Import Liberalization as Export Destruction? Evidence from the United States[*]

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Abstract

How does import policy affect export performance and welfare? In trade models with scale economies, import liberalization reduces exports within industries by shrinking domestic real market potential. We show that this export destruction mechanism reduced US export growth following the permanent normalization of trade relations with China (PNTR), implying US goods production exhibits scale economies. At the same time there was 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 shows that scale economies are economically important for trade policy analysis. Although PNTR increased aggregate US exports relative to GDP, exports declined in the most exposed industries because of the export destruction effect. We find that US gains from PNTR are positive, but around 30 percent smaller than under constant returns to scale.

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

JEL Classification: F12, F13, F15.

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1 Introduction

The role of import policy in industrial development 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. However, 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.[1]

Economic theory establishes that the trade and welfare effects of import policy hinge on whether production features increasing returns to scale at the sector level. Graham (1923) and Ethier (1982) show that scale economies can rationalize the infant industry argument for protection. Juhász (2018) documents evidence supporting the infant industry mechanism in Napoleonic France. Venables (1987) and Kucheryavyy, Lyn and Rodríguez-Clare (2020) find that import liberalization may reduce welfare 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.

Modern quantitative trade models can incorporate either constant returns to scale (Eaton and Kortum 2002, Caliendo and Parro 2015) or increasing sector-level returns (Kucheryavyy, Lyn and Rodríguez-Clare 2020). In single-sector economies the distinction is often immaterial (Arkolakis, Costinot, and Rodríguez-Clare 2012, Costinot and Rodríguez-Clare 2014), but with many sectors the effects of trade policy depend upon the returns to scale. Yet researchers lack tools to choose between constant returns and increasing returns models when undertaking trade policy analysis.

This paper studies how scale economies shape the effects of import liberalization on exports and welfare. Building on Krugman (1984), we show that the relationship between import policy and exports can be used to discriminate between constant versus increasing returns to scale in trade models. We illustrate the applicability of this approach by analyzing the permanent normalization of US trade relations with China (PNTR), a policy that increased US openness to Chinese imports (Pierce and Schott 2016, Handley and Limão 2017). We use our findings to address whether import liberalization leads to export destruction, to calibrate the strength of scale economies and to quantify the general equilibrium effects of PNTR.

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, Lyn and Rodríguez-Clare (2020) studying conditions under which trade models with

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[1] See Harrison and Rodríguez-Clare (2010) for a comprehensive survey on trade and industrial policy and Irwin (2021) for a history of economists' views on import substitution policies.

external economies of scale are well-behaved. Although Krugman (1984) presented his argument in a partial equilibrium, oligopoly model, we show that the mechanism he identified connecting import policy to export performance also exists in a class of quantitative trade models with scale economies.[2] 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.[3] The figure shows that export growth declined following PNTR in industries with higher NTR gaps, which is consistent with import liberalization leading to export destruction, but not with constant returns to scale trade models.

Building on Figure 1, we estimate the effect of PNTR on US exports using the bilateral trade equation implied by our model. 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 and imply the existence of scale economies in US goods production. All else equal, 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.

Our estimates imply that PNTR reduced export growth, all else equal. However, we also find

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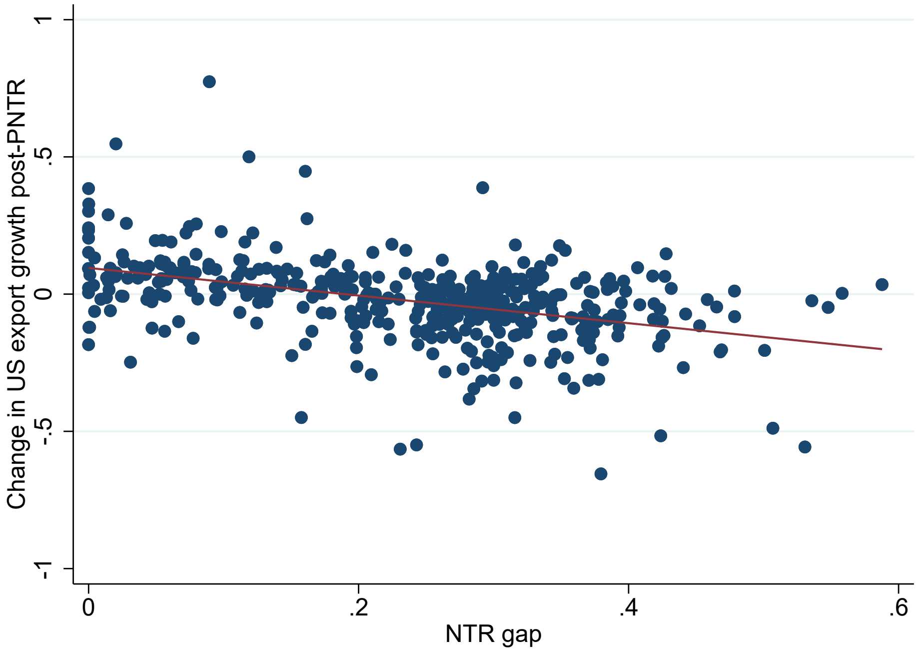
[2] This class includes models where scale economies result from external economies of scale, from love of variety with homogeneous or heterogeneous firms (Krugman 1980, Melitz 2003), or from endogenous innovation (Somale 2021).

[3] See Section 3.2 and Appendix B for details on the data.

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.

that PNTR had an export promoting effect by reducing input costs. US export growth following PNTR was greater in industries more reliant on inputs from industries with higher NTR gaps.[4] This input cost channel offset the export decline caused by greater Chinese import competition and the two effects have comparable magnitudes. We estimate 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 20 percent increase in exports.

In Section 4 we calibrate our trade model and quantify the effect of PNTR on US exports and welfare. This exercise allows us to account for impacts of PNTR that are absorbed by fixed effects in the empirical analysis and to study the importance of scale economies in general equilibrium. We use the estimation results to discipline the calibrated returns to scale. 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 our estimated effect. This yields an output elasticity of 0.821, below the

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[4] 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.

value of one found in Krugman (1980) or in the Pareto productivity version of 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).

The quantitative analysis shows that PNTR increased US exports relative to GDP on aggregate and for most goods sectors. The aggregate increase is 3.2 percent. Decomposing this change, implies that export destruction of negative 1.8 percent due to lower real market potential is more than offset by growth of 2.4 percent due to lower input costs and growth of 2.7 percent from higher foreign demand.[5] Thus, in general equilibrium the Krugman mechanism is dominated by the export promoting effects of import liberalization. We also find that 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 28 percent larger with scale economies than without, primarily because scale economies make the input cost effect almost five times stronger.

At the sector level, changes in exports are qualitatively different in the calibrated model than in the absence of scale economies. Consistent with Figure 1, our quantitative results imply that export growth is negatively correlated with the NTR gap. And we find that exports decline 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. By comparison, under constant returns export growth is positive in all sectors and, in contrast to our empirical findings, weakly positively correlated with the NTR gap. These differences illustrates the importance of scale economies for sector-level trade policy analysis.

In terms of welfare, we estimate PNTR increased US real income by 0.068 percent. This change can be decomposed into an Arkolakis, Costinot, and Rodríguez-Clare (2012) term that captures changes in trade openness and a specialization effect that exists only when there are scale economies and captures the welfare effects of sectoral reallocation. In our analysis, the specialization effect is the same order of magnitude as the trade openness term. For the US, the Arkolakis, Costinot, and Rodríguez-Clare (2012) term is positive, while the specialization effect is negative because PNTR reallocates US production towards sectors with weaker forward input-output linkages to the rest of the economy. Overall, we find that US gains from PNTR are around 30 percent smaller with scale economies than under constant returns to scale.

Our paper belongs to the empirical literature on trade policy and returns to scale. The contribution relative to this literature is twofold. We provide novel evidence documenting the existence of a scale economies channel through which import liberalization is export destroying, and we evaluate

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[5] 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.

the importance of this channel for quantitative trade policy analysis.[6] 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, Lyn and Rodríguez-Clare 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 show that accounting for scale economies (or their absence) is a prerequisite for successfully evaluating how trade policy reforms affect sector-level trade flows and welfare.

The paper is related to studies that use trade data to estimate scale economies (Antweiler and Trefler 2002, Lashkaripour and Lugovskyy 2018, Bartelme at 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 shock. Goldberg and Pavcnik (2016) highlight the importance of using changes in trade policy to discipline trade theory, rather than relying exclusively on cross-sectional variation or changes in other trade frictions such as transportation costs.

By studying US exports we also add a new dimension to the literature on PNTR and the broader China shock.[7] 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

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[6] 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.

[7] See, for example, Autor, Dorn and Hanson (2013), Autor et al. (2020), Pierce and Schott (2016, 2018), Feng, Li and Swenson (2017), Handley and Limão (2017), Jaravel and Sager (2020) and Amiti et al. (2020).

show how scale economies induce spillovers through changes in real market potential and analyze their quantitative importance.

2 Trade and scale economies

This section develops a multi-sector general equilibrium trade model that nests both the case with constant returns to scale at the sector level and the case with increasing returns to scale. We use the model to characterize how the effect of import liberalization on exports under increasing returns differs from under constant returns, which motivates our empirical analysis in Section 3.

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. In this environment firms are symmetric and sector-level scale economies result from love of variety in preferences. However, we show in Appendix A.3 that the effect of import liberalization on exports when there are increasing sector-level returns to scale is the same regardless of whether increasing returns result from love of variety, external economies of scale, firm heterogeneity in a Pareto productivity version of Melitz (2003), or endogenous technology investment.[8] It follows that while the estimates in Section 3 shed light on the magnitude of sector-level returns to scale, our results do not distinguish between alternative sources of increasing returns.

2.1 Model

The world economy has 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.

Firms in each sector make tradable varieties, which are aggregated by competitive producers to make sectoral output. Sectoral output is non-tradable and can either be consumed or used as an intermediate input. Output $Q_{n,s}$ of sector s in country n is given by:[9]

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

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[8] The equivalence results in Appendix A.3 build upon Kucheryavyy, Lyn and Rodríguez-Clare (2020) who show, in an economy without intermediate inputs, that the sectoral equilibrium conditions and bilateral trade equation implied by the Krugman model are equivalent to those that hold with external economies, or in a Melitz-Pareto model.

