Institute for Fiscal Studies

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22/34 Working paper

Are trade wars class wars? The importance of trade-induced horizontal inequality

Economic and Social Research Council

Are Trade Wars Class Wars?

The Importance of Trade-Induced Horizontal Inequality*

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September 1, 2022

Abstract

What is the nature of the distributional effects of trade? This paper demonstrates conceptually and empirically the importance of "trade-induced horizontal inequality," i.e. inequality brought about by trade shocks that occurs among workers with the same level of earnings prior to the shock. While this type of inequality does not affect the income distribution, it generates winners and losers at all income levels and may thus affect political support for trade policy. To quantify the horizontal inequality and changes in the income distribution induced by trade in a data-driven way, we develop a characterization of the welfare impacts, governed by simple and intuitive statistics of labor market and consumption exposure to trade. This characterization holds in a class of quantitative trade models allowing for a broad set of preferences, including non-homothetic, and production functions. Taking this framework to U.S. data, we find substantial heterogeneity in exposure and thus in the welfare effects of trade shocks across workers, with horizontal inequality as the dominant force. Over 99% of the variance of welfare changes from trade shocks arise *within* income deciles, rather than across. This finding runs against a popular narrative that "trade wars are class wars."

Keywords: Trade liberalization, Distributional effects, Inequality

JEL codes: F14, F16, F60, D63

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We are grateful to Pol Antràs, Ariel Burstein, Grigory Franguridi, Oleg Itskhoki, Kalina Manova, Marc Melitz, and Jonathan Vogel for insightful comments. This paper supersedes part of our earlier work, disseminated as "The Distributional Effects of Trade: Theory and Evidence from the United States." The research in this paper was conducted while Borusyak was a Special Sworn Status researcher of the U.S. Census Bureau at the Boston Census Research Data Center. Any opinions and conclusions expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed. Declarations of interest: none.

1 Introduction

Characterizing the effects of international trade shocks on the economy, in particular on welfare and inequality, is one of the key tasks of economists. Indeed, a large body of work studies changes in the income distribution induced by trade (e.g., Helpman (2018)). In this paper, we show that changes in the income distribution constitute only one of the dimensions of inequality brought about by trade, which we call "vertical inequality". We highlight conceptually and empirically the importance of "horizontal inequality", i.e. inequality occurring among workers with the same level of earnings prior to the shock.[1] This type of inequality generates winners and losers at all income levels, without affecting the income distribution. Trade-induced horizontal inequality may be of particular importance to understand political support for trade policy, to the extent that people may express support based on their economic self-interest. Using data from the United States, we find that the horizontal, rather than vertical, component is the dominant force. In our baseline specification, over 99% of the variance of welfare changes from trade shocks arise within income deciles.

To quantify horizontal and vertical inequality, we develop a data-driven characterization of the welfare impacts of trade governed by simple and intuitive statistics of labor market and consumption exposure to trade and by microeconomic primitives (i.e., income and substitution elasticities). This characterization holds in a class of quantitative trade models allowing for a broad set of preferences, including non-homothetic, and production functions. Our approach thus advances an emerging, influential literature (e.g., Adão et al. (2022), Baqaee and Farhi (2022)) that bridges the gap between large-scale computational general equilibrium models, which are traditionally used for quantitative trade policy analysis but lack transparency, and simple stylized models, which are linked to data in a transparent way but may lead to less reliable quantitative predictions.

Our theoretical analysis characterizes the unequal welfare effects of trade shocks in terms of changes in wages (the "earnings channel") and consumer prices (the "expenditure channel").[2] We show that changes in factor demand in response to small changes in iceberg trade costs can be decomposed into several terms corresponding to different economic forces: exports, import

[1] Horizontal inequality is distinct from "residual" inequality, i.e. rising wage dispersion within occupations and industries (e.g., Helpman et al. (2017)). While a change in residual inequality contributes to changes in the overall income distribution, shock-induced horizontal inequality does not, at the first order. Similarly, horizontal inequality differs from the "horizontal inequalities," understood as inequalities across ethnic or other social groups (e.g., Stewart (2005)).

[2] We thus extend the analysis of Borusyak and Jaravel (2021), who focus exclusively on the expenditure channel and on the partial equilibrium.

competition, imported intermediate inputs, non-homotheticities, and cross-industry substitution effects. Each of these terms is governed by an intuitive statistic measuring exposure to international trade. For instance, a factor whose employment is concentrated in industries that have high export ratios, directly or indirectly, will see factor demand grow after a trade liberalization, *ceteris paribus*. How factor prices respond to factor demand in turn depends on the elasticities of aggregate factor demand, which we characterize in terms of microeconomic primitives. We show that factor demand tends to be less elastic in non-traded industries, for which the wage impacts of labor demand changes are therefore stronger, providing another mechanism for the unequal effect of trade shocks.[3] Using this theoretical framework, we formally define horizontal and vertical inequality and link it to heterogeneous exposures to trade shocks, within and across income groups.

Taking our characterization to the data, we evaluate a counterfactual where trade costs fall by 10% with all trading partners of the United States.[4] We implement this analysis with a linked dataset measuring trade flows and input-output linkages across about four hundred industries covering the entire U.S. economy, matched to the heterogeneous employment structure and, following Borusyak and Jaravel (2021), consumption baskets of different groups of consumers and workers. While our theoretical results allow for any factor types, empirically we consider different groups of workers in the main analysis and study capital in a robustness check.

We first analyze a setting in which there is no mobility of workers across industries. In that case, each worker's labor market exposure is simply her industry's exposure.[5] The key lesson emerging from this empirical analysis is that exposure differences and the corresponding distributional effects are primarily concentrated within income groups, rather than across. Over 99% of the variance of welfare changes arises within income deciles, generating horizontal inequality.

Despite the substantial distributional effects, which generate sizable changes in relative earnings as well as winners and losers at all income levels, we find little impact of a fall in trade costs on the shape of the income distribution. Indeed, the Gini index fall by 0.0002 points only, and the

[3] This mechanism has been informally proposed by Rodrik (1997) and shown to be relevant when analyzing the effects of labor supply shocks from immigration by Burstein et al. (2020). We demonstrate its importance for labor demand shocks, specifically those due to trade.

[4] This is a 10% in the gross iceberg trade costs, similar in magnitude to a 10 percentage points reduction in tariffs. Following Borusyak and Jaravel (2021), we also assess the impacts of other shocks, including a trade liberalization with China specifically, historical reductions in trade costs, and the introduction of the "Trump tariffs" in 2018. We treat all of these shocks as changes in iceberg trade costs which do not generate tariff revenue, and use a first-order approximation.

[5] While the assumption of no mobility may be most appropriate in the short-run, this analysis can be generalized to the case where labor mobility follows a Roy model with a finite but non-zero elasticity of industry labor supply, as in Galle et al. (2022). We have no reason to expect that the key lesson presented below would change in that medium-run model.

standard deviation of (real) log-wages falls by 0.0005. The spread between the 10th and 90th percentiles of welfare effects is over 2 percentage points within each decile, while variation across deciles is much smaller: all groups benefit on average and the gains are slightly *higher* for poorer households, ranging from 2.0% in the bottom decile to 1.8% for the top decile.[6]

To confirm that there are no strong distributional effects *across* groups of ex-ante similar workers, we conduct a similar analysis across education groups. In this second quantitative analysis, we consider two groups of workers — those with and without a college degree — and assume perfect mobility across industries. We again find that the effects are very similar across groups. The welfare gain from the 10% fall in trade costs is 1.7% for college-educated workers, compared with 1.6% for those without a college degree. In other extensions, we continue to find that horizontal distributional effects are the driving force and that vertical inequality is small. We demonstrate the robustness of our results to choices of elasticities, study non-uniform changes in trade costs, as well as within-industry heterogeneity across firms.[7]

Thus, all our findings run against a popular narrative that "trade wars are class wars" (Klein and Pettis 2020). Rather, trade causes winners and losers at all income levels. To the extent that losers are more likely to oppose trade liberalizations than winners are likely to express support, the large magnitude of horizontal distributional effects may lead to waning support for free trade.

Related literature. This paper contributes to an emerging literature that develops new theoretical tools to connect the effects of economic shocks in quantitative macroeconomic or trade models to detailed micro-level data, characterizing and decomposing welfare impacts in general equilibrium in terms of microeconomic sufficient statistics (Baqaee and Farhi (2019), Baqaee and Farhi (2022), Adão et al. (2022), Borusyak and Jaravel (2021), Oberfield and Raval (2021), Kleinman et al. (2022)). We incorporate additional channels, in particular via non-homothetic preferences, and propose a characterization of trade-induced horizontal inequality. Our decomposition allows us to assess the relative importance of the role of skill endowment emphasized by the Stolper–Samuelson theorem, the contributions of non-homothetic preferences (Caron et al. 2020), and the complemen-

[6] Higher gains for poor households may look surprising, in particular in light of the canonical Heckscher–Ohlin model. Consistent with the Stolper–Samuelson theorem, relative labor demand for low-income workers falls after the trade shock in this analysis. Yet, an offsetting force dominates: low-income workers are employed relatively more in service industries, which have lower labor demand elasticities; as a result, a given labor demand shock induces, on average, a stronger wage response for them.

[7] Using confidential plant-level microdata from the Census of Manufactures and the Management and Organizational Practices Survey, we find that more skill-intensive plants within the same industry tend to export more, consistent with Burstein and Vogel (2017). Nonetheless, this force is small relative to between-industry differences, on which we focus in the main analysis.

tarity between goods and services (Cravino and Sotelo 2019).

In independent work subsequent to ours, Adão et al. (2022) develop a different decomposition for factor price changes due to trade into import and export channels and apply it to detailed firm-level data in Ecuador, focusing on vertical inequality. Relative to them, our characterization of trade-induced vertical inequality also captures the effects of import competition in intermediate demand (rather than in final demand only), making our model consistent with the standard industry-level gravity equation.[8] Furthermore, we isolate the negative effects of import competition from the positive productivity effects of imported intermediate inputs.

Our results complement the analysis of Borusyak and Jaravel (2021), who characterize the effects of trade on inequality in a sufficient statistics framework that focuses entirely on heterogeneous consumption baskets. Their analysis accounts for the effect of trade shocks on imported goods prices in a partial equilibrium framework holding factor prices fixed. In this paper, while mainly focusing on factor price responses to trade shocks, we account for the fact that endogenous changes in factor prices may also change households' price indices in heterogeneous ways. In this sense, we provide an exposure-based framework accounting for both the earnings and expenditure channels of trade on inequality, as well as their interaction. We thus contribute to a small literature that analyzes the expenditure and earnings channels jointly, in a unified framework.[9]

Furthermore, our analysis relates to a broad literature characterizing the effects of trade on income inequality. First, a longstanding literature uses statistics on the net factor content of trade, guided by the Heckscher–Ohlin model (e.g., Katz and Murphy (1992), Deardorff and Staiger (1988), Krugman (2000)). More recently, Burstein and Vogel (2017) and Cravino and Sotelo (2019) show that the net factor content of trade is not an appropriate statistic for welfare in richer models. Our characterization provides a set of sufficient statistics in a modern, multi-sector gravity model. Second, many studies analyze the impact of trade shocks on relative factor prices, such as the skill premium (e.g., Burstein and Vogel 2017; Costinot and Vogel 2009). Relative to them, we provide a methodology to map changes in factor prices into changes in inequality. In this respect, our analysis is similar to Helpman et al. (2017), although they do not consider trade-induced horizontal inequality. Third, recent work by Galle et al. (2022) shows, by using exact hat algebra in a multi-

[8]Their assumption of Cobb-Douglas preferences across all intermediate inputs implies that domestic firms using foreign inputs in their supply chains are forced to exit in autarky. Our framework makes a more realistic assumption that domestic firms can substitute away from foreign inputs.

[9]There are only two papers in this space: Porto (2006) uses time-series regressions to estimate the impact of trade-induced price changes on wages and domestic prices, while He (2020) generalizes the structural model of Fajgelbaum and Khandelwal (2016). We take a different approach by focusing on a set of exposure statistics measured in detailed data.

sector gravity model, that the "China shock" generates strong distributional effects. Relative to them, our contribution is to quantify the extent to which the distributional effects of the shocks we study are horizontal rather than vertical. Finally, because of data limitations, we do not consider the regional dimension of the effects of trade, which has been emphasized by Autor et al. (2013) and could be studied using our exposure-based approach given appropriate data.[10]

Finally, our focus on the winners and losers from trade shocks speaks to the growing empirical literature on attitudes toward trade (e.g., Mayda and Rodrik (2005), Jäkel and Smolka (2017)) and voting on trade (e.g., Van Patten and Méndez-Chacón (2022)). This literature assesses whether individual-level exposure to trade predicts support for trade agreements. Our analysis provides a new justification for these analyses by demonstrating, with a combination of theory and quantitative analysis, that individual-level exposure statistics govern the unequal welfare effects of trade across workers in a general equilibrium trade model. In addition, the rich set of statistics in our framework could be leveraged in future work on the political economy of trade.

The remainder of the paper is organized as follows. Section 2 presents the theoretical framework, Section 3 describes the data and elasticities used to take the theory to the data, and Section 4 presents the estimates of the distributional effects from counterfactual trade shocks in general equilibrium. Section 5 concludes.

2 Theory

In this section, we theoretically characterize the distributional effects of counterfactual trade shocks in general equilibrium. We build on Borusyak and Jaravel (2021) who show that a simple statistic — the fraction of imports in spending — governs the effects of trade shocks on the purchasing power of consumers (the "expenditure channel"), holding domestic wages fixed. We extend their analysis to a general equilibrium setting in which both relative wages (the "earnings channel") and relative purchasing power adjust. We show that intuitive observable statistics of labor market exposure to trade govern the distributional effects of trade through the earnings channel. Moreover, the earnings and expenditure channels can interact: domestic wage changes affect prices, which can lead to differential purchasing power effects across consumers. We then link them to the two types

[10] This line of work has largely been silent about the effect of trade on wage inequality: Autor et al. (2013) do not find significantly different cross-sectional effects on skilled and unskilled wages (see Tables 6 and 7) and do not document the distribution of trade shocks across commuting zones. They instead find negative effects of trade with China on manufacturing employment in the U.S. at the level of commuting zones (and industries in Acemoglu et al. (2016)), which is consistent with our model.

of inequality induced by trade shock, horizontal and vertical. Details and proofs are relegated to Appendix A.

2.1 Setting

In this section, we describe the assumptions underlying our model, regarding preferences, the labor market, and technology. We then specify the trade shocks and welfare effects we study in the remainder of the paper.

Preferences. We study a neoclassical static global economy with $C+1$ countries in which international trade is shaped by product differentiation, cross-country differences in technologies and endowments, and trade costs. We denote the Home economy $c = H$, the United States, with the set of foreign countries denoted by F. Product varieties (j, c) are defined as pairs of industry $j = 1, \ldots, J$ and country of origin c, as in multi-sector versions of the Armington (1969) model.[11] Preferences of domestic consumers across industries are characterized by a utility function $\mathcal{U}(q_1, \ldots, q_J)$, which is left unrestricted in this section, and in particular can be non-homothetic. Preferences over varieties within each industry have constant elasticity of substitution (CES):

$$q_j = \left(\sum_{c=1}^{C+1} a_{jc}^{1/\xi_j} q_{jc}^{(\xi_j - 1)/\xi_j} \right)^{\xi_j/(\xi_j - 1)}, \tag{1}$$

where a_{jc} are taste shifters and $\xi_j - 1$ is the industry's trade elasticity.[12] The corresponding spending shares are denoted s_{jc}^x for a consumer with earnings x.[13]

Labor markets. In the labor market, workers are immobile across countries and exogenously grouped into types $i = 1, \ldots, I$ with wages w_i per efficiency unit.[14] Workers of the same type are

[11] As usual, the microfoundation from Eaton and Kortum (2002) is isomorphic, and Krugman (1980) or Melitz-Pareto (Chaney 2008) versions would only differ by introducing home market effects, which tend to have small welfare impacts (Costinot and Rodríguez-Clare 2015).

[12] For consistency with industry-level data, we follow, e.g., Caron et al. (2014) in allowing for non-homothetic utility across industries but not within. This specification is in line with the finding of Borusyak and Jaravel (2021) that import spending shares within industries do not vary systematically across income groups, and it is necessary for our model to be consistent with the proportionality assumptions embedded in U.S. input-output tables. Non-homothetic demand within industries can be theoretically accommodated and would yield a characterization similar to Propositions 1 and 2 below.

[13] Throughout the paper, we indicate buyers in the superscripts and sellers in the subscripts. Agents are buyers in the product markets and sellers in the labor market.

[14] Although we focus on workers and wages for the main analysis, our theoretical framework can accommodate arbitrary factors, such as capital.

perfectly substitutable in the labor market, supply labor inelastically, and are endowed with heterogeneous efficiency units, capturing within-type income differences. We denote worker's earnings at the initial equilibrium by x; workers are thus uniquely characterized by a pair of type and earnings, (i, x). Type-i workers are freely mobile within a set of industries $\mathcal{J}_i$, but are not employed outside it. This formulation allows for a scenario with no mobility across industries (i.e., i are industry groups and $\mathcal{J}_i = \{i\}$), as well as a scenario in which i corresponds to education groups freely mobile across all domestic industries, as in our calibrations below.[15]

Technology. Domestic production in industry j combines primary factors L_i^j with composite inputs Q_ℓ^j from all industries ℓ. We assume a Cobb-Douglas production function in terms of value added and intermediate inputs, $Q_{jH} = F_j^{VA}\left(L_1^j, \ldots, L_I^j\right)^{1-\beta_j} \cdot \Pi_{\ell=1}^J \left(Q_\ell^j\right)^{\beta_\ell^j}$, with $\sum_\ell \beta_\ell^j = \beta_j$, and allow for any constant returns to scale and differentiable value-added aggregator across industries, F_j^{VA}. The Cobb-Douglas assumption for intermediate inputs is standard (e.g., Acemoglu et al. (2012), Caliendo and Parro (2015)) and consistent with the stability of input shares in the U.S. input-output (IO) table over time. Within each industry, firms aggregate varieties from different countries in the same way as final consumers, according to (1). This assumption ensures that our model implies a standard industry-level gravity equation and satisfies a proportionality assumption embedded in country-specific IO tables.

Trade and counterfactual trade shocks. We consider how domestic goods and factor prices adjust in general equilibrium (GE) following a set of infinitesimal reductions in trade costs between Home and some country (or set of countries) c. Specifically, products imported from $c \neq H$ to Home are subject to an iceberg trade cost τ_{jc}, while domestic firms face iceberg costs τ_{jc}^* when exporting to c, and both types of trade costs are allowed to change.

Since our detailed data only cover the U.S., we rule out changes in relative factor prices abroad by assuming that for every industry and foreign country, exports to Home are a small fraction of sales, and imports from Home are a small fraction of industry absorption. This assumption implies that relative product demand and price indices abroad do not significantly move after the trade shock with Home. We thus take all foreign prices as the single numeraire, while domestic factor and product prices are still fully endogenous, and trade shocks lead to terms-of-trade adjustments, as in the analysis of a small economy by Demidova and Rodríguez-Clare (2009). With our focus on a

[15] This approach can be generalized to a finite elasticity of labor supply in each industry via a Roy model; see Appendix A.4 in our early draft (Borusyak and Jaravel 2018) and Galle et al. (2022).

uniform change in trade costs with all countries, the assumption of fixed relative factor prices outside Home appears plausible, as the U.S. economy accounts for less than 6% of sales and absorption in the rest of the world.[16]

With changes in prices abroad ruled out, we remain agnostic about foreign endowments, preferences, technologies, and labor markets. We only require that foreign buyers aggregate varieties across countries of origin with the same elasticity ξ_j as domestic buyers, resulting in constant-elasticity export demand for domestic producers.

