American Economic Journal: Macroeconomics 2026, 18(3): 77–111
https://doi.org/10.1257/mac.20230213

Import Liberalization as Export Destruction? Evidence from the United States†

By Holger Breinlich, Elsa Leromain, Dennis Novy, and Thomas Sampson*

In trade models with scale economies, import liberalization reduces exports within industries by shrinking real market potential. We find this export destruction mechanism reduced US export growth following the permanent normalization of trade relations with China (PNTR). There was also an offsetting boost to exports from lower input costs. We use our estimates to calibrate a quantitative model and show 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. US gains from PNTR are positive but 30 percent smaller than under constant returns. (*JEL* D24, E23, F13, F14, O19, P33)

Many long-standing questions in macroeconomics hinge on whether industries face constant or increasing returns to scale. This distinction matters for growth and productivity (Hall 1988; Basu 1996), the propagation of fiscal and monetary shocks (Rotemberg and Woodford 1995), and the design of industrial and competition policies (Juhász, Lane, and Rodrik 2024). And in open economies, industry-level returns to scale generate the home market effect under which increased domestic demand raises industry exports (Linder 1961; Krugman 1980) and are central to studying the impact of trade policy (Lashkaripour and Lugovskyy 2023).

US leaders from Alexander Hamilton (1791) onward have often argued that American manufacturing should be protected from foreign competition. Today at least, economists tend to be skeptical of such ideas, pointing to the advantages that

*Breinlich: University of Surrey (email: h.breinlich@surrey.ac.uk); Leromain: University of Antwerp and IRES/LIDAM UC Louvain (email: elsa.leromain@uantwerpen.be); Novy: University of Warwick (email: d.novy@warwick.ac.uk); Sampson: London School of Economics (email: t.a.sampson@lse.ac.uk). The authors are listed in alphabetical order. Şebnem Kalemli-Özcan was coeditor for this article. We are grateful to David Atkin, Jan Bakker, Thibault Fally, Andrew Greenland, Réka Juhász, Lei Li, Frank Pisch, Daniel Sturm, Daniel Trefler, Jonathan Vogel, David Weinstein, and seminar participants at Aarhus, Aix-Marseille, Antwerp, Aston, Bank of Canada, Barcelona, Bayreuth, Bergen, Birmingham, Edinburgh, Groningen, Harvard-MIT, Hong Kong, LSE, Mainz, Mannheim, Munich, Queen Mary, Paris-Saclay, Surrey, Toronto, UIBE Beijing, Warwick, Chilean Society of Economics, ETSG 2021, ERWIT 2022, International Trade Online 2021, NBER ITI Summer Institute 2021, Nordic International Trade Conference 2022, Nottingham Summer Trade Workshop 2022, Vienna Workshop on International Economic Networks 2021, and the Warwick-SUFE workshop for helpful comments and suggestions. Breinlich and Novy gratefully acknowledge research support from the Economic and Social Research Council (grants EST013567/1 and ES/S007121/1). Leromain acknowledges support from the EOS programme of the Flemish (FWO) and French-speaking (FRS-FNRS) communities of Belgium (convention 30784531 on "Winners and Losers from Globalization and Market Integration: Insights from Micro-Data").

†Go to https://doi.org/10.1257/mac.20230213 to visit the article page for additional materials and author disclosure statement(s).

trade liberalization brings by reducing import costs and exposing domestic firms to the rigors of international competition.[1] Yet economic theory establishes that the trade and welfare effects of import policy depend 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, and Juhász (2018) documents evidence supporting the infant industry mechanism in Napoleonic France. Venables (1987) and Kucheryavyy, Lyn, and Rodríguez-Clare (2023) 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.

Building on Krugman's (1984) insight, this paper develops a new approach to studying scale economies by using trade policy variation to estimate the degree of industry-level returns to scale. We show that the effect of import liberalization on exports can be used to discriminate between constant versus increasing returns, and 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 empirical findings to calibrate the strength of scale economies in a quantitative trade model and to study the macroeconomic effects of PNTR on US trade and welfare.

To motivate our empirical strategy, Section I 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 (2023) studying conditions under which trade models with 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 II. Following Pierce and Schott (2016), we measure industry-level exposure to PNTR by the *normal*

[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.

[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).

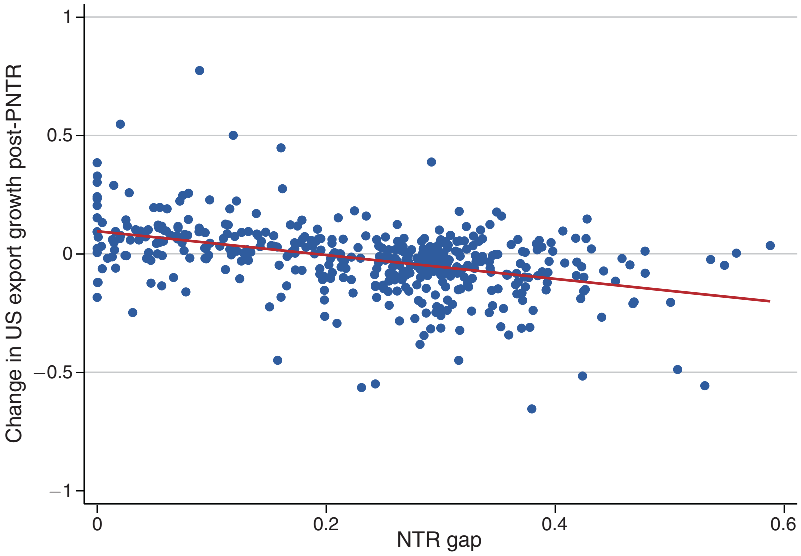

Figure 1. PNTR and US Export Growth

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 −0.50 with robust standard error of 0.057. NAICS goods industries.

trade relations (*NTR*) *gap*, defined as the tariff increase that Chinese imports would have faced if the United States had revoked China's most favored nation (MFN) 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

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

shifts output growth. The estimated elasticity of exports to output is positive, consistent with the reduced-form evidence of scale economies. This finding provides evidence of increasing returns to scale at the industry level. It complements work on industry-level scale economies in industrial organization and macroeconomics (Hall 1990; Basu and Fernald 1997) and, also, applications that focus on the estimation of internal firm-level returns to scale (Basu 2008).