[9] 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 output technology simply defines consumer preferences over sector s varieties.

where $q_{ni,s}(\omega)$ denotes the quantity of variety ω produced in country i and used in country n and $\Omega_{i,s}$ is the set of varieties produced in country i. The sectoral production function has 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 countries than across countries. The love of variety assumption generates increasing returns to scale at the sector level. However, taking the limit as $\sigma \to \infty$ gives an Armington economy with national product differentiation, Armington elasticity ϵ and constant sector-level returns to scale.

Let $X_{n,s}$ denote expenditure on sector s in country n. $X_{n,s}$ is the sum of consumer expenditure and intermediate input expenditure. Since sectoral output is non-tradable, market clearing requires $X_{n,s} = P_{n,s}Q_{n,s}$ where $P_{n,s}$ denotes the sectoral output price. 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 ω 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:

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

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

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

where w_i is the wage 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 σ, 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:

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

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 sectoral production function features love of variety. The strength of sectoral scale economies is parameterized by $\frac{1}{\sigma-1}$, which we refer to as the *scale elasticity*. An increase in σ reduces the scale elasticity because it makes varieties more substitutable, weakening the love of variety effect. As $\sigma \to \infty$ the scale elasticity tends to zero and scale economies vanish. Note also that the scale elasticity does not depend upon the elasticity of substitution ϵ between varieties from different countries.

There is free entry of firms into variety production, implying 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 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:

$$\frac{Y_{i,s}}{\sigma} = N_{i,s} f_{i,s} c_{i,s}, \tag{4}$$

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

2.2 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:

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

where $\varphi_{ni,s} = \tau_{ni,s}^{1-\epsilon}$ measures bilateral openness to trade, $\epsilon - 1$ is the *trade elasticity* and Γ_0 is a constant.[10] 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 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 label 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,[11] while the trade elasticity determines the

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[10] In particular, $\Gamma_0 \equiv \left(\frac{1}{\sigma}\right)^{\frac{\epsilon-1}{\sigma-1}} \left(\frac{\sigma-1}{\sigma}\right)^{\epsilon-1}$.

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

responsiveness of trade to lower prices as shown in equation (1). In the absence of scale economies, such as in the Armington model obtained when $\sigma \to \infty$ or in the Ricardian economy developed by Eaton and Kortum (2002), the output elasticity is zero. Consequently, the output elasticity is positive if and only if there are increasing sector-level returns to scale.

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

$$X_{ni,s} = \varphi_{ni,s} \frac{Y_{i,s}}{RMP_{i,s}} M_{n,s}, \tag{6}$$

where $M_{n,s} = X_{n,s} P_{n,s}^{\epsilon-1}$ and $RMP_{i,s} = \sum_n \varphi_{ni,s} X_{n,s} P_{n,s}^{\epsilon-1}$ is the real market potential of country i. 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). Any structural gravity equation can be expressed in this form, regardless of whether there are sectoral scale economies. However, because output generally depends upon real market potential, equation (6) does not imply that exports are increasing in output whenever structural gravity holds. In models without scale economies output is proportional to real market potential and changes in output induced by shocks to real market potential do not affect exports.

2.3 Import liberalization

How does import liberalization affect exports? Suppose there is a reduction in US barriers to Chinese imports, leading to an increase in openness $\varphi_{UC,s}$, where U denotes the US and C denotes China. In our empirical application, the reduction in US import barriers results from PNTR with China.[12]

The bilateral trade equation (5) shows that an increase in $\varphi_{UC,s}$ directly raises US imports from China. However, US import liberalization may also affect trade indirectly through changes in output, input costs, prices and expenditure. What is the effect of these changes on US exports? First, consider the constant returns to scale case where $\sigma \to \infty$. In this case, the only endogenous variables that enter the bilateral trade equation (5) are input costs $c_{i,s}$ and real foreign demand $X_{n,s} P_{n,s}^{\epsilon-1}$. Therefore, conditional on these variables, exports are independent of import costs, which gives Proposition 1.

Proposition 1. ***Constant returns to scale.*** *Conditional on foreign demand and domestic input costs, import liberalization does not affect exports when there are constant returns to scale at the sector level.*

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[12] We model PNTR as a decline in variable trade costs. However, treating it as a reduction in the fixed cost of exporting to the US for Chinese firms would not change our results (see Appendix A.3).

Proposition 1 holds not only in the Armington economy obtained as $\sigma \to \infty$, but also in economies based on the Eaton and Kortum (2002) model, which exhibit constant sector-level returns to scale.

Now suppose there are increasing returns to scale, meaning that $\sigma < \infty$ and the output elasticity of exports is strictly positive. Using $Y_{i,s} = \sum_n X_{ni,s}$, the bilateral trade equation (5) implies:[13]

$$Y_{i,s} = \Gamma_0^{\frac{\sigma-1}{\sigma-\epsilon}} T_{i,s}^{\frac{(\sigma-1)(\epsilon-1)}{\sigma-\epsilon}} \left(\frac{1}{c_{i,s}^{\sigma} f_{i,s}}\right)^{\frac{\epsilon-1}{\sigma-\epsilon}} \left(RMP_{i,s}\right)^{\frac{\sigma-1}{\sigma-\epsilon}} . \tag{7}$$

Thus, output depends upon technology, input costs and country i's real market potential $RMP_{i,s} = \sum_n \varphi_{ni,s} X_{n,s} P_{n,s}^{\epsilon-1}$. Countries that face lower trade costs to access larger markets have higher real market potential and, consequently, higher output, all else equal.

An increase in $\varphi_{UC,s}$ due to import liberalization has a direct negative effect on the US price index $P_{U,s}$ by cutting the cost of Chinese imports. All else equal, a smaller $P_{U,s}$ makes the US market more competitive, which reduces US real market potential in sector s leading to lower output. We show in Appendix A.1 that:

$$d\log Y_{U,s} = -\frac{\frac{\sigma-1}{\epsilon-1}\lambda_{UC,s}\mu_{UU,s}}{\frac{\sigma-1}{\epsilon-1} - 1 + \lambda_{UU,s}\mu_{UU,s}} d\log\varphi_{UC,s} + F\left(c_{U,s}, X_{U,s}, \{Y_{j,s}, c_{j,s}, X_{j,s}, P_{j,s}\}_{j\neq U}\right), \tag{8}$$

where $\lambda_{ni,s} = X_{ni,s}/X_{n,s}$ is the import share of country i in country n, $\mu_{ni,s} = X_{ni,s}/Y_{i,s}$ 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, as well as foreign variables. Thus, import liberalization leads to lower US output (holding the arguments of F constant) because US producers lose domestic market share to Chinese imports.

From the bilateral trade equation (5), lower output in turn reduces US exports to all destinations when $\sigma < \infty$. As output contracts, industry-level productivity declines due to scale economies leading to lower exports. This is the mechanism proposed by Krugman (1984) through which import policy affects exports. Conditional on foreign variables, domestic input costs and domestic expenditure the magnitude of the elasticity of exports to $\varphi_{UC,s}$ is increasing in the output elasticity $\frac{\epsilon-1}{\sigma-1}$. A higher scale elasticity $\frac{1}{\sigma-1}$ makes productivity more sensitive to changes in output, while a larger trade elasticity $\epsilon - 1$ implies exports are more elastic to variation in productivity. Proposition 2 summarizes these results.

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[13] 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 (7) does not hold, but $Y_{i,s}$ still depends upon country i's market access through the market clearing conditions, see Appendix A.1. If $\sigma < \epsilon$ there may be multiple equilibria even without intermediate inputs, see Kucheryavyy, Lyn and Rodríguez-Clare (2020).

Proposition 2. ***Increasing returns to scale.*** *Holding constant foreign outcomes, domestic input costs and domestic expenditure:*
(i) Import liberalization reduces exports to all destinations if and only if there are increasing returns to scale at the sector level;
(ii) The magnitude of the elasticity of exports to import openness is strictly increasing in the output elasticity.

Importantly, Proposition 2 holds not only in the love of variety model developed above, but in a broad class of trade models with increasing returns to scale. Appendix A.3 shows that equations equivalent to those used to prove the proposition hold in models where scale economies result from (i) external economies of scale; (ii) endogenous technology investment, or; (iii) Melitz-Pareto firm heterogenity.

Together, Propositions 1 and 2 imply that we can use the effect of import liberalization on exports to determine whether there are increasing sector-level returns to scale. Under a null hypothesis of constant returns, there is no effect. Alternatively, with increasing returns there is a negative relationship. However, since both propositions are partial equilibrium results, implementing this strategy also requires controlling for other channels through which import liberalization may affect exports.

In particular, the decline in US output prices $P_{U,s}$ caused by import liberalization reduces input costs by equation (2). And lower input costs increase exports, all else equal, as shown by equation (5). Through this input cost channel, import liberalization has a positive effect on exports regardless of whether there are scale economies. Our empirical strategy and quantitative analysis will allow for this effect and for other general equilibrium adjustments to import liberalization.

3 Empirical analysis

This section estimates the impact of PNTR on US exports. The estimation results provide evidence on whether import liberalization leads to export destruction and allow us to distinguish between constant returns to scale and increasing returns trade models.

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.[14] 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. Amiti et al. (2020) and Jaravel and Sager (2020) provide evidence that PNTR reduced prices in the US.[15]

Building on this literature, 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 weaker expected export growth, then these industries would have smaller NTR gaps, biasing our results away from finding a negative effect of the NTR gap on export growth.

3.2 Data

The baseline analysis uses 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:

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[14] 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.

