scale economies and close to the average value implied by the estimates of Bartelme et al. (2019). For services sectors, we set the output elasticity to zero, which implies an incentive to reallocate resources from services to goods.

The quantitative analysis shows that PNTR increased US exports relative to GDP on aggregate and for 13 out of 15 goods sectors. The aggregate increase is 3.6 percent. Decomposing these changes, we find that export destruction of  $-2.3$  percent from Krugman's import competition effect

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<sup>4</sup>We measure the input cost shock from PNTR as the input-output coefficient weighted NTR gap in upstream industries. See Section 3.2 for details.

is more than offset by growth of 3.0 percent due to lower input costs and a quantitatively important 3.1 percent increase from higher foreign demand. The foreign demand effect captures the impact of global efficiency gains due to lower trade costs, as well as the equilibrium relationship between imports and exports that operates through the trade balance.

At the sector level, export growth is negatively correlated with the NTR gap and exports fall in the Textiles and Leather, and Other Manufacturing sectors, which have the largest NTR gaps. Thus, PNTR did lead to net export destruction in the most exposed sectors and shifted US comparative advantage away from sectors with higher NTR gaps. Counterfactual analysis also shows that cutting barriers to Chinese imports in a single sector leads to export destruction in that sector, but export promotion for other sectors and on aggregate.

In terms of welfare, we estimate PNTR increased US real income by 0.08 percent. This change can be decomposed into a positive Arkolakis et al. (2012) term resulting from greater trade openness and a negative specialization effect that exists only when there are scale economies and reduces US gains from PNTR. The specialization effect is negative because PNTR reallocates US production towards sectors with weaker forward input-output linkages to the rest of the economy. We also find that China's gains from PNTR are around six times greater than US gains, reflecting the fact that China's economy was small compared to the US in 2000.

Comparing the counterfactual results to those from a model without scale economies confirms that scale economies are necessary to explain the observed negative correlation between the NTR gap and export growth across sectors. Moreover, we find that the interaction of scale economies with input-output linkages is quantitatively important and magnifies changes in specialization and trade. For example, in spite of the export destruction effect, aggregate US export growth due to PNTR is almost 50 percent larger with scale economies, primarily because the boost to exports from the input cost effect is an order of magnitude greater.

Our paper belongs to the literature studying the role of trade policy in industrial development.<sup>5</sup> The contribution relative to this literature is twofold. We provide novel evidence documenting the

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<sup>5</sup>See Harrison and Rodríguez-Clare (2010) for a comprehensive survey and Irwin (2021) for a history of economists' views on import substitution policies.

existence of a scale economies channel through which import liberalization is export destroying and we evaluate the importance of this channel for quantitative trade policy analysis.<sup>6</sup> While protectionist policies are often viewed as barriers to development, Juhász (2018) shows that temporary trade protection during the Napoleonic Wars led to persistent capacity increases in mechanized cotton spinning in France, resulting in higher exports of cotton manufactures. Juhász’s findings are consistent with French production expanding through an infant industry mechanism. Likewise, the export destruction effect we document can be viewed as a cost of import liberalization. By quantifying this effect we show that the net impact of PNTR on aggregate exports and welfare is nevertheless positive. We also inform the import protection debate by decomposing the channels through which liberalization operates and by studying sectoral heterogeneity in these channels.

The strength of scale economies is a key parameter required to calibrate quantitative trade models and perform counterfactual trade policy analysis (Costinot and Rodríguez-Clare 2014, Kucheryavyy et al. 2020). Yet existing measures of scale economies are not estimated from trade policy variation and most trade policy analysis uses Ricardian models without scale economies (e.g. Caliendo and Parro 2015, Dhingra et al. 2017). We develop an empirical methodology for exploiting changes in bilateral trade policy to test for scale economies and illustrate how this approach can be used to calibrate trade models that allow for scale economies. Our findings document how the existence of scale economies shaped the impact of PNTR on US exports. Moreover, we show that accounting for scale economies (or their absence) is a prerequisite for successfully evaluating how trade policy reforms affect both aggregate and sector-level trade flows.

The paper is related to studies that use trade data to estimate scale economies (Antweiler and Trefler 2002, Lashkaripour and Lugovskyy 2018, Bartelme et al. 2019) and test for the home market effect (Davis and Weinstein 2003, Costinot et al. 2019). The evidence we present supporting the existence of scale economies is consistent with this literature. But in contrast to prior work, we use trade policy as a source of identifying variation (rather than the factor content of trade, market size or exchange rates) and use our estimates to undertake an ex-post analysis of a trade policy

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<sup>6</sup>Dick (1994) studies whether import protection is export promoting using cross-sectional data for the US in 1970, but finds little evidence to support the hypothesis.

shock. By studying US exports we also add a new dimension to the literature on PNTR and the broader China shock.<sup>7</sup> Our results imply that the ‘surprisingly swift’ decline in US manufacturing after PNTR found by Pierce and Schott (2016) would have been smaller in the absence of scale economies, and that PNTR affected US exports and comparative advantage. Finally, our estimates are related to a small literature that studies the spillover effects of bilateral trade cost changes on third markets (Bown and Crowley 2007, Defever and Ornelas 2015, Fajgelbaum et al. 2021). We show how spillovers can result from scale economies and analyze their quantitative importance.

## 2 Trade with scale economies

We develop a model of trade with scale economies. The model generalizes Krugman (1980) to allow for many countries and sectors, intermediate inputs and an elasticity of substitution between products that differs depending upon whether or not products are produced in the same country. We use the model to characterize how import liberalization affects exports in the presence of scale economies, which motivates our empirical analysis in Section 3.

### 2.1 Model

There are  $N$  countries and  $S$  sectors. We use  $i, n$  to index countries and  $s$  to index sectors. Each country has a representative consumer with Cobb-Douglas preferences across sectors. Let  $\beta_{i,s}$  be the expenditure share of sector  $s$  in consumption demand in country  $i$ .

Within each sector firms make tradable differentiated varieties, which are aggregated by competitive producers to make non-tradable final goods. Final goods can either be consumed or used as intermediate inputs in variety production. Let  $\Omega_{i,s}$  be the set of differentiated varieties produced in country  $i$  and  $Q_{n,s}$  denote final good output in country  $n$ . The aggregation technology used to produce final goods is:<sup>8</sup>

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<sup>7</sup>See, for example, Autor et al. (2013, 2020), Pierce and Schott (2016, 2018), Feng et al. (2017), Handley and Limão (2017), Jaravel and Sager (2020) and Amiti et al. (2020).

<sup>8</sup>As in Caliendo and Parro (2015), we assume the aggregation technology is the same for consumers and intermediate input producers. In an economy without intermediate inputs, the aggregation technology simply defines consumer

$$Q_{n,s} = \left[ \sum_i \left( \int_{\omega \in \Omega_{i,s}} q_{ni,s}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1} \frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}.$$

where  $q_{ni,s}(\omega)$  denotes the quantity of variety  $\omega$  produced in country  $i$  and used in country  $n$ . The aggregation technology has constant returns to scale and a nested constant elasticity of substitution structure that embodies love of variety. In the lower nest varieties from country  $i$  are combined with elasticity of substitution  $\sigma > 1$ , while in the upper nest bundles of varieties from different countries are combined with elasticity  $\epsilon > 1$ . When  $\sigma = \epsilon$  varieties are symmetric across countries as in Krugman (1980), while if  $\sigma > \epsilon$  varieties are more substitutable within than across countries. Letting  $\sigma \rightarrow \infty$  gives an Armington economy with national product differentiation and Armington elasticity  $\epsilon$ .<sup>9</sup>

Let  $X_{n,s}$  denote final good expenditure in country  $n$ .  $X_{n,s}$  is the sum of consumer expenditure and intermediate input expenditure by variety producers. Since final goods are non-tradable, market clearing requires  $X_{n,s} = P_{n,s} Q_{n,s}$  where  $P_{n,s}$  denotes the final good price in country  $n$ . We can write  $P_{n,s} = \left( \sum_i P_{ni,s}^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}}$  where  $P_{ni,s}$  is defined as the price index for the bundle of varieties imported by country  $n$  from country  $i$ . Letting  $p_{ni,s}(\omega)$  denote the price of variety  $\omega$  produced in  $i$  and sold in  $n$ , we have:  $P_{ni,s} = \left( \int_{\omega \in \Omega_{i,s}} p_{ni,s}(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}$ . Using this definition, expenditure  $X_{ni,s}$  by country  $n$  on products from country  $i$  is given by:

$$X_{ni,s} = \left( \frac{P_{ni,s}}{P_{n,s}} \right)^{1-\epsilon} X_{n,s}. \quad (1)$$

Note that  $X_{n,s} = \sum_i X_{ni,s}$ .

Varieties are produced by monopolistically competitive firms, each of which makes a single variety using a constant marginal cost technology. Within each country and sector, all firms have access to the same technology. Suppose that the marginal cost of production in country  $i$  and sector  $s$  is  $c_{i,s}/T_{i,s}$  where  $T_{i,s}$  denotes the technology level and  $c_{i,s}$  is the unit cost of a country-preferences over sector  $s$  varieties.

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<sup>9</sup>To simplify notation, we present the model assuming  $\sigma$  and  $\epsilon$  do not vary by industry, but adding industry subscripts would not change any of the expressions.

sector specific input bundle. The input bundle is a unit elasticity of substitution aggregate of labor and intermediates from all sectors such that:

$$c_{i,s} = (w_i)^{\gamma_{i,s}} \prod_v (P_{i,v})^{\gamma_{i,sv}}, \quad \text{with } \gamma_{i,s} + \sum_v \gamma_{i,sv} = 1, \quad (2)$$

where  $w_i$  is the wage per unit of labor in country  $i$ ,  $\gamma_{i,s}$  denotes the share of value-added in production costs and  $\gamma_{i,sv}$  denotes the share of intermediates from sector  $v$  in the production costs of sector  $s$ . The  $\gamma_{i,sv}$  parameters determine the strength of input-output linkages between sectors. In an economy without intermediate inputs  $\gamma_{i,s} = 1$ , implying  $c_{i,s} = w_i$  because firms only use labor to produce.

Trade is subject to iceberg costs  $\tau_{ni,s} \geq 1$  where  $n$  denotes the importing country and  $i$  the exporting country. As firms face elasticity of demand  $\sigma$ , they charge a mark-up  $\frac{\sigma}{\sigma-1}$  over marginal costs implying  $p_{ni,s}(\omega) = \frac{\sigma}{\sigma-1} \frac{\tau_{ni,s} c_{i,s}}{T_{i,s}}$  and:

$$P_{ni,s} = \frac{\sigma}{\sigma-1} \frac{\tau_{ni,s} c_{i,s}}{T_{i,s}} N_{i,s}^{-\frac{1}{\sigma-1}}, \quad (3)$$

where  $N_{i,s}$  denotes the mass of varieties produced by country  $i$  in sector  $s$ . The price index is decreasing in the mass of varieties produced in  $i$  because the aggregation technology used for final good production features love of variety. Note that  $\frac{1}{\sigma-1}$  measures the degree of scale economies in this model, which we refer to as the *scale elasticity*. An increase in  $\sigma$  reduces the scale elasticity because it makes varieties more substitutable, weakening the love of variety effect. The existence of scale economies does not require input-output linkages in production and the scale elasticity does not depend upon the elasticity of substitution  $\epsilon$  between varieties from different countries.

There is free entry of firms into differentiated variety production, meaning that in equilibrium profits net of entry costs are zero. Suppose the entry cost is  $f_{i,s} c_{i,s}$  and let  $Y_{i,s} = \sum_n X_{ni,s}$  denote total expenditure on varieties produced in  $i$ , i.e. total sales of country  $i$ . By market clearing  $Y_{i,s}$  equals the value of output in sector  $s$ . Since profits are a fraction  $1/\sigma$  of revenues, the free entry condition is:

$$\frac{Y_{i,s}}{\sigma} = N_{i,s} f_{i,s} c_{i,s}, \quad (4)$$

which determines the mass of varieties produced in each country. This completes the specification of the model.

## 2.2 Bilateral trade

Expenditure by country  $n$  on varieties from country  $i$  is given by equation (1). Using (3) to substitute for the price index  $P_{ni,s}$  and then the free entry condition (4) to eliminate  $N_{i,s}$  yields the bilateral trade equation:

$$X_{ni,s} = \Gamma_0 \varphi_{ni,s} T_{i,s}^{\epsilon-1} \left( \frac{Y_{i,s}}{c_{i,s}^\sigma f_{i,s}} \right)^{\frac{\epsilon-1}{\sigma-1}} X_{n,s} P_{n,s}^{\epsilon-1}, \quad (5)$$

where  $\varphi_{ni,s} = \tau_{ni,s}^{1-\epsilon}$  measures bilateral openness to trade,  $\epsilon - 1$  is the *trade elasticity* and  $\Gamma_0$  is a constant.<sup>10</sup> Thus, bilateral trade satisfies a gravity equation with an export supply capacity term  $S_{i,s} = \Gamma_0 T_{i,s}^{\epsilon-1} \left( \frac{Y_{i,s}}{c_{i,s}^\sigma f_{i,s}} \right)^{\frac{\epsilon-1}{\sigma-1}}$  that depends upon both the unit input cost  $c_{i,s}$  and the scale of sectoral output  $Y_{i,s}$ . A decline in input costs  $c_{i,s}$  raises exports by reducing prices through equation (3).

The elasticity of bilateral trade to output, which we will call the *output elasticity*, equals the product of the trade elasticity  $\epsilon - 1$  and the scale elasticity  $\frac{1}{\sigma-1}$ . The scale elasticity controls the rate at which the industry price index declines as output rises,<sup>11</sup> while the trade elasticity determines the responsiveness of trade to lower prices as shown in equation (1). In the absence of scale economies, such as in an Armington model or in the Ricardian economy developed by Eaton and Kortum (2002), the output elasticity is zero. Consequently, estimating the output elasticity provides a test for the existence of scale economies. Proposition 1 summarizes this result.

**Proposition 1. *Output and exports.*** *Conditional on foreign demand and domestic input costs, sector-level exports to all markets are strictly increasing in sectoral output if and only if the scale*

<sup>10</sup>In particular,  $\Gamma_0 \equiv \left( \frac{1}{\sigma} \right)^{\frac{\epsilon-1}{\sigma-1}} \left( \frac{\sigma-1}{\sigma} \right)^{\epsilon-1}$ .

<sup>11</sup>To see this, substitute (4) into (3) to obtain:  $P_{ni,s} = \frac{\sigma}{\sigma-1} \frac{\tau_{ni,s}}{T_{i,s}} \left( \frac{Y_{i,s}}{\sigma c_{i,s}^\sigma f_{i,s}} \right)^{-\frac{1}{\sigma-1}}$ .

elasticity is strictly positive.

To solve for equilibrium output, recall that  $Y_{i,s} = \sum_n X_{ni,s}$ . Then the bilateral trade equation implies:<sup>12</sup>

$$Y_{i,s} = \Gamma_0^{\frac{\sigma-1}{\sigma-\epsilon}} T_{i,s}^{\frac{(\sigma-1)(\epsilon-1)}{\sigma-\epsilon}} \left( \frac{1}{c_{i,s}^\sigma f_{i,s}} \right)^{\frac{\epsilon-1}{\sigma-\epsilon}} \left( \sum_n \varphi_{ni,s} X_{n,s} P_{n,s}^{\epsilon-1} \right)^{\frac{\sigma-1}{\sigma-\epsilon}}. \quad (6)$$

Thus, output depends upon technology, input costs and country  $i$ 's real market potential defined by  $RMP_{i,s} = \sum_n \varphi_{ni,s} X_{n,s} P_{n,s}^{\epsilon-1}$ . Real market potential is the sum across markets of real demand  $X_{n,s} P_{n,s}^{\epsilon-1}$  weighted by bilateral openness  $\varphi_{ni,s}$  (Redding and Venables 2004, Jacks and Novy 2018).

Countries that face lower trade costs to access larger markets have higher real market potential and, consequently, higher output, all else equal. The bilateral trade equation (5) therefore implies that an increase in real market potential raises sales to all destinations, but only if there are scale economies in production. The impact of real market potential on exports is the mechanism that generates both home market effects and the relationship between import protection and exports.

Since the bilateral trade equation (5) is a structural gravity equation (as defined by Head and Mayer 2014), it can also be written as:

$$X_{ni,s} = \varphi_{ni,s} \frac{Y_{i,s}}{RMP_{i,s}} M_{n,s}, \quad (7)$$

where  $M_{n,s} = X_{n,s} P_{n,s}^{\epsilon-1}$ . Any structural gravity equation can be expressed in this form, regardless of whether there are scale economies in production. However, because output generally depends upon real market potential, equation (7) does not imply that exports are increasing in output whenever structural gravity holds. In models without scale economies, such as the Armington model or Ricardian models based on Eaton and Kortum (2002), output is proportional to real market poten-

<sup>12</sup>This expression holds assuming  $\sigma > \epsilon$ , meaning that varieties produced in the same country are closer substitutes than varieties from different countries. If  $\sigma = \epsilon$ , the output elasticity equals one as in Krugman (1980). In this case, equation (6) does not hold, but  $Y_{i,s}$  still depends upon country  $i$ 's market access through the market clearing conditions, see Appendix A. If  $\sigma < \epsilon$  there may be multiple equilibria even without intermediate inputs, see Kucheryavyy et al. (2020).

tial. Consequently, shocks to real market potential do not affect exports. By contrast, with scale economies the elasticity of output to real market potential is greater than one as shown by equation (6), implying Proposition 1 holds.