Finally, we allow for a trade imbalance in the domestic economy assuming, as in Costinot and Rodríguez-Clare (2015), that it is fixed in proportion to Home's GDP. Specifically, we assume that every consumer spends the same exogenous multiple of their earnings, ζx.[17]

Equilibrium and welfare. The equilibrium is defined by (i) utility-maximizing allocation of spending across varieties by domestic consumers of each income level, (ii) profit maximization by domestic producers, (iii) labor and product market clearing conditions, and (iv) constant-elasticity export demand with exogenous shifters (see Appendix A.1 for details).

We adopt a cardinalization of welfare by applying a monotonic transformation to utility such that at the initial prices p, welfare equals nominal expenditures for all consumers. Specifically, for any combination of earnings x' and prices p', welfare is defined as

$$\mathcal{W}(x', p') \equiv \mathcal{C}\left(\mathcal{V}\left(\zeta x', p'\right), p\right), \tag{2}$$

where $\mathcal{C}$ and $\mathcal{V}$ are the cost function and the indirect utility function corresponding to $\mathcal{U}$, respectively.

We follow the standard approach defining the *change* in welfare for a given consumer as the equivalent variation divided by initial expenditures, $(\mathcal{W}(x', p') - \zeta x)/\zeta x$ (e.g. Fajgelbaum and Khandelwal 2016; Borusyak and Jaravel 2021). For example, the welfare change is equal to 0.01 if the trade liberalization is equivalent, in utility terms, to increasing total spending by 1% at the original

[16] While the U.S. accounts for a substantial fraction of world GDP, exports from the U.S. constitute only 3.9% of absorption in other countries according to the World Development Indicators database for 2007. Exports to the U.S. similarly account for only 5.5% of foreign production. Similar to Demidova and Rodríguez-Clare (2013), our economy can be viewed as a limit with the shares of trade with the U.S. going to zero in foreign countries but U.S. trade shares held fixed.

[17] The U.S. has run a trade deficit every year since 1976, with imports exceeding exports by 48% in 2007. Although the ratio of net imports to GDP fluctuates over time, our assumption provides a better fit to the data than balanced trade. It is more common to assume that the absolute value of net imports is fixed (Dekle et al. 2008), but our approach is more tractable in a model with heterogeneous agents, as we do not need to keep track of income and expenditure changes separately.

prices. Cardinalization (2) ensures that locally around the initial equilibrium the welfare change simply equals $d\log\mathcal{W}$. By the envelope theorem (Roy's identity), a set of consumer price changes $d\log p_{jc}$ affects each consumer h in proportion to the spending shares, such that for a consumer of type i with initial income x,

$$d\log\mathcal{W}_h = \underbrace{d\log w_i}_{\text{earnings channel}} - \underbrace{\sum\nolimits_{j,c} s^x_{jc} d\log p_{jc}}_{\text{expenditure channel}}, \tag{3}$$

regardless of the demand system. Here the first term captures the change in the per-efficiency-unit wage (and thus in total earnings and expenditures) which only depends on the worker type and the second term is the change in the cost of living (the Laspeyres price index) determined solely by the initial earnings level.[18] From (3), differential welfare gains between labor types can be decomposed into components related to changes in wages and prices, which we respectively call the earnings and expenditure channels of the distributional effects of the trade shock. As we discuss below, these channels can interact: domestic wage changes affect consumer prices and thus purchasing power, and potentially differentially so across consumer groups.

Notation. We finally introduce some notation. On the import side, we define IP_{jc} as the share of imports from c in domestic absorption of j at the initial equilibrium, with IP_j for the total import penetration. Let $\widetilde{IP}_{jc}$ be the share of imports from c in industry absorption, both directly and indirectly via IO linkages, i.e. including imports of intermediate inputs. Similarly, the share of inputs imported from c, both directly and indirectly, in the cost structure of domestic production in industry j is denoted $\widetilde{IP}^{\text{Int}}_{jc}$. These shares are defined recursively as $\widetilde{IP}_{jc} = IP_{jc} + (1 - IP_j) \cdot \widetilde{IP}^{\text{Int}}_{jc}$ and $\widetilde{IP}^{\text{Int}}_{jc} = \sum_{\ell=1}^{J} \beta^j_\ell \widetilde{IP}_{\ell c}$. Finally, we define the share of imports from c in expenditures of consumers with income x by

$$ImpSh^x_c = \sum_j s^x_j \widetilde{IP}_{jc} = \underbrace{\sum_j s^x_j \cdot IP_{jc}}_{\text{Direct}} + \underbrace{\sum_j s^x_j \left(1 - IP_j\right) \widetilde{IP}^{\text{Int}}_{jc}}_{\text{Indirect}}, \tag{4}$$

where s^x_j is the spending share on industry j for those consumers. On the export side, $ExSh_{jc}$ denotes the share of exports to country c in j's domestic output. $DomSalesSh_j$ denotes the share

[18] Borusyak and Jaravel (2021) show the conditions under which (3) applies beyond neoclassical models, e.g. with endogenous product entry and exit, as in a generalization of Eaton and Kortum (2002), or the generalized Melitz-Pareto model of Kucheryavyy et al. (2020).

of domestic sales (both final and intermediate) in j's total sales. The share of final domestic customers in total sales is DFS_j, and $\mu_{x|j}$ are the shares of sales to consumers with income x in j's final sales.[19] We characterize domestic final demand of consumers with income x at the industry level by the income elasticity of expenditure shares $\psi_{xj} = \partial \log s_j^x / \partial \log x$ and the own- and cross-price elasticities $\varepsilon_{xjk} = \partial \log s_j^x / \partial \log p_k$ measuring the response of j's expenditure share to the change in industry k's CES price index.

2.2 Exposure-Based Decomposition of Labor Demand and Wage Changes

We now state our main theoretical result on the wage responses to the trade shock. For notational brevity we present it for a shock that is uniform across industries and applies to bilateral trade with country (or set of countries) c: $d\log\tau_{jc} = d\log\tau_{jc}^* = d\log\tau < 0$ for all j; an immediate generalization to non-uniform shocks across industries is found in Appendix A.4.

Proposition 1. *After a uniform reduction in bilateral trade costs with country c, changes in domestic wages $w = (w_1, \ldots, w_I)$ satisfy*

$$\frac{d\log w}{-d\log\tau} = \underbrace{\tilde{\boldsymbol{G}}}_{\substack{\textit{inverse labor demand}\\ \textit{elasticity matrix}}} \cdot \underbrace{\boldsymbol{E}\tilde{\boldsymbol{D}}\eta}_{\substack{\textit{labor demand}\\ \textit{response}}} . \tag{5}$$

Here η is a $J \times 1$ vector of direct industry exposure to the shock via several mechanisms:

$$\eta_j = (\xi_j - 1)\Big[\underbrace{ExSh_{jc}}_{\textit{export effect}} - \underbrace{IP_{jc}\cdot DomSalesSh_j}_{\textit{import competition effect}} + \underbrace{\widetilde{IP}_{jc}^{Int}\cdot(ExSh_j + IP_j\cdot DomSalesSh_j)}_{\textit{intermediate input effect}}\Big]$$
$$+ DFS_j \cdot \sum_x \mu_{x|j}\Big[\underbrace{\psi_{xj} ImpSh_c^x}_{\textit{income effect}} - \sum_{k=1}^{J}\underbrace{\varepsilon_{xjk}\left(\widetilde{IP}_{kc} - ImpSh_c^x\right)}_{\textit{substitution effects}}\Big]. \tag{6}$$

The "IO adjustment" $J \times J$ matrix $\tilde{\boldsymbol{D}}$ is such that $(\tilde{\boldsymbol{D}}\eta)_j$ is the sum of direct industry j exposure η_j and indirect exposure in industries downstream from j. The "payroll composition" $I \times J$ matrix $\boldsymbol{E}$ captures the shares of industries j in type i payroll, such that $\boldsymbol{E}\tilde{\boldsymbol{D}}\eta$ measures the payroll-weighted average shock exposure by labor type. Finally, $\tilde{\boldsymbol{G}}$ is the (negative of the) $I \times I$ inverse matrix of macro labor demand elasticities with respect to w, given by (A14) in the Appendix.

The intuition behind equation (5) is that, with fixed labor supply, trade shocks affect wages

[19] We view x as discrete only for notational clarity and because we discretize income into bins in the empirical analysis.

via shifts in labor demand. Shifts in labor demand arise from product demand in industries which employ each type of labor. The novel characterization in equation (6) shows that the product demand response to a small shock can be decomposed into several mechanisms, each driven by observable exposure measures scaled by corresponding elasticities.

In the rest of this section we (i) provide the intuition for each of the margins of exposure, (ii) explain how industry exposure to trade translates into labor demand changes across worker types and, in turn, to the wage incidence of the shock, and (iii) characterize the overall distributional effects via purchasing power in addition to wages.

Margins of industry exposure to trade. The first two terms in (6) show the *export* and *import competition effects.* As export trade costs fall, export demand grows according to the trade elasticity $\xi_j - 1$, contributing to industry labor demand growth in proportion to the export share $ExSh_{jc}$. Similarly, falling import trade costs lower import prices, which drives the industry price index down in proportion to import penetration IP_{jc}. This leads to reallocation of spending between domestic and foreign varieties within each industry. Because this effect only influences domestic consumption, it is scaled by the domestic share of industry sales, $DomSalesSh_j$.[20]

The third term relates to *imported intermediate inputs.* Access to cheaper intermediate inputs makes domestic varieties more competitive, helping them gain market shares both abroad and at home. Industries are more exposed to this mechanism when they have a higher share of imported inputs $\widetilde{IP}_{jc}^{\text{Int}}$ in production costs.

The final terms are the *income and substitution effects.* Partial equilibrium welfare gains, driven by the import share $ImpSh_c^x$ (Borusyak and Jaravel 2021, Proposition 1), lead to higher spending on income-elastic industries (those with $\psi_{xj} > 0$). Moreover, demand for a domestic industry falls if substitute industries k (those with $\varepsilon_{xjk} > 0$) become relatively cheaper, due to their above-average import share, and if complement industries have below-average import shares. Both effects only influence domestic final sales, as combining consumers of different income, hence the scaling by their shares in total sales.

[20]Unlike traditional factor content statistics, the measure of exposure to import competition in Proposition 2 is valid in the presence of international specialization. Consider an industry, such as toys, in which the U.S. has largely stopped producing. Then its factor intensity is largely irrelevant for domestic demand for labor types that span many industries (e.g. skill groups), and thus for their wages. Accordingly, such an industry does not have a sizable effect on our exposure measure, while it can have large effects on the factor content of trade (e.g. Wood 1995).

From industry exposure to labor demand and wage changes. We now explain how payroll-weighted average exposure determines the labor demand response to trade shocks in our model and which forces determine how it translates into incidence. To do so, we describe two key equations (proved in the Appendix), respectively characterizing product and labor market equilibria in changes in response to the shocks. With L denoting the vector of labor endowments in efficiency units, we first have:

$$d\log w + d\log L = \boldsymbol{E} \cdot d\log VA + \boldsymbol{V} \cdot d\log w. \tag{7}$$

This shows that the change in the total earnings of each labor type, which equals the wage change in our counterfactualsince $d\log L = 0$, can arise from two sources. First, changing industry value added, $d\log VA$, and holding the labor mix of each industry fixed, mechanically changes the earnings of each labor type according to the payroll composition matrix

$$\boldsymbol{E} = \left(e_{j|i}\right)_{i,j},$$

where $e_{j|i}$ is the share of industry j in type i's earnings. Second, changes in relative wages lead to reallocation of payroll shares across labor types, which is governed by the labor substitution matrix

$$\boldsymbol{V} = \left(\sum_j e_{j|i} \frac{\partial \log v_{i|j}}{\partial \log w_{i'}}\right)_{i,i'}.$$

The (i, i') element of this matrix characterizes the cross-wage elasticity of the fraction of j's value added that accrues to value type i, $v_{i|j}$, with respect to the wages $w_{i'}$, averaged across industries j with i's payroll composition weights. Intuitively, the earnings of type i grow if workers substitutable to them become more expensive. While $\boldsymbol{E}$ is observed, $\boldsymbol{V}$ is not, but its measurement and parameterization simplify substantially in the two special cases described in Section 3.3.

The second equation behind Proposition 1 characterizes changes in the product market equilibrium:

$$d\log VA = \eta \cdot (-d\log \tau) + \boldsymbol{D} \cdot d\log VA + \boldsymbol{G} \cdot d\log w. \tag{8}$$

The first term in this equation shows that an industry's value added is directly affected by the trade shock through the various mechanisms in (6). There are also two indirect effects. First, changes in value added propagate from downstream industries up through the demand for intermediate inputs, with $\boldsymbol{D}$ summarizing the shares of domestic intermediate buyers in j's sales. Second, wage changes affect both the purchasing power of domestic consumers and the prices of domestic goods and thus demand for them, as summarized by the $\boldsymbol{G}$ matrix.[21]

Setting the wage changes on the right-hand of (7) and (8) to zero, we obtain the expression $\boldsymbol{E}\tilde{\boldsymbol{D}}\eta \cdot (-d\log\tau)$ for the change in labor demand. Here the exposure of industries to trade, $\eta \cdot (-d\log\tau)$, propagates upstream through the IO matrix and directly affects each labor type according to their payroll composition. Further accounting for the feedback loops via labor market competition, consumer purchasing power, and the production costs (hence prices) of domestic goods, we obtain the incidence of these shocks on wages in (5).

We note that the general equilibrium feedback loops necessarily generate a gap between labor demand shocks and their wage incidence. One manifestation of this gap is that a version of Lerner's symmetry holds in our model. Specifically, in Appendix A.5 we establish an equivalence, in terms of welfare and relative wages across all workers, between reducing all importing costs by a constant $d\log\tau$ and reducing all exporting costs by industry-dependent values $\frac{\xi_j}{\xi_j-1}d\log\tau$.[22] While labor demand changes induced by these two shocks are very different, their incidence is the same.

Welfare responses. Given wage changes characterized by Proposition 1, we can obtain welfare changes for all agents. We have:

Proposition 2. *After a uniform reduction in bilateral trade costs with country c, the welfare change for agent h of type i with initial income x satisfies*

$$d\log\mathcal{W}_h = \underbrace{(d\log w_i - d\log\bar{w})}_{\textit{earnings channel}} - \underbrace{ImpSh_c^x d\log\tau}_{\textit{price effect of trade costs}} + \underbrace{ImpSh^x d\log\bar{w}}_{\textit{price effect of avg.wages}} - \underbrace{\sum_j s_j^x\left(1-\widetilde{IP}_j\right)\left(d\log\widetilde{W}_j - d\log\bar{w}\right)}_{\textit{segregation effect}}, \tag{9}$$

where $d\log\bar{w} = \sum_i v_i d\log w_i$ is the change in the average wage in the economy, v_i denotes the initial payroll share of type i, $ImpSh^x$ is the spending share on imports from all countries, $1-\widetilde{IP}_j$

[21] Appendix A.2 formally defines $\boldsymbol{D}$ and $\boldsymbol{G}$ and uses them to derive $\tilde{\boldsymbol{D}}$ and $\tilde{\boldsymbol{G}}$, which enter (5).

[22] There are two differences of this result from the standard Lerner symmetry, even in its modern general treatment by Costinot and Werning (2019): it applies to iceberg trade costs, rather than changes in import tariffs and export subsidies, and the changes in the importing and exporting costs are not equal in magnitude. Unlike the standard theorem, our result relies on the assumption of a small economy in the sense of Section 2.1.

is the share of domestic factors in the cost structure of the industry (accounting for its full supply chain) and $d \log \widetilde{W}_j$ is the average change in the wage of those factors defined by (A7).

The first term in (9) is the earnings channel, capturing the wage growth of type i (relative to the average wage change in the economy). The other three terms jointly determine the expenditure channel, i.e. the purchasing power effects of the shock. Specifically, the second term is the partial equilibrium effect of trade costs on prices, which is governed by the consumer's spending share on imports from c, directly or indirectly (Borusyak and Jaravel 2021). The third term, governed by the share of spending on imports from all foreign countries, can be viewed as a terms-of-trade adjustment: if domestic wages grow on average, all imports become relatively cheaper, benefiting the consumers who spend relatively more on them. The final term, which we label a "segregation effect," captures the idea that, if some group of consumers tends to buy goods from industries where wages grow relatively more after the shock (directly or in their supply chains), this group will benefit less. For instance, if low-income households predominantly purchase products with low skill-intensity, then a trade shock leading to a fall in the relative wage of low-skill workers would also have a positive indirect effect on the purchasing power of low-income households through the price changes induced by these wage changes.[23]

2.3 Horizontal and Vertical Inequality Induced by Trade Shocks

Given welfare effects for all agents h, $d \log \mathcal{W}_h$, which is determined by their labor market type and initial earnings, we analyze two types of estimands of independent importance. First, we characterize the heterogeneity of welfare effects across workers, decomposing it into "vertical" and "horizontal" components. Second, we characterize the impact of the shock on the income distribution, showing that only the vertical component of heterogeneous welfare effects contributes to changes in the income distribution.

The variation in welfare effects across workers arises both across and within groups of initial earnings, x. Formally, we use a variance decomposition for welfare effects into the components across and within groups of initial earnings, x, using a variance decomposition:

$$\mathrm{Var}\left[d \log \mathcal{W}\right] = \underbrace{\mathrm{Var}\left[\mathbb{E}\left[d \log \mathcal{W} \mid x\right]\right]}_{\text{“vertical” inequality}} + \underbrace{\mathbb{E}\left[\mathrm{Var}\left[d \log \mathcal{W} \mid x\right]\right]}_{\text{“horizontal” inequality}}. \tag{10}$$

[23] For the analyses of the segregation effect, see Clemens et al. (2019) and Wilmers (2017), as well as our early draft (Borusyak and Jaravel 2018).

Here the variances and expectations are taken across the distribution of workers h.

In contrast, the effects of the trade shock on the distribution of (real) incomes, at the first order, arise from the vertical component only. For instance, the following result holds for the standard deviation of log-earnings:[24]

Proposition 3. *The change in the standard deviation of log-earnings due to a small shock can only be non-zero, at the first order, if the welfare changes are correlated with the initial earnings:*

$$\mathrm{SD}\left(\log x + d\log \mathcal{W}\right) - \mathrm{SD}\left(\log x\right) = \mathrm{Corr}\left[d\log \mathcal{W}, \log x\right] \cdot \mathrm{SD}\left(d\log \mathcal{W}\right) + o(d\log \tau). \tag{11}$$

This result follows because the heterogeneity of $d\log \mathcal{W}$ has only a second-order effect on $\mathrm{Var}\left[\log x + d\log \mathcal{W}\right]$, unless the welfare change $d\log \mathcal{W}$ and the initial log-earnings $\log x$ are correlated; see Appendix A.6 for the proof.

The finding that horizontal inequality does not matter for the income distribution holds more generally. Proposition 4 in the Appendix shows that if there is no vertical inequality, the cumulative distribution function of real incomes is unchanged, at the first order. Thus, other conventional statistics of inequality, such as the Gini index, are also unchanged.