[15] Amiti et al. (2020) also document that China's accession to the WTO cut US prices because reductions in China's tariffs on intermediate inputs lowered the production costs of Chinese exporters. 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.

$$NTRGap_s = \log\left(1 + \text{Non-NTR tariff}_s\right) - \log\left(1 + \text{NTR tariff}_s\right). \tag{9}$$

Tariff data from Feenstra, Romalis and Schott (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). Consequently, the fall in prices caused by PNTR reduces input costs and the strength of this effect varies across sectors depending upon the input-output network. Let Γ_U be the matrix of input-output coefficients in the US that has elements $\gamma_{U,sv}$. We control for the effect of PNTR on input costs using an input-output weighted sum of upstream NTR gaps $CostShock$ given by:

$$CostShock = -\left(I - \Gamma_U\right)^{-1} \Gamma_U NTRGap, \tag{10}$$

where I is the identity matrix and $NTRGap$ is the vector of industry-level NTR gaps defined in equation (9). As the right hand side of equation (10) includes the Leontief inverse $\left(I - \Gamma_U\right)^{-1}$ of Γ_U, the $CostShock$ variable captures both first-order and higher-order input-output linkages between sectors. And because we multiply the right hand side of equation (10) by negative one, $CostShock$ is more negative for industries that purchase relatively more inputs from industries that are more exposed to PNTR. To construct $CostShock$, we measure $\gamma_{U,sv}$ as expenditure by industry s on inputs from industry v relative to the value of industry s output. The input-output coefficients are calculated from the Bureau of Economic Analysis Use Table for 1997.

In addition to the cost shock variable, we compute each industry's exposure to the input-output network $IOExposure$ as:

$$IOExposure = \left(I – \Gamma_U\right)^{-1} \Gamma_U \tilde{I},$$

where $\tilde{I}$ is a vector of ones. We include $IOExposure$ in all specifications that use the $CostShock$ variable to control for differences in the expected cost shock that stem purely from cross-industry variation in the strength of input-output linkages. Borusyak and Hull (2021) show that not controlling for this expected shock can lead to omitted variable bias.

Bilateral trade data from 1995 onwards at the 6-digit level of the Harmonised System classification 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 0.13. The average input cost shock is -0.14 with a standard deviation of 0.06. 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 -0.43 across all sample industries and -0.27 within manufacturing. Input-output exposure is negatively correlated with the NTR gap and positively correlated with the input cost shock, though both correlations are small. For manufacturing industries, the NTR gap is also negatively correlated with input and capital intensity, but approximately uncorrelated with skill intensity.

3.3 Estimation specification

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

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

Thus, bilateral export growth $\Delta \log X_{ni,s}$ 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 $f_{i,s}$.[16]

We estimate a reduced form version of equation (11) treating PNTR as an industry-level shock to output. We also control for changes in input costs due to PNTR using the cost shock variable and include fixed effects to absorb changes in import demand, bilateral openness and technology levels. The estimating equation is:

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

where t denotes the period, $Post^t$ is a dummy for the post-PNTR period, US_i is a dummy for

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

the exporter i being the United States, Z_s is a vector of industry characteristics and we include importer-exporter-industry, importer-exporter-period and importer-industry-period fixed effects. We perform the estimation in long differences using two periods: a pre-PNTR period from 1995-2000 and a post-PNTR period from 2000-07. The dependent variable $\Delta \log X^t_{ni,s}$ is the annualized change in log exports during period t.

The main coefficient of interest is α_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 the export growth of other sample countries. The identifying assumption is that the NTR gap is uncorrelated with unobserved shocks to relative US export growth during the post-PNTR period.

In the absence of scale economies, Proposition 1 implies that import liberalization does not affect exports conditional on foreign demand and domestic input costs. Equation (12) controls for foreign demand using importer-industry-period fixed effects and for the effect of PNTR on input costs using the cost shock variable. Therefore, under a null hypothesis of constant returns to scale $\alpha_1 = 0$.

By contrast, when there are increasing returns to scale equation (11) implies that lower output reduces exports since the output elasticity $\frac{\epsilon-1}{\sigma-1} > 0$. Consequently, whenever output growth is lower in industries with a higher NTR gap,[17] US export growth is declining in the NTR gap meaning $\alpha_1 < 0$. It follows that estimating α_1 allows us to distinguish between constant and increasing returns to scale models.

We estimate the effect of PNTR on US exports via the input cost channel by interacting $CostShock_s$ with the $Post^t$ and US_i dummy variables. When using this interaction, we also include input-output exposure $IOExposure_s$ in the vector of industry characteristics Z_s. Assuming that the direct negative effect of PNTR on US sectoral price indices dominates any offsetting general equilibrium effects, we expect $\alpha_2 < 0$ since lower input costs are export promoting. This prediction holds regardless of whether there are scale economies in US production.

The remaining controls and fixed effects in equation (12) are included to capture other shocks to US export growth that may be correlated with the NTR gap. The fixed effects absorb all three-dimensional sources of bilateral trade growth, except for variation at the exporter-industry-period level. Considering equation (11) makes explicit which sources of export growth are absorbed by the fixed effects.

Changes in import demand $X_{n,s}P^{\epsilon-1}_{n,s}$ 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

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[17] Proposition 2 shows that the direct effect of PNTR on output is negative. Empirically, we find in Section 3.5 that PNTR led to lower US output growth in industries with higher NTR gaps (see the first stage results in Table 5).

by $\delta^t_{n,s}$. 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, δ^t_{ni} controls for period-specific changes in bilateral trade costs and supply capacity that do not vary by industry.

Because the predicted effect of PNTR on US exports is not importer specific, the estimation equation does not 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 $\delta^t_{n,s}$ controls for common technology shocks across exporters, our baseline sample restricts exporters to countries 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.

3.4 Estimation results

Before analyzing bilateral exports, we consider 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 is associated with 5.0 log points lower annual export growth after 2000. Moreover, the NTR gap explains 18 percent of the variation in the change in US export growth after PNTR.

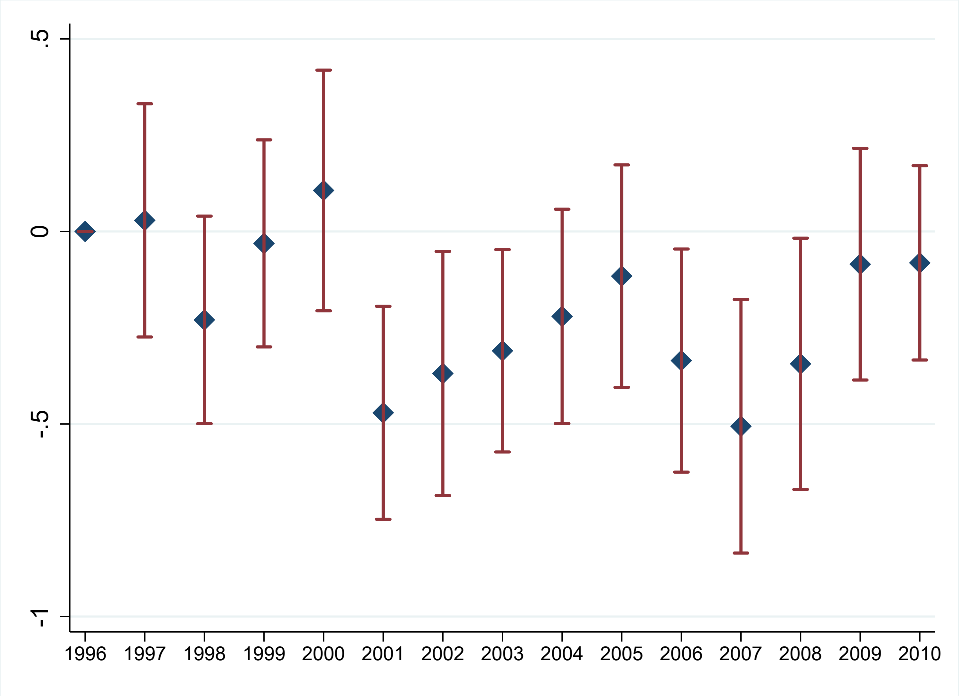
To investigate the timing of this effect, we use an event study specification:

$$\log X^t_{i,s} - \log X^{t-1}_{i,s} = \delta_{i,s} + \delta^t_i + \delta^t_s + \sum_t \zeta_t \times US_i \times NTRGap_s + \epsilon^t_{i,s}, \tag{13}$$

where t denotes the year, $X^t_{i,s}$ is the total exports of country i in industry s and year t to all destinations other than the US and we include exporter-industry, exporter-year and industry-year fixed effects. The event study coefficients ζ_t give the relationship between the NTR gap and export growth in the US relative to other countries. Equation (13) is estimated using annual data from 1995-2010 for OECD exporters and clustering standard errors by exporter-industry.

Figure 2 plots the estimated effect of the NTR gap on US export growth in each year together with 95 percent confidence intervals for the estimated coefficients. There is no sign of a relationship between the NTR gap and US export growth before 2000. But from 2001 until the global financial crisis hits in 2007-08, exports grow more slowly in higher NTR gap sectors. These estimates imply that the negative NTR gap effect cannot be explained by pre-PNTR trends in US export growth. 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.

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



Notes: Event study coefficients ζ_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 estimating the effect of PNTR on bilateral US exports using the specification in equation (12). The estimation sample covers 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 (12) omitting the input cost shock, industry characteristics and the importer-exporter-industry fixed effect. The estimate of α_1 is negative and statistically significant implying 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. We estimate that $\alpha_2 < 0$ and statistically significant, meaning industries that experienced larger falls in input costs because of PNTR had higher export growth. The estimate of α_1 also increases in magnitude, illustrating that omitting the cost shock effect biases α_1 towards zero due to the negative correlation between $NTRGap_s$ and $CostShock_s$. Column (d) adds the input-output exposure control, which is insignificant and makes a negligible difference to our estimates of α_1 and α_2. And column (e) restricts the sample to the 384 manufacturing industries in our dataset, which also yields similar results.

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

The results in Table 2 show that increased import competition after PNTR led to export destruction within industries. This finding is inconsistent with the constant returns to scale hypothesis and implies that there are increasing industry-level returns to scale in US goods production.

Table 2 also shows that PNTR boosted US exports by reducing intermediate input costs. Both the import competition and input cost channels are quantitatively important. The estimates in column (i) 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 20 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 and ranges from negative 18 percent (Cigarette manufacturing) to positive 56 percent (Automobile manufacturing). However, these numbers do not capture the full impact of PNTR on US exports, since they do not account for general equilibrium adjustments that are absorbed by the fixed effects in the regression model. We quantify the general equilibrium effects of PNTR in Section 4 below.