## 2.3 Import liberalization

This section analyzes the impact of changes in real market potential in greater detail, focussing on how import liberalization affects output and exports. Suppose there is a reduction in US barriers to Chinese imports, leading to an increase in openness  $\varphi_{UC,s}$ , where we use  $U$  to denote the US and  $C$  for China. In our empirical application, the reduction in US import barriers results from PNTR with China. The bilateral trade equation (5) shows that an increase in  $\varphi_{UC,s}$  directly raises US imports from China.

However, US import liberalization also affects trade between all country pairs indirectly through changes in output, input costs, prices and expenditure. How do these changes affect US exports holding fixed the trade costs faced by US exporters? At this level of generality, we cannot give a complete characterization of the model's comparative statics analytically. However, we can use the equilibrium conditions to characterize the impact of import liberalization on exports conditional on domestic input costs and expenditure and foreign variables.

An increase in  $\varphi_{UC,s}$  has a direct negative effect on the US price index  $P_{U,s}$  by reducing the cost of Chinese imports. We show in Appendix A that:

$$\begin{aligned} d \log P_{U,s} = & -\frac{\lambda_{UC,s}}{\epsilon - 1} d \log \varphi_{UC,s} + \frac{\lambda_{UU,s}}{\sigma - 1} (\sigma d \log c_{U,s} - d \log Y_{U,s}) \\ & + \sum_{j \neq U} \frac{\lambda_{Uj,s}}{\sigma - 1} (\sigma d \log c_{j,s} - d \log Y_{j,s}), \end{aligned} \quad (8)$$

where  $\lambda_{ni,s} = X_{ni,s}/X_{n,s}$  is the import share of country  $i$  in country  $n$ . The first term on the right hand side of equation (8) is the direct negative effect of import liberalization on domestic prices. The second term is an indirect price effect resulting from changes in US input costs and industry

output. Because of scale economies, an increase in output reduces the sectoral price index. The third term captures foreign price changes; for a small economy the third term is zero.<sup>13</sup>

A fall in  $P_{U,s}$  makes the US market more competitive, which reduces US firms' real market potential in sector  $s$ . Real market potential affects output through equation (6) and we show in Appendix A that:

$$d \log Y_{U,s} = - \frac{\frac{\sigma-1}{\epsilon-1} \lambda_{UC,s} \mu_{UU,s}}{\frac{\sigma-1}{\epsilon-1} - 1 + \lambda_{UU,s} \mu_{UU,s}} d \log \varphi_{UC,s} + F \left( c_{U,s}, X_{U,s}, \{Y_{j,s}, c_{j,s}, X_{j,s}, P_{j,s}\}_{j \neq U} \right), \quad (9)$$

where  $\mu_{ni,s} = X_{ni,s}/Y_{i,s}$  is the share of sales to country  $n$  in country  $i$  output and  $F(\cdot)$  is a function that depends upon domestic input costs and expenditure, and foreign variables. Thus, import liberalization leads to lower US output, holding the arguments of  $F(\cdot)$  constant, because US producers lose domestic market share to Chinese imports.

From the bilateral trade equation (5), lower output reduces US exports to all destinations, since scale economies imply that industry level productivity declines as output contracts. This is the mechanism identified by Krugman (1984) through which import protection affects exports. The strength of this effect is increasing in the output elasticity  $\frac{\epsilon-1}{\sigma-1}$ . In the absence of scale economies, i.e. when  $\sigma \rightarrow \infty$ , the fall in output due to lower domestic sales does not affect exports to foreign markets. Proposition 2 summarizes these results.

**Proposition 2. *Import liberalization as export destruction.*** *Holding constant foreign outcomes, domestic input costs and domestic expenditure:*

- (i) *Import liberalization reduces exports to all destinations by decreasing the domestic industry's real market potential if and only if the scale elasticity is strictly positive;*
- (ii) *The magnitude of the elasticity of exports to import openness is strictly increasing in the output*

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<sup>13</sup>Jaravel and Sager (2019) and Amiti et al. (2020) provide evidence that PNTR reduced US prices. Amiti et al. also document that China's WTO accession led to lower US prices through reductions in China's tariffs on intermediate inputs. Our empirical strategy does not exploit this source of variation in import competition because, like other concurrent Chinese policy reforms, it affected China's exports to all countries and was not a bilateral shock specific to the US.

*elasticity.*

Of course, Proposition 2 only characterizes the direct effect of import liberalization on real market potential and exports. Import liberalization may not lead to export destruction if the impact of changes in input costs, expenditure and foreign variables is both export creating and sufficiently strong. In particular, the decline in US output prices  $P_{U,s}$  caused by import liberalization also reduces input costs by equation (2). And lower input costs increase exports, all else equal, as shown by equation (5). The empirical results and quantitative analysis will shed light on the relative strength of alternative channels through which import liberalization affects US exports.

Our theory is based on a Krugman (1980) trade model where firms are homogeneous and scale economies result from love of variety. In an environment without intermediate inputs, Kucheryavyy et al. (2020) show that the industry equilibrium conditions and bilateral trade equation implied by the Krugman model are equivalent to those that hold in a model with external economies of scale, or in a Pareto productivity version of Melitz (2003) with heterogeneous firms – although in these cases the scale elasticity depends upon different underlying parameters. In Appendix A we show that, allowing for intermediate inputs, the scale economies mechanism through which import liberalization leads to export destruction exists regardless of whether scale economies result from external economies of scale, firm heterogeneity or endogenous technology investment.

### **3 Empirical analysis**

This section estimates the impact of PNTR on US exports. The twin objectives of the empirical analysis are to identify the effect of import liberalization on exports and to test for evidence of scale economies in US production.

#### **3.1 PNTR**

Our empirical strategy exploits PNTR as a liberalization shock that increased US openness to Chinese imports. China was granted temporary most favored nation (MFN) status by the US

in 1980, meaning that imports from China faced normal trade relations (NTR) tariffs instead of the higher tariffs imposed on non-MFN countries. However, there was ongoing uncertainty over whether China would retain its MFN status, especially after the Tiananmen Square protests in 1989. The House of Representatives voted to revoke China's MFN status in 1990, 1991 and 1992 and, although these bills did not pass the Senate, the threat to MFN status remained high throughout the 1990s.<sup>14</sup> Revoking China's MFN status would have resulted in substantial tariff increases. In 2000, the average US NTR tariff was 4 percent, whereas the average non-NTR tariff was 31 percent (Handley and Limão 2017).

China received permanent normal trade relations status as part of its accession to the World Trade Organization (WTO). Congress passed PNTR in October 2000 and it became effective after China joined the WTO in December 2001. While PNTR did not change the tariffs charged on Chinese imports, it removed the threat of higher tariffs. Pierce and Schott (2016) and Handley and Limão (2017) show that the reduction in uncertainty led to growth in US imports from China, as firms that had previously been unwilling to make sunk investments in export capacity found it profitable to start exporting. Building on their work, we use the industry-level difference between the non-NTR and NTR tariffs, i.e. the NTR gap, to measure exposure to PNTR and treat years after 2000 as the post-PNTR period. Unlike Handley and Limão (2017), we do not explicitly model the effects of trade policy uncertainty on entry in an environment with sunk investments. Instead, we model PNTR as a reduction in effective US import costs from China that increased bilateral openness  $\varphi_{UC,s}$ .

The NTR gap is plausibly exogenous to US export growth following PNTR. Variation in the NTR gap arises mostly from differences in non-NTR tariffs set by the Smoot-Hawley Tariff Act of 1930, differences that are unlikely to be related to economic conditions 70 years later. This reduces the possibility of endogeneity bias that could arise if, for example, NTR tariffs are higher in industries with lower expected future export growth. Moreover, note that if NTR tariffs are higher in industries with weak expected export growth, then these industries would have smaller

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<sup>14</sup>See Pierce and Schott (2016) and Handley and Limão (2017) for more detail on how the political debate around relations with China created trade policy uncertainty prior to PNTR.

NTR gaps, biasing our results away from finding a negative effect of the NTR gap on export growth.

### 3.2 Data

We use data for NAICS goods industries at the 6 digit level. We define the NTR gap in industry  $s$  as the log difference between the non-NTR tariff and the NTR tariff on US imports:

$$NTRGap_s = \log(1 + \text{Non-NTR tariff}_s) - \log(1 + \text{NTR tariff}_s).$$

Tariff data from Feenstra et al. (2002) is used to compute the NTR gap in 1999 for 8 digit Harmonized Tariff System import codes. We then calculate  $NTRGap_s$  as the average NTR gap across 8 digit products that map to industry  $s$ , where the mapping uses a concordance from Pierce and Schott (2012). A full description of the aggregation procedure and the estimation dataset can be found in Appendix B.

We also construct a variable to capture the effect of PNTR on input costs. Input cost growth is a weighted average of wage growth and changes in sectoral price indices, where the weights depend upon input-output linkages between sectors as shown in equation (2). The fall in prices caused by PNTR reduces input costs. Consequently, we control for the effect of PNTR on input costs using a production cost share weighted average of upstream NTR gaps  $CostShock_s$  defined by:

$$CostShock_s = - \sum_v \gamma_{U,sv} NTRGap_v. \quad (10)$$

Because we multiply the right hand side of equation (10) by negative one,  $CostShock_s$  is more negative for industries that purchase relatively more inputs from industries with higher NTR gaps. We measure  $\gamma_{U,sv}$  for industry  $s$  by expenditure on inputs from industry  $v$  as a share of the value of industry  $s$  output. The input-output coefficients are calculated from the Bureau of Economic Analysis Use Table for 1997.

Bilateral trade data from 1995 onwards at the 6 digit level of the Harmonised System clas-

sification is taken from the CEPII BACI database and aggregated to NAICS industries. We also obtain population by country from CEPII and use the NBER manufacturing database to measure output levels, input intensity, skill intensity and capital intensity for manufacturing industries (see Appendix B for details).

Table 1 shows descriptive statistics for the industry level variables. The NTR gap ranges between zero and 0.59 with an average of 0.23 and a standard deviation of 0.12. The average input cost shock is  $-0.08$  with a standard deviation of 0.08. The NTR gap and input cost shock are negatively correlated because industries disproportionately use their own output as intermediate inputs, i.e. the input-output matrix has a lot of weight on the diagonal elements  $\gamma_{U,ss}$ . The correlation is  $-0.52$  across all sample industries and  $-0.36$  within manufacturing. For manufacturing industries, the NTR gap is also negatively correlated with input and capital intensity, but approximately uncorrelated with skill intensity.

### 3.3 Estimation strategy

Treating PNTR as an industry-level shock to import protection that shifted US real market potential and output, we implement two alternative estimation strategies. First, we perform reduced form estimation of the impact of industry-level variation in the NTR gap on US exports. Second, we undertake structural estimation using the NTR gap as an instrument for changes in US output following PNTR. The structural approach allows us to test for scale economies by estimating the output elasticity  $\frac{\epsilon-1}{\sigma-1}$  in the second stage.

Our estimation specification is derived from the bilateral trade equation (5). Taking log differences of equation (5) yields:

$$\begin{aligned} \Delta \log X_{ni,s} = & \frac{\epsilon-1}{\sigma-1} \Delta \log Y_{i,s} - \frac{\sigma(\epsilon-1)}{\sigma-1} \Delta \log c_{i,s} + (\epsilon-1) \Delta \log \left( T_{i,s} f_{i,s}^{-\frac{1}{\sigma-1}} \right) \\ & + \Delta \log (X_{n,s} P_{n,s}^{\epsilon-1}) + \Delta \log \varphi_{ni,s}. \end{aligned} \quad (11)$$

Thus, export growth in country  $i$  depends upon changes in bilateral openness  $\varphi_{ni,s}$ , import demand in the destination country  $X_{n,s}P_{n,s}^{\epsilon-1}$  and the exporter's supply capacity  $S_{i,s}$ , which itself depends upon output  $Y_{i,s}$ , input costs  $c_{i,s}$ , the technology level  $T_{i,s}$  and entry costs  $f_{i,s}$ .<sup>15</sup>

We estimate a fixed effects version of equation (11) in long differences using two periods: a pre-PNTR period from 1995-2000 and a post-PNTR period from 2000-07. The reduced form estimating equation is:

$$\begin{aligned}\Delta \log X_{ni,s}^t = & \delta_{ni,s} + \delta_{ni}^t + \delta_{n,s}^t + \alpha_1 Post^t \times US_i \times NTRGap_s \\ & + \alpha_2 Post^t \times US_i \times CostShock_s + \beta Post^t \times US_i \times Z_s + \epsilon_{ni,s}^t, \quad (12)\end{aligned}$$

where  $t$  denotes the period,  $Post^t$  is a dummy for the post-PNTR period,  $US_i$  is a dummy for the exporter  $i$  being the United States,  $Z_s$  is a vector of industry characteristics and we control for importer-exporter-industry, importer-exporter-period and importer-industry-period fixed effects. The dependent variable  $\Delta \log X_{ni,s}^t$  is the annualized change in log exports during period  $t$ .

The main coefficient of interest is  $\alpha_1$ , which gives the effect of PNTR on US exports conditional on the fixed effects, input cost shock and industry characteristic controls. It is a triple differences estimate that is identified from changes in US bilateral export growth by sector following PNTR relative to changes in other sample countries' export growth. The identifying assumption is that the NTR gap is not correlated with unobserved shocks to relative US export growth during the post-PNTR period.

Proposition 2 implies that, in the absence of scale economies, import liberalization does not affect exports meaning  $\alpha_1 = 0$ . However, if there are scale economies, then the model predicts  $\alpha_1 < 0$ . The effect of PNTR on US exports due to changes in input costs is given by  $\alpha_2$ . Assuming the direct negative effect of PNTR on US sectoral price indices dominates general equilibrium effects, we expect to find  $\alpha_2 < 0$  since lower input costs are export promoting. This prediction

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<sup>15</sup>Recall that the supply capacity  $S_{i,s}$  of exporter  $i$  is given by  $S_{i,s} = \Gamma_0 T_{i,s}^{\epsilon-1} \left( \frac{Y_{i,s}}{c_{i,s}^\sigma f_{i,s}} \right)^{\frac{\epsilon-1}{\sigma-1}}$ .

holds regardless of whether there are scale economies in US production.

Our data varies along four dimensions: exporter, importer, industry and period. The fixed effects in equation (12) control for all three dimensional sources of bilateral trade growth, except for variation at the exporter-industry-period level. Comparing equations (11) and (12) makes explicit which sources of export growth are absorbed by the fixed effects.

Changes in import demand  $X_{n,s}P_{n,s}^{\epsilon-1}$  by period and changes in supply capacity that do not vary by exporter, such as technology shocks that vary across industries but not countries, are captured by  $\delta_{n,s}^t$ . In particular,  $\delta_{n,s}^t$  controls for the indirect impact of growth in China's export supply capacity  $S_{C,s}$  on non-Chinese exports through its effect on other countries' import demand. To see why, note that we expect lower import demand growth in country  $n$  in industries with higher growth in  $S_{C,s}$  because of greater Chinese competition.<sup>16</sup> However, this change in import demand is common across all exporters selling to country  $n$ . Therefore, it is captured by  $\delta_{n,s}^t$ . This enables us to control for the global component of the China shock to import demand and for any changes in Chinese export supply induced by PNTR.

Industry-level trends in bilateral openness  $\varphi_{ni,s}$  and exporter supply capacity  $S_{i,s}$  that do not vary before and after PNTR are captured by  $\delta_{ni,s}$ . Therefore, the inclusion of  $\delta_{ni,s}$  allows for productivity growth trends at the industry level to differ across countries. Finally,  $\delta_{ni}^t$  controls for period-specific changes in bilateral trade costs and supply capacity that do not vary across industries.

Because the predicted effect of PNTR on US exports does not vary across importers, the estimation equation cannot include an exporter-industry-period fixed effect. Consequently, a threat to identification is the possibility that the NTR gap is correlated with unobserved shocks to US export supply capacity, such as industry level shocks that affect technology levels  $T_{U,s}$  or entry costs  $f_{U,s}$ . Since technology shocks are more likely to be correlated within the OECD and  $\delta_{n,s}^t$  controls for common technology shocks across exporters, our baseline sample restricts exporters to countries

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<sup>16</sup>For example, suppose China experiences a positive productivity shock in the Plastics industry. This shock would increase Chinese export growth to all destinations including, for example, Brazil. In turn, this increase in competition from Chinese exporters would reduce the growth in Brazilian import demand for Plastics from other countries such as Canada and the United States.

that were OECD members at the start of 1995. We also control for export supply shocks that are correlated with observable industry characteristics by including measures of input, skill and capital intensity by industry in 1995 in the vector of controls  $Z_s$ . Interacting  $Z_s$  with  $Post^t \times US_i$  captures changes in US export growth that are systematically related to these industry characteristics.

Another potential source of bias would arise if the NTR gap were correlated with industry-level changes in trade costs facing the US relative to other OECD countries. However, we are not aware of trade policy changes during the post-period that would generate such a correlation.

### 3.4 Reduced form evidence

Before estimating the effect of PNTR on bilateral exports, we present evidence showing the effect of PNTR on total exports to all destinations. Figure 1 in the Introduction plots US export growth from 2000-07 relative to 1995-2000 against the NTR gap by industry. The figure shows that export growth declined following PNTR in industries with higher NTR gaps. The relationship is statistically significant and implies that a 10 log point increase in the NTR gap reduced annual export growth by 5.0 percent after 2000. In addition, the NTR gap explains 18 percent of the variation in US exports double differenced in this way.