Our estimates imply that PNTR reduced export growth, all else equal. However, we also find 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 seventy-fifth percentile of the NTR gap distribution than for an industry at the twenty-fifth percentile. Performing the same comparison for the input cost shock distribution implies a 20 percent increase in exports.

In Section III 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 macroeconomic 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 value of one 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, Costinot, Donaldson, and Rodríguez-Clare (2019).

The quantitative analysis shows that PNTR increased US exports relative to GDP for most goods sectors. The reason is that in general equilibrium, the Krugman mechanism is dominated by the export-promoting effects of import liberalization that operate through lower input costs and higher foreign demand.[5] We also find that the interaction of scale economies with input-output linkages is quantitatively important and magnifies changes in specialization and trade. For example, in spite of the export destruction effect, aggregate US export growth due to PNTR is 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

[4] We measure the input cost shock from PNTR as the input-output coefficient weighted NTR gap in upstream industries. See Section IIB for details.

[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.

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 illustrate the importance of scale economies for sector-level trade policy analysis.

In terms of welfare, we estimate that 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 United States, the Arkolakis, Costinot, and Rodríguez-Clare (2012) term is positive, while the specialization effect is negative because PNTR reallocates US production toward 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 literatures on the returns to scale and on trade policy. Our contribution relative to previous research is threefold. We introduce a new approach to estimating scale economies using trade policy shocks. We document the existence of a scale economies channel through which import liberalization is export destroying. And we evaluate the importance of this channel for quantitative trade policy analysis.[6]

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 2023). 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 strength of scale economies is a key calibration parameter. 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.

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 (2018) findings are consistent with French production expanding through an infant industry mechanism. Likewise, the export destruction effect that 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

[6] Dick (1994) studies whether import protection is export promoting using cross-sectional data for the United States in 1970, but finds little evidence to support the hypothesis.

protection debate by decomposing the channels through which liberalization operates and by studying sectoral heterogeneity in these channels.

Our analysis is related to studies that use trade data to estimate scale economies (Antweiler and Trefler 2002; Bartelme, Costinot, Donaldson, and Rodríguez-Clare 2019; Lashkaripour and Lugovskyy 2023) and test for the home market effect (Davis and Weinstein 2003). Weder (2003); Hanson and Xiang (2004); and Costinot, Donaldson, Kyle, and Williams (2019) find that increases in domestic demand raise exports, which supports the existence of the home market effect. The evidence we present showing 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. 2024). We show how scale economies induce spillovers through changes in real market potential and analyze their quantitative importance.

I. Trade and Scale Economies

We start by introducing a multisector 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 the effect of import liberalization on exports under increasing returns and under constant returns, which motivates our empirical analysis in Section II.

The model generalizes Krugman (1980) to allow for many countries and sectors, intermediate inputs, and an elasticity of substitution between products that differs for products produced in the same country versus products produced in different countries. In this model, firms are symmetric and sector-level scale economies result from love of variety in preferences. However, we show in Supplemental Appendix A.4 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

[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, Dai, Feenstra, and Romalis (2020).

investment.[8] It follows that although our empirical analysis sheds light on the magnitude of sector-level returns to scale, we do not distinguish between alternative sources of increasing returns.

A. *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 nontradable and can be either consumed or used as an intermediate input. Output $Q_{n,s}$ of sector s in country n is given by[9]

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

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.

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

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

where w_i is the wage in country i, $P_{i,v}$ is the price index for sector v in country i, $\gamma_{i,s}$ denotes the share of value added in production costs, and $\gamma_{i,sv}$ denotes the share of

[8] The equivalence results in Supplemental Appendix A.4 build upon Kucheryavyy, Lyn, and Rodríguez-Clare (2023), 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 that 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.

intermediates from sector v in the production costs of sector s. There is free entry of firms into variety production with entry cost $f_{i,s} c_{i,s}$.

B. *Trade*

Trade is subject to iceberg costs $\tau_{ni,s} \geq 1$, where n denotes the importing country and i the exporting country. Bilateral trade $X_{ni,s}$ equals expenditure by country n on products from country i in sector s, and we show in Supplemental Appendix A.1 that $X_{ni,s}$ satisfies

$$X_{ni,s} = \Gamma_0 \varphi_{ni,s} T_{i,s}^{\epsilon-1} \left(\frac{Y_{i,s}}{c_{i,s}^{\sigma} f_{i,s}}\right)^{\frac{\epsilon-1}{\sigma-1}} X_{n,s} P_{n,s}^{\epsilon-1}, \tag{2}$$

where Γ_0 is a constant,[10] $\varphi_{ni,s} \equiv \tau_{ni,s}^{1-\epsilon}$ measures bilateral openness to trade, $Y_{i,s} = \sum_n X_{ni,s}$ denotes total sales of country i in sector s, and $X_{n,s} = \sum_i X_{ni,s}$ denotes expenditure on sector s in country n. 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.