We note that the distinction between horizontal and vertical inequality is important for how optimal policy responses to trade shocks may differ from those demanded by voters. In the presence of a distortionary income tax-transfer system, in standard models the social welfare weights across agents for monetary transfers are determined by disposable income (e.g., Mirrlees (1971)). Thus, the social planner would adjust taxes and transfers in response to trade-induced vertical inequality, as in Antràs et al. (2017). Horizontal distributional effects do not create such a motive for additional redistribution, given that the social marginal utility of income is the same for workers with the same initial earnings. However, horizontal distributional effects may be a key determinant of political support for trade, to the extent that people express support for trade liberalizations based on economic self-interest (e.g., Mayda and Rodrik (2005)).[25]

[24]With our cardinalization, real expenditures (i.e., welfare) equal ζx rather than x, but the constant multiplier ζ is immaterial for inequality. For notation brevity, in Proposition 3 we add the welfare change to workers' earnings, rather than expenditures.

[25]Similarly, while vertical distributional effects may dissipate the gains from a trade liberalization when the social welfare function takes inequality into account (as in Atkinson (1970) and Galle et al. (2022)), horizontal distributional effects do not have such implications.

3 From Theory to Data

Our theoretical results provide a transparent way of connecting theory to data and guide our empirical analysis, which proceeds in six steps. First, we measure each statistic of direct industry exposure to trade in (6). Second, we adjust these statistics for input-output linkages, via the $\tilde{\boldsymbol{D}}$ matrix, for example measuring the share of industry output that is exported to c not only directly but also in downstream industries. Third, we obtain labor demand shifts for each group by averaging industry exposure using the fractions of different industries in the group's payroll, captured by the $\boldsymbol{E}$ matrix, as weights. Fourth, we translate these labor demand shifts into the general equilibrium wage changes by applying the $\tilde{\boldsymbol{G}}$ matrix, given particular assumptions on the labor market substitution introduced below. Fifth, we measure the welfare effects for all workers, $d\log\mathcal{W}_h$, accounting for changes in both wages and cost-of-living in general equilibrium, via Proposition 2. Finally, we decompose the distributional effects of the shock into the horizontal and vertical components, as well as the impacts of the shock on measures of earnings equality.

To implement these steps, Propositions 1 and 2 require three types of inputs, which we discuss in turn in this section. Section 3.1 describes the data sources used to measure statistics characterizing the initial equilibrium: the payroll composition of each type of workers, trade shares of each industry and IO linkages between them, and consumption baskets by consumer group. We supplement these statistics by specifying the relevant elasticities: on the demand side in Section 3.2 and in the labor market in Section 3.3.

3.1 Measuring Exposure to Trade

Our main dataset which characterizes the initial equilibrium at the level of detailed industries in year 2007 builds on the data from Borusyak and Jaravel (2021). They focus on heterogeneous exposure to trade shocks across consumer groups; we link their data to the payroll composition by worker type and initial earnings, which is key to characterize worker exposure to trade in the labor market, per Proposition 1. We first summarize the industry-level data construction from Borusyak and Jaravel (2021) and how we link them to worker exposure; Appendix B.1 reports the details. We then describe the confidential firm-level data on within-industry heterogeneity of worker exposure to trade from the U.S. Census Bureau used for our robustness analysis.

Our main dataset is based on the detailed BEA input-output table from 2007. The IO table provides the most detailed available accounts of the entire U.S. economy at the level of 389 six-digit industries. We use it as a source of trade shares, input-output linkages, total consumer expenditures by industry, and total payroll by industry. Measuring trade shares from the BEA data is attractive, as trade in services is accounted for and trade flows are measured from the same data as domestic output, ensuring consistency. For each industry, import penetration is computed as the fraction of total imports in absorption, defined as output plus imports minus exports, and the export share as a fraction of total exports in output. The IO table further yields the composition of suppliers for each buying industry and the composition of buyers for each supplying industry, allowing us to measure indirect import shares in equation (4) and perform the IO adjustment to labor demand in (5).

We match several other datasets to the IO table. First, we decompose industry-level trade flows by trading partner using the 2007 U.S. international trade flow tabulations from the Census Bureau made available by Schott (2008). This allows us to measure trade shares for specific countries or groups of countries separately, specifically China, NAFTA countries (Mexico and Canada), and 34 developed economies (OECD members, except NAFTA, plus Taiwan and Singapore), except for services. Second, we decompose industry-level personal consumption expenditures into bins of household income and two education groups — those with and without a college degree of the reference person — using detailed expenditure categories from the BLS Consumer Expenditure Survey (CEX). Finally, we decompose the payroll of each industry into the contributions of workers by bin of their earnings and by two education levels. To do so, we use the American Community Survey (ACS), which is the long form of the population census answered by a random 1% sample of the U.S. population every year (Ruggles et al. 2015). In all of these cases we maintain the internal consistency of our dataset by keeping the industry totals — of trade flows, personal spending, and compensation of employees, respectively — from the IO table and applying group-specific percentages to those totals.[26]

We finally supplement industry-level data with a plant-level dataset using the confidential Census Bureau data to empirically assess the importance of the within-industry heterogeneity of worker exposure to trade. Specifically, using the Census of Manufactures and the Management and Organizational Practices Survey, we measure skill intensity and export shares for a sample of manufacturing plants — and therefore the differences between skill groups in their exposure to exporting

[26] For the CEX, this approach parallels Lebow and Rudd (2003) who show that reweighting the CEX using BEA spending shares yields more accurate inflation estimates, correcting non-classical measurement error in the CEX (e.g., Garner et al. 2009); see Borusyak and Jaravel (2021) for further discussion.

both within and across industries.[27] Appendix B.2 describes the data construction steps for this analysis.

3.2 Demand System

Taking Proposition 1 to the data requires specifying a demand system, to characterize both the substitution patterns across countries of origin within each industry (i.e., the trade elasticities) and the income and substitution effects across domestic industries. We first discuss the choice of the trade elasticities. We then discipline the analysis of cross-industry demand with nested non-homothetic CES preferences. We introduce this demand system and its relevant properties and describe the choice of parameters. Income elasticities are estimated within our sample; for substitution elasticities across and within industries, we take prevailing values in the literature and consider robustness to a range of values.

Trade elasticities. Our baseline value for the elasticity of substitution between domestic and foreign varieties, ξ_j, is 3.5 in all six-digit IO industries, which is equivalent to a trade elasticity of $\xi_j - 1 = 2.5$. This baseline value is close to the median elasticity of 3.7 reported in Broda and Weinstein (2006) for ten-digit commodities, and of 3.4–3.7 in Soderbery (2015) using the same Broda-Weinstein method but for eight-digit commodities and for different years of data. It is also close to the mean elasticity of 3.6 in Ossa (2015).

In robustness checks, we consider values of ξ_j between 1.9 and 5.1. This range corresponds to the estimates from the Soderbery (2015) LIML procedure and from Simonovska and Waugh (2014), respectively, and also covers the typical values in Feenstra et al. (2018). Moreover, we also allow ξ_j to vary across three-digit IO industries according to the estimates from Broda and Weinstein (2006).[28]

Nested non-homothetic CES demand. To characterize cross-industry demand, we consider a nested version of the non-homothetic CES (NHCES) utility function (Hanoch 1975; Comin et al. 2021), proposed by Borusyak and Jaravel (2021). Under NHCES, income and substitution

[27] The information on worker types is only available in the manufacturing sector, although we do not view it as a strong limitation since manufacturing is the most tradable sector. We further do not observe worker-level earnings, precluding a similar analysis across earnings groups. Measuring import competition and isolating it from imported intermediate inputs at the plant level is beyond the scope of our work.

[28] Specifically, we take the median elasticity value across all ten-digit commodities corresponding to the three-digit IO code.

elasticities are governed by distinct parameters, allowing us to specify and analyze them separately.[29] The nested version of NHCES, which features the complementarity of goods and service consumption in the outer nest, further allows us to incorporate the mechanism from Cravino and Sotelo (2019) who show that the substitution of consumers towards services in response to a trade liberalization can affect relative wages.

Indexing the goods and services sectors by r, our nested NHCES utility function is given by

$$\begin{aligned} \mathcal{U} &= \left(\sum_{r=\text{Goods, Services}} q_r^{(\rho-1)/\rho} \right)^{\rho/(\rho-1)}, \\ q_r &= \left(\sum_{j \in r} \left(a_j \mathcal{U}^{\varphi_j(\varepsilon_r - 1)} \right)^{1/\varepsilon_r} q_j^{(\varepsilon_r-1)/\varepsilon_r} \right)^{\varepsilon_r/(\varepsilon_r-1)}. \end{aligned} \tag{12}$$

The outer nest in the first line is a CES aggregate of consumption between the goods and services sectors with elasticity ρ, and the inner nest in the second line aggregates consumption across industries within each sector ($j \in r$) with elasticity ε_r. The industry consumption q_j is the homothetic CES aggregator across country varieties from (1). Primitive parameters $\varphi_{jc} < 1$ determine how non-homothetic tastes $a_j \mathcal{U}^{\varphi_j(\varepsilon_r-1)}$ vary with consumer utility: a higher $\varphi_{jc}(\varepsilon_r - 1)$ translates into a higher income elasticity of the industry within each sector (see Equation (A20) for the formula).[30]

Substitution effects. With this demand system, the own- and cross-price elasticities are governed by ε_r and ρ exactly in the same way as they would under the standard (homothetic) nested CES preferences. In particular, in Appendix A.8 we use the results from Borusyak and Jaravel (2021) to show that, for industry j that belongs to sector r, substitution effects in (6) satisfy:

$$\begin{aligned} \sum_{k=1}^{J} \varepsilon_{xjk} \left(\widetilde{IP}_{kc} - ImpSh_c^x \right) = (1-\varepsilon_r) \left(\widetilde{IP}_{jc} - ImpSh_{rc}^x \right) \\ + (1-\rho) \left(ImpSh_{rc}^x - ImpSh_c^x \right), \end{aligned} \tag{13}$$

[29] NHCES possesses other attractive properties compared with alternative non-homothetic demand systems: income effects are non-negligible in presence of long-run economic growth (Comin et al. 2021) and the expenditure channel of trade is not mechanically biased in favor of low-income consumers (Borusyak and Jaravel 2021).

[30] This way of writing the utility function, following Borusyak and Jaravel (2021), differs slightly from that of Comin et al. (2021) to better resemble traditional nested CES when $\varphi_j \equiv 0$. A single-tier version of (12) is equivalent to equation (1) in Comin et al. (2021) with $1 - \varphi_{jc}$ as relevant income elasticity parameters. As in Comin et al. (2021), a parameter restriction $\varphi_{jc} < 1$ is required for integrability.

where $ImpSh^x_{rc} = \sum_{k \in r} s^x_k \widetilde{IP}_{kc} / \sum_{k \in r} s^x_k$ is the total (direct and indirect) average share of imports in expenditures on sector r for a consumer with income x.

Equation (13) shows that, provided $\varepsilon_r > 1$, in response to a uniform trade liberalization consumers reallocate consumption towards industries (within sectors) with the share of imports that is higher than the sectoral average, other things equal. Similarly, provided $\rho < 1$ (a condition satisfied under the prevalent estimates, as discussed below), they substitute away from the manufacturing sector, where the import share is larger than in services.

We set the elasticity of substitution between goods and services to $\rho = 0.6$, obtained from Cravino and Sotelo (2019). For robustness we consider the range between 0.2 and 0.85, as in Comin et al. (2021) (see also Cravino and Sotelo (2019)). These values all indicate complementarity between goods and services in consumption.

The elasticities of substitution between industries within goods and services, ε_r, are more difficult to obtain (Dawkins et al. 2001; Costinot and Rodríguez-Clare 2015). As they are expected to lie between ρ and ξ_j, we set $\varepsilon_r = 2$ in the baseline analysis and consider values between 0.6 and 3.5. A recent paper by Redding and Weinstein (2017) estimates the elasticities of substitution between 6- and 4-digit NAICS industries to be 1.47 and 1.34, respectively. The estimate by Hottman and Monarch (2020) using 4-digit HS industries is 2.78. The range of elasticities we use covers all of these values.

Income effects. Proposition 1 requires the knowledge of income elasticities, which characterize industry-level Engel curves. We estimate them directly using CEX data on the heterogeneity of consumption baskets across income groups. Specifically, we first estimate income semi-elasticities by regressing, for each spending category in the CEX, spending shares on the log of average expenditure across income bins. We then convert them to elasticities ψ_j by IO industries; Appendix B.3 provides a complete discussion of the estimation steps. The resulting estimates are in line with those reported by Aguiar and Bils (2015) at a more aggregated level.

As Comin et al. (2021) point out, the empirical evidence suggests that the slopes of the Engel curves (in logs) are stable with respect to income. We therefore ignore the possibility that income elasticities can vary by income levels and set $\psi_{xj} \equiv \psi_j$ for all x.[31]

[31] An alternative approach would be to estimate the primitive φ_j parameters of NHCES and learn the heterogeneity of income elasticities across income levels from the structure of the demand system. That approach, however, would rely more heavily on parametric assumptions.

3.3 Labor Market Mobility and Labor Substitution

To implement Proposition 1, we also need to specify substitution patterns in the labor market. To assess the nature of the distributional effects of trade, and in particular whether they occur primarily within or across ex-ante similar groups of workers, we consider two polar cases. We first present the setting for the worker-level analysis, assuming no mobility of workers across industries; then we turn to a setting with perfect labor mobility across industries and two labor types defined by education.

3.3.1 Setting for the Worker-Level Analysis

We first consider a setting in which workers cannot move across industries, i.e. $\mathcal{J}(i)$ is a singleton for any type i. The lack of mobility simplifies the analysis in several ways. Since $\boldsymbol{E}$ maps each labor type to its industry, the change in labor demand is the same for all worker types in the same industry, and it equals the industry exposure from (6). Moreover, we show in Appendix A.9.1 that wage responses to the trade shock are identical for all workers in the same industry, equal to the (endogenous) growth of industry value added, and unaffected by within-industry labor substitution in $\boldsymbol{V}$. Thus, we can equivalently view each worker as a distinct type in the labor market (as our "worker-level analysis" label suggests) or group all workers from the same industry into the same type. For computational tractability, we choose the latter option, setting $I = J$, $\boldsymbol{E} = \mathbb{I}_J$, and $\boldsymbol{V} = 0_{J \times J}$. Finally, the inverse labor demand matrix $\tilde{\boldsymbol{G}}$ is fully characterized by observable statistics of the initial equilibrium and the demand parameters from Section 3.2, in the same way as η in (6).

While the inverse labor demand matrix is generally a complex $J \times J$ matrix, this tractable setting allows us to make progress in understanding how exposure to trade maps into the incidence of trade shocks. Specifically, we show that in industries with lower trade shares (i.e., export shares and import penetration rates), wages are more responsive to shifts in labor demand, compared to more traded industries, as Rodrik (1997) informally argued (see also Slaughter (2001) and Burstein et al. (2020)). Intuitively, the own-wage elasticity of labor demand is higher for more traded industries because the strongest substitutability in our model is between domestic and foreign varieties within an industry. When domestic wages grow, prices of domestic varieties increase, inducing shifts in demand. Both domestic and foreign buyers can substitute away to foreign varieties in highly traded industries, but not so much in others.

We prove this result in a restricted model, in which only the export and import competition effects arise, while intermediate inputs, income, and substitution effects are shut down. We find in our analysis of Section 4.1 that this result holds qualitatively even when all mechanisms are operative. Formally, suppose $\tilde{\boldsymbol{D}} = \mathbb{I}_J$ (i.e., there are no intermediate inputs), $\psi_{xj} \equiv 0$, and $\varepsilon_{xjk} \equiv 0$ (i.e., preferences are Cobb-Douglas across industries), and consider a set of shifts to labor demand $d \log L_j^D$ (or, equivalently, a similar reduction in labor supply). Then we prove in Appendix A.9.1 that the wage response to these shifts, $d \log w = \tilde{\boldsymbol{G}} \cdot d \log L^D$, satisfies

$$d \log w_j = \frac{d \log L_j^D}{1 + (\xi_j - 1) T_j} + \frac{DomSalesSh_j}{\zeta_2 (1 + (\xi_j - 1) T_j)} \cdot \left(\sum_{k=1}^{J} \frac{e_k d \log L_k^D}{1 + (\xi_k - 1) T_k} \right), \tag{14}$$

where $T_j = ExSh_j + IP_j \cdot DomSalesSh_j$, $\zeta_2 = 1 - \sum_j \frac{e_j DomSalesSh_j}{1 + (\xi_j - 1) T_j} \in (0, 1)$, and e_j is the payroll share of industry j in the economy. The first term in (14) shows that wages in more traded industries are less responsive to shifts in labor demand in their own industry, via the T_j term which increases in both the export share and the import penetration rate. The second term shows that they are also less sensitive to the economy average shift in labor demand, via both higher T_j and lower $DomSalesSh_j$.

3.3.2 Setting for the Analysis across Two Education Groups

We next consider a setting with full labor mobility across industries and two labor types — education groups in our empirical analysis — which we denote H and L (high and low skilled). The general result of Proposition 1 simplifies again, but in different ways. We first show that this model features a sufficient statistic which summarizes labor substitution in all industries, which we refer to as the macro elasticity of labor substitution, σ_{macro}. The local elasticities of substitution between the two labor types at the initial equilibrium in industries j, σ_j, enter the $\boldsymbol{V}$ matrix, and therefore $\tilde{\boldsymbol{G}}$, through this scalar parameter. Specifically, Appendix A.9.2 proves that

$$\boldsymbol{V} = (\sigma_{\text{macro}} - 1) \begin{pmatrix} -v_L & v_L \\ v_H & -v_H \end{pmatrix}, \tag{15}$$

where

$$\sigma_{\text{macro}} - 1 = \sum_j e_j \frac{v_{H|j} v_{L|j}}{v_H v_L} (\sigma_j - 1), \tag{16}$$

e_j is the payroll share of industry j in the economy, and as before $v_{i|j}$ and v_i are payroll shares of type $i = H, L$ in industry j and the overall economy, respectively.[32]

We follow Burstein and Vogel (2017), Cravino and Sotelo (2019), and Caron et al. (2020) in calibrating the macro elasticity directly rather than aggregating it from micro estimates. For the baseline analysis, we use the estimate of $\sigma_{\text{macro}} = 1.41$ obtained by Katz and Murphy (1992). We check robustness to the range of $[1.41, 1.8]$, with the upper bound corresponding to the estimates from Acemoglu (2002) and Acemoglu and Autor (2011).

The simple structure of the $\boldsymbol{V}$ matrix allows us to gain insight into the wage responses to the trade shock in this setting. Appendix A.9.2 shows that the skill group that is initially specialized in industries that will grow faster after the shock will experience a higher wage growth, all the more so if σ_{macro} is small:

$$d \log \frac{w_H}{w_L} = \frac{1}{\sigma_{\text{macro}}} \left(\sum_j v_{H|j} d \log VA_j - \sum_j v_{L|j} d \log VA_j \right). \tag{17}$$

According to (8), which industries grow faster depends on their exposure to the shock, although it also depends on the general equilibrium feedback loops encoded in the $\boldsymbol{G}$ matrix.

4 Quantitative Results

To assess the importance of both vertical and horizontal distributional effects, we first consider the "worker-level" setting with no mobility of workers across industries. Second, to shed more light on the distributional effects that may arise across groups of ex-ante similar workers, we consider the setting with two education groups, assuming perfect mobility of each group of workers across industries. Third, we present several robustness checks and extensions. In all analyses, we find little role for the distributional effects across income and education groups.

4.1 Trade-Induced Inequality across Workers

In this section, we conduct the worker-level analysis of the welfare effects of a counterfactual 10% fall in iceberg trade costs.[33] We first quantify the relative importance of horizontal and vertical

[32] We note that $\sigma_{\text{macro}} - 1$ is generally not a weighted average of $\sigma_j - 1$: the sum of weights, $\sum_j e_j \frac{v_{H|j} v_{L|j}}{v_H v_L}$, is smaller than one unless all industries have the same skill composition.