To investigate the timing of this effect, we use an event study specification:

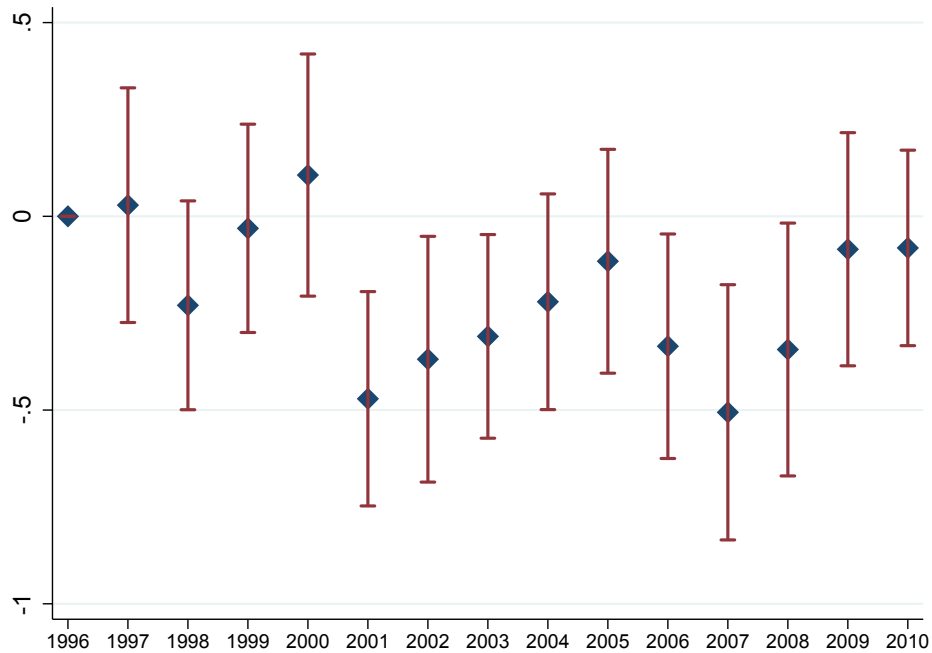
$$\log \left( \frac{X_{i,s}^t}{X_{i,s}^{t-1}} \right) = \delta_{i,s} + \delta_i^t + \delta_s^t + \sum_t \zeta_t \times US_i \times NTRGap_s + \epsilon_{i,s}^t, \quad (13)$$

where  $X_{i,s}^t$  denotes total exports of country  $i$  in industry  $s$  and year  $t$  to all destinations other than the US,  $t$  denotes the year,  $\delta_{i,s}$  is an exporter-industry fixed effect,  $\delta_i^t$  is an exporter-year fixed effect,  $\delta_s^t$  is an industry-year fixed effect and  $\epsilon_{i,s}^t$  is the error term. The event study coefficients  $\zeta_t$  give the relationship between US export growth (relative to other countries) and the NTR gap. Equation (13) is estimated using annual data from 1995-2010 for OECD exporters and clustering standard errors by exporter-industry.

Figure 2 plots the event study coefficients and their 95 percent confidence intervals with 1996

as the excluded category. Before 2000 there is no evidence of a relationship between the NTR gap and US export growth. After 2000 the relationship is negative in most years until the global financial crisis occurs in 2007-08. These results are consistent with PNTR negatively affecting US export growth at the industry level.

Figure 2: NTR gap and US export growth: event study estimates



Notes: Event study coefficients  $\zeta_t$  and 95 percent confidence intervals from estimating equation (13). Exporters restricted to OECD members at start of 1995 with population above one million in 1995. NAICS goods industries.

We now turn to our baseline specification in equation (12). The estimation sample covers bilateral exports from 23 OECD countries including the US to 141 importers for 444 NAICS goods industries. We omit the US, China, Hong Kong and Macao from the sample of importers, as these countries are directly affected by PNTR. We also drop all small countries that have a population below one million in 1995.

The estimation results are shown in Table 2 with standard errors clustered by exporter-industry pairs. We start in column (a) by estimating equation (5) omitting the input cost shock, industry characteristics and the importer-exporter-industry fixed effect. The estimate of  $\alpha_1$  is negative and statistically significant meaning that PNTR led to lower export growth in industries with higher

NTR gaps. Column (b) introduces the importer-exporter-industry fixed effect, causing the magnitude of the estimated NTR gap effect to more than double. The estimates in columns (a) and (b) differ because the NTR gap is positively correlated with US export growth in the pre-PNTR period. Failing to control for this correlation biases estimates of the impact of PNTR on US exports towards zero.

In column (c) we add the input cost shock variable. The estimated effect of the NTR gap on export growth in the post-period remains negative and the magnitude of the coefficient increases slightly. A 10 log point increase in the NTR gap is estimated to reduce export growth by 2.9 percent per year, leading to a cumulative 21 percent decline in exports over the seven year post-PNTR period. In addition, we estimate  $\alpha_2 < 0$  meaning industries that experienced larger falls in input costs because of PNTR had higher export growth.<sup>17</sup> Column (d) restricts the sample to the 384 manufacturing industries in our dataset, which gives similar estimates.

These results are consistent with the predictions of the model developed in Section 2. We find that PNTR led to export destruction within industries all else equal, which implies there are scale economies in US production. We also find evidence that PNTR boosted US exports by reducing intermediate input costs.

In columns (e)-(h) we include the input, skill and capital intensity controls. The estimates imply that US relative export growth increased in the post-period in more input and capital intensive industries, but declined in more skill intensive industries. The inclusion of the input intensity control also reduces the size of the estimated NTR gap effect. However, we continue to find that industries with greater NTR gaps had lower export growth following PNTR and that industries with larger input cost reductions due to PNTR had higher export growth.

The fact that both  $\alpha_1$  and  $\alpha_2$  are estimated to be negative implies that the results are unlikely to be driven by unobserved technology shocks to US industries. To generate a negative correlation between the NTR gap and US export growth, unobserved technology shocks would have to be less

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<sup>17</sup>The input cost shock control  $CostShock_s$  only accounts for first-order input-output linkages between sectors (see equation 10). Pre-multiplying  $CostShock_s$  by the Leontief inverse of the matrix of input-output coefficients  $\gamma_{U,sv}$  gives an alternative input cost shock measure that also incorporates higher-order linkages. Our empirical results are very similar when this alternative measure is used to control for the input cost shock caused by PNTR.

positive in industries with higher NTR gaps. This implies price growth would be greater in such industries (see equation 17 in Appendix A). But then downstream industries that mainly source inputs from industries with higher NTR gaps would face greater input cost growth leading to lower exports. This implies  $\alpha_2 > 0$ , which is the opposite of what we find.

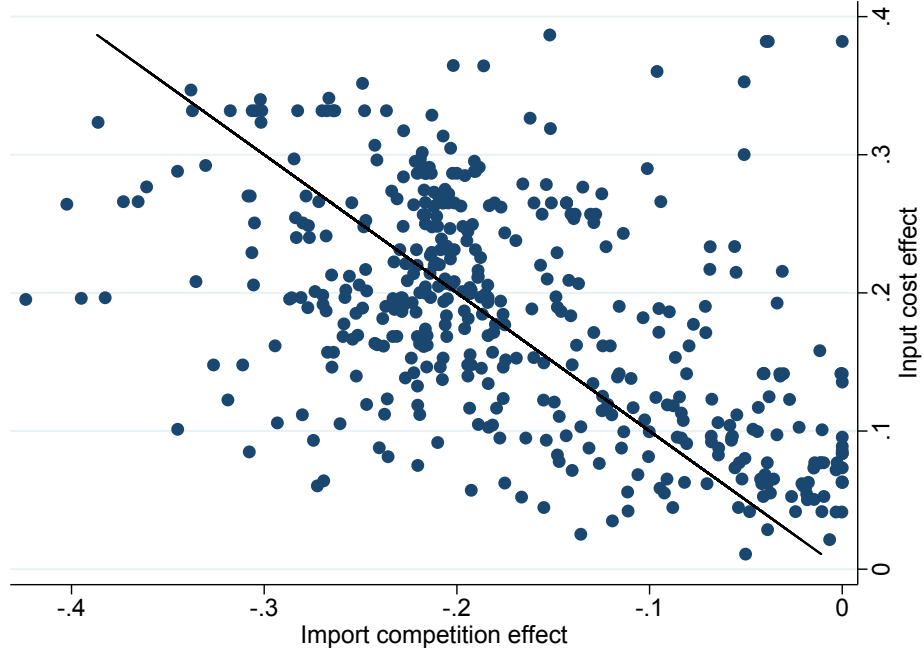
Table 2 implies PNTR affected US exports through two offsetting channels: negatively because of reduced scale due to increased import competition from China and positively due to lower input costs. Both channels are quantitatively important. The estimates in column (h) imply that, conditional on input cost changes, PNTR reduced exports by 13 percent more by the end of the post-period for an industry at the 75th percentile of the NTR gap distribution than for an industry at the 25th percentile. At the same time, conditional on the NTR gap, PNTR increased exports by 14 percent more for an industry at the 75th percentile of the input cost shock distribution than for an industry at the 25th percentile.

The net effect of these two forces varies substantially across industries. This is shown in Figure 3, which uses the coefficient estimates in column (h) to plot the predicted input cost effect against the predicted import competition effect for each industry. The net effect ranges between negative 24 percent (Cigarette manufacturing) and positive 38 percent (Ice manufacturing) and is negative for 41 percent of industries, i.e. those that lie below the negative 45 degrees line in the figure. However, this does not mean that PNTR was export destroying for 41 percent of industries. Figure 3 does not account for general equilibrium effects of PNTR that are absorbed by the fixed effects in the regression model. We quantify the general equilibrium effects of PNTR in Section 4 below.

*Robustness.* Table 3 presents a series of robustness checks on the baseline reduced form results. Unless noted otherwise, the robustness checks use the specification from column (h) of Table 2.

Although Congress approved PNTR in October 2000, China did not formally join the WTO until December 2001. However, dating PNTR to 2001 and using 1995-2001 as the pre-period and 2001-07 as the post-period makes little difference to the estimates (column a). Defining the NTR gap by  $NTRGap_s = \text{Non-NTR tariff}_s - \text{NTR tariff}_s$  as in Pierce and Schott (2016) reduces the statistical significance of the NTR gap, but the estimated coefficient remains negative and

Figure 3: Import competition and input cost effects of PNTR



Notes: Observations are NAICS goods industries. Import competition effect is the predicted effect of the NTR gap variable on cumulative change in log exports 2000-07 for the US. Input cost effect is the predicted effect of the cost shock variable on the same outcome. Effects computed using estimates in Table 2, column (h). For observations below the solid negative 45 degrees line, the net impact of the two effects on export growth is negative.

significant at the 10 percent level (column b).<sup>18</sup> Alternatively, using Handley and Limão's (2017) NTR gap measure  $NTRGap_s = 1 - [(1 + \text{Non-NTR tariff}_s) / (1 + \text{NTR tariff}_s)]^{-3}$  increases the significance of the NTR gap compared to the baseline estimates (column c).

The results are also robust to estimating the export growth equation in levels using Poisson pseudo-maximum likelihood (PPML) estimation instead of OLS (column d). The bilateral trade data contains many missing values, probably corresponding to zeroes in the trade matrix.<sup>19</sup> To investigate whether our estimates are biased by missing zeroes, we aggregate across all importers to obtain total exports by industry. After aggregating, we observe positive total exports for over 99 percent of the possible exporter-industry-period combinations in our OECD exporter sample. Using the aggregated data, we find that US industries with higher NTR gaps had lower total export

<sup>18</sup>When changing the NTR gap measure, we also recalculate the input cost shock  $CostShock_s$  using equation (10).

<sup>19</sup>Note that the PPML estimation in column (d) does not include zero trade flows since the dependent variable is  $X_{ni,s}^t / X_{ni,s}^{t-1}$ .

growth following PNTR regardless of whether we estimate the model using OLS (column e) or PPML (column f). Although it is worth noting that the input cost shock variable loses significance in these specifications.

Another threat to our results is the possibility of pre-trends in US export growth that are correlated with the NTR gap. Specifically, if US industries with higher NTR gaps had been experiencing declining export growth over time, our estimates could mistakenly attribute this trend to PNTR. However, Figure 2 shows no evidence of any such trend before 2000, suggesting our results cannot be explained by pre-PNTR trends in US export growth.

Further reduced form results can be found in Appendix C. Table A1 shows that the baseline estimates are robust to varying the set of exporters, importers and industries in the estimation sample and to allowing PNTR to affect domestic expenditure. Table A2 shows that the baseline findings hold when controlling for growth in imports from China caused by shocks other than PNTR. In addition, it presents evidence that our findings are not driven by competition between US and Chinese exports in third markets. This evidence rules out an alternative explanation for our empirical results which does not require the existence of scale economies – namely that PNTR reduced US export growth by causing changes in the within-industry composition of China’s export basket that increased the substitutability between Chinese and US exports in higher NTR gap industries. To rule out the third market competition hypothesis, we show that the effect of the NTR gap on US exports is unrelated to the strength of Chinese competition, as measured by either the level or increase of China’s share of destination-market imports (see Appendix C for details).

We also find that the negative effect of PNTR on US export growth remains present when sectors are defined by 6 digit Harmonised System (HS) products instead of NAICS industries (Table A3). For this more disaggregated classification, we do not observe the input cost shock or industry characteristic variables. Nevertheless, we find that even within NAICS industries, US products with higher NTR gaps had lower export growth in the post-PNTR period. Interestingly, the estimated effect of the NTR gap on export growth at the product level is roughly half as large as in column (h) of Table 2, which is consistent with the hypothesis that scale economies are stronger

at the NAICS industry level than for 6 digit products.

### 3.5 Structural estimates

The reduced form results provide evidence that PNTR led to export destruction through the scale economies mechanism described by Krugman (1984). Next, we estimate the bilateral trade equation (5) structurally using PNTR as a source of exogenous variation in industry output. The structural approach allows us to directly estimate the output elasticity  $\frac{\epsilon-1}{\sigma-1}$ . Specifically, we replace the NTR gap interaction in the reduced form specification with US output growth and estimate:

$$\begin{aligned}\Delta \log X_{ni,s}^t &= \delta_{ni,s} + \delta_{ni}^t + \delta_{n,s}^t + \alpha_3 US_i \times \Delta \log Y_{U,s}^t \\ &+ \alpha_4 Post^t \times US_i \times CostShock_s + \beta Post^t \times US_i \times Z_s + \epsilon_{ni,s}^t,\end{aligned}\quad (14)$$

where  $US_i \times \Delta \log Y_{U,s}^t$  is instrumented by  $Post^t \times US_i \times NTRGap_s$ . The inclusion of importer-exporter-industry fixed effects implies that, for the instrument to be relevant, the NTR gap needs to explain changes in US output growth between the pre-PNTR and post-PNTR periods, i.e.  $\Delta \log Y_{U,s}^{Post} - \Delta \log Y_{U,s}^{Pre}$ . The main coefficient of interest is  $\alpha_3$ , which gives the output elasticity  $\frac{\epsilon-1}{\sigma-1}$ . If there are no scale economies, then  $\alpha_3 = 0$ .

Table 4 presents the results of estimating (14) using the baseline sample of manufacturing industries. In column (a) we estimate the model without controlling for the input cost shock. As expected, industries with higher NTR gaps experienced lower output growth following PNTR, which generates a strong first stage.<sup>20</sup> In the second stage, the estimated output elasticity is 0.66 and is significantly different from zero, which supports the existence of scale economies.

When we control for the input cost shock in column (b), the output elasticity increases to 1.10. As before, we find that industries with greater input cost declines had higher export growth following PNTR, and the magnitude of this effect is larger than in the reduced form estimates.

<sup>20</sup>The first stage is related to Pierce and Schott's (2016) finding that PNTR led to employment declines in industries with higher NTR gaps. However, in our case the dependent variable is output rather than employment.

In column (c) we add the controls for input, skill and capital intensity. With these controls, the estimated output elasticity falls to 0.78, but remains significant at the 10 percent level. However, the additional controls reduce the power of the instrument and the first stage F-statistic in column (c) is below conventional thresholds used to test for weak instruments.

Another potential source of bias in the structural estimates is that the NTR gap could be correlated with shocks to output growth outside the US through general equilibrium effects of PNTR. Although any such effects are likely to be small, this would violate the exclusion restriction given that output growth in countries other than the US is part of the error term. To explore this possibility, we drop all exporters other than the US from the sample and use importer-industry and importer-period fixed effects. Regardless of whether the industry characteristic controls are omitted (column d) or included (column e), we continue to estimate a positive output elasticity. This alleviates any concern that the estimates in columns (a)-(c) are driven by correlation between foreign output shocks and the NTR gap.

Together, the results in Table 4 reinforce the reduced form evidence that US production exhibits scale economies. In particular, we estimate that the output elasticity is greater than zero. However, we cannot reject either the hypothesis that the output elasticity equals one as in Krugman (1980), or that it falls within the range of values estimated by Bartelme et al. (2019).<sup>21</sup> The first stage estimates also show that industries with higher NTR gaps experienced lower output growth after 2000, confirming that PNTR reduced export growth in more exposed industries.

## 4 Quantitative analysis

We have shown that PNTR affected US exports both negatively through increased competition from Chinese imports and positively due to input cost reductions. However, the empirical estimates do not account for general equilibrium effects of PNTR on trade and do not address the welfare

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<sup>21</sup>Bartelme et al. (2019) estimate the scale elasticity for 15 manufacturing industries. The product of their scale elasticity estimates (Table 1, column 2) and the trade elasticities they impose ranges between 0.68 for Chemicals and 0.96 for Wood Products with a mean of 0.83.

consequences of import liberalization.