The elasticity of bilateral trade to output, $(\epsilon - 1)/(\sigma - 1)$, which we label the *output elasticity*, equals the product of the *trade elasticity,* $\epsilon - 1$, and the *scale elasticity,* $\frac{1}{\sigma - 1}$. The trade elasticity determines the responsiveness of trade to lower prices, while the scale elasticity controls the rate at which the industry price index declines as output rises. To see this, note that the price index $P_{ni,s}$ for imports by country n from country i in sector s is given by

$$P_{ni,s} = \frac{\sigma}{\sigma - 1} \frac{\tau_{ni,s}}{T_{i,s}} \left(\frac{Y_{i,s}}{\sigma c_{i,s}^{\sigma} f_{i,s}}\right)^{-\frac{1}{\sigma-1}}.$$

Higher output reduces the price index because it increases the mass of varieties of produced, leading to a decline in $P_{ni,s}$ due to love of variety. An increase in σ reduces the scale elasticity because it makes varieties more substitutable, weakening the love-of-variety effect. In the absence of scale economies, such as in the Armington model obtained when $\sigma \to \infty$, the scale elasticity and the output elasticity both equal 0. Thus, the output elasticity is positive if and only if there are increasing sector-level returns to scale.

Since the bilateral trade equation (2) is a structural gravity equation (as defined by Head and Mayer 2014), it can also be written as

$$X_{ni,s} = \varphi_{ni,s} \frac{Y_{i,s}}{RMP_{i,s}} M_{n,s}, \tag{3}$$

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

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 (3) 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.

C. *Import Liberalization*

How does import liberalization affect exports? Suppose that there is a reduction in US barriers to Chinese imports, leading to an increase in openness $\varphi_{UC,s}$, where U denotes the United States and C denotes China. In our empirical application, the reduction in US import barriers results from PNTR with China.[11]

The bilateral trade equation (2) 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?

Suppose that there are increasing returns to scale, meaning that $\sigma < \infty$ and that the output elasticity of exports is strictly positive. Using $Y_{i,s} = \sum_n X_{ni,s}$, the bilateral trade equation (2) implies that if $\sigma > \epsilon$, meaning that varieties produced in the same country are closer substitutes than varieties from different countries, then

$$Y_{i,s} = \Gamma_0^{\frac{\sigma-1}{\sigma-\epsilon}} T_{i,s}^{\frac{(\sigma-1)(\epsilon-1)}{\sigma-\epsilon}} \left(\frac{1}{c_{i,s}^{\sigma} f_{i,s}}\right)^{\frac{\epsilon-1}{\sigma-\epsilon}} \left(RMP_{i,s}\right)^{\frac{\sigma-1}{\sigma-\epsilon}}. \tag{4}$$

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. When $\sigma = \epsilon$, as in Krugman (1980), equation (4) does not hold. However, $Y_{i,s}$ still depends upon country i's market access through the market clearing conditions, and Proposition 1 below still applies (see Supplemental Appendix A.2).

The increase in $\varphi_{UC,s}$ caused by 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 lower $P_{U,s}$ makes the US market more competitive, leading to a fall in US real market potential in sector s. And by equation (4), smaller real market potential reduces output $Y_{U,s}$ as US producers lose domestic market share to Chinese imports.

Lower output in turn implies a decline in sector-level productivity because of scale economies, and the bilateral trade equation (2) shows that this results in a reduction in US exports to all destinations. This is the mechanism proposed by

[11] We model PNTR as a decline in variable trade costs. However, treating it as a reduction in the fixed cost of exporting to the United States for Chinese firms would not change our results (see Supplemental Appendix A.4).

Krugman (1984) through which import policy affects exports. Formally, we show in Supplemental Appendix A.2 that, holding foreign variables, domestic input costs, and domestic expenditure constant, the effect of $\varphi_{UC,s}$ on US exports satisfies

$$(5) \qquad \frac{\partial \log X_{nU,s}}{\partial \log \varphi_{UC,s}} = -\frac{\lambda_{UC,s}\mu_{UU,s}}{\frac{\sigma-1}{\epsilon-1} - 1 + \lambda_{UU,s}\mu_{UU,s}} < 0,$$

where $\lambda_{ni,s} \equiv X_{ni,s}/X_{n,s}$ is the import share of country i in country n and $\mu_{ni,s} \equiv X_{ni,s}/Y_{i,s}$ is the share of sales to country n in country i output. Equation (5) shows that 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 that exports are more elastic to variation in productivity. Proposition 1 summarizes these results.

PROPOSITION 1: *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 1 holds not only in the love-of-variety model developed above but in a broad class of trade models with increasing returns to scale. Supplemental Appendix A.4 shows that equations equivalent to those used to prove Proposition 1 hold in models where scale economies result from (i) external economies of scale, (ii) endogenous technology investment, or (iii) Melitz-Pareto firm heterogenity.

The bilateral trade equation (2) also implies that in the constant returns to scale case where $\sigma \rightarrow \infty$, exports do not depend on output. It follows that, conditional on input costs $c_{i,s}$ and real foreign demand $X_{n,s}P_{n,s}^{\epsilon-1}$, import liberalization does not affect exports when there are constant returns to scale at the sector level. This observation holds not only in an Armington economy but also in economies based on the Eaton and Kortum (2002) model.

Proposition 1 implies 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 these predictions 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 (1). And lower input costs increase exports, all else equal, as shown by equation (2). 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.

II. 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 and increasing returns trade models. Our approach leverages international trade data to test for the presence of scale economies at the industry level (Breinlich, Leromain, Novy, and Sampson 2026). This approach complements methods used in industrial organization and macroeconomics to estimate scale economies in closed economy settings (Hall 1990).