[33] Since we use the first-order approximation, the choice of the size of the shock is immaterial and is based on presentation clarity only.

distributional effects in Section 4.1.1. We then decompose each type of distributional effects into several mechanisms, starting with vertical distributional effects in Section 4.1.2 and then turning to horizontal distributional effects in Section 4.1.3.

4.1.1 The Relative Importance of Trade-Induced Horizontal and Vertical Inequality

Figure 1 depicts the measures of worker exposure to trade by decile of the income distribution, showing that exposure varies primarily within deciles rather than across. This is the key data fact that explains why trade-induced inequality is primarily horizontal. Using Proposition 1, we present the five components of worker exposure, $\boldsymbol{E}\tilde{\boldsymbol{D}}\eta$, multiplying these terms by the 10% change in trade costs. The results are directly informative about the drivers of the labor demand response to trade liberalizations for different workers. For each income decile, we report average worker exposure along with the 10th and 90th percentiles of the worker-level exposure distribution. The within-decile variation arises from different industries employing workers from the same income decile.

Panel A shows changes in labor demand resulting from the export effect after a 10% fall in trade costs. The increase in labor demand is larger for higher-income workers, ranging from about +1.2% for the average worker in the first (i.e., bottom) decile to about +2.5% on average within the top decile. The change in labor demand varies substantially more across workers within deciles, with 90-10 gaps between 3.6p.p. and 5.1p.p. Panel B reports the changes in labor demand from the import competition effect: the fall in labor demand is more pronounced for higher-income workers, with a change of about -1.8% in the top decile compared with -0.9% in the bottom decile. Heterogeneity in the labor demand effects of import competition is large within each decile, with 90-10 gaps of 1.9 to 4.4p.p.[34] On net, increases in labor demand from exposure to both export opportunities and import competition, reported in Panel C, are stronger for richer workers. This "net exports" composite effect ranges from about 0.3% on average in the bottom decile to 0.8% in the top decile, while the variation within each decile is substantial, with 90-10 gaps over 1.5p.p.[35]

Next, Panel D shows that the increase in labor demand from the imported inputs effect is also

[34]The finding that high-earning workers are on average more exposed to import competition contrasts with the traditional two-sector, two-factor formulation of the Heckscher-Ohlin model, in which low-paid workers are more exposed to import competition and lose from trade. Instead, our results highlight the importance of heterogeneous trade costs across industries: high-earning workers (except the very top earnings decile) are more likely to be employed in the more tradable manufacturing sector (see Appendix Figure S1), as well as in more tradable industries within both manufacturing and services and are therefore more exposed to import competition.

[35]We put net exports in quotes because, as Footnote 20 explains, the relevant industry exposure measure from Proposition 1 which is reported here is not based on the difference between the values of exports and imports.

largest in the top decile relative to the bottom (at 0.6% vs 0.3%), again with large heterogeneity within deciles shown by the 90-10 gaps of 0.7-1.5p.p. Panel E reports changes in labor demand from income effects, which are relatively flat across deciles and close to zero on average, but vary substantially within each decile, with 90-10 gaps of 0.2-0.5p.p. Similarly, Panel F shows that changes in labor demand from substitution effects are essentially flat across the distribution, with 90-10 gaps of 0.7-0.9p.p.[36]

Following Propositions 1 and 2, Figure 2 reports the overall change in labor demand on Panel A, combining the five mechanisms from Figure 1, and in welfare on Panel B, i.e. accounting for general equilibrium changes in both wages and price indices. Panel A shows that there is higher growth of labor demand at higher income deciles, from +0.8% at the bottom to +1.5% at the top. Again, heterogeneity between workers occurs primarily within rather than across deciles: the spread between the 10th and 90th percentiles is 2–4p.p. For the welfare change in general equilibrium on Panel B, heterogeneity in the equivalent variation is also much larger within income deciles than across. Within each decile, the 10-90 gap in welfare effects is over 2 percentage points, while variation across income deciles is much smaller, from 2.1% in the first decile to 1.8% at the tenth.

Table 1 quantifies the relative importance of trade-induced horizontal and vertical inequality formally. Panel A shows that the shock has very heterogeneous effects across workers: while the median welfare gain is 2.30%, it is below 0.73% for 10% of workers and over four times larger, above 3.16% for another 10% of them. The standard deviation of the welfare changes is 1.44p.p. Despite this large heterogeneity in welfare gains, Panel B shows that the effect of the shock on the shape of the income distribution is very small. To measure this effect, we add the estimated welfare change to the initial (nominal) income of each worker, leveraging the cardinalization of utility from Section 2.1. We then obtain changes in the distribution of welfare, e.g. $\text{SD}\left(\log x + d\log\mathcal{W}\right) - \text{SD}\left(\log x\right)$. The shock leaves the shape of income distribution essentially unchanged: the Gini index falls by 0.0002 points, while the standard deviation of (real) log-wages falls by 0.0005. As shown by Proposition 3, the standard deviation of real log-wages remains unchanged despite large distributional effects of the shocks if the magnitude of welfare gains does not covary with the initial level of income. Accordingly, we find that the standard deviation of welfare effects is 26 times larger than the change in the standard deviation of the log-income distribution. In this sense, a fall in trade costs primarily

[36] We find that the patterns in Figure 1 are driven primarily by the heterogeneity of worker exposure to export ratios, import penetration, cost shares of intermediate inputs, and income elasticities of their industries, rather than by IO and other adjustments from Proposition 1. We show this result in Appendix Figure S2, which reports "raw" exposure statistics and finds patterns similar to Figure 1, both within and across income groups.

generates horizontal inequality.

Figure 3 depicts these patterns graphically. Panel A reports the distribution of real wages before and after the 10% fall in trade costs. It shows that the wage distribution remains essentially unchanged, even in the tail of the distribution. In contrast, Panel B shows that some workers experience substantial changes in welfare. Plotting the distribution of the worker-level welfare changes by quintile of their initial earnings, this panel shows that the distribution of welfare changes across workers is very similar across quintiles, including in the tail of the distribution of welfare changes. As in Panel B of Figure 2, about 80% of workers in each income quintile experience welfare gains ranging between 1% and 3%. The welfare gains or losses become large in the tails of the distribution, with welfare losses up to 8% at the bottom and welfare gains close to 7% at the top, which are observed for all income groups. The full distribution of welfare changes confirms the finding from Table 1: the distributional effects of trade can be large but are entirely driven by heterogeneity across workers within the same income group.

4.1.2 Decomposing Trade-Induced Vertical Inequality

Although we found that trade shocks primarily generate horizontal rather than vertical inequality, it is instructive to decompose vertical inequality to understand the mechanisms at play.

First, it is notable that, in contrast to the change in labor demand in Panel A of Figure 2, which is higher at the top of the income distribution, the average welfare gains in Panel B are slightly *higher* at the bottom of the income distribution. The change in slope when accounting for the $\tilde{\boldsymbol{G}}$ matrix is explained by the role of the service sector. As Section 3.3.1 showed, when labor demand grows, less traded industries, such as services, experience a larger increase in wages. Services also tend to have relatively more lower-income workers, as Appendix Figure S1 reports. Thus, this larger wage response benefits the low-income group more.

Next, we investigate the economic forces driving the differences in the labor demand and wage effects of the shock across deciles of initial earnings. Starting with the change in labor demand, i.e., $\boldsymbol{E}\tilde{\boldsymbol{D}}\eta \cdot (-d \log \tau)$, Figure 4 reports the contribution of the mechanisms corresponding to the components of η from equation (6), normalizing the bottom decile to zero. The key differences arise in the exposure to net exports and intermediate inputs, which both favor richer workers. Income and substitution effects do not play a significant role.

The decomposition for welfare changes in GE is richer, following equation (3) and Proposition 2. Panel A of Figure 5 decomposes welfare changes in GE, again relative to the first decile, into the earnings and expenditure channels. The panel shows that the earnings and expenditure channels both have non-monotonic welfare effects across deciles. The expenditure channel generates the largest welfare gains for the third decile of the income distribution, and the smallest gains for the top income decile. In contrast, the earnings channel generates the largest welfare gains for the bottom income decile, and the smallest for the fourth decile. Together, the two channels general a monotonic fall in welfare effects across deciles, driven by the earnings channel at the bottom and the expenditure channel at the top. To understand these patterns, Panels B and C of Figure 5 further decompose the earnings and expenditure channels, respectively.

Panel B decomposes the wage response in GE into the mechanisms from equation (6). Compared with the partial equilibrium labor demand response in Figure 4, substitution effects now play a much larger role than in the partial equilibrium analysis of labor demand, contributing to a fall in wage inequality. Intuitively, substitution effects compound the larger increase in wages in general equilibrium for less traded industries like services: since the elasticity of substitution between goods and services is below one, consumers reallocate spending toward services as wages in this sector increase, leading to a further increase in wages for service workers. The net exports and intermediate inputs effects also lead to an increase in the relative wage at the bottom, again because a given labor demand change has a stronger wage effect in non-traded industries.

Finally, Panel C of Figure 5 decomposes the expenditure channel into three mechanisms following equation (9) in Proposition 2, isolating the contribution of the price of imports through falling trade costs, the change in average wage, and the segregation effect. This panel shows that the lower welfare gain for higher-income workers via the expenditure channel is explained primarily by the segregation effect: domestic wages increase more in sectors that cater to richer households.[37] The other two mechanisms push slightly in the opposite direction. Compared with the bottom income decile, the fall in prices from lower trade costs benefits richer workers slightly more because the import share of their consumption baskets, including both direct and indirect imports, is slightly higher, as shown by Borusyak and Jaravel (2021).[38] Prices also change because average domestic wages increase in general equilibrium, through the terms-of-trade effect. The response of domestic prices to this change is proportional to and smaller than the effects of lower trade costs, with a

[37]In unreported analyses, we find that the segregation effect stems from two forces: first, wages (and thus domestic prices) grow more in services, whose expenditure share is higher for richer workers; second, within services domestic prices grow more for those services consumed more by richer workers.

[38]Specifically, Borusyak and Jaravel (2021) show that import shares are similar across the distribution of household incomes, with a slight increase from the bottom to the top income deciles. As explained in Appendix B.1, we match household income deciles to worker earnings deciles.

limited impact on inequality across deciles. Overall, absent the segregation effect, the welfare gains of falling trade costs would be nearly equal across income deciles, instead of being larger at the bottom.

4.1.3 Decomposing Trade-Induced Horizontal Inequality

In this section, we use several decompositions to understand the horizontal inequality induced by falling trade costs. We document the role of sectoral exposure for the heavy left tail of worker-level welfare changes and use Proposition 1 to decompose the variance of worker-level distributional effects.

We first assess the role played by sectoral differences in the tails of the distribution of welfare changes. Figure 6 depicts the worker-level distribution of welfare changes within goods-producing industries and within services. The panel shows that the large welfare changes in the tails are driven by goods. While workers in services all experience welfare gains, within goods-producing industries about 60% of workers experience a welfare loss, including 5% with a welfare loss in excess of 4%. Large welfare gains are also more common for goods-producing industries (e.g. due to the growing export demand), with about 5% of workers experiencing a welfare gain above 5%, which is higher than for any worker within services. Sectoral differences thus play a key role for the tails of worker-level welfare changes.

Next, we characterize the relative importance of different economic forces for the heterogeneity of labor demand and wage effects of trade across workers. In Column (1) of Table 2, we regress the worker-level labor demand response on the five margins of exposure to the labor market effects of trade: exports, import competition, intermediate inputs, income effects, and substitution effects. This analysis parallels Figure 4, but the regression is estimated across workers rather than income deciles to focus on the horizontal inequality induced by trade. In our model, the heterogeneous labor demand effects across workers are fully explained by the five margins of their industry's exposure. Therefore, the regression coefficients in Column (1) are all equal to 1 and the R^2 is 100%. Column (2) uses the Shapley decomposition of the R^2 to assess the relative importance of each mechanism in explaining the overall variation. Exports explain 54% of the variation, imports 21% and intermediate inputs 19%, while income effects and substitution effects play more minor roles. These results thus suggest that export exposure is the key driving force.

In general equilibrium, the wage effects also depend on the $\tilde{\boldsymbol{G}}$ matrix. We therefore run a regression to assess whether the labor demand response is a good predictor of the overall wage effect, at the worker level. Column (3) of Table 2 reports the result: the R^2 falls to 38%, indicating that the overall exposure to trade shocks is an imperfect predictor of the wage effect. However, Column (4) shows that the R^2 increases to 96% when using the five exposure margins from Column (1) as separate regressors, allowing for different regression coefficients for each margin. The estimated coefficients now range from 0.31 for exports to 1.21 for intermediate inputs.[39] This result shows that the earnings channel of trade in general equilibrium can be almost perfectly recovered using as linear predictors the margins of exposure we study, as long as the coefficients on the different margins are allowed to vary.[40] These findings speak to a growing empirical literature on attitudes toward trade (e.g., Mayda and Rodrik (2005), Jäkel and Smolka (2017), Van Patten and Méndez-Chacón (2022)), which assesses whether individual-level exposure to trade predicts support for trade agreements, typically using linear regressions. Our analysis provides a novel foundation for these analyses, since we find that partial equilibrium exposure measures retain very strong predictive power in general equilibrium in a standard, fully-specified quantitative trade model.

4.1.4 Takeaways

The analysis in this section yields three main lessons. First and foremost, the distributional effects of trade shocks are primarily concentrated within income deciles, i.e. trade-induced inequality is primarily horizontal. There is little impact of a fall in trade costs on the shape of the income distribution, but there are substantial distributional effects creating sizable changes in relative wages, as well as winners and losers at all income levels. This finding is not a mechanical feature of the model but results from the fact that the welfare effects of trade shocks are only weakly correlated with income. If specialization patterns had been sufficiently different across income deciles, we could have found an effect across deciles as large as the effect obtained within deciles.[41]

[39] The heterogeneous coefficients imply that the the relative predictive importance of different margins is very different from the labor demand analysis of Column (2). Using the Shapley decomposition of the R^2, Column (5) shows that exposure to exports explains only 11.7% of the variation, consistent with the lower coefficient on this margin, while import competition now explains 50.1%, followed by substitution effects at 18.7%, and intermediate inputs at 13.8%. Income effects are still relatively unimportant, at 5.7%.

[40] This result is not a mechanical feature of the model since, for each worker, the welfare effect is determined by the exposure of their own industry with industry-specific coefficients (diagonal elements of $\tilde{\boldsymbol{G}}$) as well as exposure of other industries (non-diagonal elements). Appendix Table S1 shows that the five margins of labor demand exposure very accurately predict not only the overall wage response to a trade shock but also each of the five margins of the wage response separately, with the heterogeneous coefficients shown in the table. Thus, one can approximately view the mapping $\tilde{\boldsymbol{G}}$ from labor demand to wage changes as a rotation of the five mechanisms through which labor demand shocks happen in response to a trade shock.

[41] This first lesson from our analysis echoes the empirical findings of Hummels et al. (2014) who estimate the effects of exports and offshoring on wages of different groups of workers in a reduced-form framework. The economic mechanisms they study are different, as our framework does not incorporate offshoring (although it can be introduced by modeling it as skill-biased import competition, as in our early draft, Borusyak and Jaravel (2018)). They find

Second, the average gains from trade liberalizations are positive for all income deciles. Third, direct exposure measures turn out to be sufficient to closely approximate the overall welfare effects of trade across workers, offering new a justification for the growing literature studying attitudes toward trade depending on individual exposure statistics.

4.2 Trade-Induced Inequality across Education Groups

To verify that there is a robust pattern of weak distributional effects across groups of observably similar workers in general equilibrium, we now conduct the analysis with two groups, considering worker with or without a college degree and assuming they are freely mobile across industries. Our focus is therefore on the college wage premium, which has played an important role in the evolution of U.S. income inequality (e.g. Autor et al. (2008) and Goldin and Katz (2007)). Figure 7 reports the effects of a 10% reduction in trade costs in this setting.

Using Proposition 1, Panel A reports shifts in labor demand and their drivers across education groups. We find that labor demand grows by more for college graduates, mainly because they are employed in industries with higher "net exports." Favorable income and substitution effects magnify the difference slightly, while exposure to imported inputs is lower for college graduates, which partially offsets the gap. In total, labor demand grows by 1.4% for the group of college graduates and 1.2% for workers without a college degree in response to the shock.

Panel B reports welfare changes across education groups in general equilibrium using Propositions 1 and 2. We find that both groups benefit from reduced trade costs and the college wage premium remains almost unchanged. The equivalent variation is 1.7% for college-educated workers, compared with 1.6% for those without a college degree; the small difference of 0.11p.p. arises from the earnings channel. The expenditure channel, also reported in this figure, is distributionally neutral.

Taken together, the results of our two analyses – across workers and across education groups – show that trade can induce sizable horizontal inequality when labor mobility is limited; vertical inequality is not found either with or without labor mobility. These findings also illustrate how our theoretical results can be used to assess the importance of different mechanisms and different labor market assumptions in governing the distributional effects of trade shocks.

that the distributional effects of globalization arise primarily *within* groups of ex-ante similar workers because of their heterogeneous exposure (Table 6).

4.3 Robustness and Extensions

In this section, we first demonstrate the robustness of the results to different choices of elasticities. We then consider several extensions, allowing for other counterfactual shocks, within-industry heterogeneity, and capital as a separate factor.

Robustness of main results to choice of elasticities. Figure 8 shows that the welfare effects of the uniform 10% shock remain similar in both our quantitative analyses when we vary the trade elasticity $\xi - 1$, substitution elasticities in demand (ρ and ε) or the labor substitution elasticity σ_{macro} within the ranges used in the literature. Since exposure to trade is similar across worker groups, elasticities do not play a decisive role.

Non-uniform changes in trade costs. We follow Borusyak and Jaravel (2021) and consider reductions of trade costs with specific trading partners, as well as counterfactuals inspired by recent changes in trade policy and trade costs. Panel A of Figure 9 analyzes a 10% fall in iceberg costs for imports from China, NAFTA or 34 advanced economies separately, for the worker-level analysis. Panel B investigates the impact of the import tariffs introduced by the Trump administration in 2018 (on solar panels, washing machines, steel and aluminum products, and a large set of products from China), the observed change in U.S. import tariffs in 1992–2007, and the observed change in transportation and insurance costs in the same period.[42] Figure 10 repeats the same analyses across education groups. The results are similar to the baseline analyses: substantial distributional effects of trade are found only within income deciles in the absence of labor mobility.

Within-industry heterogeneity. To assess the potential importance of within-industry heterogeneity, in Table 3 we use the plant-level microdata from the Census of Manufactures and the Management and Organizational Practices Survey. These data allow us to analyze, at a more granular level, one of the mechanisms from Proposition 1: the difference in exposure to exports between skill groups, as measured by education groups or groups of non-production and production workers. We find that more skill-intensive plants within the same industry tend to export more, in line with Burstein and Vogel (2017). However, this within component is small relative to differences arising across manufacturing industries, which we have analyzed previously.

[42] Appendix B.4 describes the data sources, and Appendix A.4 explains how to apply Propositions 1 and 2 to shocks which are not uniform across industries.

Relative factor demand for capital and labor. Finally, Figure 11 documents changes in the partial equilibrium factor demand for capital vs. labor after a fall in trade costs, quantifying all mechanisms from Proposition 1: exposure to net exports, intermediate inputs, income, and substitution effects. We find that relative factor demand remains similar after a uniform fall in trade costs.