This section quantifies the impact of PNTR on trade and welfare using the trade model with scale economies developed in Section 2. We use our empirical results to calibrate the strength of scale economies. We then use the calibrated model to simulate the impact of PNTR on the global economy and analyze how its general equilibrium effects are shaped by the existence of scale economies and input-output linkages.

## 4.1 Model calibration

We solve the model in changes using exact hat algebra. For any variable or parameter that takes value  $z$  in the initial equilibrium and  $z'$  in the new equilibrium, let  $\hat{z} = z'/z$  to be the relative change in this variable. Appendix D derives the equilibrium in relative changes and shows that it can be reduced to a system of equations in output changes  $\hat{Y}_{i,s}$  and price index changes  $\hat{P}_{i,s}$ .

The solution depends upon four sets of parameters and variables that we calibrate: (i) import shares  $\lambda_{ni,s}$ , expenditure  $X_{i,s}$  and output  $Y_{i,s}$  in the initial equilibrium; (ii) expenditure shares in final demand  $\beta_{i,s}$  and cost shares of value-added and intermediate inputs in production  $\gamma_{i,s}$  and  $\gamma_{i,sv}$ ; (iii) changes in US openness to Chinese imports due to PNTR  $\hat{\phi}_{UC,s}$ , and; (iv) the parameters  $\epsilon$  and  $\sigma$  that determine the trade and output elasticities.

We calibrate the initial values in set (i) and the parameters in set (ii) using the World Input-Output Tables for 2000 (Timmer et al. 2015). The calibrated economy has 12 economies, including the US and China, and 24 sectors, including 15 goods sectors.<sup>22</sup>

*Openness shock.* PNTR lowered US barriers to Chinese imports by reducing uncertainty over future tariff levels (Handley and Limão 2017). We do not model the mapping from tariff uncertainty to trade costs. Instead we calibrate the reduced form effect of PNTR on openness  $\hat{\phi}_{UC,s}$  by estimating the bilateral trade equation (11) allowing the NTR gap to affect growth in US imports from China. We estimate:

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<sup>22</sup>Appendix D details the country and sectoral aggregations used in the calibration.

$$\Delta \log X_{ni,s}^t = \delta_{ni,s} + \delta_{ni}^t + \delta_{n,s}^t + \delta_{i,s}^t + \alpha_5 Post^t \times US_n \times China_i \times NTRGap_s + \epsilon_{ni,s}^t, \quad (15)$$

where  $US_n$  is a dummy for the importer  $n$  being the United States and  $China_i$  is a dummy for the exporter  $i$  being China. We estimate this specification in long differences with 1995-2000 as the pre-PNTR period and 2000-07 as the post-PNTR period. Because PNTR is a bilateral shock, we include in equation (15) the complete set of three-way fixed effects. The fixed effects control for all variation in trade growth that is not importer-exporter-industry-period specific, including the indirect effects of PNTR on expenditure, prices and exporter supply capacity.

The coefficient of interest  $\alpha_5$  gives the impact of PNTR on US imports from China due to changes in bilateral openness. Since the estimation strategy uses cross-industry variation to identify changes in openness, we must also normalize the level of the PNTR effect. We assume that PNTR did not affect US openness to imports from China in a hypothetical industry with a zero NTR gap. Therefore, we set  $\hat{\varphi}_{UC,s} = \exp(7 \times \alpha_5 \times NTRGap_s)$ , where we multiply the estimated effect by seven because the dependent variable in equation (15) is annualized trade growth.

Table 5 shows the estimation results using our dataset of bilateral trade for NAICS goods industries. The baseline sample in column (a) restricts the set of importers to be OECD countries.<sup>23</sup> As expected, we estimate that PNTR increased US imports from China by more in industries where the NTR gap is higher. This finding is robust to restricting the set of exporters to non-OECD countries (column b), expanding the set of importers to include both OECD and non-OECD countries (column c) and only using manufacturing industries (column d). Finally, in column (e) we examine whether the relationship between the NTR gap and openness is non-linear by including  $Post^t \times US_n \times China_i \times NTRGap_s^2$  as an additional regressor. We do not find evidence of statistically significant non-linearity in the relationship.

We calibrate PNTR using  $\alpha_5 = 0.43$  as estimated in column (a). To obtain  $\hat{\varphi}_{UC,s}$  for the goods

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<sup>23</sup>As in Section 3, we drop all small countries with a population below one million in 1995 from the sample. We also omit China from the sample of importers, the US from the sample of exporters and Hong Kong and Macao from both samples.

sectors used in the calibration, we average the openness shock across NAICS industries that map to each sector. We also set  $\hat{\varphi}_{ni,s} = 1$  unless  $n = U$  and  $i = C$ , i.e. unless the US is importing from China, and  $\hat{\varphi}_{UC,s} = 1$  for services sectors.

The calibration of  $\hat{\varphi}_{UC,s}$  does not impose any restrictions on the trade elasticity. However, given a value for the trade elasticity, we can assess the magnitude of the PNTR shock by calculating the ad-valorem equivalent effect of PNTR on trade costs:  $\hat{\tau}_{UC,s} = (\hat{\varphi}_{UC,s})^{\frac{-1}{\epsilon-1}}$ . Suppose the trade elasticity equals five, which is the value used below to calibrate  $\epsilon$ . Then our estimates imply that PNTR was equivalent to a 13 percent reduction in trade costs on US imports from China for the average NAICS goods industry, with a standard deviation across industries of 6.6 percent.<sup>24</sup>

*Output and trade elasticities.* We set the trade elasticity  $\epsilon - 1$  equal to five, based on the preferred estimate of Head and Mayer (2014). We also set the output elasticity for services sectors equal to zero following Costinot and Rodríguez-Clare (2014), Bartelme et al. (2019) and Kucheryavyy et al. (2020). Allowing for scale economies in goods sectors, but not services, implies that shifting production from services to goods can raise welfare. We examine the robustness of our quantitative results to allowing for scale economies in services at the end of Section 4.2.

We calibrate the output elasticity for goods sectors by matching the simulated effect of the NTR gap on US manufacturing exports in the model to the reduced form effect identified empirically. Specifically, we target the estimate from column (h) of Table 2 that the conditional elasticity of annual US export growth to the NTR gap equals  $-0.10$ . We compute the simulated NTR gap effect for a given output elasticity by estimating a specification equivalent to equation (12) using simulated data from solving the calibrated model (see Appendix D for details).

Trade models incorporating both scale economies and input-output linkages may have multiple equilibria (Krugman and Venables 1995). In Krugman and Venables' model the output elasticity equals one and the existence of multiple equilibria depends upon the level of trade costs, the trade elasticity and the strength of input-output linkages. Kucheryavyy et al. (2020) show that trade models with scale economies are well behaved for quantitative work when the output elasticity

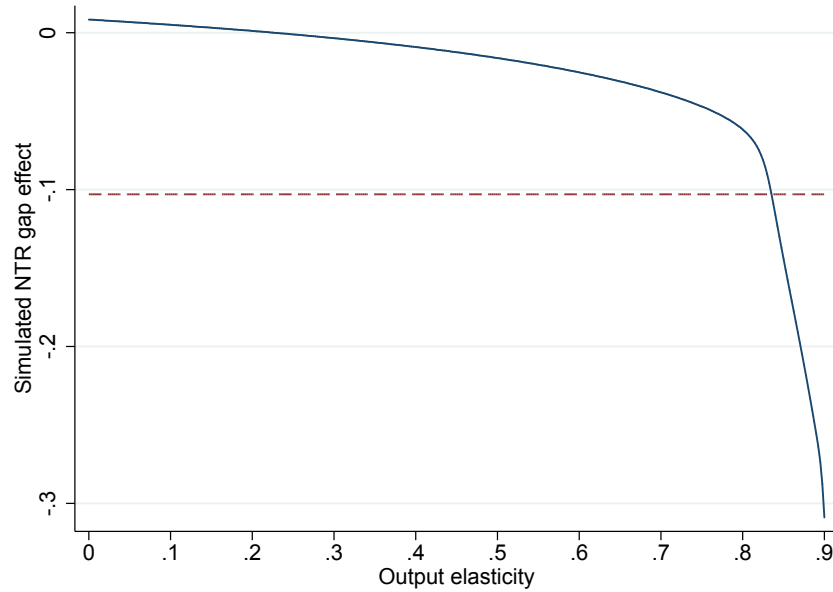
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<sup>24</sup>By comparison, Handley and Limão (2017) estimate, using a structural model of trade and uncertainty, that PNTR lowered US prices by the equivalent of a 13 percentage point permanent decrease in tariffs on Chinese imports.

does not exceed one, although their framework does not include intermediate inputs. Numerically, we find that our calibrated model has a unique solution for the impact of PNTR whenever the output elasticity for goods is below 0.95. However, for output elasticities above 0.95, our solution algorithm is not always well behaved.

Figure 4 shows the simulated NTR gap effect as a function of the output elasticity. The relationship is negative and concave, which is consistent with the direct effect of import liberalization on exports characterized analytically in Proposition 2. The magnitude of the simulated effect is small compared to the estimated effect when the output elasticity is below around 0.75, but increases rapidly thereafter as the output elasticity approaches one. To match the estimated NTR gap effect, we calibrate the output elasticity equal to 0.835 for goods sectors.

Figure 4: Output elasticity and simulated effect of NTR gap on US exports

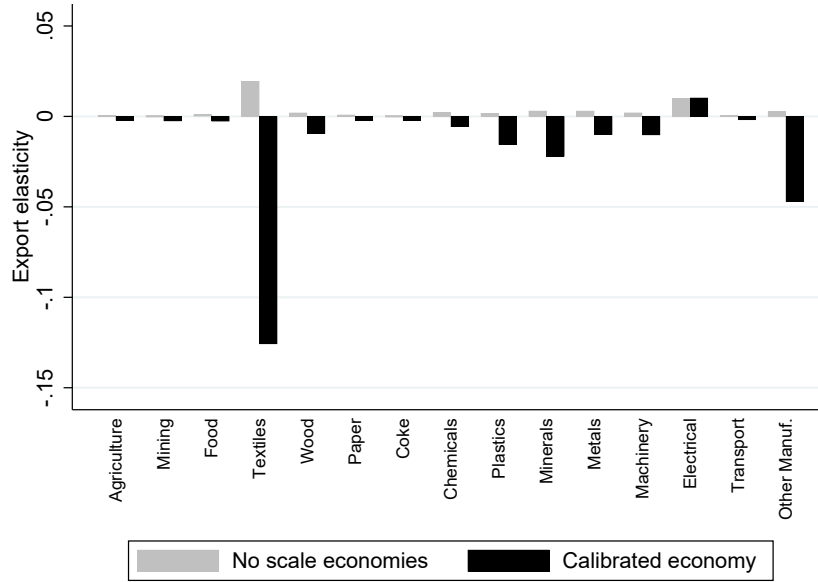


Notes: Simulated NTR gap effect in the calibrated model. Output elasticity on horizontal axis is for goods sectors. For services sectors, output elasticity always equals zero. The horizontal dashed line shows the target estimated NTR gap effect of  $-0.103$  from Table 2, column (h).

## 4.2 Quantitative results

*Exports.* We use the calibrated model to study how import liberalization affects exports. Before analyzing PNTR, which liberalized all goods sectors simultaneously, it is useful to consider the impact of opening up a single sector at a time to Chinese imports. To this end, we simulate the local elasticity of US exports  $EX_{U,s} = \sum_{n \neq U} X_{nU,s}$  to openness  $\varphi_{UC,s}$  at the calibrated equilibrium with aggregate US GDP as the numeraire.<sup>25</sup> Figure 5 plots the export elasticity for each goods sector in the calibrated model (right hand bar for each sector) and in an alternative model without scale economies where the output elasticity equals zero in all sectors (left hand bar).

Figure 5: Within sector elasticity of US exports to openness to Chinese imports



Notes: Simulated within sector percent change in US exports resulting from a one percent increase in openness to Chinese imports, holding openness of all other sectors constant. In calibrated economy output elasticity is 0.835 for goods sectors and zero for services sectors. In model without scale economies output elasticity is zero for all sectors. US GDP is the numeraire. Goods sectors only.

With scale economies the elasticities are negative in all but one sector, implying that reducing barriers to Chinese imports in a given sector generally reduces US exports relative to GDP in the same sector. In this sense, import liberalization is export destroying within sectors. However,

<sup>25</sup>Formally, we solve for  $\widehat{EX}_{U,s}$  when US openness to Chinese imports increases by one percent in sector  $s$  (i.e.  $\hat{\varphi}_{UC,s} = 1.01$ ) and is unchanged in all other sectors.

in the model without scale economies the elasticities are positive for all sectors. Moreover, the correlation between the elasticities with and without scale economies is  $-0.79$ . This comparison illustrates how the existence of scale economies leads to qualitative changes in the within-sector effects of import liberalization.

By contrast, we find that the local elasticity of total US exports  $\sum_v EX_{U,v}$  to openness  $\varphi_{UC,s}$  is positive for all sectors  $s$  regardless of whether there are scale economies. And the correlation between the total export elasticities with and without scale economies is  $0.49$ . This occurs because the cross-sectoral impact of import liberalization is export promoting and does not depend upon the existence of scale economies.

Now we turn to PNTR itself. We use the values of  $\hat{\varphi}_{UC,s}$  obtained from Table 5 to simulate the impact of PNTR in the calibrated model. Figure 6 plots changes in US exports and revealed comparative advantage due to PNTR for goods sectors. Exports are given by the right hand bar for each sector and expressed relative to US GDP. Revealed comparative advantage (left hand bar) is defined as the share of sector  $s$  in US exports relative to the share of sector  $s$  in world exports and shows how changes in US exports compare to changes for other countries. The sectors are ordered with the NTR gap increasing from left to right.

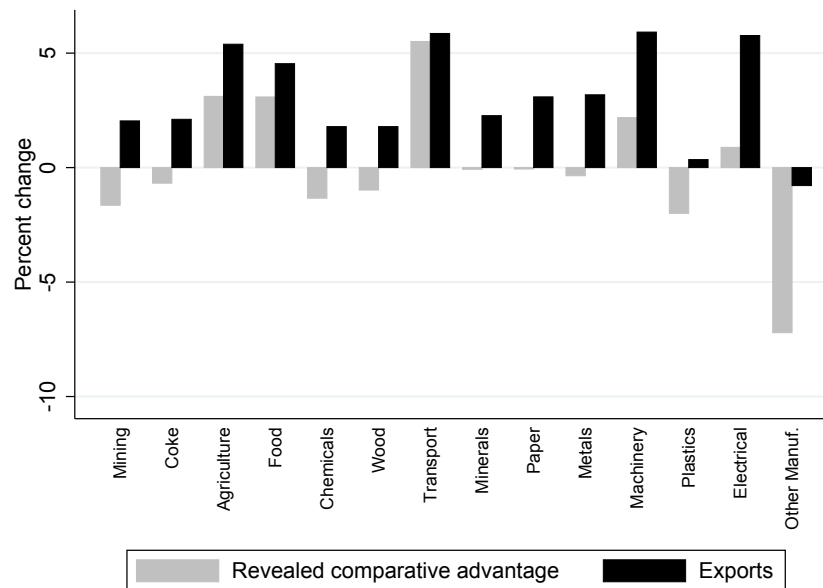
Table 6, panel A expands on Figure 6 by reporting changes in exports, revealed comparative advantage and output for groups of sectors. It compares goods to services and divides goods sectors into groups with low, medium and high NTR gaps.<sup>26</sup> We find that for low and medium NTR gap sectors, exports increased by 4.1 percent and 4.5 percent, respectively. However, for high NTR gap sectors, exports increased by only 1.9 percent, while revealed comparative advantage declined by 5.1 percent. The same pattern holds for output. Output increased by 0.3 percent for low NTR gap sectors and 1.2 percent for medium NTR gap sectors, but fell by 6.1 percent for high NTR gap sectors.

We draw two principal conclusions from these results. First, PNTR was export promoting, both on aggregate and for most sectors. Total US exports relative to GDP increased by 3.6 per-

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<sup>26</sup>Table A4 shows how sectors are classified into the low, medium and high NTR gap groups.

Figure 6: Impact of PNTR on US revealed comparative advantage and exports



Notes: Simulated percent changes in model with output elasticity of 0.835 for goods sectors and zero for services sectors. Sectors ordered with NTR gap increasing from left to right. US GDP is the numeraire. Goods sectors only. Textiles and Leather not shown.

cent and exports rose following PNTR in 13 out of 15 goods sectors.<sup>27</sup> Thus, for most sectors, the cross-sector export promoting effect of PNTR dominated the within-sector export destruction effect shown in Figure 5. Second, export growth was, on average, lower in sectors with higher NTR gaps, although this effect was driven by a few sectors with large NTR gaps. This implies that PNTR shifted US production and exports away from sectors that experienced the largest import liberalizations.