Threats to identification. The negative NTR gap effect estimated in Table 2 provides evidence of scale economies in US production. Next, we consider whether the results could arise from two alternative mechanisms that do not require increasing returns to scale. First, unobserved, US-specific technology shocks in the post-PNTR period that are negatively correlated with the NTR gap and are not captured by the input, skill and capital intensity controls could generate a negative NTR gap effect. To examine this possibility, we estimate the impact of PNTR at a more disaggregated level, while controlling for technology shocks to the NAICS industries used in the baseline specification. In particular, we estimate equation (12) with sectors s defined by HS 6-digit products. At this level of aggregation, we do not observe the input cost shock or industry characteristic variables. But we can include NAICS industry-exporter-period fixed effects. These fixed effects absorb all of the variation used in Table 2, including any unobserved exporter-period technology shocks at the NAICS industry level.

The results are shown in Table 3. In column (a) we only include US exports. Column (b) uses the baseline sample of OECD exporters from Table 2. Column (c) adds NAICS industry-exporter-period fixed effects and column (d) restricts the sample to products that belong to NAICS manufacturing industries.[18] In all cases, we estimate that products with higher NTR gaps experienced lower export growth in the post-PNTR period. This finding, which exploits different variation to the baseline estimates, reduces the likelihood that the negative NTR gap effect is driven by unobserved technology shocks to NAICS industries.

The second potential threat to our identification strategy comes from competition between US and Chinese exports in third markets. Suppose PNTR (or other shocks to the Chinese economy) affected China's exports to countries outside the US through changes in China's export supply capacity $S_{C,s}$. Our baseline specification controls for the impact of $S_{C,s}$ on non-Chinese exports to country n using importer-industry-period fixed effects $\delta^t_{n,s}$. To see this, note that higher $S_{C,s}$ reduces import demand growth in country n because of greater Chinese competition. But this change in import demand is common across all exporters selling to country n. Therefore, it is captured by $\delta^t_{n,s}$.

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. In the model in Section 2.1, this condition is satisfied because the trade elasticity ϵ is symmetric across country pairs. However, suppose PNTR led China to specialize within industries in products previously exported by the US. This change in the composition of China's export basket might increase the substitutability between Chinese and US exports in higher NTR gap industries, leading to lower US exports. Any such effect would be stronger in markets where China is a more important competitor. Consequently, 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 our baseline specification in column (i) of Table 2. Column (a) of Table 4 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 (b) uses the change in China's import share

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[18] The dataset includes 4,698 HS 6-digit products. In columns (c) and (d) we drop products that do not map to a unique NAICS industry, which reduces the number of products by 6 percent.

between 2000 and 2007. The quadruple interaction effect is 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 NTR gap and input cost shock estimates are unaffected. Columns (c) and (d) include the Chinese market share controls in the HS 6-digit specification used in Table 3. Again there is no evidence that the NTR gap effect is more negative in markets with greater Chinese competition. These results are inconsistent with the hypothesis that Chinese competition in third markets explains the post-PNTR decline in US export growth in higher NTR gap industries.

Robustness. Appendix C presents additional robustness checks on the baseline estimates. It shows that our results are robust to: starting the post-PNTR period in 2001 instead of 2000; using alternative definitions of the NTR gap; aggregating exports across destinations; varying the set of exporters, importers and industries in the estimation sample; allowing PNTR to affect domestic expenditure, and; controlling for growth in imports from China caused by shocks other than PNTR.

3.5 Structural estimates

The reduced form results provide evidence of increasing returns to scale in US production, implying that the output elasticity $\frac{\epsilon-1}{\sigma-1}$ is strictly positive. An alternative approach is to estimate the output elasticity structurally from equation (11) using the NTR gap as an instrument for US output growth following PNTR. To implement this strategy, we estimate:

$$\begin{aligned}\Delta \log X^t_{ni,s} &= \delta_{ni,s} + \delta^t_{ni} + \delta^t_{n,s} + \alpha_3 US_i \times \Delta \log Y^t_{U,s} \\ &\quad + \alpha_4 Post^t \times US_i \times CostShock_s + \beta Post^t \times US_i \times Z_s + \epsilon^t_{ni,s}, \end{aligned} \tag{14}$$

where $US_i \times \Delta \log Y^t_{U,s}$ is instrumented by $Post^t \times US_i \times NTRGap_s$. This equation differs from the reduced form specification (12) only through the inclusion of $US_i \times \Delta \log Y^t_{U,s}$ in place of the NTR gap interaction. The presence 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. $\Delta \log Y^{Post}_{U,s} - \Delta \log Y^{Pre}_{U,s}$. The coefficient of interest is α_3, which gives the output elasticity $\frac{\epsilon-1}{\sigma-1}$. Under a null hypothesis of constant returns to scale $\alpha_3 = 0$.

Table 5 presents the results of estimating equation (14) using the sample of manufacturing industries. Column (a) omits all industry controls. Column (b) includes the input cost shock and input-output exposure variables and column (c) adds the remaining industry controls. As expected, the first stage results show that industries with higher NTR gaps experienced lower output growth following PNTR. This result validates interpreting the negative NTR gap effect estimated from the reduced form specification as evidence of increasing returns to scale (see Section 3.3 and footnote 17). The first stage is closely 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 the second stage, the estimated output elasticity is positive and significantly different from zero at the 10 percent level in all three columns. For our preferred specification in column (c), the estimated output elasticity is 0.74. But note that including the full set of industry controls reduces the power of the instrument and the first stage F-statistic in column (c) is below conventional thresholds used to test for weak instruments. This contributes to an imprecise estimate of the output elasticity with standard error 0.41.

Nevertheless, the results in Table 5 reinforce the reduced form evidence that US production exhibits scale economies. In particular, we estimate that the output elasticity is greater than zero. However, based on the structural estimates 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 below one estimated by Bartelme at al. (2019).[19]

4 Quantitative analysis

We have shown that PNTR affected US exports both negatively through scale effects caused by 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 and do not allow us to assess the welfare 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 and then simulate the effects of PNTR in the calibrated model. The goals of the quantitative analysis are to understand how the trade and welfare effects of import liberalization are shaped by the existence of scale economies and input-output linkages, and to evaluate whether PNTR led to export destruction in general equilibrium.

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.1 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 $\hat{P}_{i,s}$.

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[19] Bartelme at al. (2019) estimate the scale elasticity for 15 manufacturing industries. Multiplying these scale elasticity estimates (Table 1, column 2) by the trade elasticities they impose yields the implied output elasticity. The estimated output elasticities range from 0.68 for Chemicals to 0.96 for Wood Products with a mean of 0.83.

The solution depends upon four sets of parameters and variables: (i) import shares $\lambda_{ni,s}$, expenditures $X_{i,s}$ and output levels $Y_{i,s}$ 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 $\hat{\varphi}_{UC,s}$, and; (iv) the parameters ϵ and σ 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.[20]

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 $\hat{\varphi}_{UC,s}$ by estimating the bilateral trade equation (11) allowing the NTR gap to affect growth in US imports from China. We estimate:

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

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-dimensional 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 α_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 $\hat{\varphi}_{UC,s} = \exp\left(7 \times \alpha_5 \times NTRGap_s\right)$, where we multiply the estimated effect by seven because the dependent variable in equation (15) is annualized trade growth.

Table 6 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.[21] 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-

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[20] Appendix D.2 details the country and sectoral aggregations used in the calibration.

[21] 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.

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 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 ϵ. 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.[22]

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 at al. (2019) and Kucheryavyy, Lyn and Rodríguez-Clare (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 including 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 (i) of Table 2 that the conditional elasticity of annual US export growth to the NTR gap equals -0.10. To compute the simulated NTR gap effect, we estimate a specification equivalent to our estimating equation (12), but using simulated data obtained by solving the calibrated model for a given output elasticity (see Appendix D.3 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, Lyn and Rodríguez-Clare (2020) show that trade models with scale economies are well behaved for quantitative work when the

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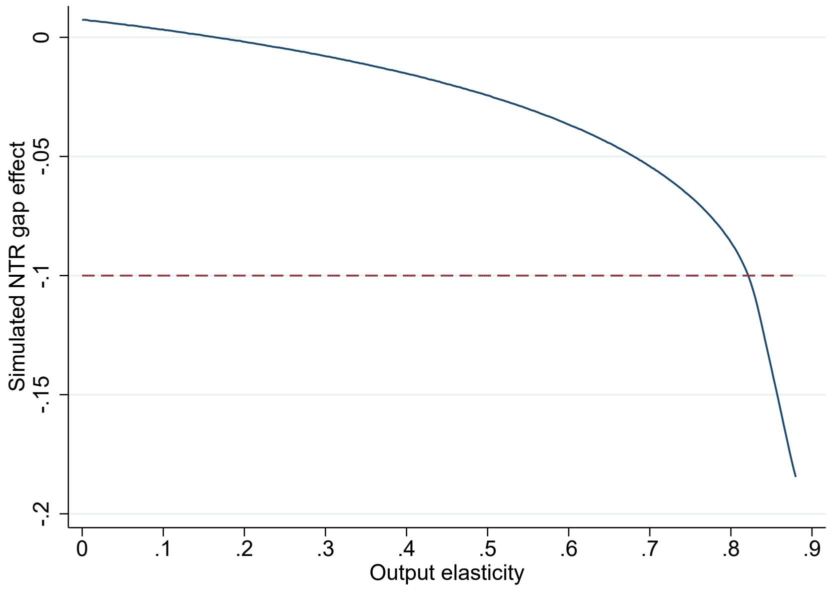
[22] For comparison, Handley and Limão (2017) estimate, using a structural model of trade and uncertainty, that PNTR lowered US prices by the equivalent of a 13 percentage point permanent decrease in tariffs on Chinese imports.

output elasticity 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 3 plots the simulated NTR gap effect as a function of the output elasticity. The simulated effect is decreasing in the output elasticity, which is consistent with part (ii) of Proposition 2. The magnitude of the simulated effect is small compared to the estimated effect when the output elasticity is below around 0.6, but increases rapidly thereafter as the output elasticity approaches one. To match the estimated NTR gap effect, we calibrate the output elasticity to 0.821 for goods sectors. Reassuringly, this value is close to our structural estimate of the output elasticity from Section 3.5, which equals 0.74 in column (c) of Table 5.