5 Conclusion

In this paper, we conceptualized the notion of trade-induced horizontal and vertical inequality, and studied their relative importance in the United States. We accounted for changes in both prices and wages in a unified general equilibrium framework and found empirically that horizontal inequality is the dominant force, because exposure to trade is heterogeneous primarily within groups of ex-ante similar workers. Since trade shocks generate winners and losers at all income levels but do not change the shape of the income distribution, our findings run against a popular narrative that "trade wars are class wars" (Klein and Pettis 2020). Our exposure-based theoretical framework contributes to an emerging literature characterizing the welfare effects of trade or other macroeconomic shocks in terms of microeconomic sufficient statistics and elasticities (e.g., Baqaee and Farhi (2019), Baqaee and Farhi (2022), Adão et al. (2022), Kleinman et al. (2022)). Our framework can be readily applied to study the effects of other counterfactual shocks of interest, beyond trade shocks. For example, the framework can accommodate any productivity shock (e.g., carbon abatement costs due to the net-zero transition) or labor supply shock (e.g., shocks to education or immigration). Expanding the framework to account for the role of local labor markets and within-country trade would be another interesting direction for further research. This framework thus offers several avenues for novel applications and extensions in future work.

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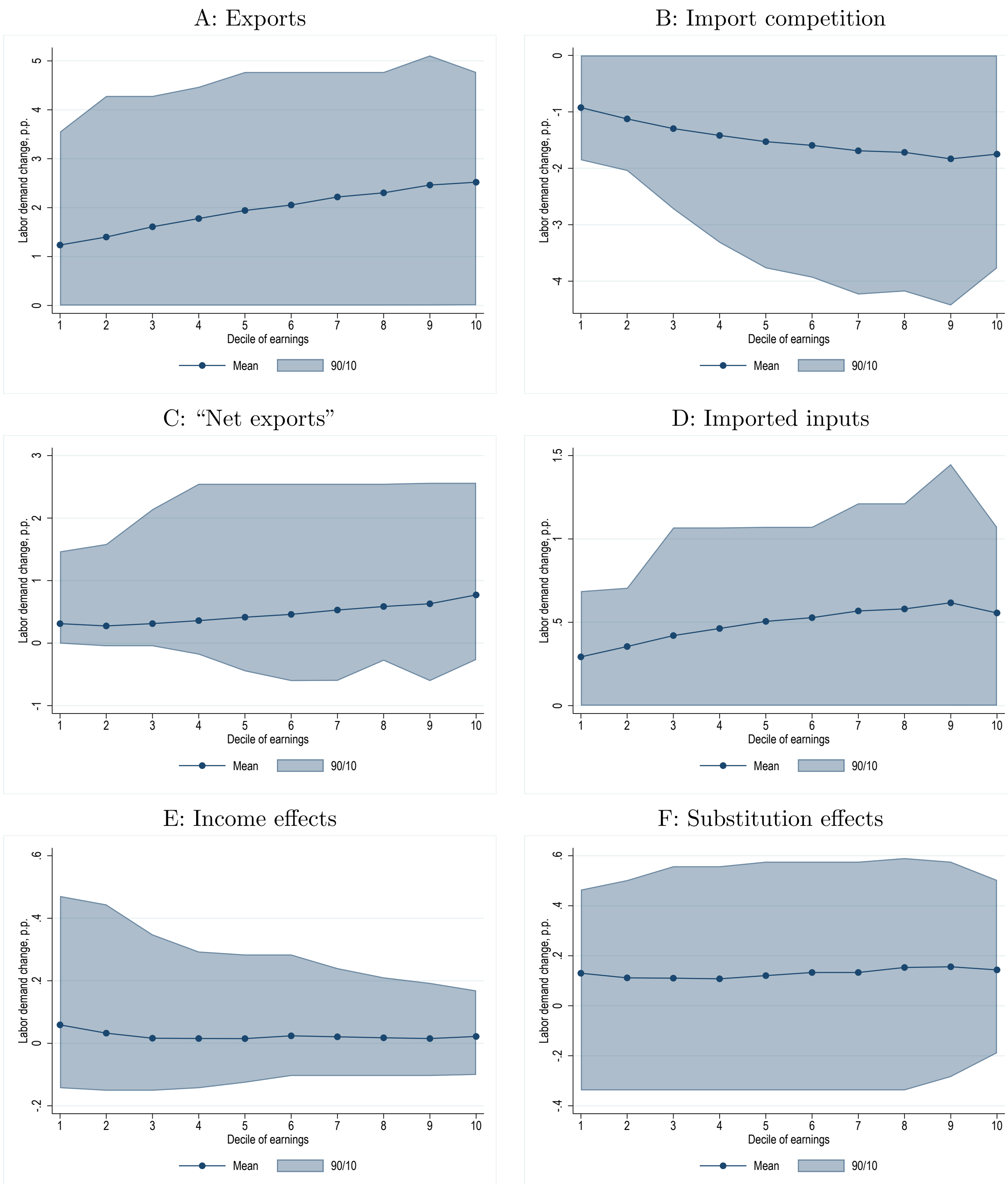
Figures and Tables

Figure 1: Margins of Worker-Level Exposure to a Fall in Trade Costs, Across and Within Income Deciles

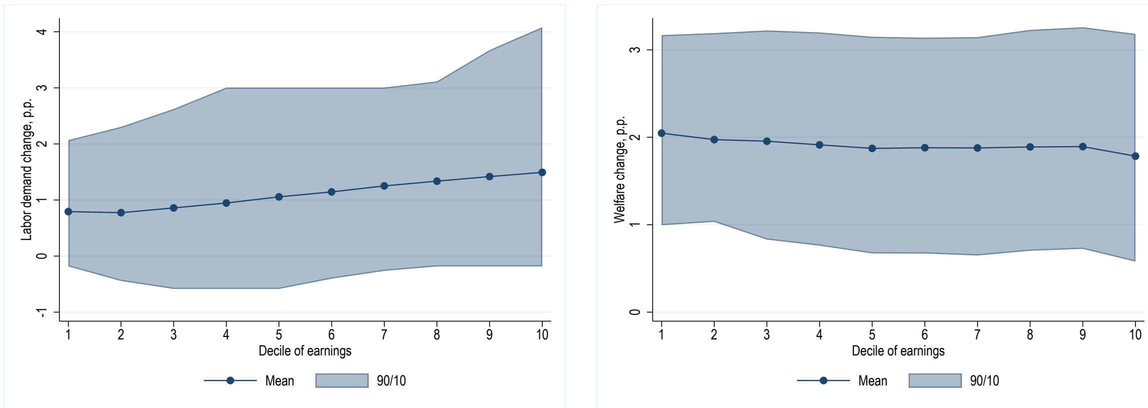


Notes: This figure groups workers from the ACS data by decile of earnings and plots the margins of the labor demand response following a uniform 10% fall in trade costs. Panels A–B and D–F correspond to the five components of $\boldsymbol{E}\tilde{\boldsymbol{D}}\eta \cdot 10\%$ in Proposition 1, while Panel C shows the sum of exposures to exports and import competition. Each panel reports the average, the 10th percentile, and the 90th percentile across workers in each bin.

Figure 2: Worker-Level Effects of a 10% Fall in Trade Costs on Labor Demand and Wages, Across and Within Income Deciles

A: Worker-level labor demand responses, partial equilibrium

B: Worker-level welfare effects, general equilibrium

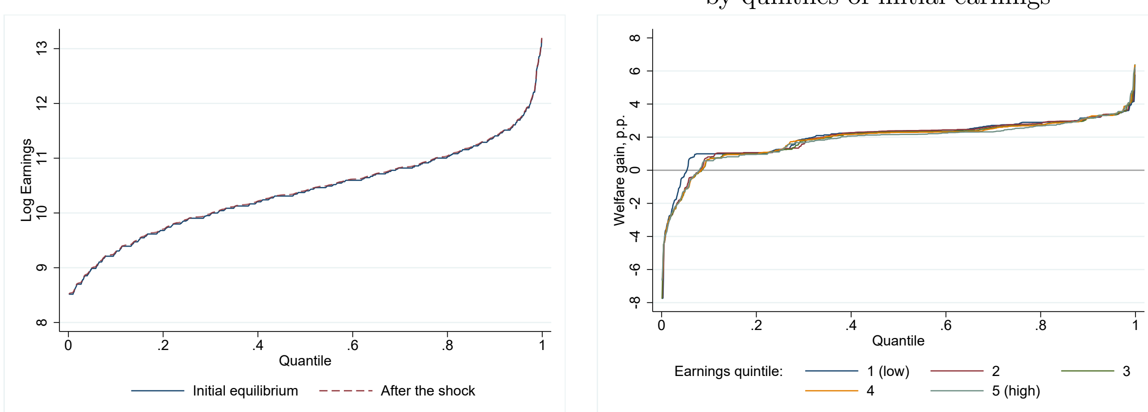


Notes: For the worker-level analysis of Section 4.1, Panel A plots the labor demand responses following a uniform 10% fall in trade costs, while Panel B shows general equilibrium welfare changes, defined as the equivalent variation as a fraction of initial expenditures. Each panel reports the average effects by decile of worker initial earnings, along with 10th and 90th percentiles within each decile.

Figure 3: Distributions of Worker-Level Effects of a 10% Fall in Trade Costs

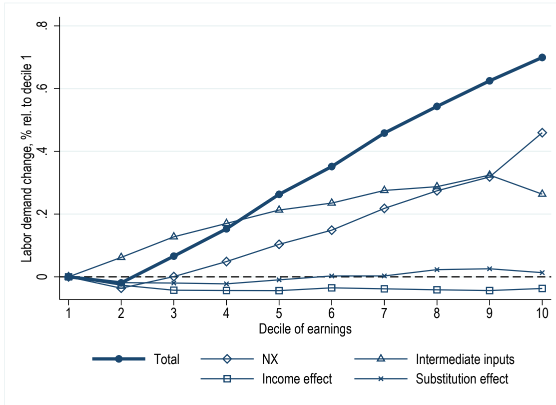
A: Changes in the earnings distribution

B: Unequal effects across workers by quintiles of initial earnings



Notes: For the worker-level analysis of Section 4.1, this figure plots the change in the (real) earnings distribution (Panel A) and the distribution of welfare changes by quintile of worker initial earnings (Panel B), following a uniform 10% fall in trade costs. Welfare changes are defined as the equivalent variation as a fraction of initial expenditures. A worker's log-earnings after the trade shock is defined as the initial (nominal) log-earnings plus the welfare change, leveraging the cardinalization of utility from Section 2.1. In both panels, the distributions are reported as quantile functions, i.e. with quantiles on the horizontal axis.

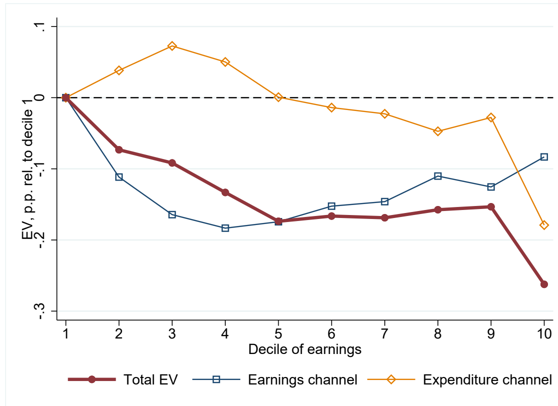
Figure 4: Decomposing the Effects of a 10% Fall in Trade Costs on Labor Demand across Income Deciles



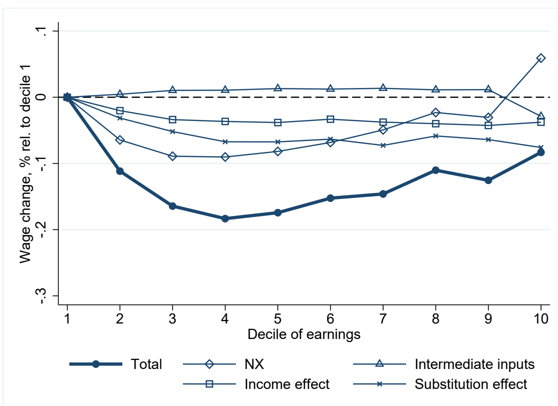
Notes: For the worker-level analysis of Section 4.1, this figure plots the average labor demand responses following a uniform 10% fall in trade costs across deciles of worker initial earnings. The bottom decile is normalized to zero and the overall change relative to the bottom decile is decomposed into different mechanisms according to Proposition 1.

Figure 5: Decomposing the Effects of a 10% Fall in Trade Costs on Welfare across Income Deciles

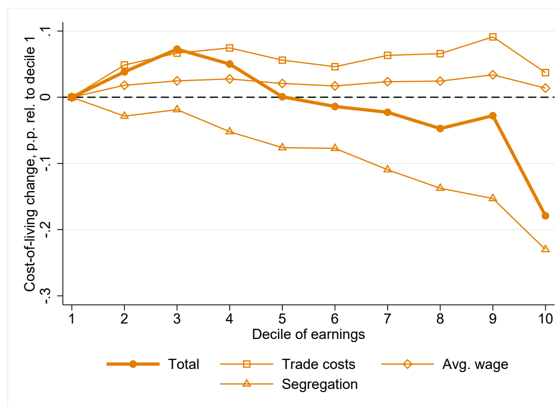
A: Decomposition of welfare into earnings and expenditure channels



B: Decomposition of the earnings channel into mechanisms

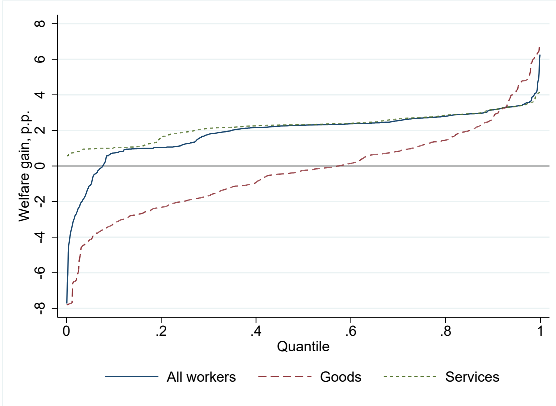


C: Decomposition of the expenditure channel into mechanisms



Notes: For the worker-level analysis of Section 4.1, this figure plots the average welfare responses following a uniform 10% fall in trade costs across deciles of worker initial earnings, with the bottom decile normalized to zero. Welfare changes are defined as the equivalent variation as a fraction of initial expenditures. Panel A decomposes welfare effects into the expenditure and earnings channels using equation (3). Panel B decomposes the earnings channel into four mechanisms using equation (6) in Proposition 1, while Panel C decomposes the expenditure channel into three mechanisms, using equation (9) in Proposition 2.

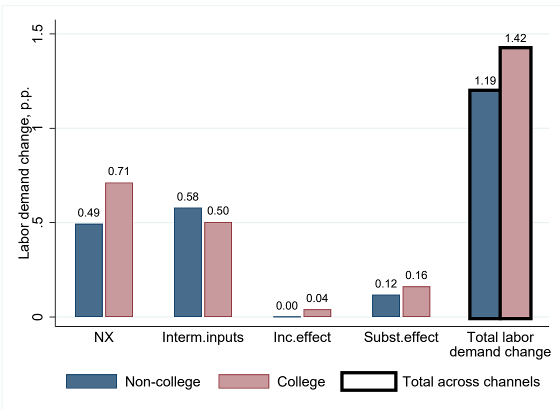
Figure 6: Unequal Effects across Workers by Sector



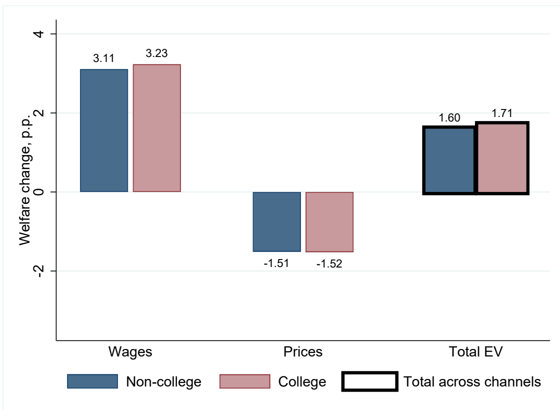
Notes: For the worker-level analysis of Section 4.1, this figure plots the distribution of worker-level welfare changes by sector (goods or services) following a uniform 10% fall in trade costs. Welfare changes are defined as the equivalent variation as a fraction of initial expenditures, and are reported by quantiles.

Figure 7: Welfare Effects of a 10% Fall in Trade Costs across Education Groups

A: Labor demand response



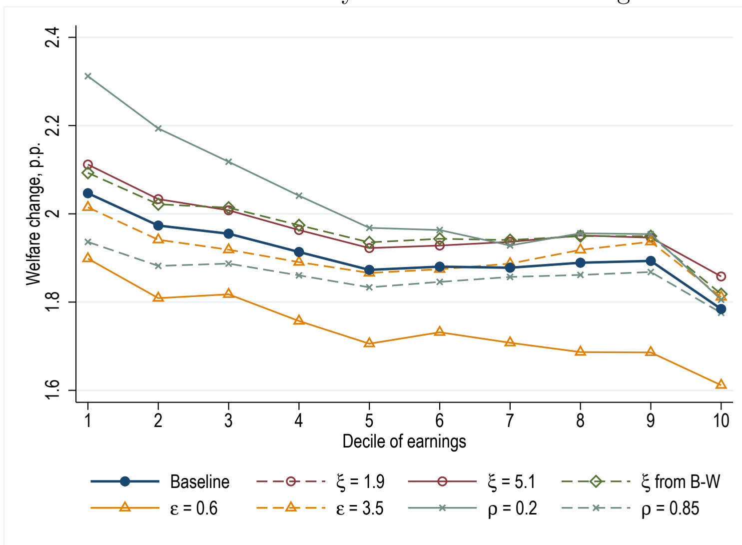
B: Welfare response in GE



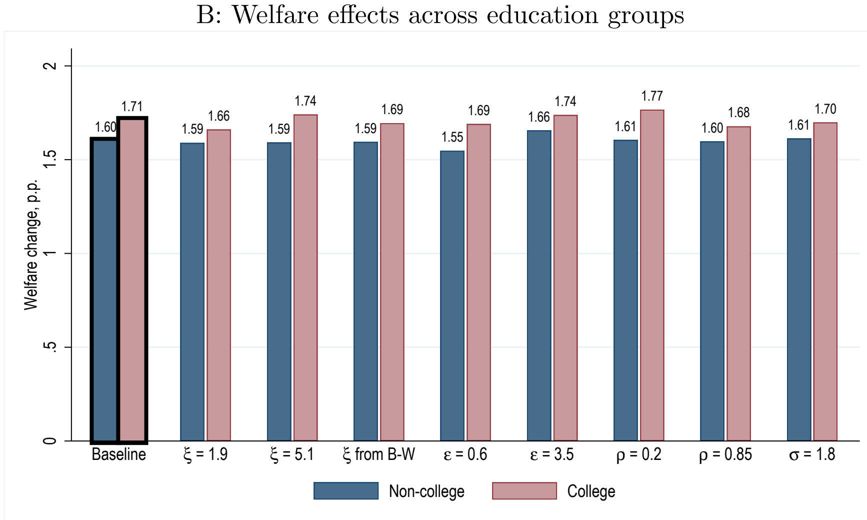
Notes: For the analysis across education groups of Section 4.2, this figure plots the partial equilibrium labor demand response (Panel A) and the welfare response in GE (Panel B) to a uniform 10% reduction in trade costs for workers with and without a college degree. Welfare changes are defined as the equivalent variation as a fraction of initial expenditures. Panel A decomposes the effects into several mechanisms according to Proposition 1, and Panel B uses equation (3) for the decomposition.