To further understand the mechanisms behind these results, we can decompose the change in US exports into the change in supply capacity – which in turn depends upon a real market potential effect and an input cost effect – and the change in foreign demand:

<sup>27</sup>For clarity, the Textiles and Leather sector is not shown in Figure 6 or Figure 7. Revealed comparative advantage declined by 45 percent for this sector and exports by 35 percent. The fall in exports can be decomposed into a negative 46 percent real market potential effect, a positive 13 percent input cost effect and a positive 5.5 percent foreign demand effect. The large declines result from Textiles and Leather having both the highest NTR gap of all sectors and a relatively low share of value-added in output. Textiles and Leather is part of the high NTR gap group in Table 6.

$$\begin{aligned}
\widehat{EX}_{U,s} &= \hat{S}_{U,s} \times \sum_{n \neq U} \chi_{nU,s} \hat{X}_{n,s} \hat{P}_{n,s}^{\epsilon-1} \\
&= \underbrace{\left( \widehat{RMP}_{U,s} \right)^{\frac{\epsilon-1}{\sigma-\epsilon}}}_{\text{Real market potential}} \times \underbrace{\left( \hat{c}_{U,s} \right)^{-\frac{\sigma(\epsilon-1)}{\sigma-\epsilon}}}_{\text{Input cost}} \times \underbrace{\sum_{n \neq U} \chi_{nU,s} \hat{X}_{n,s} \hat{P}_{n,s}^{\epsilon-1}}_{\text{Foreign demand}}. \tag{16}
\end{aligned}$$

In this expression, the change in real market potential is given by  $\widehat{RMP}_{U,s} = \sum_n \mu_{nU,s} \hat{X}_{n,s} \hat{P}_{n,s}^{\epsilon-1}$ , while  $\chi_{nU,s} = X_{nU,s}/EX_{U,s}$  denotes the initial share of country  $n$  in US exports. The real market potential effect exists only if there are scale economies in sector  $s$ . Import liberalization has a direct, negative, within sector effect on real market potential as shown in Section 2.3, together with an indirect general equilibrium effect due to changes in expenditure and price indices. With US GDP as the numeraire, the input cost effect exists only if there are input-output linkages between sectors. It operates both within and across sectors, with the balance depending upon the structure of input-output linkages. The foreign demand effect captures all other general equilibrium impacts of PNTR, including the aggregate link between imports and exports through the trade balance.<sup>28</sup> It is primarily a cross-sector effect.

The empirical results in Section 3 show that PNTR had an export destroying effect through reduced real market potential caused by greater Chinese import competition, and an export promoting effect through lower input costs. The decomposition in equation (16) allows us to quantify the magnitude of these channels in equilibrium and to evaluate changes in foreign demand due to PNTR, which are absorbed by importer-industry-period fixed effects in the empirical specification.

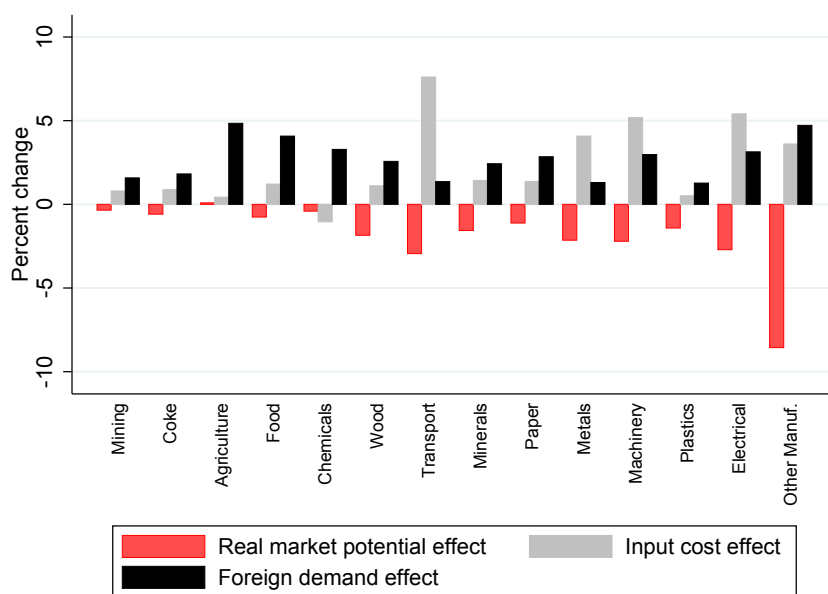
Figure 7 shows the export growth decomposition for goods sectors and Table 6 reports the contribution of each component by sector groups. The real market potential effect is negative in all but one sector and stronger in sectors with higher NTR gaps. This shows how import liberalization reduces real market potential within sectors. However, export destruction caused by this channel

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<sup>28</sup>When solving the model we hold constant each country's trade deficit as a share of global value-added, as discussed in Appendix D. This trade deficit constraint induces a positive relationship between import growth and export growth at the aggregate level.

is more than offset by export growth due to reduced input costs and higher foreign demand. The input cost effect is positively correlated with the NTR gap (due to the disproportionate weight on the diagonal of the input-output table), which dampens heterogeneity in sector-level export growth. It also explains why export growth is higher for medium NTR gap sectors than for low NTR gap sectors in Table 6.

Figure 7: Decomposition of export changes due to PNTR



Notes: Simulated percent changes in model with output elasticity of 0.835 for goods sectors and zero for services sectors. Decomposition of change in exports into real market potential effect, input cost effect and foreign demand effect defined in equation (16). Sectors ordered with NTR gap increasing from left to right. US GDP is the numeraire. Goods sectors only. Textiles and Leather not shown.

Growth in foreign demand results from the expansion of the global economy due to PNTR and is positive for all sectors, but uncorrelated with the NTR gap. Demand growth is particularly high in China, which is the main beneficiary of PNTR. The model implies that PNTR increased US exports to China by 43 percent. However, imports from China grew even faster, causing the bilateral US trade deficit with China to rise by 161 percent. The importance of the foreign demand effect illustrates the need to account for general equilibrium in trade policy analysis.

Panel B of Table 6 reports the impact of PNTR in a model without scale economies. In this case the model is an Armington economy and is equivalent for quantitative purposes to the Eaton

and Kortum (2002) style model used by Caliendo and Parro (2015) to study NAFTA and by Dhingra et al. (2017) to analyze Brexit. Comparing the panels of Table 6 shows that, in spite of the negative real market potential effect, aggregate US export growth is 1.1 percentage points greater in the calibration with scale economies. The difference arises primarily because scale economies strengthen the input cost effect, since sectoral expansion due to lower input costs boosts productivity through increased scale. This finding illustrates that the interaction between scale economies and input-output linkages is quantitatively important.

Scale economies also affect sector-level export growth. Without scale economies export growth is positive in all sectors and weakly positively correlated with the NTR gap because higher NTR gap sectors benefit more from the input cost effect. By contrast, with scale economies, there is more heterogeneity in export growth across sectors and growth is negatively correlated with the NTR gap. Thus, as with the sector-specific shocks analyzed in Figure 5, we find that the impact of import liberalization on sector-level exports is qualitatively different under scale economies. In particular, within-sector export destruction implies sectors that experience greater import liberalization have lower average export growth.

*Welfare.* Next we consider the effect of PNTR on welfare. Kucheryavyy et al. (2020) show that scale economies can boost the gains from trade liberalization by allowing for greater specialization according to comparative advantage. However, as proved originally by Venables (1987) and generalized by Kucheryavyy et al. (2020), import liberalization can also be welfare reducing if it reallocates resources to sectors with weaker scale economies. We find that PNTR did cause such a reallocation in the US, shifting production from goods sectors with positive scale economies to services sectors without scale economies. Table 6, panel A shows that goods output declined by 0.7 percent, while services output rose 0.1 percent.<sup>29</sup>

Welfare results are reported in Table 7. Overall, we find the US gains from PNTR as shown in panel A. We estimate PNTR increased US real expenditure by 0.10 percent and real income by 0.08 percent.<sup>30</sup> For comparison, Caliendo and Parro (2015) find NAFTA increased US welfare by

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<sup>29</sup>Note that, for our choice of numeraire, employment changes equal output changes at the sector level in the US.

<sup>30</sup>Income and expenditure differ because trade is not balanced as explained in footnote 28. As is standard in

0.08 percent, while Fajgelbaum et al. (2020) estimate that the US-China trade war initiated by President Trump reduced US real income by 0.04 percent.

US gains from PNTR are smaller in the calibrated model than if there are no scale economies (see Table 7, panel B). To understand why, we follow Costinot and Rodríguez-Clare (2014) and decompose gains in real income  $M_i$  into the ACR effect resulting from changes in the share of expenditure on domestic goods (Arkolakis et al. 2012) and a specialization effect due to scale economies:

$$\hat{M}_i = \underbrace{\prod_{s,v} \left( \hat{\lambda}_{ii,v} \right)^{-\frac{\beta_{i,s} \tilde{\gamma}_{i,sv}}{\epsilon_v - 1}}}_{\text{ACR}} \underbrace{\prod_{s,v} \left( \hat{L}_{i,v} \right)^{\frac{\beta_{i,s} \tilde{\gamma}_{i,sv}}{\sigma_v - 1}}}_{\text{Specialization}},$$

where  $\tilde{\gamma}_{i,sv}$  denotes the elements of  $(I - A)^{-1}$  with  $I$  the  $S \times S$  identity matrix and  $A$  an adjusted input-output matrix with typical element  $\frac{\sigma_s}{\sigma_s - 1} \gamma_{i,sv}$ .

The ACR term in this decomposition takes the same form as in economies without scale effects, although  $\hat{\lambda}_{ii,s}$  will in general differ across models. The specialization term only exists because of scale effects and captures the welfare effect of changes in industry productivity due to reallocation of employment across sectors. The specialization effect is positive when employment growth is concentrated in sectors with strong scale effects and large forward linkages to the rest of the economy (i.e. high values of the adjusted Leontief inverse coefficients  $\tilde{\gamma}_{i,sv}$ ).

Table 7 shows that the ACR effect raises US real income by 0.31 percent with scale economies, but only 0.10 percent without, implying that scale economies magnify the impact of PNTR on openness. However, the additional gains from this channel are more than offset by a negative 0.23 percent specialization effect caused by the reallocation of employment across sectors. Consequently, scale economies reduce total US gains from PNTR.<sup>31</sup>

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quantitative trade policy analysis our model features constant mark-ups and full employment. Consequently, the welfare estimates do not allow for any pro-competitive effects of PNTR (Jaravel and Sager 2020, Amity et al. 2020) or any impact of import competition on employment levels (Autor et al. 2013). We also follow the literature in assuming that, conditional on its observed effect on US imports from China, PNTR is equivalent to a decline in iceberg trade costs.

<sup>31</sup>Although we find US gains from PNTR are positive, the specialization effect can result in negative gains from liberalization in our calibrated model. The simulated local elasticities of both real income and real expenditure to

We find that Chinese gains from PNTR are around six times greater than US gains (see Table 7, panel A). This difference reflects the fact that the US economy was much larger than the Chinese economy in 2000, meaning PNTR was a bigger shock to China than the US. In addition, China's nominal wage relative to the US rose by 6.1 percent, implying PNTR made a notable contribution to international factor price convergence. The rest of the world also benefits from increased trade, although the impact is smaller than for the US or China.

As for the US, China's gains from PNTR are smaller with scale economies than without. Scale economies magnify China's gains from the ACR effect, but also generate a substantial negative specialization effect even though goods output in China increases relative to services output. The specialization effect is negative because PNTR shifts resources out of goods sectors with high forward linkages. In particular, production declines in the Electrical and Metals sectors are the biggest contributors. This highlights the role input-output linkages play in shaping welfare effects when there are scale economies.

*Alternative calibrations.* Appendix D provides further insight into the properties of the calibrated economy by analyzing how the simulated impact of PNTR changes under alternative calibrations. A few findings stand out.

First, using a model without input-output linkages weakens the real market potential effect and reduces cross-sectoral heterogeneity in export growth. Consequently, the simulated NTR gap effect is smaller and there is less reallocation of production from goods to services. This finding confirms the importance of the interaction between input-output linkages and scale economies in explaining the quantitative results. Second, allowing for scale economies in services sectors has little effect on the results. Moreover, cross-sectoral heterogeneity in scale economies makes a quantitatively negligible contribution to the negative specialization effect for the US obtained in the baseline calibration. Instead, the interaction of scale economies with input-output linkages is again responsible.

Third, the baseline results are robust to combining the Textiles and Leather sector with Other

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a sector-specific increase in US openness to Chinese imports are negative for four sectors (Food, Wood, Coke and Transport).

Manufacturing. This reaggregation shows that the results are not solely driven by the sharp contraction in the Textiles and Leather sector in the baseline simulation. Finally, the impact of PNTR on US exports relative to GDP and welfare remains positive when we calibrate the model using trade and output elasticities that vary across sectors from Bartelme et al. (2019). However, the sectoral heterogeneity reduces the simulated NTR gap effect below its estimated value.

## 5 Concluding comments

The introduction posed three questions for this paper to address. First, all else equal, does import liberalization destroy exports within industries? Studying US export growth after PNTR, we find evidence of lower export growth in industries more exposed to increased import competition from China. This finding provides novel evidence establishing the existence of a channel connecting import protection to export performance as hypothesized by Krugman (1984), and implies the existence of scale economies in US goods production.

Second, what is the net effect of liberalization on industry exports in equilibrium? Our empirical results show that PNTR boosted exports by reducing input costs and that export growth from this channel is comparable in magnitude to the direct negative effect of greater import competition. Quantifying the impact of PNTR in a trade model with scale economies, we find that PNTR increased aggregate US exports relative to GDP because the combination of lower input costs and greater foreign demand more than offset export destruction from greater import competition. The interaction between scale economies and input-output linkages is quantitatively important in explaining these changes. At the sector level, PNTR increased exports in most sectors, but not in those with the highest NTR gaps. We also show that liberalizing imports in a single sector generally reduces that sector's exports. It follows that targeted import protection can be used to promote sector-level (although not aggregate) exports.

Third, how did import liberalization resulting from PNTR affect welfare? The quantitative analysis shows that the US and China both gain from PNTR, although as the smaller economy

China gains more. In both cases, welfare effects are positive because the gains from greater trade openness more than offset a negative specialization effect resulting from the existence of scale economies.

Our results provide new evidence to inform the policy debate on import protection. The implications are nuanced and underline the importance of accounting for all general equilibrium effects when evaluating trade policy. On the one hand, the findings support the existence of the scale economies channel that has traditionally been used to rationalize demands for protection. And they imply that import protection prior to PNTR shifted US comparative advantage towards the most protected industries. On the other hand, we find that the export destruction effect of PNTR is dominated at the aggregate level by channels that promote exports. Similarly, although scale economies generate a negative specialization effect that reduces US gains from PNTR, it is more than offset by traditional gains from trade.

The analysis in this paper considers a single liberalization episode. However, the empirical methodology we develop to test the export destruction mechanism could be applied to other bilateral trade policy shocks. We hope that future applications of this approach will shed further light on the extent to which scale economies and trade in inputs shape the effects of import protection.

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Table 1: Industry-level descriptive statistics

Panel A: Summary statistics						
	Mean	Median	Std. dev.	Min.	Max.	Observations
NTRGap	0.23	0.26	0.12	0	0.59	444
CostShock	-0.08	-0.08	0.04	-0.17	0.00	444
Input Intensity	0.50	0.49	0.12	0.19	0.85	384
Skill Intensity	0.28	0.26	0.11	0.05	0.69	384
Capital Intensity	4.31	4.25	0.87	2.31	7.27	384
Panel B: Correlations						
	NTRGap	CostShock	Input Intensity	Skill Intensity		
NTRGap						
CostShock	-0.52					
Input Intensity	-0.30	-0.19				
Skill Intensity	-0.06	0.06	-0.21			
Capital Intensity	-0.47	0.40	0.18	0.21		

Notes: NAICS goods industries. Input, skill and capital intensity for manufacturing industries in 1995 calculated from NBER manufacturing database.

Table 2: PNTR and US export growth, reduced form estimates

Dependent variable	$\Delta \text{ Log Exports}$							
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Post x US x NTRGap	-0.094 (0.020)	-0.23 (0.040)	-0.29 (0.045)	-0.25 (0.049)	-0.12 (0.045)	-0.25 (0.045)	-0.21 (0.055)	-0.10 (0.045)
Post x US x CostShock			-0.44 (0.14)	-0.53 (0.14)	-0.16 (0.14)	-0.44 (0.13)	-0.65 (0.14)	-0.32 (0.14)
Post x US x Input Intensity					0.27 (0.037)			0.19 (0.038)
Post x US x Skill Intensity						-0.24 (0.039)		-0.22 (0.037)
Post x US x Capital Intensity							0.017 (0.0065)	0.019 (0.0062)
Fixed effects								
Exporter-industry-importer	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-exporter-period	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-industry-period	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry sample	Goods	Goods	Goods	Manuf.	Manuf.	Manuf.	Manuf.	Manuf.
Observations	1,069,951	1,069,951	1,069,951	1,010,551	1,010,551	1,010,551	1,010,551	1,010,551
R-squared	0.25	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Notes: OLS estimates. Standard errors clustered by exporter-industry in parentheses. Estimated in long differences using 1995-2000 as pre-PNTR period and 2000-07 as post-PNTR period. Industry sample covers 444 NAICS goods industries in columns (a)-(c) and 384 NAICS manufacturing industries in columns (d)-(h). Country sample includes countries with population above one million in 1995 and requires exporters to be OECD members at start of 1995. Input, skill and capital intensity for US industries in 1995 calculated from NBER manufacturing database.