A. *PNTR*

Our empirical strategy exploits PNTR as a liberalization shock that increased US openness to Chinese imports. China was granted temporary MFN status by the United States in 1980, meaning that imports from China faced 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.[12] 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 NTR 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, Dai, Feenstra, and Romalis (2020) and Jaravel and Sager (2020) provide evidence that PNTR reduced prices in the United States.[13]

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

[12] 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.

[13] Amiti, Dai, Feenstra, and Romalis (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 United States.

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.

B. *Data*

The baseline analysis uses data for NAICS goods industries at the six-digit level. We define the NTR gap in industry s as the log difference between the non-NTR tariff and the NTR tariff on US imports:

$$NTRGap_s = \log\left(1 + \textit{Non-NTR tariff}_s\right) - \log\left(1 + \textit{NTR tariff}_s\right). \tag{6}$$

Tariff data from Feenstra, Romalis, and Schott (2002) is used to compute the NTR gap in 1999 for eight-digit Harmonized Tariff System import codes. We then calculate $NTRGap_s$ as the average NTR gap across eight-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 Supplemental 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 (1). 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 United States 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

$$CostShock = -\left(I - \Gamma_U\right)^{-1}\Gamma_U NTRGap, \tag{7}$$

where I is the identity matrix and *NTRGap* is the vector of industry-level NTR gaps defined in equation (6). As the right-hand side of equation (7) 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 (7) by -1, *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

TABLE 1—INDUSTRY-LEVEL DESCRIPTIVE STATISTICS

	Mean	Median	Std. dev.	Min.	Max.	Observations
Panel A. Summary statistics						
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

	NTRGap	CostShock	IOExposure	Input intensity	Skill intensity
Panel B. Correlations					
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

Note: NAICS goods industries.

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 (2023) show that not controlling for this expected shock can lead to omitted variable bias.

Bilateral trade data from 1995 onward at the six-digit level of the Harmonized 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 National Bureau of Economic Research manufacturing database to measure output levels, input intensity, skill intensity, and capital intensity for manufacturing industries (see Supplemental Appendix B for details).

Table 1 shows descriptive statistics for the industry-level variables. The NTR gap ranges between 0 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.

C. *Estimation Specification*

Our estimation specification is derived from the bilateral trade equation (2). Taking log differences of equation (2) yields

$$(8)\quad \Delta\log X_{ni,s} = \frac{\epsilon-1}{\sigma-1}\Delta\log Y_{i,s} - \frac{\sigma(\epsilon-1)}{\sigma-1}\Delta\log c_{i,s} + (\epsilon-1)\Delta\log\left(T_{i,s}f_{i,s}^{-\frac{1}{\sigma-1}}\right) + \Delta\log\left(X_{n,s}P_{n,s}^{\epsilon-1}\right) + \Delta\log\varphi_{ni,s}.$$

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 $f_{i,s}$.[14]

We estimate a reduced-form version of equation (8) 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

$$(9)\quad \Delta\log X_{ni,s}^{t} = \delta_{ni,s} + \delta_{ni}^{t} + \delta_{n,s}^{t} + \alpha_1 Post^t \times US_i \times NTRGap_s + \alpha_2 Post^t \times US_i \times CostShock_s + \beta Post^t \times US_i \times Z_s + \epsilon_{ni,s}^{t},$$

where t denotes the period, $Post^t$ is a dummy for the post-PNTR period, US_i is a dummy for the exporter i being the United States, Z_s is a vector of industry characteristics, and we 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 to 2000 and a post-PNTR period from 2000 to 2007. The dependent variable $\Delta\log X_{ni,s}^{t}$ is the annualized change in log exports during period t.

The main coefficient of interest is 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, import liberalization does not affect exports conditional on foreign demand and domestic input costs. Equation (9) 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, $\alpha_1 = 0$.

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

By contrast, when there are increasing returns to scale, equation (8) 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,[15] 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 (9) 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 (8) makes explicit which sources of export growth are absorbed by the fixed effects.

Changes in import demand $X_{n,s} P_{n,s}^{\epsilon-1}$ by period and changes in supply capacity that do not vary by exporter, such as technology shocks that vary across industries but not countries, are captured by $\delta_{n,s}^t$. 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_{ni}^t 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 $\delta_{n,s}^t$ 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.

D. *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 to 2007 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.

[15] Proposition 1 shows that the direct effect of PNTR on output is negative. Empirically, we find in Section IIE that PNTR led to lower US output growth in industries with higher NTR gaps (see the first-stage results in Table 5).

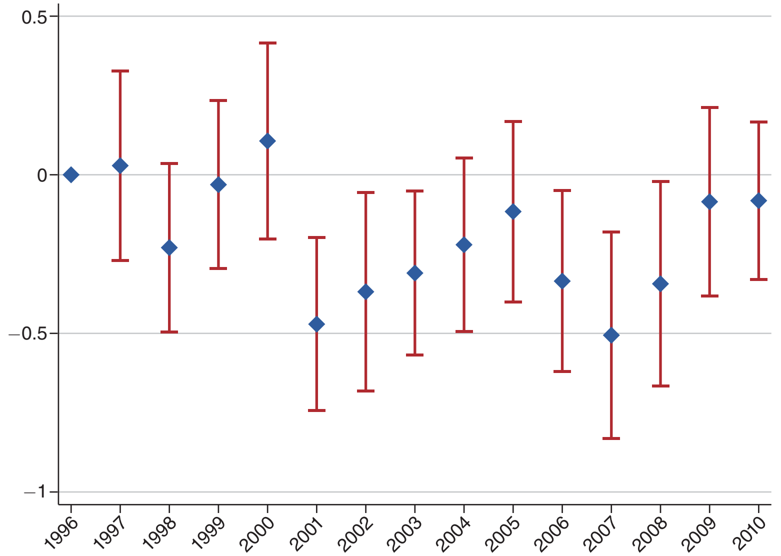

Figure 2. NTR Gap and US Export Growth: Event-Study Estimates

Notes: Event-study coefficients ζ_t and 95 percent confidence intervals from estimating equation (10). Exporters restricted to OECD members at start of 1995 with population above one million in 1995. NAICS goods industries.