Figure 3: Output elasticity and simulated effect of NTR gap on US exports



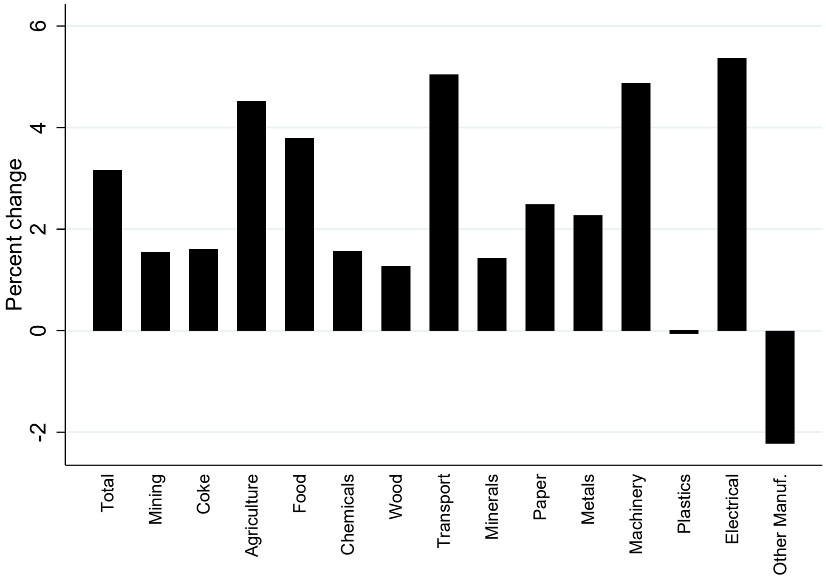
Notes: Simulated NTR gap effect in the calibrated model. Output elasticity on horizontal axis is for goods sectors. For services sectors, output elasticity equals zero. The horizontal dashed line shows the target estimated NTR gap effect of -0.10 from Table 2, column (i).

4.2 Quantitative results

To quantify the effects of PNTR, we shock the calibrated model using the values of $\hat{\varphi}_{UC,s}$ implied by column (a) of Table 6. We start by reporting the impact of PNTR on US exports and then consider its welfare consequences. In order to assess the quantitative importance of scale economies, we compare results from the calibrated model with those obtained from a constant returns economy that is identical to the calibrated model except that the output elasticity is zero in all sectors. The constant returns 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.

Exports. We draw two principal conclusions from the quantitative results for exports. First, PNTR was export promoting, both on aggregate and for most sectors. Figure 4 plots the percent change in US exports relative to GDP due to PNTR, on aggregate (left most bar) and by goods sector. The sectors are ordered with the NTR gap increasing from left to right. We find that total US exports relative to GDP increased by 3.2 percent and that exports rose following PNTR in 12 out of 15 goods sectors.[23]

Figure 4: Impact of PNTR on US exports relative to GDP



Notes: Simulated percent changes in model with output elasticity of 0.821 for goods sectors and zero for services sectors. Sectors ordered with NTR gap increasing from left to right. Goods sectors only. Textiles and Leather not shown.

To understand the mechanisms behind these findings, we can decompose US export growth 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:

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[23] For clarity, the Textiles and Leather sector is not shown in Figure 4 or Figure 5. Exports relative to GDP declined by 22 percent in this sector, which can be decomposed into a negative 32 percent real market potential effect, a positive 8.5 percent input cost effect and a positive 4.6 percent foreign demand effect. The large fall results from Textiles and Leather having both the highest NTR gap of all sectors and a relatively low share of value-added in output.

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

In this expression the change in real market potential is defined by $\widehat{RMP}_{U,s} = \sum_n \mu_{nU,s} \hat{X}_{n,s} \hat{P}_{n,s}^{\epsilon-1}$ and $\chi_{nU,s} = X_{nU,s}/EX_{U,s}$ denotes the initial share of country n in US exports. Note that the real market potential effect operates only if there are scale economies in sector s and, with US GDP as the numeraire, the input cost effect operates only if there are input-output linkages between sectors.

The estimation results in Section 3 establish that PNTR reduced exports by shrinking real market potential and boosted exports by cutting input costs. The decomposition in equation (16) allows us to quantify the magnitude of these channels when incorporating both the direct effects identified empirically and indirect general equilibrium effects due to changes in expenditure and prices. It also allows us to quantify changes in foreign demand due to PNTR, which are absorbed by importer-industry-period fixed effects in the empirical specification. The foreign demand effect captures, among other general equilibrium adjustments, the aggregate link between imports and exports through the trade balance.[24]

Figure 5 shows the export decomposition in equation (16) on aggregate and by goods sector. The real market potential effect is negative in all goods sectors and stronger in sectors with higher NTR gaps. However, export destruction caused by this channel is 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. The foreign demand effect is positive for all sectors, due to the expansion of the global economy, but uncorrelated with the NTR gap. Demand growth is particularly high in China, which is the main beneficiary of PNTR. Together, the input cost and foreign demand effects outweigh the real market potential effect for most sectors. It follows that, although import liberalization causes within-sector export destruction when there are increasing returns to scale, this channel is dominated by the export promoting effects of PNTR.

Not only was PNTR export promoting, we also find that, in spite of the negative real market potential effect, total US export growth is 0.7 percentage points greater in the calibrated model than under constant returns. This surprising result arises primarily because scale economies strengthen

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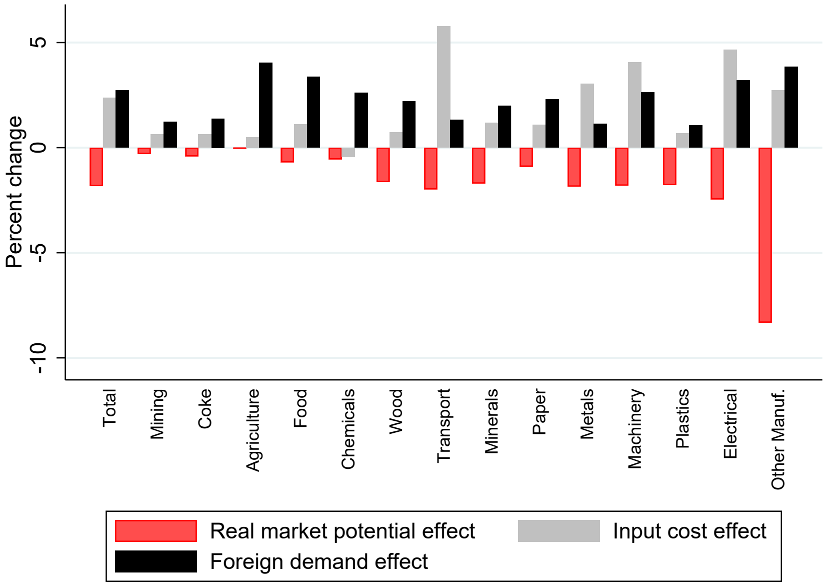
[24] When solving the model we hold constant each country's trade deficit as a share of global value-added, as discussed in Appendix D.1. This trade deficit constraint induces a positive relationship between import growth and export growth at the aggregate level.

Figure 5: Decomposition of change in US exports due to PNTR



Notes: Simulated percent changes in model with output elasticity of 0.821 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). Total exports decomposition averaged across sectors using pre-PNTR US export shares as weights. Sectors ordered with NTR gap increasing from left to right. US GDP is the numeraire. Goods sectors only. Textiles and Leather not shown.

the input cost effect, as sectoral expansion due to lower input costs boosts productivity through increased scale. The input cost effect is 2.4 percent in the calibrated model compared to 0.5 percent with constant returns. This difference highlights that the interaction between scale economies and input-output linkages is quantitatively important, which is an important implication of our analysis.

Our second principal conclusion is that the pattern of sector-level export growth resulting from PNTR is qualitatively different due to the existence of scale economies. Figure 6 plots export growth by sector against the NTR gap in the calibrated model (blue circles) and under constant returns (red squares). 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 greater heterogeneity in export growth across sectors, growth is weakly negatively correlated with the NTR gap because of the real market potential effect, and export growth is negative in three of the four sectors with the highest NTR gaps.[25]

Perhaps most importantly, the correlation between sector-level export growth with and without

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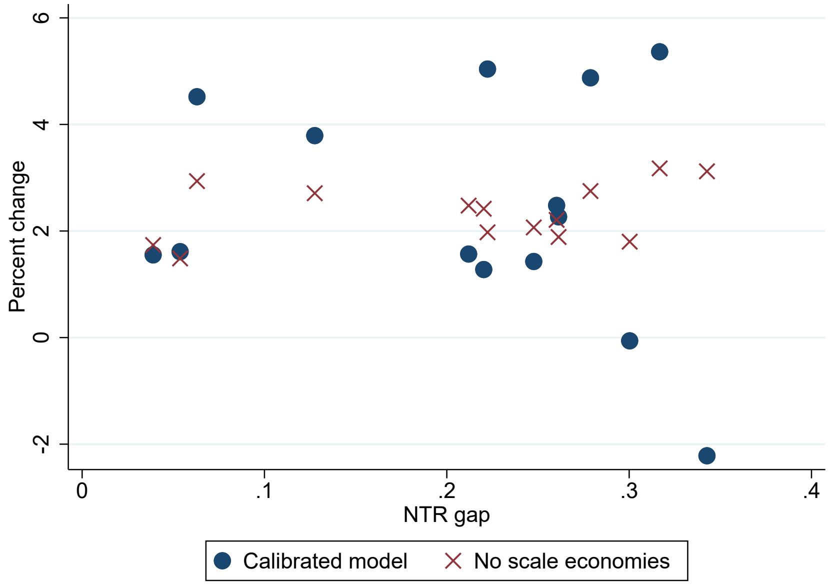
[25] For clarity, the Textiles and Leather sector is not shown in Figure 6. Under constant returns exports relative to GDP increase by 5.0 percent in this sector, meaning it has the highest export growth under constant returns compared to the lowest export growth in the calibrated model.

scale economies is insignificant when excluding the Textiles and Leather sector (and significantly negative if it is included). It follows that misspecifying the strength of returns to scale in quantitative trade models can lead to qualitatively misleading conclusions about cross-sector variation in trade growth. Our results imply that PNTR shifted US exports away from sectors that experienced the largest import liberalizations. This shift would not have occurred under constant returns to scale.[26]

Figure 6: US export growth by sector due to PNTR



Notes: Simulated percent changes in exports. Calibrated model has output elasticity of 0.821 for goods sectors and zero for services sectors. Constant returns model has output elasticity of zero in all sectors. US GDP is the numeraire. Goods sectors only. Textiles and Leather not shown.