Table 3: PNTR and US export growth, robustness checks

Dependent variable	Export growth					
	PNTR in 2001 (a)	Pierce- Schott NTR gap (b)	Handley- Limão NTR gap (c)	PPML (d)	Total exports OLS (e)	Total exports PPML (f)
Post x US x NTRGap	-0.11 (0.047)	-0.053 (0.032)	-0.084 (0.031)	-0.087 (0.033)	-0.15 (0.060)	-0.10 (0.049)
Post x US x CostShock	-0.35 (0.15)	-0.27 (0.11)	-0.18 (0.077)	-0.44 (0.16)	0.020 (0.24)	-0.098 (0.27)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry controls	Yes	Yes	Yes	Yes	Yes	Yes
Aggregation of exports	Bilateral	Bilateral	Bilateral	Bilateral	Total	Total
Estimator	OLS	OLS	OLS	PPML	OLS	PPML
Observations	1,019,305	1,010,551	1,010,551	1,010,551	17,573	17,573
R-squared	0.50	0.50	0.50	0.02	0.63	0.01

Notes: Standard errors clustered by exporter-industry in parentheses. Estimated using 1995-2000 as pre-PNTR period and 2000-07 as post-PNTR period, except column (a) where pre-period is 1995-2001 and post-period is 2001-07. Industry sample covers 384 NAICS manufacturing industries. Country sample includes countries with population above one million in 1995 and requires exporters to be OECD members at start of 1995. The NTR gap is defined as the log difference between the US Non-NTR and NTR tariffs, except in column (b) where the difference in levels is used as in Pierce and Schott (2016) and column (c) where the NTR gap is defined following Handley and Limão (2017). All columns include triple interactions of a post-period dummy, a US exporter dummy and the input, skill and capital intensity of US industries in 1995 calculated from NBER manufacturing database. All columns except (e) and (f) include exporter-industry-importer, importer-exporter-period and importer-industry-period fixed effects. For columns (e) and (f) the dependent variable is based on total exports to all destinations and these columns include exporter-industry, exporter-period and industry-period fixed effects.

Table 4: Instrumental variable estimates of output elasticity

Dependent variable	$\Delta$ Log Exports				
	(a)	(b)	(c)	(d)	(e)
US x $\Delta$ Log Output	0.66 (0.20)	1.10 (0.29)	0.78 (0.45)	1.33 (0.32)	1.27 (0.62)
Post x US x CostShock		-1.20 (0.30)	-0.74 (0.33)	-1.29 (0.33)	-0.98 (0.46)
	First Stage				
Post x US x NTRGap	-0.30 (0.048)	-0.23 (0.044)	-0.13 (0.051)	-0.24 (0.045)	-0.13 (0.054)
Kleibergen-Paap F-statistic	37.6	27.8	6.6	26.8	5.9
Fixed effects	Yes	Yes	Yes	Yes	Yes
Industry controls	No	No	Yes	No	Yes
Exporter sample	OECD	OECD	OECD	US	US
Observations	1,011,530	1,011,530	1,010,551	69,054	69,003

Notes: Instrumental variable estimates with US x  $\Delta$  Log Output instrumented by Post x US x NTR Gap. Standard errors clustered by exporter-industry in parentheses. Estimated in long differences using 1995-2000 as pre-PNTR period and 2000-07 as post-PNTR period. Industry sample covers 384 NAICS manufacturing industries. Importer sample includes countries with population above one million in 1995. Exporter sample in columns (a)-(c) includes OECD members at start of 1995 with population above one million. Columns (d) and (e) restricted to US as only exporter. Industry controls are triple interactions of a post-period dummy, a US exporter dummy and the input, skill and capital intensity for US industries in 1995 calculated from NBER manufacturing database. Columns (a)-(c) include exporter-industry-importer, importer-exporter-period and importer-industry-period fixed effects. Columns (d) and (e) include importer-period and importer-industry fixed effects.

Table 5: PNTR and US imports from China

Dependent variable	$\Delta$ Log Trade				
	(a)	(b)	(c)	(d)	(e)
Post x US Importer x China Exporter x NTRGap	0.43 (0.13)	0.41 (0.14)	0.33 (0.14)	0.39 (0.15)	0.54 (0.40)
Post x US Importer x China Exporter x NTRGap Squared					-0.24 (0.80)
Fixed effects					
Exporter-industry-importer	Yes	Yes	Yes	Yes	Yes
Importer-exporter-period	Yes	Yes	Yes	Yes	Yes
Importer-industry-period	Yes	Yes	Yes	Yes	Yes
Exporter-industry-period	Yes	Yes	Yes	Yes	Yes
Industry sample	Goods	Goods	Goods	Manuf.	Goods
Importer sample	OECD	OECD	All	OECD	OECD
Exporter sample	All	Non-OECD	All	All	All
Observations	670,445	929,615	1,913,939	616,724	670,445
R-squared	0.55	0.59	0.53	0.55	0.55

Notes: OLS estimates. Standard errors clustered by importer-industry in parentheses. Bilateral trade. Estimated in long differences using 1995-2000 as pre-PNTR period and 2000-07 as post-PNTR period. Industry sample covers 444 NAICS goods industries in columns (a)-(c) and (e) and 385 NAICS manufacturing industries in column (d). Importer and exporter samples exclude countries with population below one million in 1995. OECD membership status defined at start of 1995.

Table 6: Impact of PNTR on US exports and output in general equilibrium (percent changes)

	NTR gap group					
	Low	Medium	High	Goods	Services	Total
Panel A: Calibrated model						
Exports	4.1	4.5	1.9	3.5	3.9	3.6
<i>of which: Real market potential effect</i>	-0.4	-2.0	-6.3	-3.4	<i>n/a</i>	-2.3
<i>Input cost effect</i>	0.9	4.3	5.5	4.4	0.1	3.0
<i>Foreign demand effect</i>	3.7	2.3	3.3	2.8	3.8	3.1
Revealed comparative advantage	1.4	2.0	-5.1	-0.7	2.5	n/a
Output	0.3	1.2	-6.1	-0.7	0.1	-0.1
Panel B: No scale economies						
Exports	2.5	2.3	3.2	2.6	2.1	2.5
<i>of which: Real market potential effect</i>	<i>n/a</i>	<i>n/a</i>	<i>n/a</i>	<i>n/a</i>	<i>n/a</i>	<i>n/a</i>
<i>Input cost effect</i>	0.1	0.6	1.2	0.7	0.1	0.5
<i>Foreign demand effect</i>	2.4	1.7	2.0	1.9	2.0	1.9
Revealed comparative advantage	0.4	-0.1	-0.3	-0.1	0.6	n/a
Output	0.3	0.1	-2.2	-0.4	0.1	0.0

Notes: Simulated percent changes. Panel A: output elasticity of 0.835 for goods sectors and zero for services sectors. Panel B: output elasticity zero in all sectors. US GDP is the numeraire. Exports and exports decomposition changes averaged across sectors using pre-PNTR US export shares as weights. Output changes averaged across sectors using pre-PNTR US output shares as weights. Goods sectors divided into groups with low, medium and high NTR gaps. Low group includes goods sectors with NTR gap below 0.2. Medium group includes sectors with NTR gap between 0.2 and 0.3. High group includes sectors with NTR gap above 0.3.

Table 7: Welfare effects of PNTR (percent changes)

	Real expenditure	Total	Real income <i>ACR effect</i>	<i>Specialization effect</i>	Nominal wage relative to US
Panel A: Calibrated model					
US	0.10	0.08	<i>0.31</i>	<i>-0.23</i>	n/a
China	0.66	0.47	<i>3.20</i>	<i>-2.65</i>	6.1
Rest of world	0.04	0.04	<i>0.04</i>	<i>-0.01</i>	0.6
Panel B: No scale economies					
US	0.11	0.10	<i>0.10</i>	<i>n/a</i>	n/a
China	0.72	0.59	<i>0.59</i>	<i>n/a</i>	3.9
Rest of world	-0.01	-0.01	<i>-0.01</i>	<i>n/a</i>	0.3

Notes: Simulated percent changes. Panel A: output elasticity of 0.835 for goods sectors and zero for services sectors. Panel B: output elasticity zero in all sectors. Rest of world results averaged across countries using pre-PNTR GDP shares as weights.

# Appendix

## A Proofs and derivations

### Derivation of equation (8)

Substituting the free entry condition (4) into equation (3) yields:

$$P_{nj,s} = \frac{\sigma}{\sigma - 1} \sigma^{\frac{1}{\sigma-1}} \frac{\varphi_{nj,s}^{\frac{1}{1-\epsilon}}}{T_{j,s}} \left( \frac{c_{j,s}^\sigma f_{j,s}}{Y_{j,s}} \right)^{\frac{1}{\sigma-1}}.$$

Next, substituting this expression into  $P_{n,s} = \left( \sum_j P_{nj,s}^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}}$  gives:

$$P_{n,s} = \frac{\sigma}{\sigma - 1} \sigma^{\frac{1}{\sigma-1}} \left[ \sum_j \frac{\varphi_{nj,s}}{T_{j,s}^{1-\epsilon}} \left( \frac{c_{j,s}^\sigma f_{j,s}}{Y_{j,s}} \right)^{\frac{1-\epsilon}{\sigma-1}} \right]^{\frac{1}{1-\epsilon}}. \quad (17)$$

Differentiating this expression with  $n = U$  while holding all trade costs other than  $\varphi_{UC,s}$  constant gives equation (8).

### Derivation of equation (9)

Differentiating (6) with  $i = U$  gives:

$$\begin{aligned} d \log Y_{U,s} &= -\frac{\sigma(\epsilon - 1)}{\sigma - \epsilon} d \log c_{U,s} + \frac{\sigma - 1}{\sigma - \epsilon} \mu_{UU,s} (d \log X_{U,s} + (\epsilon - 1) d \log P_{U,s}) \\ &\quad + \frac{\sigma - 1}{\sigma - \epsilon} \sum_{j \neq U} \mu_{jU,s} (d \log X_{j,s} + (\epsilon - 1) d \log P_{j,s}). \end{aligned}$$

Substituting equation (8) into this expression then yields:

$$\begin{aligned} d \log Y_{U,s} &= \frac{1}{\frac{\sigma-1}{\epsilon-1} - 1 + \lambda_{UU,s} \mu_{UU,s}} \left\{ -\frac{\sigma-1}{\epsilon-1} \lambda_{UC,s} \mu_{UU,s} d \log \varphi_{UC,s} - \sigma (1 - \lambda_{UU,s} \mu_{UU,s}) d \log c_{U,s} \right. \\ &\quad + \frac{\sigma-1}{\epsilon-1} \mu_{UU,s} d \log X_{U,s} + \frac{\sigma-1}{\epsilon-1} \sum_{j \neq U} \mu_{jU,s} (d \log X_{j,s} + (\epsilon-1) d \log P_{j,s}) \\ &\quad \left. + \sum_{j \neq U} \lambda_{Uj,s} \mu_{UU,s} (\sigma d \log c_{j,s} - d \log Y_{j,s}) \right\}, \end{aligned}$$

which gives equation (9) in the main text. Note that for a small country the final two terms,

which only depend on changes in foreign variables, are zero. In addition, when firms do not use intermediate inputs, equation (2) gives  $c_{i,s} = w_i$  and, since only consumers demand non-tradable output, we have  $X_{i,s} = \beta_{i,s} w_i L_i$ . Therefore,  $d \log c_{i,s} = d \log X_{i,s} = d \log w_i$ .

## Proof of Proposition 2

Differentiating the bilateral trade equation (5) and using equation (9), while holding domestic input costs, domestic expenditure and all foreign variables constant, gives that for all destinations  $n$ :

$$\frac{\partial \log X_{nU,s}}{\partial \log \varphi_{UC,s}} = - \frac{\lambda_{UC,s} \mu_{UU,s}}{\frac{\sigma-1}{\epsilon-1} - 1 + \lambda_{UU,s} \mu_{UU,s}},$$

which (in absolute terms) is decreasing in  $\sigma$ , increasing in  $\epsilon$  and increasing in the output elasticity  $\frac{\epsilon-1}{\sigma-1}$ .

## Equilibrium conditions

Labor is the only primary factor of production. Therefore, labor market clearing implies that labor income equals the sum of value-added in all sectors:

$$w_i L_i = \sum_s \gamma_{i,s} Y_{i,s}. \quad (18)$$

Consumer expenditure in country  $i$  is the sum of labor income and the trade deficit  $D_i$ , which we treat as being exogenously determined with  $\sum_i D_i = 0$ . Since total expenditure by country  $i$  on sector  $s$  output is the sum of consumer expenditure and intermediate input expenditure we have:

$$X_{i,s} = \beta_{i,s} (w_i L_i + D_i) + \sum_v \gamma_{i,vs} Y_{i,v}. \quad (19)$$

Equations (2), (6), (17), (18) and (19) form a system of  $N + 4NS$  equations in the set of wages  $w_i$ , expenditure levels  $X_{i,s}$ , output levels  $Y_{i,s}$ , price indices  $P_{i,s}$  and input costs  $c_{i,s}$ . We define an equilibrium as a solution to this set of equations.<sup>32</sup>

## Alternative models with scale economies

The baseline model in Section 2 is a generalization of the Krugman (1980) homogeneous firms model in which scale economies result from love of variety. To obtain Propositions 1 and 2, we used the bilateral trade equation (5) together with the equilibrium conditions (6) for output and

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<sup>32</sup>If  $\sigma = \epsilon$ , equation (6) is not well-defined and is replaced by:  $1 = \Gamma_0 \frac{T_{i,s}^{\epsilon-1}}{c_{i,s}^\sigma f_{i,s}} \sum_n \varphi_{ni,s} X_{n,s} P_{n,s}^{\epsilon-1}$ .

(17) for the price index. We now show that equilibrium conditions equivalent to equations (5), (6) and (17) hold in three alternative scale economies models featuring: (i) external economies of scale; (ii) endogenous technology investment, or; (iii) heterogeneous firms. It follows that the mechanism through which import liberalization reduces exports by lowering real market potential exists in each of these models of trade with scale economies.

(i) *External economies.* Suppose the economy is as described in Section 2.1 except that varieties from the same country are perfect substitutes (i.e.  $\sigma \rightarrow \infty$ ) and that there are sector-level external economies of scale in production. In particular, assume the marginal cost of production in country  $i$  and sector  $s$  is  $\frac{c_{i,s}}{T_{i,s}} \left( \frac{w_i L_{i,s}}{\gamma_{i,s} c_{i,s}} \right)^{-\psi}$  where  $L_{i,s}$  denotes employment in sector  $s$  in country  $i$  and  $\psi$  determines the degree of external economies of scale.<sup>33</sup> We assume  $0 < \psi < 1/(\epsilon - 1)$ . Firms take sector-level employment as given when making production decisions.

Since sector-level profits are zero, labor market clearing requires  $w_i L_{i,s} = \gamma_{i,s} Y_{i,s}$ . Using this expression, following the same steps required to solve the baseline model, and letting  $\sigma \rightarrow \infty$  gives the bilateral trade equation:

$$X_{ni,s} = \Gamma_0 \varphi_{ni,s} T_{i,s}^{\epsilon-1} \left( \frac{Y_{i,s}}{\frac{c_{i,s}}{\gamma_{i,s}^\psi}} \right)^{\psi(\epsilon-1)} X_{n,s} P_{n,s}^{\epsilon-1}.$$

Summing sales across destinations then implies that equilibrium output satisfies:

$$Y_{i,s} = \Gamma_0^{\frac{1}{1-\psi(\epsilon-1)}} T_{i,s}^{\frac{\epsilon-1}{1-\psi(\epsilon-1)}} c_{i,s}^{-\frac{(1+\psi)(\epsilon-1)}{1-\psi(\epsilon-1)}} \left( \sum_n \varphi_{ni,s} X_{n,s} P_{n,s}^{\epsilon-1} \right)^{\frac{1}{1-\psi(\epsilon-1)}},$$

and solving for the sectoral price index yields:

$$P_{n,s} = \left[ \sum_j \frac{\varphi_{nj,s}}{T_{j,s}^{1-\epsilon}} \left( \frac{c_{j,s}}{Y_{j,s}} \right)^{\psi(1-\epsilon)} \right]^{\frac{1}{1-\epsilon}}.$$

Inspection of these equations shows that they are equivalent to equations (5), (6) and (17) in the baseline model (in terms of their dependence on endogenous variables) except that the scale elasticity equals  $\psi$  instead of  $\frac{1}{\sigma-1}$ .

It is also worth noting that with external economies of scale equations (2), (18) and (19) are unchanged from the baseline model. It follows that the external economies model is equivalent to

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<sup>33</sup> Assuming the marginal cost depends upon  $(w_i/\gamma_{i,s} c_{i,s})^\psi$  in addition to employment  $L_{i,s}$  is a normalization that ensures all sectoral equilibrium conditions are equivalent to the baseline model even when production uses intermediate inputs. Without this normalization, the equations for  $X_{ni,s}$ ,  $Y_{i,s}$  and  $P_{n,s}$  in the external economies model would include additional terms in  $\gamma_{i,s} c_{i,s}/w_i$ . These terms would affect counterfactual quantitative analysis, but not the qualitative impact of import liberalization on exports.

the baseline model for quantitative purposes.

(ii) *Endogenous technology investment.* Suppose the economy is as described in Section 2.1, except that the mass of varieties  $N_{i,s}$  is exogenous and each firm makes a technology investment before producing that determines its productivity. To obtain productivity  $z$ , the firm must invest  $z^\xi$  units of the country  $i$  sector  $s$  input good at cost  $c_{i,s}z^\xi$ . The parameter  $\xi$  determines the convexity of technology investment costs and we assume  $\xi > \sigma - 1 \geq \epsilon - 1$ . The marginal production cost of a firm with productivity  $z$  is  $c_{i,s}/(zT_{i,s})$ .