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:

$$\log X_{i,s}^{t} - \log X_{i,s}^{t-1} = \delta_{i,s} + \delta_{i}^{t} + \delta_{s}^{t} + \sum_{t} \zeta_t \times US_i \times NTRGap_s + \epsilon_{i,s}^{t}, \tag{10}$$

where t denotes the year, $X_{i,s}^{t}$ is the total exports of country i in industry s and year t to all destinations other than the United States, 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 United States relative to other countries. Equation (10) is estimated using annual data from 1995 to 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 2007–2008, 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.

TABLE 2—PNTR AND US EXPORT GROWTH, REDUCED-FORM ESTIMATES

Dependent variable	Δ log exports								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Post × US × 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 × US × 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 × US × 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 × US × Input intensity						0.24			0.16
						(0.039)			(0.038)
Post × US × Skill intensity							−0.22		−0.22
							(0.039)		(0.036)
Post × US × 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^2	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 2000–2007 as post-PNTR period. Industry sample covers 444 NAICS goods industries in columns 1–4 and 384 NAICS manufacturing industries in columns 5–9. Country sample includes countries with population above one million in 1995 and requires exporters to be OECD members at start of 1995.

We now turn to estimating the effect of PNTR on bilateral US exports using the specification in equation (9). The estimation sample covers exports from 23 OECD countries including the United States to 141 importers for 444 NAICS goods industries. We omit the United States, 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 1 by estimating equation (9), 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 2 introduces the importer-exporter-industry fixed effect, causing the magnitude of the estimated NTR gap effect to more than double. The estimates in columns 1 and 2 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 toward zero.

In column 3 we add the input cost shock variable. We estimate that $\alpha_2 < 0$ and is statistically significant, meaning that 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 toward zero due to the negative correlation between $NTRGap_s$ and $CostShock_s$. Column 4 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 5 restricts the sample to the 384 manufacturing industries in our dataset, which also yields similar results.

In columns 6–9, we include the input, skill and capital intensity controls. The estimates imply that export growth in the United States 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 9 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 seventy-fifth percentile of the NTR gap distribution than for an industry at the twenty-fifth percentile. At the same time, conditional on the NTR gap, PNTR increased exports by 20 percent more for an industry at the seventy-fifth percentile of the input cost shock distribution than for an industry at the twenty-fifth percentile. The net effect of these two forces varies substantially across industries and ranges from -18 percent (cigarette manufacturing) to $+56$ 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 III.

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 (9) with sectors s defined by HS six-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 1 we only include US exports. Column 2 uses the baseline sample of OECD exporters from Table 2. Column 3

Table 3—PNTR and US Export Growth, HS Six-Digit Sectors

Dependent variable	Δ log exports			
	US exports only (1)	OECD exporters (2)	OECD exporters, within NAICS industries (3)	OECD exporters, within NAICS manufacturing industries (4)
Post × US × 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^2	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 2000–2007 as post-PNTR period. Sectors defined by HS six-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 1 includes only US exports. Columns 3 and 4 include NAICS industry-exporter-period fixed effects for the NAICS industries that contain each HS six-digit sector. Column 4 restricts the sample to sectors belonging to NAICS manufacturing industries.

adds NAICS industry-exporter-period fixed effects, and column 4 restricts the sample to products that belong to NAICS manufacturing industries.[16] 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 that PNTR (or other shocks to the Chinese economy) affected China's exports to countries outside the United States 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 that 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 IA, this condition is satisfied because the trade elasticity ϵ is symmetric across country pairs. However, suppose that PNTR led China to specialize within industries in products previously exported by the United States. This change in the composition of China's export basket might increase the substitutability between Chinese and US exports

[16] The dataset includes 4,698 HS six-digit products. In columns 3 and 4, we drop products that do not map to a unique NAICS industry, which reduces the number of products by 6 percent.

Table 4—PNTR and US Export Growth, Third Market Competition

Dependent variable	Δ log exports			
Sample	NAICS industries		HS six-digit products	
	Initial China import share in destination (1)	Δ China import share in destination (2)	Initial China import share in destination (3)	Δ China import share in destination (4)
Post × US × NTRGap	−0.12	−0.11	−0.050	−0.051
	(0.049)	(0.049)	(0.022)	(0.021)
Post × US × China market share	0.0032	−0.31	0.032	0.0094
	(0.077)	(0.60)	(0.033)	(0.20)
Post × US × NTRGap × 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^2	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 2000–2007 as post-PNTR period. Sectors defined by NAICS manufacturing industries in columns 1 and 2 and by HS six-digit products in columns 3 and 4. 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 1 and 3, "China market share" is China's share of total imports by destination-industry in 2000. In columns 2 and 4, China Market Share is the change in China's share of total imports by destination-industry between 2000 and 2007. Columns 1 and 2 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 3 and 4 include NAICS industry-exporter-period fixed effects.