Welfare. Next we consider the effect of PNTR on welfare. Kucheryavyy, Lyn and Rodríguez-Clare (2020) show that scale economies may 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, Lyn and Rodríguez-Clare (2020), import liberalization can also be welfare reducing if it reallocates resources to sectors with weaker scale economies. We find that goods output declined by 0.55 percent, while services output rose 0.11 percent, implying that PNTR shifted production and employment towards services sectors without scale economies.[27]

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[26] Appendix D.4 further analyzes how returns to scale affect sector-level export growth. It shows that the within-sector effect of import liberalization reduces exports with increasing returns, but increases exports under constant returns. This difference illustrates why sector-level export growth patterns are sensitive to the strength of scale economies.

[27] See Appendix Table A4. Note that, for our choice of numeraire, sector-level employment growth equals sector-level output growth in the US.

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 0.087 percent and real income by 0.068 percent.[28] For comparison, Caliendo and Parro (2015) find NAFTA increased US welfare by 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 around 30 percent 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, Costinot, and Rodríguez-Clare 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 or with large forward linkages to the rest of the economy as captured by high values of the adjusted Leontief inverse coefficients $\tilde{\gamma}_{i,sv}$.

Table 7 shows that the ACR effect raises US real income by 0.22 percent with scale economies, but only 0.10 percent without, implying that scale economies magnify the impact of PNTR on trade openness. However, the additional gains from this channel are more than offset by a negative 0.15 percent specialization effect caused by the reallocation of employment across sectors. Consequently, allowing for scale economies reduces total US gains from PNTR.

The specialization effect is negative because PNTR shifted resources both towards sectors with weaker scale economies (i.e. from goods to services) and towards sectors with weaker forward input-output linkages. Appendix D.5 shows that the latter effect drives our results, while cross-sectoral heterogeneity in scale economies makes a quantitatively negligible contribution to the negative specialization effect. Setting the output elasticity in services sectors equal to the calibrated

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[28] Income and expenditure differ because trade is not balanced as explained in footnote 24. As is standard in quantitative trade policy analysis our model features constant mark-ups and full employment. Consequently, the welfare estimates do not incorporate any pro-competitive effects of PNTR (Jaravel and Sager 2020, Amiti et al. 2020) or any impact of import competition on employment levels (Autor, Dorn and Hanson 2013).

value for goods yields a specialization effect of negative 0.14 percent (see Appendix Table A4). This result again illustrates the quantitative importance of the interaction between scale economies and input-output linkages.

We find that Chinese gains from PNTR are more than ten 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 6.0 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.

Alternative calibrations. Appendix D.5 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. However, total export growth is essentially unchanged because shutting down the input cost effect offsets the weaker real market potential effect. Second, allowing for scale economies in services sectors increases US gains from PNTR because it raises the ACR effect and slightly shrinks the specialization effect.

Third, the baseline results are robust to combining the Textiles and Leather sector with Other 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 is similar to the baseline when we calibrate the model using trade and output elasticities that vary across sectors from Bartelme et al. (2019). An increase in the average trade elasticity reduces US gains from PNTR, but we still find that PNTR induces a negative specialization effect which partially offsets the positive ACR effect.

5 Concluding comments

Scale economies lie at the heart of many debates over trade and industrial policy. In this paper, we develop a methodology that exploits changes in trade policy to estimate the strength of scale economies by analyzing the effect of import liberalization on exports. We then use our estimation results to discipline the returns to scale in a quantitative trade model and investigate the quantitative importance of scale economies for trade policy analysis.

To implement our approach, we study US export growth after PNTR. Empirical analysis provides evidence of lower export growth in industries more exposed to increased import competition from China. This finding establishes the existence of a channel connecting import protection to export performance as hypothesized by Krugman (1984), and implies that there are increasing returns to scale at the sector level in US goods production. We also show that PNTR boosted exports by reducing imported input costs and that export growth from this channel is comparable in magnitude to the export destruction caused by greater import competition.

Calibrating a quantitative trade model to match our estimates, we find that, for a given trade elasticity, scale economies are slightly weaker than in Krugman (1980) or in Melitz-Pareto models. Nevertheless, quantifying the effects of PNTR shows that scale economies have important effects on trade and welfare in the calibrated model. Three effects are particularly noteworthy. First, within-sector export destruction due to lower real market potential reduces export growth in those sectors most exposed to import liberalization. Consequently, variation in export growth across sectors is negatively correlated with changes under constant returns to scale. A corollary of this finding is that targeted import protection can be used to promote sector-level exports in our calibrated model, but not with constant returns.

Second, the interaction between scale economies and input-output linkages is quantitatively important. It acts to magnify cross-sector reallocation and changes in trade flows. We even find that total export growth is greater in the calibrated model than under constant returns to scale because stronger input cost and foreign demand effects more than offset the negative real market potential effect that occurs with scale economies. Third, the welfare effects of changes in sectoral specialization are the same order of magnitude as those of changes in trade openness. For the US, we find that PNTR induced a negative specialization effect and that the gains from PNTR are around 30 percent smaller than in a constant returns economy.

Our results provide new evidence to inform debates over import protection. The implications are nuanced and underline the importance of accounting for 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, for most sectors and in aggregate, by channels that promote exports. Indeed, total export growth is greater with, than without, scale economies. 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 intermediate inputs shape the effects of international trade.

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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	0.13	0	0.59	444
CostShock	-0.14	-0.14	0.06	-0.29	-0.03	444
IOExposure	1.19	0.37	2.07	0.00	15.13	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	IOExposure	Input Intensity	Skill Intensity
NTRGap					
CostShock	-0.43				
IOExposure	-0.17	0.08			
Input Intensity	-0.30	-0.33	0.13		
Skill Intensity	-0.06	0.13	-0.02	-0.21	
Capital Intensity	-0.47	0.35	0.36	0.18	0.21

Notes: NAICS goods industries.

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

Dependent variable	Δ Log Exports								
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Post x US x NTRGap	-0.094	-0.23	-0.30	-0.29	-0.25	-0.14	-0.24	-0.19	-0.10
	(0.020)	(0.040)	(0.042)	(0.043)	(0.046)	(0.044)	(0.044)	(0.051)	(0.044)
Post x US x CostShock			-0.39	-0.39	-0.47	-0.21	-0.37	-0.56	-0.31
			(0.082)	(0.083)	(0.087)	(0.093)	(0.085)	(0.090)	(0.092)
Post x US x IOExposure				0.0031	0.0018	0.00018	0.0013	-0.00098	-0.0029
				(0.0021)	(0.0023)	(0.0020)	(0.0023)	(0.0024)	(0.0021)
Post x US x Input Intensity						0.24			0.16
						(0.039)			(0.038)
Post x US x Skill Intensity							-0.22		-0.22
							(0.039)		(0.036)
Post x US x Capital Intensity								0.021	0.024
								(0.0065)	(0.0063)
Fixed effects									
Importer-exporter-industry	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-exporter-period	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-industry-period	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry sample	Goods	Goods	Goods	Goods	Manuf.	Manuf.	Manuf.	Manuf.	Manuf.
Observations	1,069,951	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	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)-(d) and 384 NAICS manufacturing industries in columns (e)-(i). Country sample includes countries with population above one million in 1995 and requires exporters to be OECD members at start of 1995.

Table 3: PNTR and US export growth, HS 6-digit sectors

Dependent variable	Δ Log Exports			
	US exports only	OECD exporters	OECD exporters, within NAICS industries	OECD exporters, within NAICS manufacturing industries
	(a)	(b)	(c)	(d)
Post x US x NTRGap	-0.082	-0.054	-0.045	-0.051
	(0.013)	(0.014)	(0.020)	(0.020)
Fixed effects				
Importer-exporter-sector	Yes	Yes	Yes	Yes
Importer-exporter-period	Yes	Yes	Yes	Yes
Importer-sector-period	No	Yes	Yes	Yes
NAICS industry-exporter-period	No	No	Yes	Yes
Observations	363,775	3,658,798	3,172,658	3,031,300
R-squared	0.36	0.52	0.53	0.53

Notes: OLS estimates. Standard errors clustered by exporter-sector in parentheses. Estimated in long differences using 1995-2000 as pre-PNTR period and 2000-07 as post-PNTR period. Sectors defined by HS 6-digit products. 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) includes only US exports. Columns (c) and (d) include NAICS industry-exporter-period fixed effects for the NAICS industries that contain each HS 6-digit sector. Column (d) restricts the sample to sectors belonging to NAICS manufacturing industries.

Table 4: PNTR and US export growth, third market competition

Dependent variable	Δ Log Exports			
Sample	NAICS industries		HS 6-digit products	
	Initial China import share in destination (a)	Δ China import share in destination (b)	Initial China import share in destination (c)	Δ China import share in destination (d)
Post x US x NTRGap	-0.12	-0.11	-0.050	-0.051
	(0.049)	(0.049)	(0.022)	(0.021)
Post x US x China Market Share	0.0032	-0.31	0.032	0.0094
	(0.077)	(0.60)	(0.033)	(0.20)
Post x US x NTRGap x China Market Share	0.33	0.72	-0.028	-0.014
	(0.25)	(1.91)	(0.094)	(0.57)
Fixed effects	Yes	Yes	Yes	Yes
Industry controls	Yes	Yes	No	No
Observations	1,010,551	1,010,551	3,031,300	3,031,300
R-squared	0.50	0.50	0.53	0.53

Notes: OLS estimates. Standard errors clustered by exporter-sector in parentheses. Estimated in long differences using 1995-2000 as pre-PNTR period and 2000-07 as post-PNTR period. Sectors defined by NAICS manufacturing industries in columns (a) and (b) and by HS 6-digit products in columns (c) and (d). Sample restricted to manufacturing sectors. Country sample includes countries with population above one million in 1995 and requires exporters to be OECD members at start of 1995. In columns (a) and (c) China Market Share is China's share of total imports by destination-industry in 2000. In columns (b) and (d) China Market Share is the change in China's share of total imports by destination-industry between 2000 and 2007. Columns (a) and (b) include triple interactions of a post-period dummy, a US exporter dummy and the cost shock, input-output exposure, and input, skill and capital intensity variables. All columns include importer-exporter-sector, importer-exporter-period and importer-sector-period fixed effects. Columns (c) and (d) include NAICS industry-exporter-period fixed effects.