Figure 8: Robustness to Choice of Elasticities

A: Welfare effects by decile of initial earnings



B: Welfare effects across education groups

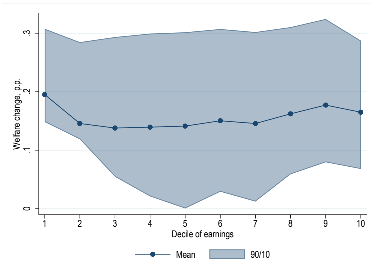


Notes: This figure reports the welfare effects of a 10% uniform fall in trade costs by worker groups, under different assumptions about the relevant elasticities of substitution. Panel A considers the worker-level analysis from Section 4.1, while Panel B focuses on education groups, as in Section 4.2. The baseline from Figures 2 and 7, reproduced here, uses the following elasticities of substitution in demand: across countries of origin within industries, $\xi_j = 3.5$; across industries within manufacturing or services, $\varepsilon_r = 2$; between manufacturing and services, $\rho = 0.6$. Panel B further uses the macro elasticity of substitution between workers with and without a college degree, $\sigma = 1.41$ (this elasticity is not relevant for Panel A). The figure then consider ranges of $\xi_j \in [1.9, 3.5]$, $\varepsilon_r \in [0.6, 3.5]$, $\rho \in [0.2, 0.85]$, and $\sigma \in [1.41, 1.8]$, capturing the values found in the literature (see Section 3.2). We also allow ξ_j to vary across 3-digit IO industries according to the estimates from Broda and Weinstein (2006), labeled "B-W" in the figure.

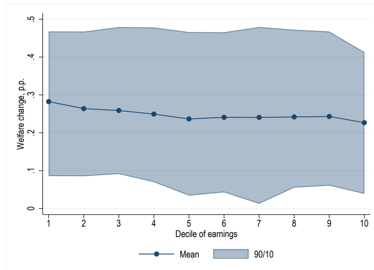
Figure 9: Worker-level Welfare Effects of Non-Uniform Trade Shocks

A: By trading dartner

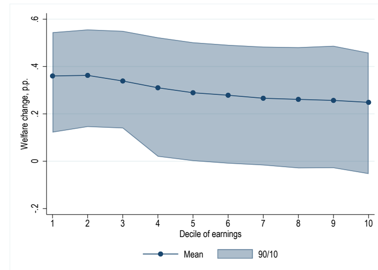
i: China



ii: NAFTA

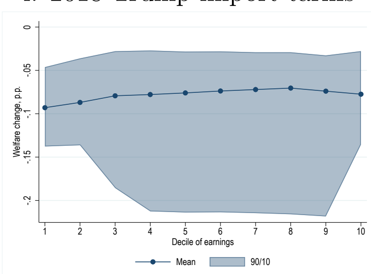


iii: Developed economies

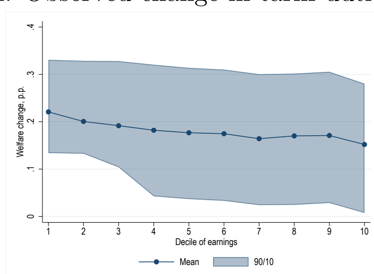


B: Observed changes in trade costs

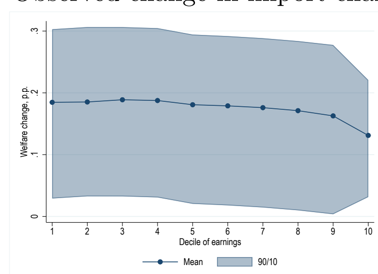
i: 2018 Trump import tariffs



ii: Observed change in tariff duties



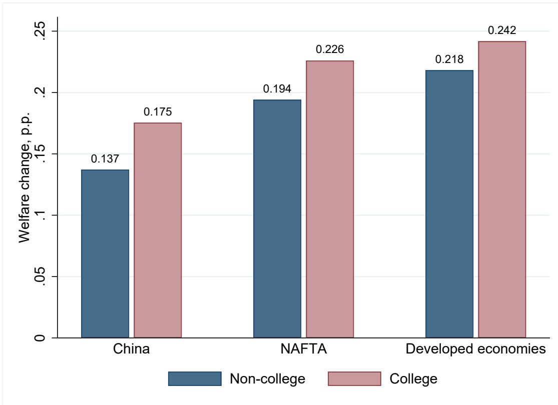
iii: Observed change in import charges



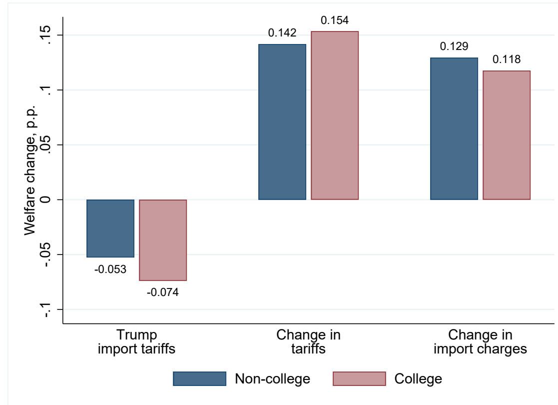
Notes: For the worker-level analysis of Section 4.1, Panel A plots the welfare effects of a 10% fall in trade costs for goods imported from specific trading partners. NAFTA corresponds to Canada and Mexico, while 34 developed economies are OECD members, excluding NAFTA, plus Taiwan and Singapore. Panel B plots the welfare effects from observed shocks to the costs of importing goods: the introduction of import tariffs in 2018 by the Trump administration, changes in U.S. tariff duties between 1992 and 2007, and changes in import charges (i.e., total transportation and insurance costs) between 1992 and 2007; see Appendix B.4 for details. Each panel reports average effects by decile of initial earnings, along with the 10th and 90th percentile within each decile. Panel A follows Proposition 1, while Appendix B.4 describes the methodology for Panel B.

Figure 10: Welfare Effects of Non-Uniform Trade Shocks across Education Groups

A: By trading partner

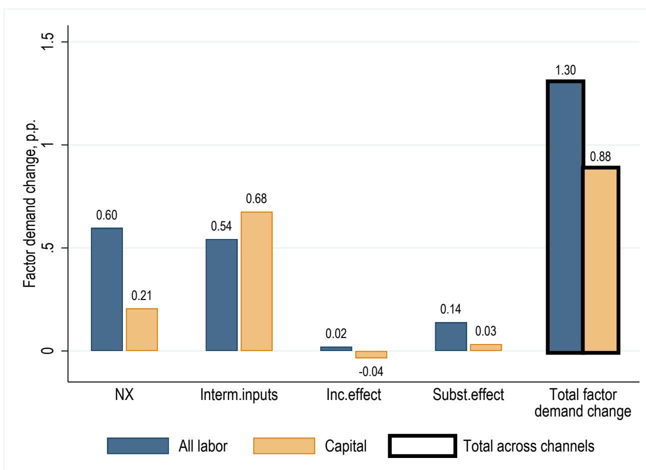


B: Observed changes in trade costs



Notes: This figure plots the welfare effects from non-uniform trade shocks across education groups for the calibration of Section 4.2. Panel A considers a 10% fall in trade costs of importing goods from specific countries (China, Mexico and Canada, and 34 developed economies), while Panel B studies the effects of observed trade shocks, as in Figure 9B. Panel A follows Proposition 1, while Appendix B.4 describes the methodology for Panel B.

Figure 11: Changes in Factor Demand for Capital Owners and Workers for a Uniform Fall in Trade Costs



Notes: This figure reports the partial equilibrium change in factor demand for labor and capital for a uniform 10% fall in trade costs, decomposing the change into the several mechanisms as in Proposition 1. The composition of industries in payments to capital owners is obtained from the "Gross operating surplus" row in the IO Table, similarly to how "Compensation of employees" is used for labor in the main industry-level dataset.

Table 1: Unequal Effects across Workers vs. Changes in the Income Distribution

A: Unequal effects of the shock across workers

	SD (1)	p10 (2)	p50 (3)	p90 (4)
Welfare change, p.p.	1.44	0.73	2.30	3.16

B: Effects of the shock on the income distribution

	SD(log wage) (1)	p10 (2)	p50 (3)	p90 (4)	Gini index (5)
Initial income level	0.8230	10,700	32,500	90,000	0.4509
Counterfactual	0.8225	10,838	33,086	90,517	0.4507
Change	–0.0005	+1.29%	+1.80%	+0.57%	–0.0002

Notes: Panel A reports statistics of the distribution of welfare changes across workers after a uniform 10% fall in trade costs in the worker-level analysis of Section 4.1. Panel B shows how the same shocks affects the distribution of (real) incomes, by reporting statistics for two income distributions: the one observed in the data and the counterfactual one, in which the estimated welfare effects are added to each worker's initial earnings. Both panels show the standard deviation and 10th, 50th, and 90th percentiles, while Panel B additionally reports Gini indices.

Table 2: Accounting for the Distributional Effects of Trade through Exposure

	Labor demand change		Wage change	Wage change	
	Coef.	R^2 Shapley decomp., %	Coef.	Coef.	R^2 Shapley. decomp, %
	(1)	(2)	(3)	(4)	(5)
Exports	1.000	54.33		0.310	11.70
				(0.026)	
Import competition	1.000	21.35		0.800	50.14
				(0.030)	
Intermediate inputs	1.000	19.05		0.694	13.77
				(0.098)	
Income effects	1.000	2.00		0.986	5.66
				(0.042)	
Substitution effects	1.000	3.28		1.205	18.74
				(0.085)	
Labor demand change, all five mechanisms			0.374		
			(0.037)		
R^2	1.000		0.377	0.959	

Notes: For the worker-level analysis of Section 4.1, this table reports ordinary least square regressions of the labor demand response (column (1)) and the wage response (columns (3), and (4)) to a uniform 10% fall in trade costs. The explanatory variables in columns (1) and (4) are the components of the labor demand response corresponding to each term in equation (6). In column (3) the explanatory variable is the total labor demand response. Columns (2) and (5) report the Shapley decomposition of the R^2, in percent of the total regression R^2. The analysis is implemented using the 1,128,862 workers in the ACS data. Column (1) suppresses standard errors because of the perfect fit; columns (3) and (4) show standard errors clustered by worker's industry.

Table 3: Skill-Bias of Exporters in Census Microdata

	Skill group definition:			
	College graduates	Non-production workers		
	MOPS 2010	CMF 2007	ASM 2010	MOPS 2010
	(1)	(2)	(3)	(4)
Average export share, %	22.84	14.70	19.47	22.84
Differential export share, skilled minus unskilled, p.p.:				
Overall	+5.26	+4.50	+4.52	+5.36
→ Between industries	+4.49	+4.09	+4.51	+5.20
→ Within industries	+0.77	+0.41	+0.01	+0.16
N establishments	33,400	294,200	50,500	33,400

Notes: This table shows the payroll-weighted average export shares (exports as % of sales) for three samples of manufacturing establishments: the 2010 MOPS (Columns 1 and 4), the 2007 Census of Manufactures (Column 2) and the 2010 Annual Survey of Manufactures (Column 3); see Appendix B.2 for data description. The table also shows the differential exposure for skilled and unskilled workers and decomposes it into the components "between" and "within" six-digit NAICS industries. Skilled workers are defined as college graduates in column 1 and non-production workers in the other columns. Observation numbers are rounded to the nearest 100 to preserve confidentiality.

For Online Publication

Appendix to "Are Trade Wars Class Wars? The Importance of Trade-Induced Horizontal Inequality"

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Xavier Jaravel, LSE and CEPR

September 1, 2022

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A Theoretical Appendix

A.1 Equilibrium Conditions

The equilibrium is defined by a set of quantities and prices that satisfy:

1. Utility maximization for each type of domestic agents with income x across industries: $\max_{\{q_j^x\}_j} \mathcal{U}(q_1^x, \ldots, q_J^x)$ s.t. $\sum_j P_j q_j^x = \zeta x$, with income determined by the wage of their labor type and the number of efficiency units;

2. Profit maximization by domestic producers in industry j: $\max_{\{L_i^j\}_i, \{Q_\ell^j\}_\ell} p_{jH} Q_{jH} - \sum_i w_i L_i^j - \sum_{\ell=1}^J P_\ell Q_\ell^j$ subject to technology;

3. Optimal allocation across varieties by consumers and domestic firms within each industry according to (1);

4. Product market clearing for domestic varieties: $Q_{jH} = \sum_x L_x q_{jH}^x + \sum_{k=1}^J Q_{jH}^k + Q_{jH}^{\text{Export}}$ for each j, where L_x is the number (or density) of consumers with income x;

5. Labor market clearing for each type of agents in efficiency units: $\sum_j L_i^j = L_i$;

6. Export demand: $Q_{jH}^c = a_j^c \left(p_{jH} \tau_{jc}^*\right)^{-\xi_j}$ for each industry j and foreign country c, with exogenous shifters a_j^c.

A.2 Proof of Proposition 1

We consider changes in the $I \times 1$ vector of wages w and the $J \times 1$ vector of value-added by industry (measured in monetary terms) VA. As in (7), we allow not only trade costs but also the labor supply vector L to change; this additional generality will be useful to define the macro elasticity of factor demand.

We first derive equations (7) and (8), respectively characterizing labor and product market equilibria in log-changes,and discuss the relevant matrices $\boldsymbol{E}$, $\boldsymbol{V}$, $\boldsymbol{G}$, and $\boldsymbol{D}$. We then prove Proposition 1 using these equations.

Labor market equilibrium and proof of (7). Let $v_{i|j}$ be the share of value added from industry j that accrues to labor type i (with $\sum_i v_{i|j} = 1$) and, conversely, $e_{j|i}$ be the share of total labor income of type i that stems from industry j (with $\sum_j e_{j|i} = 1$). We start from an accounting identity, that the total wage payments of type i labor equal the sum of wage payments across industries, which can be expressed as:

$$w_i L_i = \sum_j v_{i|j} \cdot VA_j, \tag{A1}$$

with summation across $j \in \mathcal{J}_i$. Log-differentiating it yields

$$d\log w_i + d\log L_i = \sum_j e_{j|i} \left(d\log v_{i|j} + d\log VA_j \right). \tag{A2}$$

We now argue that changes in the composition of payroll across types in a given industry, $d\log v_{i|j}$, depend fully on the wage changes without direct effects of trade costs or total labor supply. This follows from our assumption on the production function, in which all labor inputs enter via an aggregator F^{VA}. Thus, the optimal composition of labor per unit of value added solves

$$W_j \equiv \min_{L_1^j \ldots L_I^j} \sum_i w_i L_i^j \quad \text{s.t. } F_j^{VA}(L_1^j, \ldots, L_I^j) \geq 1. \tag{A3}$$

This problem yields within-industry payroll shares $v_{i|j}(w)$, which are homogeneous functions of degree 0 that depend on wages only and capture patterns of labor substitution within the industry. This problem also yields the value-added cost index W_j which we will use later. Thus,

$$d\log v_{i|j} = \sum_{i'=1}^{I} \frac{\partial \log v_{i|j}}{\partial \log w_{i'}} d\log w_{i'}.$$

Together with (A2), this implies (7).

Product market equilibrium and proof of (8). To derive equation (8) for value-added changes in each industry, we first solve for the price changes after the shock in terms of observables and unknown wage changes. We then use price and income elasticities, as well as the structure of foreign demand and domestic intermediate demand, to translate the price and consumer income changes into VA changes.

Changes in prices. We first explain how our assumption of a small economy, in the sense of Demidova and Rodríguez-Clare (2009), implies that relative price indices and relative product demand do not change in foreign countries in response to the counterfactual shock. Consider some variety from foreign country c in industry j. Since exports to Home are assumed to be a small fraction of this variety's worldwide sales, shocks to trade costs with H have negligible effects on the total demand for it. Likewise, shocks to wages in H have a negligible impact on total demand for this variety. Moreover, since imports from Home are a small fraction of absorption abroad, shocks to trade costs and to wages in H have negligible impacts on industry-j consumer price indices in all foreign countries. Thus, the demand for variety (j, c) from consumers outside H remains unchanged after the shocks. These observations have direct implications for factor prices, since factor demand arises from the relative demand for goods: absent changes in relative demand, relative foreign factor prices stay constant.[43]

Turning to price changes in the domestic economy, we characterize changes in the industry consumer prices P_{jH} and the prices of domestic varieties, p_{jH}. Log-differentiating the consumer price index (i.e. the CES aggregator of consumer prices across selling countries for a given industry), we have by Roy's identity:

$$d \log P_{jH} = IP_{jc} d \log \tau + (1 - IP_j)\, d \log p_{jH}. \tag{A4}$$

By Shephard's lemma and using perfect competition,

$$d \log p_{jH} = (1 - \beta_j)\, d \log W_j + \sum_{\ell=1}^{J} \beta_\ell^j d \log P_{jH}. \tag{A5}$$

Denote the domestic input requirement (i.e., input-output) matrix by $\boldsymbol{B} = \left(\beta_\ell^j\right)$, and by $\tilde{\boldsymbol{B}} = \left(\mathbb{I}_J - \text{diag}\,(1 - IP_j)\, \boldsymbol{B}'\right)^{-1}$ its Leontief inverse matrix, such that $\tilde{\boldsymbol{B}} y$ is a weighted sum of variable y in the reference industry j and in all upstream industries in the domestic supply chain of j. Solving

[43] More formally, one could consider the effects of a trade shock in a sequence of economies with the share of Home in imports and exports abroad converging to zero, while domestic trade shares do not change along the sequence to match our data. In the limit, the effects of the trade shock on foreign prices become negligible, even though the responses of the demand for Home's varieties and relative goods and factor prices at Home remain non-vanishing.

the system of (A4)–(A5) yields

$$d\log p_{jH}=\widetilde{IP}_{jc}^{\text{Int}}d\log\tau+\left(1-\widetilde{IP}_{j}^{\text{Int}}\right)d\log\tilde{W}_j\qquad\text{and}\tag{A6a}$$

$$d\log P_{jH}=\widetilde{IP}_{jc}d\log\tau+\left(1-\widetilde{IP}_{j}\right)d\log\tilde{W}_j,\tag{A6b}$$

where $\left\{\widetilde{IP}_{jc}\right\}_{j=1}^{J}=\tilde{\boldsymbol{B}}\cdot\{IP_{jc}\}_{j=1}^{J}$ collects the IO-adjusted shares of imports from c in industry absorption, $\left\{\widetilde{IP}_{jc}^{\text{Int}}\right\}=\boldsymbol{B}\cdot\left\{\widetilde{IP}_{jc}\right\}$ collects the shares of inputs imported from c in the costs of domestic varieties, $\widetilde{IP}_{j}^{\text{Int}}$ and $\widetilde{IP}_{j}$ are their aggregates across all foreign countries, and $d\log\tilde{W}_j$ is the average change in the value added cost in the domestic part of the supply chain resulting in j, defined by

$$\left\{\left(1-\widetilde{IP}_{j}\right)d\log\tilde{W}_j\right\}=\tilde{\boldsymbol{B}}\cdot\left\{\left(1-\widetilde{IP}_{j}\right)(1-\beta_j)\,d\log W_j\right\}.\tag{A7}$$

Domestic price changes in (A5) imply consumer price changes for domestic varieties in foreign countries: after a bilateral liberalization, prices change by $d\log p_{jH}$ in countries other than c and by $d\log p_{jH}+d\log\tau$ in c. Equation (A4) also yields the Laspeyres price index for a domestic consumer with income x, as

$$d\log P_x=\sum_j s_j^x d\log P_{jH}=ImpSh_c^x d\log\tau+\sum_j s_j^x\left(1-\widetilde{IP}_{j}\right)d\log\tilde{W}_j.\tag{A8}$$

Changes in industry sizes. To characterize the change in industry VA, as required by (7), we first observe that it equals the change in the value of industry output Y_{jH}, i.e. $d\log VA_j=d\log Y_{jH}$. This follows since production functions are Cobb-Douglas in value added and inputs. To characterize changes in domestic output, we start from the product market clearing condition: domestic output can be sold to domestic final and intermediate consumers, or as exports. That is, $Y_{jH}=Y_{jH}^{\text{Final}}+Y_{jH}^{\text{Int}}+Y_{jH}^{\text{Export}}$, where $Y_{jH}^{\text{Int}}=\sum_k Y_{jH}^k$ measures total intermediate sales as a sum across domestic downstream industries k. The change in total sales is thus determined by the shares of different modes of sales at the initial equilibrium and by the changes in each component after the shock.