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 9 of Table 2. Column 1 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 2 uses the change in China's import share 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 3 and 4 include the Chinese market share controls in the HS six-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.—Supplemental 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 and the input cost shock; 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.

E. *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 (8) using the NTR gap as an instrument for US output growth following PNTR. To implement this strategy, we estimate

$$(11) \qquad \Delta \log X_{ni,s}^{t} = \delta_{ni,s} + \delta_{ni}^{t} + \delta_{n,s}^{t} + \alpha_3 US_i \times \Delta \log Y_{U,s}^{t}$$
$$+ \alpha_4 Post^t \times US_i \times CostShock_s + \beta Post^t \times US_i \times Z_s + \epsilon_{ni,s}^{t},$$

where $US_i \times \Delta \log Y_{U,s}^{t}$ is instrumented by $Post^t \times US_i \times NTRGap_s$. This equation differs from the reduced-form specification (9) only through the inclusion of $US_i \times \Delta \log Y_{U,s}^{t}$ 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., $\Delta \log Y_{U,s}^{Post} - \Delta \log Y_{U,s}^{Pre}$. 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 (11) using the sample of manufacturing industries. Column 1 omits all industry controls. Column 2 includes the input cost shock and input-output exposure variables, and column 3 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 IIC and footnote 15). 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 3, 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 3 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 0. However, based on the structural estimates we cannot reject

Table 5—Instrumental Variable Estimates of Output Elasticity

Dependent variable	Δ log exports		
	(1)	(2)	(3)
US $\times$ Δ log Output	0.66	0.98	0.74
	(0.20)	(0.24)	(0.41)
Post $\times$ US $\times$ CostShock		−0.81	−0.55
		(0.16)	(0.20)
	First stage		
Post $\times$ US $\times$ 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 $\times$ Δ log Output instrumented by Post $\times$ US $\times$ NTR Gap. Standard errors clustered by exporter-industry in parentheses. Estimated in long differences using 1995–2000 as pre-PNTR period and 2000–2007 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.

either the hypothesis that the output elasticity equals 1 as in Krugman (1980) or that it falls within the range of values below 1 estimated by Bartelme, Costinot, Donaldson, and Rodríguez-Clare (2019) and Lashkaripour and Lugovskyy (2023).[17]

III. 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 I. 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

[17] Bartelme, Costinot, Donaldson, and Rodríguez-Clare (2019) estimate the scale elasticity for 15 manufacturing industries. Multiplying their scale elasticity estimates (table 1, column 2) by the trade elasticities that 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. Lashkaripour and Lugovskyy (2023) estimate output elasticities for 14 goods industries (table 3). Their estimates range from 0.36 for transport equipment to 0.94 for "not elsewhere classified" and recycling, with a mean of 0.79.

scale economies and input-output linkages, and to evaluate whether PNTR led to export destruction in general equilibrium.

A. *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. Supplemental 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 $\hat{P}_{i,s}$.

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 United States and China, and 24 sectors, including 15 goods sectors.[18]

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 (8) allowing the NTR gap to affect growth in US imports from China. We estimate

$$\Delta \log X^t_{ni,s} = \delta_{ni,s} + \delta^t_{ni} + \delta^t_{n,s} + \delta^t_{i,s} + \alpha_5 Post^t \times US_n \times China_i \times NTRGap_s + \epsilon^t_{ni,s}, \tag{12}$$

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 2000–2007 as the post-PNTR period. Because PNTR is a bilateral shock, we include in equation (12) 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

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

Table 6—PNTR and US Imports from China

Dependent variable	Δ log trade				
	(1)	(2)	(3)	(4)	(5)
Post × US importer × China exporter × NTRGap	0.43	0.41	0.33	0.39	0.54
	(0.13)	(0.14)	(0.14)	(0.15)	(0.40)
Post ×US importer × China exporter × 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^2	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 2000–2007 as post-PNTR period. Industry sample covers 444 NAICS goods industries in columns 1–3 and 5 and 385 NAICS manufacturing industries in column 4. Importer and exporter samples exclude countries with population below one million in 1995. OECD membership status defined at start of 1995.

set $\hat{\varphi}_{UC,s} = exp(7 \times \alpha_5 \times NTRGap_s)$, where we multiply the estimated effect by seven because the dependent variable in equation (12) 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 1 restricts the set of importers to be OECD countries.[19] As expected, we estimate that PNTR increased US imports from China by more in industries where the NTR gap is higher. This finding is robust to restricting the set of exporters to non-OECD countries (column 2), expanding the set of importers to include both OECD and non-OECD countries (column 3) and only using manufacturing industries (column 4). Finally, in column 5 we examine whether the relationship between the NTR gap and openness is nonlinear 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 nonlinearity in the relationship.

We calibrate PNTR using $\alpha_5 = 0.43$ as estimated in column 1. 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 United States 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

[19] As in Section II, 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 United States from the sample of exporters and Hong Kong and Macao from both samples.

costs: $\hat{\tau}_{UC,s} = (\hat{\varphi}_{UC,s})^{\frac{-1}{\epsilon-1}}$. Suppose that the trade elasticity equals 5, 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.[20]

Output and Trade Elasticities.—We set the trade elasticity $\epsilon - 1$ equal to 5, based on the preferred estimate of Head and Mayer (2014). We also set the output elasticity for services sectors equal to 0 following Costinot and Rodríguez-Clare (2014); Bartelme, Costinot, Donaldson, and Rodríguez-Clare (2019); and Kucheryavyy, Lyn, and Rodríguez-Clare (2023). 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 IIIB.