Table 5: Instrumental variable estimates of output elasticity

Dependent variable		Δ Log Exports	
	(a)	(b)	(c)
US x Δ Log Output	0.66	0.98	0.74
	(0.20)	(0.24)	(0.41)
Post x US x CostShock		-0.81	-0.55
		(0.16)	(0.20)
		First Stage	
Post x US x NTRGap	-0.30	-0.25	-0.14
	(0.048)	(0.043)	(0.051)
Kleibergen-Paap F-statistic	37.6	34.1	7.5
Fixed effects	Yes	Yes	Yes
Industry controls			
Input-output exposure	No	Yes	Yes
Input, skill and capital intensity	No	No	Yes
Observations	1,011,530	1,011,530	1,010,551

Notes: Instrumental variable estimates with US x Δ Log Output instumented 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. Country sample includes countries with population above one million in 1995 and requires exporters to be OECD members at start of 1995. Industry controls interacted with a post-period dummy and a US exporter dummy. All columns include importer-exporter-industry, importer-exporter-period and importer-industry-period fixed effects.

Table 6: PNTR and US imports from China

Dependent variable	Δ Log Trade				
	(a)	(b)	(c)	(d)	(e)
Post x US Importer x China Exporter x NTRGap	0.43	0.41	0.33	0.39	0.54
	(0.13)	(0.14)	(0.14)	(0.15)	(0.40)
Post x US Importer x China Exporter x NTRGap Squared					-0.24
					(0.80)
Fixed effects					
Importer-exporter-industry	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. 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 7: Welfare effects of PNTR (percent changes)

		Real income			
	Real expenditure	Total	*ACR effect*	*Specialization effect*	Nominal wage relative to US
Panel A: Calibrated model					
US	0.087	0.068	*0.22*	*-0.15*	n/a
China	1.1	0.87	*1.90*	*-1.0*	6.0
Rest of world	0.014	0.013	*0.017*	*-0.0036*	0.52
Panel B: No scale economies					
US	0.11	0.10	0.10	*n/a*	n/a
China	0.72	0.59	0.59	*n/a*	3.9
Rest of world	-0.0094	-0.0094	-0.0094	*n/a*	0.35

Notes: Simulated percent changes. Panel A: output elasticity of 0.821 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.

Online Appendix for

“Import Liberalization as Export Destruction? Evidence from the United States”

by

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March 2023

A Proofs and derivations

A.1 Proof of Proposition 2

We start by solving for the sectoral price index. Substituting the free entry condition (4) into equation (3) yields:

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

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

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

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

$$\begin{aligned} d\log P_{U,s} = {} & -\frac{\lambda_{UC,s}}{\epsilon - 1} d\log\varphi_{UC,s} + \frac{\lambda_{UU,s}}{\sigma - 1}\left(\sigma d\log c_{U,s} - d\log Y_{U,s}\right) \\ & + \sum_{j \neq U} \frac{\lambda_{Uj,s}}{\sigma - 1}\left(\sigma d\log c_{j,s} - d\log Y_{j,s}\right), \end{aligned} \tag{18}$$

The first term on the right hand side of equation (18) 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.

Next, differentiating equation (7) with $i = U$ gives:

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

Substituting equation (18) into this expression then yields:

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

which gives equation (8) 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, $d\log c_{i,s} = d\log X_{i,s} = d\log w_i$, which does not vary by sector.

Finally, differentiating the bilateral trade equation (5) and using equation (8), while holding domestic input costs, domestic expenditure and all foreign variables constant, gives that for all destinations n:

$$\frac{\partial \log X_{nU,s}}{\partial \log \varphi_{UC,s}} = -\frac{\lambda_{UC,s}\mu_{UU,s}}{\frac{\sigma-1}{\epsilon-1} - 1 + \lambda_{UU,s}\mu_{UU,s}} < 0,$$

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

A.2 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:

$$w_i L_i = \sum_s \gamma_{i,s} Y_{i,s}. \tag{19}$$

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:

$$X_{i,s} = \beta_{i,s} \left(w_i L_i + D_i \right) + \sum_v \gamma_{i,vs} Y_{i,v}. \tag{20}$$

Equations (2), (7), (17), (19) and (20) 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.[29]

A.3 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 (7) for output and (17) for the price index. We now show that equilibrium conditions equivalent to equations (5), (7) 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 ψ determines the degree of external economies of scale.[30] 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:

---

[29] If $\sigma = \epsilon$, equation (7) is not well-defined and is replaced by: $1 = \Gamma_0 \frac{T_{i,s}^{\epsilon-1}}{c_{i,s}^{\sigma} f_{i,s}} \sum_n \varphi_{ni,s} X_{n,s} P_{n,s}^{\epsilon-1}$.

[30] 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.

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

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:

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

Inspection of these equations shows that they are equivalent to equations (5), (7) and (17) in the baseline model (in terms of their dependence on endogenous variables) except that the scale elasticity equals ψ instead of $\frac{1}{\sigma-1}$.

It is also worth noting that with external economies of scale equations (2), (19) and (20) are unchanged from the baseline model. It follows that the external economies model is equivalent to 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^{ξ} units of the country i sector s input good at cost $c_{i,s} z^{\xi}$. The parameter ξ 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 (19) and the expenditure equation (20). 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 $\tilde{f}^x_{ni,s}$ to enter market n. We assume $k > \sigma - 1 > \epsilon - 1$.

To solve this model it is convenient to define the real market potential of country i in sector s as:

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

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

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

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 and depend upon how the fixed market entry costs $\tilde{f}^{x}_{ni,s}$ are denominated, 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 $\frac{1}{k}$. Using these observations it is straightforward to show 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. In addition, trade costs enter the equations above only through the bundle $\tau^{s}_{ni} \left(\tilde{f}^{x}_{ni,s} \right)^{\frac{k+1-\sigma}{k(\sigma-1)}}$. It follows that a reduction in the fixed trade cost $\tilde{f}^{x}_{ni,s}$ has qualitatively the same effects on trade flows as a decline in the variable trade cost τ^{s}_{ni}.

B 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, Romalis and Schott (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 $CostShock$ and $IOExposure$ variables are 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 use these coefficients to calculate $CostShock$ and $IOExposure$ for input-output industries. Finally, we map these variables 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

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

Table A1. 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 a negligible difference to our 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 significant at the 10 percent level (column b). Alternatively, using Handley and Limão's

(2017) NTR gap measure $NTRGap_s = 1 - [(1 + \text{Non-NTR tariff}_s) \,/\, (1 + \text{NTR tariff}_s)]^{-3}$ slightly increases the significance of the NTR gap compared to the baseline estimates (column c).[31]

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.[32] To investigate whether our estimates are biased by missing zeroes, we aggregate across all importers (except for US, China, Hong Kong and Macao) 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 growth following PNTR regardless of whether we estimate the model using OLS (column e) or PPML (column f). But it is worth noting that the input cost shock variable loses significance in these specifications.

Table A2. Column (a) omits all exporters other than the US from the sample. This requires dropping the importer-industry-period fixed effects $\delta^t_{n,s}$ 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. We prefer the baseline specification to column (a) as dropping $\delta^t_{n,s}$ implies we do not control 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.[33]

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.

PNTR occurred around the same time as the broader China shock that led to rapid growth in Chinese exports to the US and other countries (Autor, Dorn and Hanson 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, Dorn and Hanson (2013), we measure

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[31] When using the Pierce and Schott (2016) or Handley and Limão (2017) NTR gap measures, we also recalculate the input cost shock $CostShock_s$ based on equation (10).

[32] Note that the PPML estimation in column (d) does not include zero trade flows since the dependent variable is $X^t_{ni,s}/X^{t-1}_{ni,s}$.

[33] We do not include China, Hong Kong and Macao in the expanded samples.

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 (f) 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.

Proposition 2 characterizes the effect of import liberalization on exports conditional on domestic expenditure. In addition to the direct effect of greater Chinese import competition, PNTR may have affected US real market potential through changes in downstream demand for intermediate inputs. To control 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 $CostShock_s$ and $IOExposure_s$.

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 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 is unaffected.

D Calibration

D.1 Counterfactual changes

Using equations (2), (7), (17), (19) and (20), the equilibrium in changes can be written as:

$$\hat{c}_{i,s} = (\hat{w}_i)^{\gamma_{i,s}} \prod_v \left(\hat{P}_{i,v}\right)^{\gamma_{i,sv}}, \tag{21}$$

$$\hat{Y}_{i,s} = \hat{c}_{i,s}^{-\frac{\sigma(\epsilon-1)}{\sigma-\epsilon}} \left(\sum_n \mu_{ni,s} \hat{\varphi}_{ni,s} \hat{X}_{n,s} \hat{P}_{n,s}^{\epsilon-1}\right)^{\frac{\sigma-1}{\sigma-\epsilon}}, \tag{22}$$

$$\hat{P}_{i,s} = \left[\sum_j \lambda_{ij,s} \hat{\varphi}_{ij,s} \left(\frac{\hat{c}_{j,s}^{\sigma}}{\hat{Y}_{j,s}}\right)^{\frac{1-\epsilon}{\sigma-1}}\right]^{\frac{1}{1-\epsilon}}, \tag{23}$$

$$\hat{w}_i = \sum_s \frac{\gamma_{i,s} Y_{i,s}}{Y_i} \hat{Y}_{i,s}, \tag{24}$$

$$\hat{X}_{i,s} = \frac{\beta_{i,s} Y_i}{X_{i,s}} \hat{w}_i + \frac{\beta_{i,s} D_i'}{X_{i,s}} + \sum_v \frac{\gamma_{i,vs} Y_{i,v}}{X_{i,s}} \hat{Y}_{i,v}. \tag{25}$$

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 ϵ, σ, $\beta_{i,s}$, $\gamma_{i,s}$ 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 (21), (24) and (25) to substitute for $\hat{w}_i$, $\hat{X}_{i,s}$ and $\hat{c}_{i,s}$ in equations (22) and (23) 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:

$$\hat{X}_{ni,s} = \hat{\varphi}_{ni,s} \left(\frac{\hat{Y}_{i,s}}{\hat{c}_{i,s}^{\sigma}}\right)^{\frac{\epsilon-1}{\sigma-1}} \hat{X}_{n,s} \hat{P}_{n,s}^{\epsilon-1}, \tag{26}$$

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:

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

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

D.2 Calibration 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 each of the G7 nations, 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. Table A3 shows the sector classification used for the calibration, together with the NTR gap for each sector.