Solving this model implies that the equilibrium productivity  $z_{i,s}$  of producers in country  $i$  and sector  $s$  is given by:

$$z_{i,s} = \left[ \frac{1}{\xi} \left( \frac{\sigma - 1}{\sigma} \right)^\epsilon N_{i,s}^{-\frac{\sigma-\epsilon}{\sigma-1}} \frac{T_{i,s}^{\epsilon-1}}{c_{i,s}^\epsilon} \right]^{\frac{1}{\xi-(\epsilon-1)}} \left( \sum_n \varphi_{ni,s} X_{n,s} P_{n,s}^{\epsilon-1} \right)^{\frac{1}{\xi-(\epsilon-1)}}.$$

Thus, productivity is increasing in real market potential and decreasing in the unit input cost  $c_{i,s}$ . Given this expression for  $z_{i,s}$  it can be shown that:

$$\begin{aligned} X_{ni,s} &= \Gamma_1 \varphi_{ni,s} N_{i,s}^{\frac{\xi-(\sigma-1)}{\xi} \frac{\epsilon-1}{\sigma-1}} T_{i,s}^{\epsilon-1} \left( \frac{Y_{i,s}}{c_{i,s}^{1+\xi}} \right)^{\frac{\epsilon-1}{\xi}} X_{n,s} P_{n,s}^{\epsilon-1}, \\ Y_{i,s} &= \Gamma_1^{\frac{\xi}{\xi-(\epsilon-1)}} N_{i,s}^{\frac{\xi-(\sigma-1)}{\xi-(\epsilon-1)} \frac{\epsilon-1}{\sigma-1}} T_{i,s}^{\frac{\xi(\epsilon-1)}{\xi-(\epsilon-1)}} c_{i,s}^{-\frac{(1+\xi)(\epsilon-1)}{\xi-(\epsilon-1)}} \left( \sum_n \varphi_{ni,s} X_{n,s} P_{n,s}^{\epsilon-1} \right)^{\frac{\xi}{\xi-(\epsilon-1)}}, \\ P_{n,s} &= \xi^{\frac{1}{\xi}} \left( \frac{\sigma}{\sigma-1} \right)^{\frac{1+\xi}{\xi}} \left[ \sum_j \frac{\varphi_{nj,s}}{T_{j,s}^{1-\epsilon}} N_{j,s}^{\frac{\xi-(\sigma-1)}{\xi} \frac{\epsilon-1}{\sigma-1}} \left( \frac{c_{j,s}^{1+\xi}}{Y_{j,s}} \right)^{\frac{1-\epsilon}{\xi}} \right]^{\frac{1}{1-\epsilon}}, \end{aligned}$$

where  $\Gamma_1 \equiv \left( \frac{1}{\xi} \right)^{\frac{\epsilon-1}{\xi}} \left( \frac{\sigma-1}{\sigma} \right)^{\frac{(1+\xi)(\epsilon-1)}{\xi}}$ . Inspection of these equations shows they are equivalent to those in the baseline model except that the scale elasticity equals  $\frac{1}{\xi}$ . Thus, with endogenous technology investment the strength of scale economies is decreasing in the convexity of technology investment costs.

Since there is no entry, sector-level profits are positive and enter the labor market clearing condition (18) and the expenditure equation (19). Consequently, the model's quantitative implications are not identical to the baseline model. However, this difference disappears if entry is permitted. In a model featuring both free entry and endogenous technology investment, all adjustment to trade shocks occurs on the extensive margin of entry, profits net of entry costs are zero, and the scale elasticity again equals  $\frac{1}{\sigma-1}$ .

(iii) *Heterogeneous firms.* Suppose we modify the baseline model in Section 2.1 to allow for

firm heterogeneity following Melitz (2003). Assume that after paying the entry cost  $f_{i,s}c_{i,s}$  a firm draws its productivity  $z$  from a Pareto distribution with scale parameter one and shape parameter  $k$ . The marginal production cost of a firm with productivity  $z$  is  $c_{i,s}/(zT_{i,s})$ . Firms in country  $i$  and sector  $s$  must also pay a fixed cost  $\tilde{f}_{ni,s}^x$  to enter market  $n$ . We assume  $k > \sigma - 1 > \epsilon - 1$ .

We can solve this model in the usual way. In this case it is convenient to define the real market potential of country  $i$  in sector  $s$  as:

$$RMP_{i,s} = \sum_n \left[ \left( \tilde{f}_{ni,s}^x \right)^{-\frac{(\epsilon-1)(k+1-\sigma)}{k(\sigma-1)}} \tau_{ni,s}^{1-\epsilon} X_{n,s} P_{n,s}^{\epsilon-1} \right]^{\frac{k(\sigma-1)}{k(\sigma-\epsilon)+(\epsilon-1)(\sigma-1)}}.$$

Then bilateral trade, output and the price index are given by:

$$\begin{aligned} X_{ni,s} &= \Gamma_2 \left( \frac{T_{i,s} Y_{i,s}^{\frac{1}{k}}}{c_{i,s}^{\frac{1+k}{k}} f_{i,s}^{\frac{1}{k}}} \right)^{\frac{k(\epsilon-1)(\sigma-1)}{k(\sigma-\epsilon)+(\epsilon-1)(\sigma-1)}} \left[ \left( \tilde{f}_{ni,s}^x \right)^{-\frac{(\epsilon-1)(k+1-\sigma)}{k(\sigma-1)}} \tau_{ni,s}^{1-\epsilon} X_{n,s} P_{n,s}^{\epsilon-1} \right]^{\frac{k(\sigma-1)}{k(\sigma-\epsilon)+(\epsilon-1)(\sigma-1)}}, \\ Y_{i,s} &= \Gamma_2^{\frac{k(\sigma-\epsilon)+(\epsilon-1)(\sigma-1)}{k(\sigma-\epsilon)}} \left( \frac{T_{i,s}}{c_{i,s}^{\frac{1+k}{k}} f_{i,s}^{\frac{1}{k}}} \right)^{\frac{(\epsilon-1)(\sigma-1)}{\sigma-\epsilon}} RMP_{i,s}^{\frac{k(\sigma-\epsilon)+(\epsilon-1)(\sigma-1)}{k(\sigma-\epsilon)}}, \\ P_{n,s} &= (\sigma-1)^{\frac{k+1-\sigma}{k(\sigma-1)}} \left( \frac{\sigma}{\sigma-1} \right)^{\frac{\sigma}{\sigma-1}} (k+1-\sigma)^{\frac{1}{k}} \\ &\quad \times \left\{ \sum_j \left[ \frac{\tau_{nj,s}}{T_{j,s}} \frac{c_{j,s}^{\frac{1+k}{k}} f_{j,s}^{\frac{1}{k}}}{Y_{j,s}^{\frac{1}{k}}} \left( \frac{\tilde{f}_{ni,s}^x}{X_{n,s}} \right)^{\frac{k+1-\sigma}{k(\sigma-1)}} \right]^{\frac{k(1-\epsilon)(\sigma-1)}{k(\sigma-\epsilon)+(\epsilon-1)(\sigma-1)}} \right\}^{\frac{k(\sigma-\epsilon)+(\epsilon-1)(\sigma-1)}{k(1-\epsilon)(\sigma-1)}}, \end{aligned}$$

where:

$$\Gamma_2 \equiv \left[ \left( \frac{1}{\sigma-1} \right)^{k(\epsilon-1)} \left( \frac{\sigma-1}{\sigma} \right)^{k\sigma(\epsilon-1)} \left( \frac{\sigma-1}{k+1-\sigma} \right)^{(\epsilon-1)(\sigma-1)} \right]^{\frac{1}{k(\sigma-\epsilon)+(\epsilon-1)(\sigma-1)}}.$$

These expressions are more complex than the corresponding equations in the models considered above. They also depend upon the form taken by the fixed market entry cost  $\tilde{f}_{ni,s}^x$ , which we have not specified. However, note that the equation for  $X_{ni,s}$  implies that in this model the trade elasticity is  $\frac{k(\epsilon-1)(\sigma-1)}{k(\sigma-\epsilon)+(\epsilon-1)(\sigma-1)}$ , while the scale elasticity equals the inverse Pareto shape parameter  $\frac{1}{k}$ . It is straightforward to check that when written in terms of the trade elasticity and the scale elasticity, the dependence of  $X_{ni,s}$ ,  $Y_{i,s}$  and  $P_{n,s}$  on bilateral trade costs  $\tau_{ni,s}$ , output  $Y_{i,s}$  and the input cost  $c_{i,s}$  is the same as in the previous models. Therefore, conditional on foreign outcomes

and domestic input costs, expenditure and market entry costs, import liberalization reduces exports by lowering real market potential.

## B Data

### Estimation data

Bilateral trade data for 1995-2017 at the 6 digit level of the Harmonised System (HS) 1992 classification is from the CEPII BACI database. We aggregate the trade data to NAICS industries at approximately the 6 digit level using a concordance from Pierce and Schott (2012). The concordance maps Schedule B US export codes, which are 10 digit extensions of HS codes, to NAICS industries. We use the 1995 concordance and allocate each 6 digit trade flow across industries using the share of 10 digit codes with that 6 digit base that map to each NAICS industry. For 94 percent of 6 digit codes, all 10 digit products map to the same NAICS industry.

We calculate the NTR gap using tariff rates on 8 digit US imports from Feenstra et al. (2002). To obtain NTR gaps by NAICS industry, we use a concordance from 10 digit US Harmonized Tariff System import codes to NAICS industries from Pierce and Schott (2012). We calculate the NTR gap for each NAICS industry as a weighted average of NTR gaps at the 8 digit level, where the weights are given by the share of 10 digit codes within the 8 digit group that map to the NAICS industry. In our analysis the tariffs and concordance are for 1999, but using data for other years before 2000 makes little difference to the results.

The CostShock variable is constructed from the 1997 US input-output accounts. We start by mapping the NTR gap from NAICS industries to input-output industries using a Bureau of Economic Analysis concordance. The mapping is one-to-one for most industries and we take the simple average across industries in cases with many-to-one mappings. We then calibrate the input-output coefficients  $\gamma_{U,sv}$  from the Use Table as the ratio of expenditure on industry  $v$  inputs by industry  $s$  to the output of industry  $s$  and calculate CostShock for input-output industries. Finally, we map CostShock back to NAICS industries.

From the NBER manufacturing database, we obtain the annual output (value of shipments) of each NAICS manufacturing industry and calculate measures of industry level input, skill and capital intensity in 1995. Input intensity is defined as one minus the ratio of value-added to output. Skill intensity is defined as the share of non-production workers in employment and capital intensity is defined as the log capital stock per worker. Population data is taken from the CEPII gravity dataset.

## C Empirical analysis

### Reduced form robustness

Tables A1 and A2 report additional robustness checks on the baseline reduced form results from Table 2. Except noted otherwise, the specification and sample are the same as in column (h) of Table 2.

In column (a) of Table A1 we omit all exporters other than the US. This requires dropping the importer-industry-period fixed effect  $\delta_{n,s}^t$  since the sample no longer includes the control group of non-US exports. Making this change increases the magnitude of the estimated NTR gap effect. However, we prefer the baseline specification to column (a) as dropping  $\delta_{n,s}^t$  implies we are not controlling for either technology shocks that are common across exporters or import demand shocks such as those caused by growth in China's export supply capacity.

Expanding the sample to include non-OECD exporters with a population above one million in 1995 (column b) or to include all exporters and importers in the trade data (column c) makes little difference to the estimates.<sup>34</sup>

The next two columns restrict the set of sample industries. In column (d) we drop industries that have an NTR gap in the bottom or top 5 percent of the NTR gap distribution for manufacturing industries. In column (e) we drop all industries in the textiles and apparel sector. In both cases we continue to find that PNTR led to lower export growth in industries with higher NTR gaps. This alleviates any concern that our baseline results are driven by outlier industries or by the abolition of Multi Fibre Arrangement quotas for textile and apparel trade at the end of 2004.

Proposition 2 characterizes the effect of import liberalization on exports conditional on domestic expenditure. However, in addition to the direct effect of greater Chinese import competition, PNTR may also have affected US real market potential through changes in downstream demand for intermediate inputs. To allow for this channel, we define:

$$ExpenditureShock_s = - \sum_v \nu_{U,vs} NTRGap_v,$$

where  $\nu_{U,vs}$  denotes the share of industry  $s$  output sold to industry  $v$ .  $ExpenditureShock_s$  is a sales share weighted average of downstream NTR gaps. We also calculate the share of industry  $s$  output sold to final demand, which we label  $Final_s$ . The expenditure shock and final demand share variables are constructed from the 1997 US input-output accounts following the same procedure used for  $CostShock_s$ .

In column (f) we add  $Post^t \times US_i \times ExpenditureShock_s$  to the baseline specification, while in column (g) we also control for  $Post^t \times US_i \times Final_s$ . We find that industries where final demand

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<sup>34</sup>We do not include China, Hong Kong and Macao in the expanded samples.

accounts for a higher share of sales had greater export growth in the post-PNTR period, while the expenditure shock coefficient changes signs across the two specifications and is insignificant. However, the estimated NTR gap effect remains negative.

PNTR occurred at roughly the same time as the broader China shock that led to rapid growth in Chinese exports to the US and other countries (Autor et al. 2013). We do not expect shocks to China's export supply capacity to affect export growth for the US relative to other OECD countries because, unlike PNTR, the global China shock is not US-specific. Nevertheless, it is useful to assess whether our results are robust to controlling for growth in US imports from China due to shocks other than PNTR. In the spirit of Autor et al. (2013), we measure the China shock in period  $t$  as the annualized change in US imports from China during the period relative to start-of-period industry employment:

$$ChinaShock_s^t = \frac{\Delta X_{UC,s}^t}{L_{U,s}^{t-1}},$$

where imports are measured in million US dollars. In column (a) of Table A2 we include  $US_i \times ChinaShock_s^t$  as an additional control. Since US imports from China are endogenous to US demand and supply shocks, we instrument this variable with  $US_i$  times the change in Chinese exports to non-OECD countries relative to industry employment five years before the start of the period. As anticipated, the China shock effect is insignificant and the estimated NTR gap and input cost shock coefficients are similar to before. We have also experimented with using growth in US imports from China as a measure of the China shock (not normalizing by industry employment) while constructing the instrument using Chinese export growth to non-OECD countries, either on its own or relative to the export growth of other non-OECD countries to non-OECD destinations. Again, the baseline results are unaffected and we do not find a significant impact of the China shock.

Another potential threat to our identification strategy relates to the substitutability between US and Chinese exports. We control for import demand shocks caused by growth in Chinese exports to third markets using importer-industry-period fixed effects. This approach is valid provided the within-industry substitutability between Chinese and US exports, relative to the substitutability between Chinese and non-US OECD exports, is uncorrelated with the NTR gap. However, suppose PNTR led China to specialize (within industries) in products previously exported by the US. This might increase the substitutability between Chinese and US exports in higher NTR gap industries and lead to a decline in US exports through increased competition in destination markets. This third market competition effect could explain our empirical findings without requiring the existence of scale economies in US production.

Any decline in US exports due to Chinese competition should be larger in markets where China is a more important competitor. Therefore, to look for evidence of a third market competition

effect, we test whether the effect of PNTR on US exports is more negative in destinations where China has a higher market share. To implement this test, we add the interactions of  $Post^t \times US_i$  and  $Post^t \times US_i \times NTRGap_s$  with China's market share to the baseline specification. Column (b) of Table A2 reports results when China's market share is measured by China's share of total imports in country  $n$  and industry  $s$  in 2000, while column (c) uses the change in China's import share between 2000 and 2007. The quadruple interaction effect is estimated to be positive and insignificant, implying that the effect of the NTR gap on US exports does not depend upon the strength of Chinese competition. In addition, the baseline results are unaffected. These findings are inconsistent with Chinese competition in third markets explaining the post-PNTR decline in US export growth in higher NTR gap industries.

## HS 6 digit sectors

We have also estimated the reduced form specification in equation (12) with sectors  $s$  defined by HS 6 digit product codes. At this level of aggregation there are 4,698 sectors in our dataset. The results are shown in Table A3.

Column (a) reports the effect of PNTR on US export growth for the same sample of OECD exporters and importers with population above one million in 1995 used in Table 2. We find that products with higher NTR gaps experienced lower export growth in the post-PNTR period. This finding is robust to dropping all exporters other than the US (column b) and to expanding the sample to include non-OECD exporters with a population above one million in 1995 (column c) or to include all importers and exporters in the trade data (column d).<sup>35</sup>

We do not observe the data required to compute the input cost shock or the industry input, skill and capital intensity measures for HS 6 digit sectors. However, in column (e) we control for NAICS industry-exporter-period fixed effects, which capture any changes in US export growth correlated with differences in these variables across NAICS industries. The results show that, even within-NAICS industries, PNTR led to lower export growth in products with higher NTR gaps. This finding continues to hold when we restrict the sample to 6 digit products that belong to NAICS manufacturing industries (column f).<sup>36</sup>

Finally, in columns (g) and (h) we test whether the results are driven by third market competition with Chinese exports following the same approach used in Table A2. Regardless of whether China's market share is measured by its import share in country  $n$  and product  $s$  in 2000 (column g) or the change in its import share between 2000 and 2007 (column h), we find no evidence of a

<sup>35</sup>As above, we omit China, Hong Kong and Macao from the expanded samples and we do not include the US in the sample of importers.

<sup>36</sup>In columns (e) and (f) we drop products that do not map to a unique NAICS industry, which reduces the number of products by 6 percent (see Appendix B for details).

third market competition effect.