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 9 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 (9), but using simulated data obtained by solving the calibrated model for a given output elasticity (see Supplemental 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's (1995) model, the output elasticity equals 1 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 (2023) show that trade models with scale economies are well behaved for quantitative work when the output elasticity does not exceed 1, 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 1. 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 1. 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 IIE, which equals 0.74 in column 3 of Table 5.

[20]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.

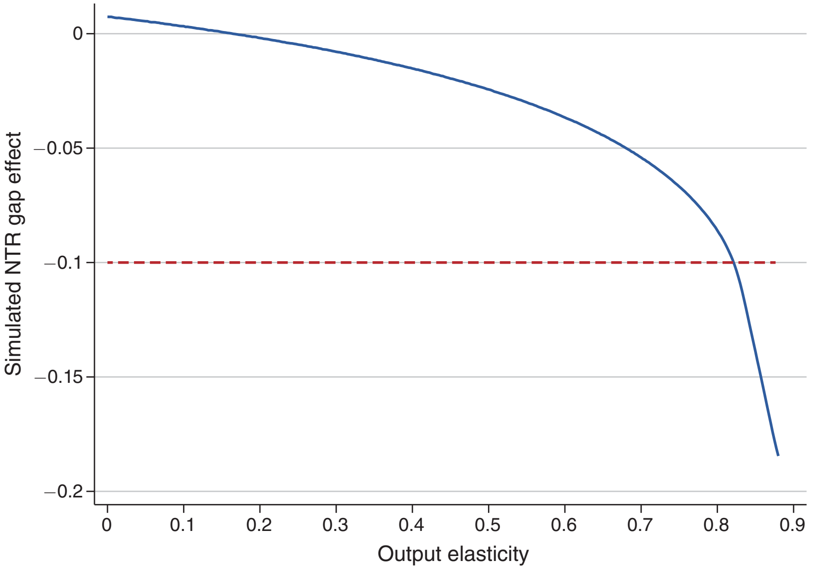

Figure 3. Output Elasticity and Simulated Effect of NTR Gap on US Exports

Notes: Simulated NTR gap effect in the calibrated model. Output elasticity on horizontal axis is for goods sectors. For services sectors, output elasticity equals 0. The horizontal dashed line shows the target estimated NTR gap effect of −0.10 from Table 2, column 9.

B. *Quantitative Results*

To quantify the effects of PNTR, we shock the calibrated model using the values of $\hat{\varphi}_{UC,s}$ implied by column 1 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 0 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 the North American Free Trade Agreement (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 for most sectors. Figure 4 plots the percent change in US exports relative to GDP due to PNTR, on aggregate (leftmost bar) and by goods sector. The sectors are ordered with the NTR gap increasing from left to right. We find that exports rose following PNTR in 12 out of 15 goods sectors.[21]

[21] 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 −32 percent real market potential effect, a +8.5 percent input cost effect, and a +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.

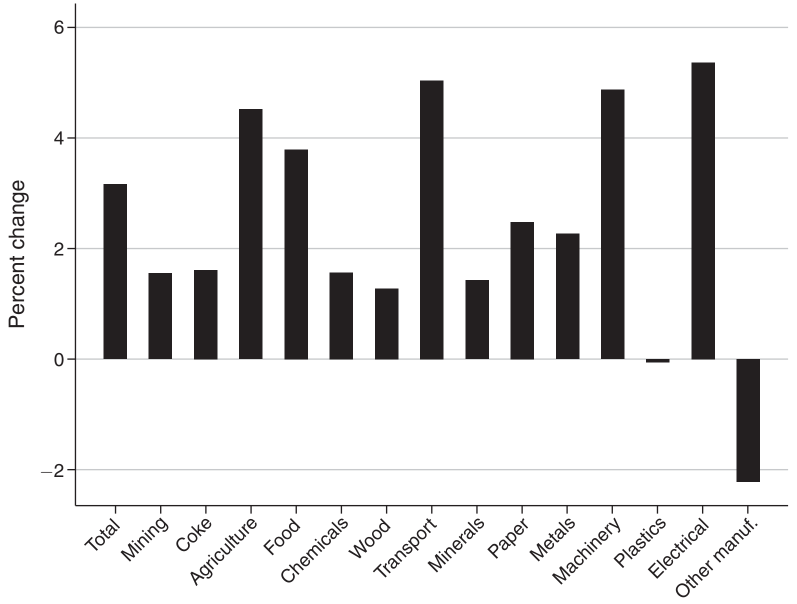

FIGURE 4. IMPACT OF PNTR ON US EXPORTS RELATIVE TO GDP

Notes: Simulated percent changes in model with output elasticity of 0.821 for goods sectors and 0 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:

$$\widehat{EX}_{U,s} = \hat{S}_{U,s} \times \sum_{n \neq U} \chi_{nU,s} \hat{X}_{n,s} \hat{P}_{n,s}^{\epsilon-1} \tag{13}$$

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

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 II establish that PNTR reduced exports by shrinking real market potential and boosted exports by cutting input costs. The decomposition in equation (13) 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