The NAICS goods industries in our estimation dataset map many-to-one into WIOT sectors. To calculate the NTR gap, CostShock and IOExposure for WIOT goods sectors, and the input intensity, skill intensity and capital intensity for WIOT manufacturing sectors, we take the average across NAICS industries within each WIOT sector.

D.3 Output elasticity calibration

To compute the simulated effect of the NTR gap on US exports for a given output elasticity ψ, we start by solving the calibrated model with the output elasticity equal to ψ 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 on US exports by estimating:

$$\frac{1}{7}\log \hat{S}_{i,s} = \delta_i + \delta_s + \alpha_{Sim,1} US_i \times NTRGap_s + \alpha_{Sim,2} US_i \times CostShock_s + \beta_{Sim} US_i \times Z_s + \epsilon_{i,s}, \tag{27}$$

where Z_s includes sector-level input-output exposure together with each sector's input, skill and capital intensity. Equation (27) is the model equivalent of the specification estimated in column (i) of Table 2 and $\alpha_{Sim,1}$ gives the simulated NTR gap effect shown in Figure 3.[34] To ensure

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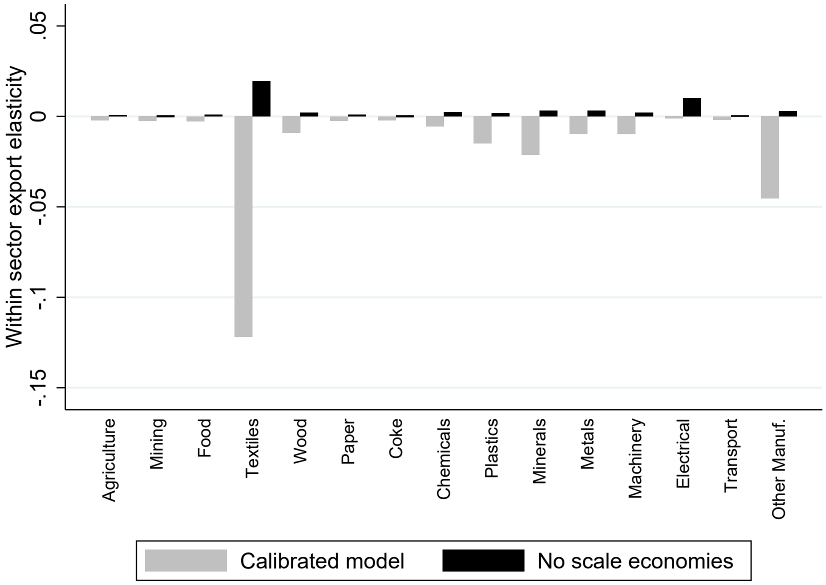
[34] Note from equation (26) that $\alpha_{Sim,1}$ can be estimated using $\hat{S}_{i,s}$ instead of $\hat{X}_{ni,s}$ because $\hat{\varphi}_{ni,s} = 1$ for all exporters other than China. Consequently, the simulated NTR gap effect on US exports is separable from changes in openness and import demand.

consistency with the empirical estimates, when estimating equation (27) we do not include China in the set of exporters and only use manufacturing sectors.

D.4 Sectoral import liberalization

It is instructive 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.[35] Figure 7 plots the export elasticity for each goods sector in the calibrated model (left hand bar for each sector) and in an alternative model without scale economies where the output elasticity equals zero in all sectors (right hand bar).

Figure 7: 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 0.821 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 sectors, implying that reducing barriers to Chinese imports in a given sector decreases US exports relative to GDP in the same sector. In this sense, import liberalization is export destroying within sectors. However, in the model without scale economies the elasticities are positive for all sectors. Moreover, the correlation between the

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[35] 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.

elasticities with and without scale economies is negative 0.83. This comparison shows 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 0.58. This occurs because the cross-sectoral impact of import liberalization is export promoting and does not depend upon the existence of scale economies.

D.5 Alternative calibrations

Table A4 reports the impact of PNTR on US exports and welfare for a range of alternative calibrations. For reference, column (a) summarizes the results from the baseline calibration used in Section 4.2 and column (b) summarizes the results for the calibration with constant returns to scale. In column (c) 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 (c) 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 -0.079 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 (d) we set the output elasticity equal to 0.821 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, 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 (e) 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 (e) are very similar to the baseline. At the sector level, we find that PNTR reduced exports in the merged Textiles and Leather plus Other Manufacturing sector by 14 percent.

In column (f) 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).[36] For all other sectors, the calibration is unchanged from the baseline economy. The model with heterogeneous elasticities yields a slightly less 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 (f) the average trade elasticity for goods sectors increases to 6.5), but remain positive.

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[36] 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.

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Table A1: PNTR and US export growth, robustness checks

Dependent variable	Export growth					
	PNTR in 2001	Pierce-Schott NTR gap	Handley-Limão NTR gap	PPML	Total exports OLS	Total exports PPML
	(a)	(b)	(c)	(d)	(e)	(f)
Post x US x NTRGap	-0.11	-0.056	-0.081	-0.089	-0.15	-0.11
	(0.047)	(0.031)	(0.030)	(0.033)	(0.057)	(0.047)
Post x US x CostShock	-0.30	-0.25	-0.16	-0.38	-0.11	-0.14
	(0.10)	(0.071)	(0.049)	(0.11)	(0.14)	(0.17)
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 in long differences 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. 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-output exposure, and input, skill and capital intensity variables. All columns except (e) and (f) include importer-exporter-industry, importer-exporter-period and importer-industry-period fixed effects. In 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 A2: PNTR and US export growth, additional robustness checks

Dependent variable	Δ Log Exports							
	Only US exports	OECD & Non-OECD exporters	All exporters & importers	Trim sample on NTR gap	Drop textiles & apparel industries	China shock	Expenditure shock	Expenditure shock & final demand share
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Post x US x NTRGap	-0.17	-0.088	-0.098	-0.17	-0.096	-0.11	-0.10	-0.10
	(0.054)	(0.043)	(0.041)	(0.062)	(0.049)	(0.046)	(0.045)	(0.044)
Post x US x CostShock	-0.30	-0.28	-0.27	-0.39	-0.16	-0.33	-0.31	-0.21
	(0.10)	(0.093)	(0.091)	(0.096)	(0.11)	(0.093)	(0.091)	(0.094)
US x ChinaShock						0.63		
						(0.99)		
Post x US x ExpenditureShock							0.020	-0.092
							(0.052)	(0.066)
Post x US x Final								0.040
								(0.016)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Estimator	OLS	OLS	OLS	OLS	OLS	IV	OLS	OLS
Kleibergen-Paap F-stat.						12.1		
Observations	69,003	1,762,374	1,978,551	931,509	903,938	998,539	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. 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. In column (f) 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. All columns include triple interactions of a post-period dummy, a US exporter dummy and the input-output exposure, and input, skill and capital intensity variables. All columns except (a) include importer-exporter-industry, importer-exporter-period and importer-industry-period fixed effects. Column (a) includes importer-industry and importer-period fixed effects.

Table A3: Calibration sectors

Code	Name	NTR gap	Group
AtB	Agriculture	0.06	Other Goods
C	Mining	0.04	Other Goods
15t16	Food	0.13	Manufacturing
17t19	Textiles & Leather	0.35	Manufacturing
20	Wood	0.22	Manufacturing
21t22	Paper	0.26	Manufacturing
23	Coke	0.05	Manufacturing
24	Chemicals	0.21	Manufacturing
25	Plastics	0.30	Manufacturing
26	Minerals	0.25	Manufacturing
27t28	Metals	0.26	Manufacturing
29	Machinery	0.28	Manufacturing
30t33	Electrical	0.32	Manufacturing
34t35	Transport	0.22	Manufacturing
36t37	Other Manufacturing	0.34	Manufacturing
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. Goods comprises Manufacturing and Other Goods sectors.

Table A4: Impact of PNTR on US exports, output and welfare for alternative model calibrations (percent changes)

	Baseline (a)	No scale economies (b)	No input-output linkages (c)	Scale economies in services (d)	23 sectors (e)	Heterogeneous elasticities (f)
Total exports	3.2	2.5	3.2	3.2	3.4	3.0
of which: Real market potential effect	*-1.8*	*n/a*	*-0.17*	*-2.4*	*-1.7*	*-1.4*
Input cost effect	*2.4*	*0.53*	*n/a*	*3.1*	*2.3*	*2.7*
Foreign demand effect	*2.7*	*1.9*	*3.4*	*2.6*	*2.9*	*1.8*
Simulated NTR gap effect	-0.10	0.0075	-0.079	-0.10	-0.098	-0.071
Goods output	-0.55	-0.36	-0.36	-0.61	-0.49	-0.25
Services output	0.11	0.075	0.12	0.12	0.13	0.054
Real income	0.068	0.10	0.037	0.10	0.071	0.027
of which: ACR effect	*0.22*	0.10	*0.067*	*0.24*	*0.19*	*0.13*
Specialization effect	*-0.15*	*n/a*	*-0.030*	*-0.14*	*-0.11*	*-0.10*

Notes: Simulated percent changes. Services sectors: trade elasticity is five; output elasticity is zero, except in column (d) where output elasticity is 0.821. Goods sectors: trade elasticity is five in columns (a)-(e); output elasticity is 0.821 in columns (a), (c), (d) (and (e); output elasticity is zero in column (b); model in column (f) calibrated using trade and output elasticities for goods sectors from Bartelme et al. (2019). In column (e) 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.