We use the IO table to measure the composition of different modes of sales. A challenge arises because the IO table does not fully report modes of sales. Specifically, the IO table reports the share of exports *in output* and the share of final consumers and each downstream industry k *in absorption*. Modes of sales can be computed using the proportionality condition (see footnote 12). Specifically, we introduce the intermediate absorption coefficients $\delta_j^k = Y_j^k/\text{Absorption}_j$ which measure the share of industry j's absorption that is used as intermediate inputs to downstream industry k. While β_k^j characterize industry j's suppliers, δ_j^k characterize its buyers. By proportionality, shares δ_j^k can be applied to the domestic sales of *domestic* varieties specifically, i.e. $Y_{jH}^k/\left(Y_{jH}^{\text{Final}} + X_{jH}^{\text{Int}}\right) = \delta_j^k$. Therefore, the share of domestic output that goes to k equals $Y_{jH}^k/Y_{jH} = DomSalesSh_j \cdot \delta_j^k$. Similarly, the share of domestic output that is sold to domestic final consumers is $DomSalesSh_j \cdot (1-\delta_j) \equiv DFS_j$, where $\delta_j = \sum_k \delta_j^k$ measures the share of intermediate sales in absorption. As a result,

$$d\log VA_j = ExSh_j \cdot d\log Y_{jH}^{\text{Export}} + DFS_j \cdot d\log Y_{jH}^{\text{Final}} + \sum_{k=1}^{J} DomSalesSh_j \delta_j^k \cdot d\log Y_{jH}^k. \quad \text{(A9)}$$

We now turn to the changes in each component of sales in (A9). First, consider exports to some country $c' \neq H$. Since the consumer price for the domestic variety in j changes in country c' by $d\log p_{jH} + \mathbf{1}[c' \in c]\, d\log\tau$, purchases by final and intermediate buyers in c' change by

$$d\log Y_{jH}^{\text{Export},c'} = d\log Y_j^{c'} + (1-\xi_j)\left(d\log p_{jH} + \mathbf{1}\left[c' \in c\right] d\log\tau - d\log P_{jc'}\right),$$

where $Y_j^{c'}$ is the total spending on all varieties of j by all buyers in c' and $P_{jc'}$ is the industry price index in that country. By Assumption 4, $d\log P_{jc'} = 0$ and $d\log Y_j^{c'} = 0$. Thus, exports to an individual country change by $d\log Y_{jH}^{\text{Export},c'} = (1-\xi_j)\left(d\log p_{jH} + \mathbf{1}[c' \in c]\, d\log\tau\right)$. Aggregating across foreign countries, we have

$$ExSh_j \cdot d\log Y_{jH}^{\text{Export}} = (1-\xi_j)\left(ExSh_j d\log p_{jH} + ExSh_{jc} d\log\tau\right).$$

Second, domestic final sales in (A9) are the total of purchases by various consumer groups defined by type i and initial income level x, Y_{jH}^{ix}, and thus

$$d\log Y_{jH}^{\text{Final}} = \sum_{x,i} \mu_{x,i|j} d\log Y_{jH}^{ix},$$

where $\mu_{x,i|j}$ captures the composition of final buyers of industry j by income and labor market type.[44] By the assumption of CES preferences within industries, $d\log Y_{jH}^{ix} = d\log Y_j^{ix} +$

[44] Because labor market data (e.g. industries) are not available for the consumers in the CEX, we do not observe $\mu_{x,i|j}$ directly. However, with identical non-homothetic preferences the industry does not matter for consumption baskets conditionally on income. Thus, we measure $\mu_{x,i|j}$ as the product of the share of income decile x in the CEX

$(1-\xi_j)\left(d\log p_{jH} - d\log P_{jH}\right)$, where Y_j^{ix} measures total spending by the consumer group on industry j varieties, domestic or foreign. By definition of income and price elasticities,

$$
\begin{aligned}
d\log Y_j^{ix} &= (1+\psi_{xj})d\log w_i + \sum_{k=1}^{J}\varepsilon_{xjk}d\log P_{kH} \\
&= d\log w_i + \psi_{xj}\left(d\log w_i - d\log P_x\right) + \sum_{k=1}^{J}\varepsilon_{xjk}\left(d\log P_{kH} - d\log P_x\right). \qquad \text{(A10)}
\end{aligned}
$$

Here in the first line we equated expenditure and wage changes using the assumption that each consumer spends a constant multiple of their income. The second line used $\psi_{xj} + \sum_k \varepsilon_{xjk} = 0$, which follows because increasing income and prices proportionately does not change expenditure shares.

Finally, for intermediate sales in (A9) we use the Cobb-Douglas assumption again. The share of spending by industry k on *all* varieties of j is fixed, so the change in expenditures equals the change in k's value added: $d\log Y_j^k = d\log Y_{kH} = d\log VA_k$. But substitution between domestic and foreign varieties implies that domestic sales of j to k change by

$$
d\log Y_{jH}^k = d\log VA_k + (1-\xi_j)\left(d\log p_{jH} - d\log P_{jH}\right).
$$

Equation (8) now follows by plugging price changes derived above into the expressions for the changes in exports, domestic final sales, and domestic intermediate sales, plugging those in turn into (A9), and rearranging terms. Specifically, all terms that enter with $-d\log\tau$ are collected in the η vector, yielding (6). The terms with $d\log VA_k$, arising from intermediate demand only, define the $\boldsymbol{D}$ matrix:

$$
\boldsymbol{D} = \left(DomSalesSh_j \cdot \delta_j^k\right)_{j,k}. \qquad \text{(A11)}
$$

Pre-multiplication by its Leontief inverse $\tilde{\boldsymbol{D}} = \left(\mathbb{I}_J - \boldsymbol{D}\right)^{-1}$ is interpreted as the IO adjustment that accounts for the propagation of shocks from downstream industries up through changes in domestic intermediate demand. For example, the elements of $\tilde{\boldsymbol{D}} \cdot ExSh$ are the shares of domestic output that is exported either directly or indirectly (by selling to domestic downstream industries that export).

Finally, collecting the terms related to wage changes defines the $\boldsymbol{G}$ matrix of dimensions $J \times I$,

expenditures on industry j, $\mu_{x|j}$, and the share of type-i workers in the total payroll of workers in income decile x in the ACS, $v_{i|x}$.

as follows:

$$
\begin{aligned}
(\boldsymbol{G} \cdot d\log w)_j \equiv (1-\xi_j)\,(ExSh_j + DomSalesSh_j IP_j)\left(1-\widetilde{IP}_j^{\mathrm{Int}}\right) d\log \tilde{W}_j \\
+ DFS_j \sum_{x,i} \mu_{x,i|j} \left[d\log w_i + \psi_{xj}\left(d\log w_i - \sum_{\ell=1}^{J} s_\ell^x \left(1-\widetilde{IP}_\ell\right) d\log \tilde{W}_\ell \right)\right. \\
\left. + \sum_{k=1}^{J} \varepsilon_{xjk} \left(\left(1-\widetilde{IP}_k\right) d\log \tilde{W}_k - \sum_{\ell=1}^{J} s_\ell^x \left(1-\widetilde{IP}_\ell\right) d\log \tilde{W}_\ell \right) \right],
\end{aligned}
\tag{A12}
$$

with $d\log \tilde{W}_k$ linearly related to $d\log w$ via (A7). The first line of (A12) captures the loss of competitiveness of domestic varieties (relative to foreign varieties in the same industry) in both domestic and foreign markets when domestic wages grow. The second line captures the change in domestic final demand when consumer incomes change, as well as income effects from changing both consumer income and inflation. The third line captures the substitution effects driven by domestic wage changes.

Proof of Proposition 1. Equation (8) implies

$$
d\log VA = \tilde{\boldsymbol{D}}\left(-\eta \cdot d\log\tau + \boldsymbol{G}\cdot d\log w\right).
$$

and, letting $\tilde{\boldsymbol{V}} = (\mathbb{I}_I - \boldsymbol{V})^{-1}$, (7) yields

$$
\begin{aligned}
d\log w &= \tilde{\boldsymbol{V}}\left(\boldsymbol{E}\cdot d\log VA - d\log L\right) \\
&= \tilde{\boldsymbol{V}}\left(-\boldsymbol{E}\tilde{\boldsymbol{D}}\eta \cdot d\log\tau + \boldsymbol{E}\tilde{\boldsymbol{D}}\boldsymbol{G}\cdot d\log w - d\log L\right) \\
&= \tilde{\boldsymbol{G}}\left(\boldsymbol{E}\tilde{\boldsymbol{D}}\eta\cdot(-d\log\tau) - d\log L\right).
\end{aligned}
\tag{A13}
$$

Here

$$
\tilde{\boldsymbol{G}} = \left(\mathbb{I}_I - \tilde{\boldsymbol{V}}\boldsymbol{E}\tilde{\boldsymbol{D}}\boldsymbol{G}\right)^{-1}\tilde{\boldsymbol{V}}
\tag{A14}
$$

captures the GE response of factor prices to an exogenous decline in factor supply and therefore can be interpreted as the (negative of the) inverse labor demand elasticity matrix. With $d\log L = 0$, equation (A13) reduces to (5), establishing Proposition 1. We note that the $\tilde{\boldsymbol{G}}$ matrix generalizes the macro elasticity of factor substitution that Oberfield and Raval (2021) derived for a closed economy with homothetic preferences and only two factors.

A.3 Proof of Proposition 2

We have:

$$
\begin{aligned}
d\log \mathcal{W}_{ix} &= d\log w_i - d\log P_x \\
&= d\log w_i - ImpSh_c^x d\log\tau - \sum_j s_j^x\left(1-\widetilde{IP}_j\right) d\log\tilde{W}_j \\
&= d\log w_i - ImpSh_c^x d\log\tau - \left(1-ImpSh^x\right) d\log\bar{w} \\
&\quad - \sum_j s_j^x\left(1-\widetilde{IP}_j\right)\left(d\log\tilde{W}_j - d\log\bar{w}\right) \\
&= \left(d\log w_i - d\log\bar{w}\right) - ImpSh_c^x d\log\tau + ImpSh^x d\log\bar{w} \\
&\quad - \sum_j s_j^x\left(1-\widetilde{IP}_j\right)\left(d\log\tilde{W}_j - d\log\bar{w}\right).
\end{aligned}
$$

Here the first line used the Roy identity, the second equation used (A8), the third line used the definition of $ImpSh^x = \sum_j s_j^x \widetilde{IP}_j$, and the last line rearranged the terms.

A.4 Non-Uniform Trade Shocks

Propositions 1 and 2 extend easily to counterfactual shocks with magnitudes that vary across industries and are potentially different on the importing and exporting sides. Specifically, for a country or set of countries c, consider a counterfactual with $d\log\tau_{jc} = z_j d\log\tau$ and $d\log\tau_{jc}^* = z_j^* d\log\tau$ (and no changes in trade costs with other countries), where the asymmetries are characterized by $\left\{z_j, z_j^*\right\}$. Repeating the proof of Proposition 1 in this case yields (5) with the same matrices $\tilde{\boldsymbol{G}}$, $\boldsymbol{E}$, and $\tilde{\boldsymbol{D}}$ but a different vector of direct exposures:

$$
\begin{aligned}
\eta_j = (\xi_j - 1)\Big[&\underbrace{ExSh_{jc}z_j^*}_{\text{export effect}} - \underbrace{IP_{jc}z_j\cdot DomSalesSh_j}_{\text{import competition effect}} + \underbrace{\widetilde{IP}_{jcz}^{\text{Int}}\cdot\left(ExSh_j + IP_j\cdot DomSalesSh_j\right)}_{\text{intermediate input effect}}\Big] \\
&+ DFS_j\cdot\sum_x \mu_{x|j}\Big[\underbrace{\psi_{xj}ImpSh_{cz}^x}_{\text{income effect}} - \underbrace{\sum_{k=1}^J \varepsilon_{xjk}\left(\widetilde{IP}_{kcz} - ImpSh_{cz}^x\right)}_{\text{substitution effects}}\Big],
\end{aligned}
\tag{A15}
$$

where $\left\{\widetilde{IP}_{jcz}\right\}_{j=1}^J = \tilde{\boldsymbol{B}}\cdot\left\{IP_{jc}z_j\right\}_{j=1}^J$ collects the IO-adjusted exposure of industry j consumer prices to the import price reductions, $\left\{\widetilde{IP}_{jcz}^{\text{Int}}\right\} = \boldsymbol{B}\cdot\left\{\widetilde{IP}_{jcz}\right\}$ is the corresponding exposure of producer prices in j, and $ImpSh_{cz}^x = \sum_j s_j^x \widetilde{IP}_{jcz}$ is the consumer exposure to price changes induced by the shock (in partial equilibrium, i.e. without wage adjustments, as in Borusyak and Jaravel

(2021)). Similarly, $ImpSh_c^x$ is replaced with $ImpSh_{cz}^x$ in the second term of Proposition 2, with no other change required in that result.

A.5 Lerner's Symmetry for Iceberg Trade Costs

We characterize the wage and welfare consequences of a shock that uniformly increases the iceberg trade costs for importing from all foreign countries, while also increasing the exporting costs in proportion to $\frac{\xi_j}{\xi_j - 1}$. We show that in response domestic nominal wages grow uniformly across labor types and domestic values added grows proportionally but the welfare effects are null for all agents:

$$d \log w = \iota_I d \log \tau, \qquad d \log VA = \iota_J d \log \tau, \qquad d \log \mathcal{W} = 0, \tag{A16}$$

where ι_I and ι_J denote the $I \times 1$ and $J \times 1$ unit vectors, respectively.

Proof. We use the results of Appendix A.4 with $z_j = 1$, $z_j^* = -\frac{\xi_j}{\xi_j - 1}$, and $c = F$. Specifically, we verify that (7) and (8) are satisfied by (A16). Here (7) is satisfied because $\boldsymbol{E} \cdot \iota_J = \iota_I$ by construction of $e_{j|i}$ and $\boldsymbol{V} \cdot \iota_J = 0$ by the zero-degree homotheticity of $v_{i|j}$. We now consider the three terms in (8) when plugging in (A16). First, from (A15) and since import shocks are uniform,

$$\eta_j = -\xi_j ExSh_j + (\xi_j - 1)\left[-IP_j \cdot DomSalesSh_j + \widetilde{IP}_j^{\text{Int}} \cdot (ExSh_j + IP_j \cdot DomSalesSh_j)\right]$$
$$+ DFS_j \cdot \sum_x \mu_{x|j}\left[\psi_{xj} ImpSh^x - \sum_{k=1}^{J} \varepsilon_{xjk}\left(\widetilde{IP}_k - ImpSh^x\right)\right]. \tag{A17}$$

Second, $(\boldsymbol{D} \cdot \iota_J)_j = 1 - ExSh_j - DFS_j$ is the share of intermediate sales. Finally, we note that $d \log w = \iota_I d \log \tau$ implies that supply chain-averaged wage changes are uniform too, $d \log \tilde{W} =$

$\iota_I d\log\tau$ in (A7). Thus, from (A12),

$$\begin{aligned}
(\boldsymbol{G}\cdot\iota_I)_j &\equiv (1-\xi_j)\left(ExSh_j + DomSalesSh_j IP_j\right)\left(1-\widetilde{IP}_j^{\text{Int}}\right) \\
&\quad + DFS_j \sum_{x,i}\mu_{xi|j}\left[1+\psi_{xj}\left(1-\sum_{\ell=1}^{J}s_\ell^x\left(1-\widetilde{IP}_\ell\right)\right)\right. \\
&\quad \left. + \sum_{k=1}^{J}\varepsilon_{xjk}\left(\left(1-\widetilde{IP}_k\right)-\sum_{\ell=1}^{J}s_\ell^x\left(1-\widetilde{IP}_\ell\right)\right)\right]. \\
&= (1-\xi_j)\left(ExSh_j + DomSalesSh_j IP_j\right)\left(1-\widetilde{IP}_j^{\text{Int}}\right) \\
&\quad + DFS_j \sum_{x}\mu_{x|j}\left[1+\psi_{xj} ImpSh^x + \sum_{k=1}^{J}\varepsilon_{xjk}\left(ImpSh^x - \widetilde{IP}_k\right)\right].
\end{aligned}$$

Combining the three terms and simplifying yields

$$\left(\eta\cdot(-d\log\tau) + \boldsymbol{D}\cdot\iota_J d\log\tau + \boldsymbol{G}\cdot\iota_I d\log\tau\right)_j = d\log\tau = d\log VA_j$$

and thus (8) is satisfied.

It remains to show that $d\log\mathcal{W}=0$. Using Proposition 2 for non-uniform trade shocks, we have $d\log\bar{w}=d\log\tau$, and

$$d\log\mathcal{W}_h = -ImpSh^x d\log\tau + ImpSh^x d\log\bar{w} = 0$$

for any agent.

A.6 Proof of Proposition 3

We consider a sequence of $d\log\mathcal{W} = Zd\log\tau$ for a fixed random variable Z and $d\log\tau\to 0$. Then:

$$
\begin{aligned}
\mathrm{SD}\left(\log X + d\log\mathcal{W}\right) &= \sqrt{\mathrm{Var}\left[\log X\right] + 2\mathrm{Cov}\left[\log X, Z\right] d\log\tau + \mathrm{Var}\left[Z\right] d\log\tau^2} \\
&= \mathrm{SD}\left(\log X\right)\cdot\sqrt{1 + 2\frac{\mathrm{Cov}\left[\log X, Z\right]}{\mathrm{Var}\left[\log X\right]} d\log\tau + o(d\log\tau)} \\
&= \mathrm{SD}\left(\log X\right)\left(1 + \frac{\mathrm{Cov}\left[\log X, Z\right]}{\mathrm{Var}\left[\log X\right]}\cdot d\log\tau\right) + o(d\log\tau) \\
&= \mathrm{SD}\left(\log X\right) + \mathrm{Corr}\left[\log X, Z\right]\cdot\mathrm{SD}\left(Z\right) d\log\tau + o(d\log\tau) \\
&= \mathrm{SD}\left(\log X\right) + \mathrm{Corr}\left[\log X, d\log\mathcal{W}\right]\cdot\mathrm{SD}\left(d\log\mathcal{W}\right) + o(d\log\tau).
\end{aligned}
$$

A.7 Horizontal Inequality Does not Affect the CDF of Welfare

Proposition 4. *Consider the joint distribution of initial log-earnings and welfare changes across agents in response to a small shock,* $(\log x, Zd\log\tau)$*, where random variable* Z *defines exposure of an agent to the shock and* $\log x$ *is absolutely continuous on some domain* $A \subseteq \mathbb{R}$*. Then if the shock does not induce vertical inequality, i.e. if* $\mathbb{E}\left[Z \mid \log x\right] = 0$*, the shock has no first-order effect on the cumulative distribution function (CDF) of welfare after the shock:*[45]

$$
\frac{d}{d\log\tau} Pr\left(\log x + Zd\log\tau \leq a\right) = 0 \qquad \textit{for all } a \in A.
$$

Proof. To simplify notation, we suppose that Z is discrete with values $z_1, \ldots, z_K$ taken with probabilities $\pi_1, \ldots, \pi_K$. We denote by $f_{\log x}(\cdot)$, $f_{\log x, Z}(\cdot,\cdot)$ and $f_{\log x \mid Z}(\cdot \mid \cdot)$ the marginal density of $\log x$, the joint density of $(\log x, Z)$, and the conditional density of $\log x \mid Z$, respectively. Then for

[45] We could similarly allow $\mathbb{E}\left[Z \mid \log x\right]$ to be a non-zero constant, in which case the CDF of welfare would shift to the right by that constant, at the first-order.