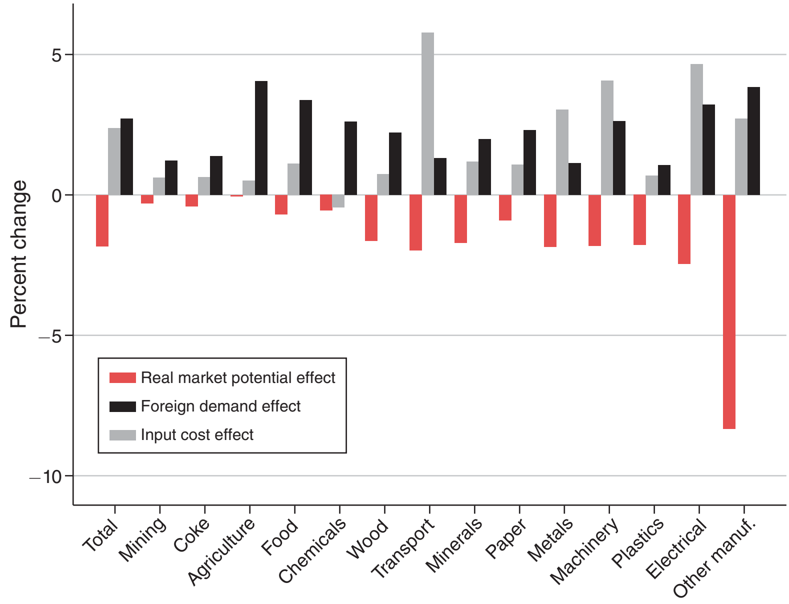

Figure 5. Decomposition of Change in US Exports Due to PNTR

Notes: Simulated percent changes in model with output elasticity of 0.821 for goods sectors and 0 for services sectors. Decomposition of change in exports into real market potential effect, input cost effect, and foreign demand effect defined in equation (13). 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.

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.[22]

Figure 5 shows the export decomposition in equation (13) 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.

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

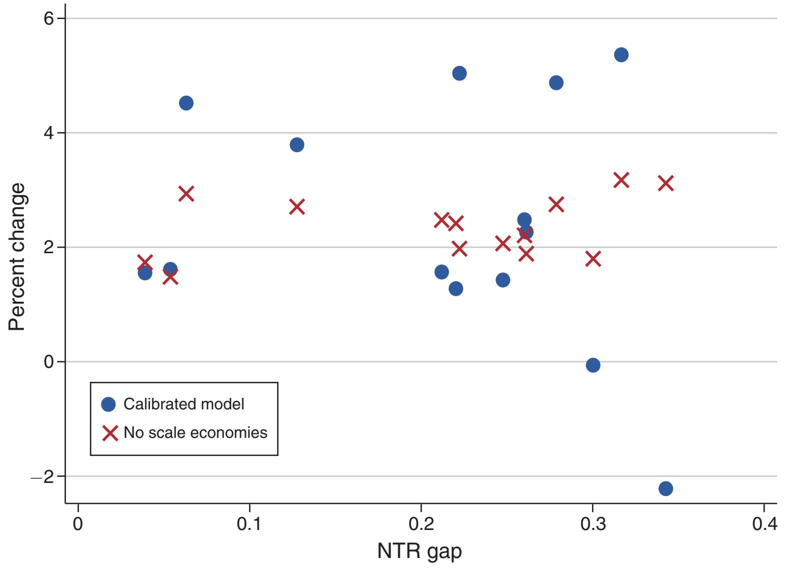

FIGURE 6. US EXPORT GROWTH BY SECTOR DUE TO PNTR

Notes: Simulated percent changes in exports. Calibrated model has output elasticity of 0.821 for goods sectors and 0 for services sectors. Constant returns model has output elasticity of 0 in all sectors. US GDP is the numeraire. Goods sectors only. "Textiles and leather" not shown.

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 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.[23]

[23] 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 that it has the highest export growth under constant returns compared to the lowest export growth in the calibrated model.

Table 7—Welfare Effects of PNTR (Percent Changes)

	Real expenditure	Real income: Total	Real income: ACR effect	Real income: Specialization effect	Real income: Nominal wage relative to United States
Panel A. Calibrated model					
United States	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					
United States	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 0 for services sectors. Panel B: output elasticity 0 in all sectors. Rest of world results averaged across countries using pre-PNTR GDP shares as weights.

Perhaps most importantly, the correlation between sector-level export growth with and without 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.[24]

Welfare.—Next, we consider the effect of PNTR on welfare. Kucheryavyy, Lyn, and Rodríguez-Clare (2023) 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 (2023), 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 toward services sectors without scale economies.[25]

Welfare results are reported in Table 7. Overall, we find that the United States 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.[26] For comparison, Caliendo and Parro (2015) find that NAFTA increased US welfare by

[24] Supplemental 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.

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

[26] Income and expenditure differ because trade is not balanced, as explained in footnote 22. As is standard in quantitative trade policy analysis, our model features constant markups and full employment. Consequently, the welfare estimates do not incorporate any procompetitive effects of PNTR (Jaravel and Sager 2020; Amiti, Dai, Feenstra, and Romalis 2020) or any impact of import competition on employment levels (Autor, Dorn, and Hanson 2013).

0.08 percent, while Fajgelbaum, Goldberg, Kennedy, and Khandelwal (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 $\left(I - A\right)^{-1}$ 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 by 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 -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 toward sectors with weaker scale economies (i.e., from goods to services) and toward sectors with weaker forward input-output linkages. Supplemental 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 value for goods yields a specialization effect of -0.14 percent (see Supplemental 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 that PNTR was a bigger shock to China than the United States. In addition, China's nominal wage relative to the United States rose by 6.0 percent, implying that 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 it is for the United States or China.

Alternative Calibrations.—Supplemental 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, Costinot, Donaldson, and Rodríguez-Clare (2019). An increase in the average trade elasticity reduces US gains from PNTR, but we still find that PNTR induces a negative specialization effect that partially offsets the positive ACR effect.

IV. Concluding Comments

Scale economies lie at the heart of many macroeconomic policy debates. 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. Our 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 United States, 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 toward the most protected industries. On the other hand, we find that the export destruction effect of PNTR is dominated for most sectors 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 that 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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