## D Calibration

### Counterfactual changes

Using equations (2), (6), (17), (18) and (19), the equilibrium in changes can be written as:

$$\hat{c}_{i,s} = (\hat{w}_i)^{\gamma_{i,s}} \prod_v \left( \hat{P}_{i,v} \right)^{\gamma_{i,sv}}, \quad (20)$$

$$\hat{Y}_{i,s} = \hat{c}_{i,s}^{-\frac{\sigma(\epsilon-1)}{\sigma-\epsilon}} \left( \sum_n \mu_{ni,s} \hat{\varphi}_{ni,s} \hat{X}_{n,s} \hat{P}_{n,s}^{\epsilon-1} \right)^{\frac{\sigma-1}{\sigma-\epsilon}}, \quad (21)$$

$$\hat{P}_{i,s} = \left[ \sum_j \lambda_{ij,s} \hat{\varphi}_{ij,s} \left( \frac{\hat{c}_{j,s}^\sigma}{\hat{Y}_{j,s}} \right)^{\frac{1-\epsilon}{\sigma-1}} \right]^{\frac{1}{1-\epsilon}}, \quad (22)$$

$$\hat{w}_i = \sum_s \frac{\gamma_{i,s} Y_{i,s}}{Y_i} \hat{Y}_{i,s}, \quad (23)$$

$$\hat{X}_{i,s} = \frac{\beta_{i,s} Y_i}{X_{i,s}} \hat{w}_i + \frac{\beta_{i,s} D'_i}{X_{i,s}} + \sum_v \frac{\gamma_{i,vs} Y_{i,v}}{X_{i,s}} \hat{Y}_{i,v}. \quad (24)$$

Given trade shares  $\mu_{ni,s}$  and  $\lambda_{ij,s}$ , output levels  $Y_{i,s}$ , expenditure  $X_{i,s}$  and aggregate value-added  $Y_i = w_i L_i$  in the initial equilibrium, the parameters  $\epsilon$ ,  $\sigma$ ,  $\beta_{i,s}$ ,  $\gamma_{i,s}$  and  $\gamma_{i,sv}$ , the trade deficit in the new equilibrium  $D'_i$ , and the trade openness shocks  $\hat{\varphi}_{ni,s}$ , this system of equations determines  $\hat{w}_i$ ,  $\hat{X}_{i,s}$ ,  $\hat{c}_{i,s}$ ,  $\hat{Y}_{i,s}$  and  $\hat{P}_{i,s}$  for all countries  $i$  and sectors  $s$ . We set the trade deficit  $D'_i$  such that each country's deficit as a share of global value-added is unaffected by PNTR. Using equations (20), (23) and (24) to substitute for  $\hat{w}_i$ ,  $\hat{X}_{i,s}$  and  $\hat{c}_{i,s}$  in equations (21) and (22) allows us to simplify the above system to  $2NS$  equations in  $\hat{Y}_{i,s}$  and  $\hat{P}_{i,s}$ .

From equation (5), the change in bilateral trade between any pair of countries satisfies:

$$\hat{X}_{ni,s} = \hat{\varphi}_{ni,s} \left( \frac{\hat{Y}_{i,s}}{\hat{c}_{i,s}^\sigma} \right)^{\frac{\epsilon-1}{\sigma-1}} \hat{X}_{n,s} \hat{P}_{n,s}^{\epsilon-1}, \quad (25)$$

and the change in the export supply capacity of country  $i$  in sector  $s$  is:

$$\hat{S}_{i,s} = \left( \frac{\hat{Y}_{i,s}}{\hat{c}_{i,s}^\sigma} \right)^{\frac{\epsilon-1}{\sigma-1}}.$$

Let  $M_i$  denote real income per capita in country  $i$  and  $E_i$  denote real expenditure per capita. Since the representative consumer has Cobb-Douglas preferences, the changes in real income and expenditure per capita are given by:

$$\hat{M}_i = \frac{\hat{w}_i}{\prod_v (\hat{P}_{i,v})^{\beta_{i,v}}}, \quad \hat{E}_i = \frac{\frac{w_i L_i}{w_i L_i + D_i} \hat{w}_i + \frac{D'_i}{w_i L_i + D_i}}{\prod_v (\hat{P}_{i,v})^{\beta_{i,v}}}.$$

When trade is balanced,  $D_i = D'_i = 0$ , meaning that real income and real expenditure are equal.

## Data

The calibration uses data for 2000 from the 2013 release of the World Input-Output Tables (WIOT). The tables cover 40 countries plus a rest of the world aggregate and 35 ISIC Revision 3 industries. To reduce the dimensionality of the computational problem, we aggregate the data to 12 countries and 24 sectors. The countries are the G7, China, regional aggregates for Europe, Asia and the Americas, and the rest of the world aggregate from WIOT. We preserve the WIOT industry aggregation for goods sectors, except for combining the Leather and Textiles industries, and we aggregate services industries to nine sectors.

The NAICS goods industries in our estimation dataset map one-to-one into WIOT sectors. We calculate the NTR gap and CostShock for WIOT goods sectors, and the input intensity, skill intensity and capital intensity for WIOT manufacturing sectors, as the average of the respective variables across NAICS industries within each WIOT sector.

Table A4 shows the sector classification used for the calibration, together with the NTR gap for each sector and the division of goods sectors into low, medium and high NTR gap sectors. The low NTR gap group comprises sectors with a NTR gap below 0.2. The medium NTR gap group includes sectors with a NTR gap between 0.2 and 0.3. The high NTR gap group contains sectors with a NTR gap above 0.3.

## Output elasticity calibration

To compute the simulated effect of the NTR gap on US exports for a given output elasticity  $\psi$ , we start by solving the calibrated model with the output elasticity equal to  $\psi$  for goods sectors and zero for services sectors. Solving the model gives the change in export supply capacity  $\hat{S}_{i,s}$  due to PNTR. We then calculate the NTR gap effect by estimating:

$$\frac{1}{7} \log \hat{S}_{i,s} = \delta_i + \delta_s + \alpha_{Sim} US_i \times NTRGap_s + \alpha_6 US_i \times CostShock_s + \beta US_i \times Z_s + \epsilon_{i,s}, \quad (26)$$

where  $Z_s$  includes input, skill and capital intensity by sector. Equation (26) is the model equivalent of the specification estimated in column (h) of Table 2 and  $\alpha_{Sim}$  gives the simulated NTR gap effect shown in Figure 4. To ensure consistency with the empirical estimates, we do not include China in the set of exporters and only use manufacturing sectors.<sup>37</sup>

## Alternative calibrations

Table A5 reports the impact of PNTR on US exports and welfare for a range of alternative calibrations of the global economy. For reference, column (a) summarizes the baseline results from Tables 6 and 7. In column (b) we use a model without input-output linkages between sectors. To calibrate this model, we set value-added equal to observed output from WIOT. Since US GDP is the numeraire, the input cost effect does not impact US exports in this case. As is well known, the gains from trade liberalization are smaller when there is no trade in intermediate inputs (Costinot and Rodríguez-Clare 2014). Comparing column (b) to column (a) also shows that removing input-output linkages weakens the real market potential effect leading to a lower simulated NTR gap effect of  $-0.06$  and a less negative specialization effect on real income. This comparison confirms that the interaction of input-output linkages with scale economies is quantitatively important to explain the baseline results.

The baseline calibration assumes that there are no scale economies in services sectors. In column (c) we set the output elasticity equal to 0.835 for all sectors, implying that the strength of scale economies is the same for goods and services. We find that the existence of scale economies in services leads to slight increases in the strength of the real market potential and input cost effects, as well as a higher ACR effect, which boosts the gains from trade. However, these changes are quantitatively small and the results are qualitatively unaffected. In addition the specialization effect is essentially unchanged from column (a). It follows that cross-sectoral heterogeneity in scale economies is quantitatively unimportant for understanding the welfare effects of PNTR. Instead, the negative specialization effect results from the combination of scale economies with input-output linkages.

A notable feature of the baseline results is the large contraction of the Textiles and Leather sector. In column (d) we calibrate a 23 sector version of the model where Textiles and Leather is merged with Other Manufacturing, which is the sector with the second highest NTR gap. Otherwise, the calibration is unchanged. The results in column (d) are very similar to the baseline, although the simulated NTR gap effect declines slightly to  $-0.08$ . At the sector level, we find that PNTR reduced exports in the merged Textiles and Leather plus Other Manufacturing sector by 18

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<sup>37</sup>Note from equation (25) that  $\alpha_{Sim}$  can be calculated using  $\hat{S}_{i,s}$  instead of  $\hat{X}_{ni,s}$  since  $\hat{\varphi}_{ni,s} = 1$  for all exporters other than China. Consequently, the simulated NTR gap effect on US exports is separable from changes in openness and import demand.

percent.

In column (e) we calibrate the model allowing the trade and output elasticities to vary across goods sectors. For manufacturing sectors (except Other Manufacturing) we use trade and scale elasticities from Bartelme et al. (2019).<sup>38</sup> For all other sectors, the calibration is unchanged from the baseline economy. The model with heterogeneous elasticities yields a small, negative simulated NTR gap effect, partly because there is a negative correlation between the NTR gap and the calibrated trade elasticities. However, we continue to find that PNTR increased US exports relative to GDP because the positive input cost and foreign demand effects more than offset export destruction due to the real market potential effect. US gains from PNTR are smaller than in the baseline calibration (reflecting the fact that in column (e) the average trade elasticity for goods sectors increases to 6.5), but remain positive.

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<sup>38</sup>We use the median trade elasticities reported in Table B.3 and the scale elasticity estimates from column (2) of Table 1. Consistent with our model, we compute the output elasticity as the product of the trade and scale elasticities.

Table A1: PNTR and US export growth, additional robustness checks

Dependent variable	$\Delta$ Log Exports						
	Only US exports	OECD & Non-OECD exporters	All exporters & importers	Trim sample on NTR gap	Drop textiles & apparel industries	Expenditure shock	Expenditure shock & final demand share
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Post x US x NTRGap	-0.17 (0.055)	-0.087 (0.043)	-0.097 (0.041)	-0.18 (0.064)	-0.098 (0.050)	-0.095 (0.045)	-0.093 (0.043)
Post x US x CostShock	-0.32 (0.16)	-0.29 (0.14)	-0.27 (0.14)	-0.45 (0.15)	-0.13 (0.15)	-0.32 (0.14)	-0.16 (0.14)
Post x US x ExpenditureShock						0.050 (0.053)	-0.10 (0.067)
Post x US x Final							0.050 (0.016)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Estimator	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Observations	69,003	1,762,374	1,978,551	931,509	903,938	1,010,551	1,010,551
R-squared	0.42	0.48	0.48	0.51	0.50	0.50	0.50

Notes: Standard errors clustered by exporter-industry in parentheses. Bilateral trade. Estimated in long differences using 1995-2000 as pre-PNTR period and 2000-07 as post-PNTR period. Industry sample covers 384 NAICS manufacturing industries, except column (d) drops industries that have an NTR gap in the bottom or top 5 percent of the NTR gap distribution and column (e) drops all textile and apparel industries. Country sample includes countries with population above one million in 1995 and requires exporters to be OECD members at start of 1995, except column (a) drops all exporters other than US, column (b) includes all exporters with population above one million in 1995 and column (c) includes all exporters and importers regardless of population or OECD membership. All columns include triple interactions of a post-period dummy, a US exporter dummy and the input, skill and capital intensity of US industries in 1995 calculated from NBER manufacturing database. All columns except (a) include exporter-industry-importer, importer-exporter-period and importer-industry-period fixed effects. Column (a) includes industry-importer and importer-period fixed effects.

Table A2: PNTR and US export growth, China shock robustness checks

Dependent variable	$\Delta$ Log Exports		
	China shock	Initial China	$\Delta$ China import
		import share in	share in
	(a)	destination	destination
Post x US x NTRGap	-0.11 (0.047)	-0.12 (0.050)	-0.11 (0.049)
Post x US x CostShock	-0.38 (0.14)	-0.31 (0.14)	-0.33 (0.14)
US x ChinaShock	0.80 (1.01)		
Post x US x China Market Share		-0.0035 (0.079)	-0.42 (0.60)
Post x US x NTRGap x China Market Share		0.37 (0.26)	1.09 (1.92)
Fixed effects	Yes	Yes	Yes
Industry controls	Yes	Yes	Yes
Estimator	IV	OLS	OLS
Kleibergen-Paap F-stat.	11.9		
Observations	998,539	1,010,551	1,010,551
R-squared		0.50	0.50

Notes: Standard errors clustered by exporter-industry in parentheses. Bilateral trade. Estimated in long differences using 1995-2000 as pre-PNTR period and 2000-07 as post-PNTR period. Industry sample covers 384 NAICS manufacturing industries. Country sample includes countries with population above one million in 1995 and requires exporters to be OECD members at start of 1995. In column (a) ChinaShock is the annualized change in US imports from China during the period in million dollars relative to start-of-period industry employment and US x ChinaShock is instrumented with US times the annualized change in Chinese exports to non-OECD countries relative to industry employment five years before the start of the period. In column (b) China Market Share is China's share of total imports by destination-industry in 2000. In column (c) China Market Share is the change in China's share of total imports by destination-industry between 2000 and 2007. All columns include triple interactions of a post-period dummy, a US exporter dummy and the input, skill and capital intensity of US industries in 1995 calculated from NBER manufacturing database. All columns include exporter-industry-importer, importer-exporter-period and importer-industry-period fixed effects.

Table A3: PNTR and US export growth, HS 6 digit sectors

Dependent variable	Δ Log Exports							
	OECD exporters	US exports only	OECD & Non-OECD exporters	All exporters & importers	OECD exporters, within NAICS industries	OECD exporters, within NAICS manufacturing industries	Third market competition Initial China import share	Δ China import share
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Post x US x NTRGap	-0.054 (0.014)	-0.082 (0.013)	-0.047 (0.014)	-0.046 (0.014)	-0.045 (0.020)	-0.051 (0.020)	-0.050 (0.022)	-0.051 (0.021)
Post x US x China Market Share							0.032 (0.033)	0.0094 (0.20)
Post x US x NTRGap x China Market Share							-0.028 (0.094)	-0.014 (0.57)
Fixed effects								
Exporter-sector-importer	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-exporter-period	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-sector-period	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
NAICS industry-exporter-period	No	No	No	No	Yes	Yes	Yes	Yes
Observations	3,658,798	363,775	5,196,186	5,574,796	3,172,658	3,031,300	3,031,300	3,031,300
R-squared	0.52	0.36	0.50	0.50	0.53	0.53	0.53	0.53

Notes: OLS estimates. Standard errors clustered by exporter-industry in parentheses. Bilateral trade. Estimated in long differences using 1995-2000 as pre-PNTR period and 2000-07 as post-PNTR period. Sectors defined by HS 6 digit product codes. Country sample includes countries with population above one million in 1995 and requires exporters to be OECD members at start of 1995, except column (b) includes only US exports, column (c) includes all exporters with population above one million in 1995 and column (d) includes all exporters and importers regardless of population or OECD membership. Columns (e)-(h) include NAICS industry-exporter-period fixed effects for the NAICS industries that contain each HS 6 digit sector. Columns (f)-(h) restrict the sample to sectors belonging to NAICS manufacturing industries. In column (g) China Market Share is China's share of total imports by destination-sector in 2000. In column (h) China Market Share is the change in China's share of total imports by destination-sector between 2000 and 2007.

Table A4: Calibration sectors

Code	Name	NTR gap	Group
AtB	Agriculture	0.06	Low
C	Mining	0.04	Low
15t16	Food	0.13	Low
17t19	Textiles & Leather	0.35	High
20	Wood	0.22	Medium
21t22	Paper	0.26	Medium
23	Coke	0.05	Low
24	Chemicals	0.21	Medium
25	Plastics	0.30	High
26	Minerals	0.25	Medium
27t28	Metals	0.26	Medium
29	Machinery	0.28	Medium
30t33	Electrical	0.32	High
34t35	Transport	0.22	Medium
36t37	Other Manufacturing	0.34	High
E	Utilities		Services
F	Construction		Services
50-52	Retail & Wholesale		Services
H	Hospitality		Services
60-64	Transport Services		Services
J	Finance		Services
70	Real Estate		Services
71t74	Business Services		Services
L-P	Other Services		Services

Notes: ISIC Revision 3 sectors. Sectoral NTR gap defined as average NTR gap for NAICS goods industries within each sector. Low group includes goods sectors with NTR gap below 0.2. Medium group includes sectors with NTR gap between 0.2 and 0.3. High group includes sectors with NTR gap above 0.3.

Table A5: Impact of PNTR on US exports, output and welfare for alternative model calibrations (percent changes)

	Baseline	No input-output linkages	Scale economies in services	23 sectors	Heterogeneous elasticities
	(a)	(b)	(c)	(d)	(e)
Total exports	3.6	3.2	3.8	3.8	3.0
<i>of which: Real market potential effect</i>	-2.3	-0.2	-3.1	-2.0	-1.4
<i>Input cost effect</i>	3.0	<i>n/a</i>	4.1	2.7	2.7
<i>Foreign demand effect</i>	3.1	3.4	3.1	3.2	1.8
Simulated NTR gap effect	-0.10	-0.06	-0.11	-0.08	-0.01
Goods output	-0.7	-0.4	-0.8	-0.6	-0.3
Services output	0.1	0.1	0.1	0.2	0.1
Real income	0.08	0.04	0.12	0.08	0.03
<i>of which: ACR effect</i>	0.31	0.07	0.36	0.22	0.13
<i>Specialization effect</i>	-0.23	-0.03	-0.24	-0.14	-0.10

Notes: Simulated percent changes. Services sectors: trade elasticity is five; output elasticity is zero, except in column (c) where output elasticity is 0.835. Goods sectors: trade elasticity is five and output elasticity is 0.835 in columns (a)-(d); model in column (e) calibrated using trade and output elasticities for goods sectors from Bartelme et al. (2019). In column (d) Textiles & Leather sector merged with Other Manufacturing. US GDP is the numeraire. Export decomposition terms averaged across sectors using pre-PNTR US export shares as weights.