$a \in A$,

$$\begin{aligned}
\frac{d}{d\log\tau} Pr\left(\log x + Z d\log\tau \leq a\right) &= \frac{d}{d\log\tau}\sum_{k=1}^{K}\pi_k Pr\left(\log x \leq a - z_k d\log\tau \mid Z = z_k\right) \\
&= -\sum_k \pi_k z_k f_{\log x|Z}(a \mid z_k) \\
&= -\sum_k z_k f_{\log x, Z}(a, z_k) \\
&= -\sum_k z_k f_{\log x}(a) Pr(Z = z_k \mid \log x = a) \\
&= -f_{\log x}(a) \cdot \mathbb{E}\left[Z \mid \log x = a\right] \\
&= 0.
\end{aligned}$$

Subject to appropriate regularity conditions, smooth statistics of the CDF, such as the Gini index, are therefore not affected at the first-order either. $\square$

A.8 Substitution and Income Elasticities with Nested NHCES Demand

Substitution elasticities. We prove (13) and a similar expression for the substitution effects in the last line of (A12):

$$\begin{aligned}
&\sum_{k=1}^{J}\varepsilon_{xjk}\left(\left(1-\widetilde{IP}_k\right)d\log\tilde{W}_k - \sum_{\ell=1}^{J}s_\ell^x\left(1-\widetilde{IP}_\ell\right)d\log\tilde{W}_\ell\right) = \\
&(1-\varepsilon_r)\left(\left(1-\widetilde{IP}_j\right)d\log\tilde{W}_j - \sum_{k\in r}s_{k|r}^x\left(1-\widetilde{IP}_k\right)d\log\tilde{W}_k\right) \\
&+(1-\rho)\left(\sum_{k\in r}s_{k|r}^x\left(1-\widetilde{IP}_k\right)d\log\tilde{W}_k - \sum_{k=1}^{J}s_k^x\left(1-\widetilde{IP}_k\right)d\log\tilde{W}_k\right),
\end{aligned} \tag{A18}$$

where $s_{k|r}^x = s_k^x / \sum_{j\in r} s_j^x$.

The derivations for nested NHCES demand from Borusyak and Jaravel (2021, Appendix B.2) imply that, after a set of income and price changes, changes in expenditures of consumer i with income x on the aggregate good of industry j within sector r are given by

$$\begin{aligned} d\log Y_j^{ix} &= d\log w_i + \psi_{xj}\left(d\log w_i - \sum_{k=1}^{J} s_k^i d\log P_{kH}\right) \\ &+ (1-\varepsilon_r)\left(d\log P_{jH} - \sum_{k\in r} s_{k|r}^i d\log P_{kH}\right) + (1-\rho)\left(\sum_{k\in r} s_{k|r}^i d\log P_{kH} - \sum_{k=1}^{J} s_k^i d\log P_{kH}\right). \end{aligned} \tag{A19}$$

We use this expression instead of the more general (A10) and follow the remaining part of the proof of Proposition 2, plugging in prices from (A6) and isolating the terms with $d\log\tau$ and $d\log\tilde{W}_k$. Then the substitution effects from the second line of (A19) yield (13) and (A18).

Income elasticities. As Borusyak and Jaravel (2021, Appendix B.2) show, the income elasticity of the expenditure share for industry j in sector r for a consumer with income x satisfies:

$$\psi_{xj} = \frac{(\varepsilon_r - 1)(\varphi_j - \bar{\varphi}_{xr}) + (\rho - 1)(\bar{\varphi}_{rx} - \bar{\varphi}_x)}{1 - \bar{\varphi}_x}, \tag{A20}$$

where $\bar{\varphi}_{xr} = \sum_{j\in r}\frac{s_j^x}{s_r^x}\varphi_j$ and $\bar{\varphi}_x = \sum_r s_r^x \bar{\varphi}_{xr}$. Since $\varphi_k < 1$ for all k, Clearly, if $\varphi_j(\varepsilon_r - 1) > \varphi_k(\varepsilon_r - 1)$ for industries j, k in the same sector r, $\psi_{xj} > \psi_{xk}$ for any income level x.

A.9 Proofs of Section 3.3 Results

A.9.1 Worker-Level Analysis

No heterogeneity of wage responses within industries. Let $\mathcal{I}_j$ be the set of labor types in industry j. We show that $d\log w_i = d\log VA_j$ for all $i\in\mathcal{I}_j$.

Absent labor mobility across industries, matrix $\boldsymbol{V}$ has a block structure, such that $\partial\log v_{i|j}/\partial\log w_{i'} = 0$ for any $i\in\mathcal{I}_j$ and $i'\notin\mathcal{I}_j$. Moreover, $e_{j|i} = \mathbf{1}[i\in\mathcal{I}_j]$. Thus, in a counterfactual with $d\log L = 0$, (7) can be rewritten, for $i\in\mathcal{I}_j$, as

$$d\log w_i = d\log VA_j + \sum_{i'\in\mathcal{I}_j}\frac{\partial\log v_{i|j}}{\partial\log w_{i'}}d\log w_{i'}. \tag{A21}$$

Since $\sum_{i'\in\mathcal{I}_j}\frac{\partial\log v_{i|j}}{\partial\log w_{i'}} = \sum_{i'=1}^{I}\frac{\partial\log v_{i|j}}{\partial\log w_{i'}} = 0$ by homotheticity of $v_{i|j}$ of degree 0, it is clear that $d\log w_i = d\log VA_j$ for all $i\in\mathcal{I}_j$ satisfies (A21) (and uniqueness of the solution is assumed like elsewhere).

Proof of equation (14). Under the simplifying conditions discussed in Section 3.3.1, $DFS_j = DomSalesSh_j$. In the absence of non-homotheticities, $\sum_x \mu_{xi|j} = e_i$ for any j. Thus, equation (A12) simplifies to

$$\left(\boldsymbol{G} \cdot d\log w\right)_j = \left(1-\xi_j\right) T_j d\log w_j + DomSalesSh_j \cdot \sum_i e_i d\log w_i.$$

In matrix form,

$$\boldsymbol{G} = -\operatorname{diag}\left[\left(\xi_j - 1\right) T_j\right] + DomSalesSh \cdot e'.$$

By the Sherman-Morrison formula in linear algebra, its Leontief inverse equals

$$\tilde{\boldsymbol{G}} = \operatorname{diag}\left[1+\left(\xi_j-1\right)T_j\right]^{-1} + \frac{\operatorname{diag}\left[1+\left(\xi_j-1\right)T_j\right]^{-1} DomSalesSh \cdot e' \operatorname{diag}\left[1+\left(\xi_j-1\right)T_j\right]^{-1}}{1 - e' \operatorname{diag}\left[1+\left(\xi_j-1\right)T_j\right]^{-1} DomSalesSh}.$$

Expanding these terms, $\tilde{\boldsymbol{G}} \cdot d\log L^D$ satisfies (14).

A.9.2 Analysis across Education Groups

Proof of (15)–(17). By definition of the labor substitution elasticity in j,

$$d\log \frac{v_{H|j}}{v_{L|j}} = \left(1-\sigma_j\right) d\log \frac{w_H}{w_L}.$$

Since $v_{L|j} = 1 - v_{H|j}$ and using $d\log \frac{z}{1-z} = \frac{1}{1-z} d\log z$, we obtain:

$$d\log v_{H|j} = v_{L|j}\left(1-\sigma_j\right) d\log \frac{w_H}{w_L}. \tag{A22}$$

Thus,

$$\boldsymbol{V}_{HH} = \sum_j e_{j|H} v_{L|j}\left(1-\sigma_j\right) = v_L \sum_j e_j \frac{v_{H|j}}{v_H}\frac{v_{L|j}}{v_L}\left(1-\sigma_j\right) = -v_L\left(\sigma_{\text{macro}}-1\right),$$

where the first equality follows by definition of and (A22), the second one rewrites $e_{j|H} = \frac{e_j v_{H|j}}{v_H}$, and the last uses the definition of σ_{macro}. The other elements of $\boldsymbol{V}$ are obtained analogously, yielding (15). Plugging in (15) into (7) for $d\log w_H$ and $d\log w_L$ and taking the difference, one obtains (17).

B Data Appendix

B.1 Industry-Level Data

In this appendix, we provide the details on the construction of our main industry-level dataset.

IO table. Following Borusyak and Jaravel (2021), we adjust the IO tables for the "distribution margins," which refer to the costs of retailing, wholesaling, and transportation. To implement this adjustment, we combine "producer-value" and "purchasing value" versions of the IO table; please refer to Borusyak and Jaravel (2021) for details.

Trade shares by trading partner. Following Borusyak and Jaravel (2021), we use the 2007 U.S. international trade flow tabulations from the Census Bureau, which were made available by Schott (2008). We obtain them at the level of NAICS industry codes using the concordance from Pierce and Schott (2012) and convert them to IO codes. IO codes are based on the NAICS classification and, with a small number of exceptions, simply combine one or several NAICS codes. Trade flow statistics are only available for trade in goods; we therefore assign zero trade with specific trading partners in all service industries. This does not constitute an important limitation for China and Mexico. For instance, China constitutes less than 3% of total U.S. imports of services according to the BEA International Services tables for 2007. This limitation is likely to be more important when considering trade with developed economies.

CEX. Following Borusyak and Jaravel (2021) again, we combine two surveys underlying the CEX: interviews, which cover the complete range of expenditures, and diaries, which provide additional details for select categories, such as food and clothing. We additionally include imputed rents of owned homes, as in Aguiar and Bils (2015). This results in 668 detailed consumption categories, which Borusyak and Jaravel (2021) match to 170 final IO industries. Each survey includes around 6,900 households per quarter; we pool data from 2006–08 to increase sample size. We drop households with reported income below $5,000 because of concerns about misreporting and temporary unemployment. We then split households into deciles of pre-tax household income using the variable `FINCBTXM` in the interview survey and `FINCBEFX` in the diary survey. Deciles of household incomes are defined the following cutoffs (in $000): 10, 20, 30, 40, 50, 60, 75, 90, 110, and 150. We also split households into two education groups, based on whether the person filling out the survey ("reference person") has a bachelor's degree or higher (via variable `EDUC_REF`).

ACS. We use the 2007 ACS from IPUMS and select only employed workers, further dropping those in the public administration sector or earning below $5,000. We split workers into ten deciles of pre-tax earnings via the `incwage` variable, which captures total pre-tax wage and salary income during the previous calendar year, with the cutoffs, in $000, of 10.7, 16.0, 21.3, 27.0, 32.2, 40.0, 49.0, 60.0, and 85.0. We also decompose workers into two education groups: those with and without a college degree.

Since industries in ACS are more aggregated than IO codes (there are 253 codes overall, recorded in the variable `ind`), we have built a weighted crosswalk from ACS industries to IO codes. First, for each ACS industry we find the set of corresponding NAICS industries using a crosswalk provided by IPUMS.[46] Second, we allocate each ACS code to those NAICS industries with weights proportional to the total payroll by NAICS, which we obtain from the 2007 Quarterly Survey of Employment and Wages.[47] Third, we aggregate NAICS industries to IO codes.

We note that earnings are measured somewhat differently in the CEX and ACS: by the entire household vs. individual worker, respectively, and with correspondingly different cutoffs. When implementing Propositions 1 and 2, we assign spending shares to workers from each earnings decile in the ACS as the expenditure shares of that income decile in the CEX (reweighted to match the IO table industry totals, as described in the main text).

B.2 Exposure to Exports and Skill Intensity within Industries

Until recently, Census surveys did not ask establishments about education of their workers, which led to a long tradition to proxy for skill intensity by the payroll or employment share of non-production workers (e.g. Berman et al. 1994; Autor et al. 1998), who are considered to be more skilled than production workers (Berman et al. 1998). The situation has changed with the arrival of the 2010 Management and Organizational Practices Survey (MOPS) survey, which is a supplement to the Annual Survey of Manufactures (ASM), covering all largest firms as well as a sample of smaller ones.

We use MOPS questions 32–35, which ask for number of managers and employees, as well as the share of managers and non-managers with a college (bachelor) degree.[48] The shares are listed

[46] Only in one case (NAICS industry 519130) the same NAICS code corresponds to two IND codes. We split this NAICS code into two proportionately to the IND payroll.

[47] The QCEW tabulations are published by the Bureau of Labor Statistics based on unemployment insurance statistics.

[48] The questionnaire is available at https://www2.census.gov/programs-surveys/mops/technical-documentation/questionnaires/mop-2010.pdf; also see Bloom et al. (2019). We drop observations where answers to

in terms of discrete bins, so we use the midpoints of those bins.[49] This yields an estimate of the share college graduates in total employment, $v^{\mathrm{Emp}}_{\mathrm{college}|j}$. Unfortunately we do not observe wages of college- and non-college workers. Therefore, to impute the payroll share we use the economy-wide average wages of these groups from the U.S. Census Bureau (DeNavas-Walt et al. 2011). They show that the median wage of college graduates is about 80% higher than that of non-college workers (considering individuals in the labor force and 25 years or older), so we measure the payrolls share of college graduates in each establishment j as

$$v_{\mathrm{college}|j} = \frac{1.8 \cdot v^{\mathrm{Emp}}_{\mathrm{college}|j}}{1.8 \cdot v^{\mathrm{Emp}}_{\mathrm{college}|j} + \left(1 - v^{\mathrm{Emp}}_{\mathrm{college}|j}\right)}.$$

It is very strongly correlated with $v^{\mathrm{Emp}}_{\mathrm{college}|j}$, so the details of imputation are not consequential. We then distribute each firm's total payroll to the two education groups according to these shares to compute the payroll-weighted average export shares by group in Table 3.

Besides the MOPS sample, we use the 2010 ASM and the full 2007 Census of Manufactures (CMF), which report payroll to production and non-production workers directly. We match all of them to the Customs microdata (LFTTD) to measure export shares. Like Bernard et al. (2018), we do not use the CMF and ASM questions about plant exports, which are less reliable than direct observation of trade transactions. For firms with multiple establishments, we attribute firm exports proportionately to the value of establishment sales (shipments). We drop firms where exports exceed twice the total value of manufacturing sales, as those are likely to result from measurement error or other firm establishments which are not part of the sample (e.g. the non-manufacturing ones). We compute the export share of an establishment relative to the value of shipments.

B.3 Estimating Income Elasticities

Here, we describe how we estimate income elasticities. Intuitively, higher-income consumers have larger expenditure shares on income-elastic products. Using this logic, we first compute the income *semi*-elasticity for each spending category by regressing spending shares on the logged total expenditure and then convert the estimates to elasticities and aggregate them into the IO industries.

Specifically, we split households in the CEX sample (see Appendix B.1) into 11 bins by the

any of these questions are missing.

[49] The bins are under 20%, 21–40%, 41–60%, 61–80%, and over 80% for managers and 0%, 1–10%, 11–20%, and over 20% for non-managers (we assign 25% to the last category).

reported pre-tax household income and compute consumption shares across all spending categories (UCC) j for each of the bins i separately (s_j^i) and overall (s_j). Then for each spending category we estimate the income *semi*-elasticity by regressing, across income bins, spending shares on the log of total expenditure in this income group, averaged across households:

$$s_j^i = \text{constant}_j + \psi_j^{\text{semi}} \log \text{Expenditures}_i + \text{error term}_{ij}.$$

Observations are weighted by the number of households in each income bin. For an income-elastic spending category, the share is increasing in the total expenditures, so $\psi_j^{\text{semi}} > 0$, and the reverse holds for income-inelastic products. We then convert the semi-elasticity into the elasticity ψ_j for an average consumer of product j:

$$\psi_j = \frac{\hat{\psi}_j^{\text{semi}}}{s_j}.$$

The intermediate step with semi-elasticities guarantees that the spending-weighted average of income elasticities across all spending categories is equal to one, as it should be theoretically:

$$\sum_j \psi_j s_j = \sum_j \hat{\psi}_j^{\text{semi}} = 0,$$

where the second equality follows because spending shares sum up to a constant (one) for each income group, and the regression of a constant on $\log \text{Expenditures}_i$ yields a zero slope.

Expenditures are used on the right-hand side instead of income because in the CEX, total expenditures do not vary one-to-one with reported income. That relationship is increasing but much less than proportionate, which may be a consequence of imperfect measurement of income—either because current income is not a good proxy for permanent income, or for pure measurement error reasons. In either case, income elasticity estimates would be biased towards one if income was used on the right-hand side.

We winsorize a small number of ψ_j to be between −2 and 2. At the end we convert the UCC-level income elasticities to IO codes in the same way as we do for the expenditure shares.

B.4 Observed Changes in Trade Costs

While our main analysis considered hypothetical trade shocks that are uniform across industries, here we follow Borusyak and Jaravel (2021) and consider the counterfactuals based on shocks observed in the data. We calibrate the effects of three shocks to importing costs: the introduction of Trump tariffs in 2018 (on solar panels, washing machines, steel and aluminum products, and Chinese products), the observed change in tariffs between 1992 and 2007, and the observed change in "import charges" (defined as transportation and insurance costs) in the same period. We view tariffs as iceberg trade costs, ignoring tariff revenue. In all three cases, we first measure the shock at the level of HS codes and then average it at the level of the corresponding IO code using the HS-NAICS concordance from Pierce and Schott (2012).

The first shock is the set of tariffs introduced by the Trump administration in 2018. We combine three sets of tariffs:

1. *Solar panels and washing machines.* Actual tariffs on solar panels and large residential washing machines have a complicated structure: their rates vary over time, they are combined with quotas, and certain exceptions are provided, as described in Presidential Proclamations 9693 and 9694 of January 23, 2018. We approximate these rates by using the base rates (30% for solar panels and 20% for washers) applied to the main HS codes described in the Proclamations and to all U.S. trading partners.

2. *Steel and aluminum products.* Tariff duties on imports of steel and aluminum by trading partners are given in Section 232 of the Trade Expansion Act of 1962. The tariff increases were proposed on March 1 and amended on May 31, 2018. We identify the steel and aluminum products that were affected by these tariff increases using the published lists of HS codes. We apply a 25% tariff on steel products, excluding imports from Argentina, Australia, Brazil and South Korea, and a 10% tariff on aluminum products excluding Argentina and Australia.

3. *China tariffs.* Tariffs on products imported from China were introduced according to Section 301 of the Trade Act of 1974. They were released by the Office of the U.S. Trade Representative in three tranches with different lists of products. The first two were finalized on June 15 and August 7, 2018, taxing approximately \$34bln and \$16bln (in terms of 2018 imports), respectively, with a rate of 25%. The third one, finalized on September 17, introduced a tariff of 10% on approximately \$200bln of imports.

The other two shocks we consider are the observed changes in (i) tariffs and (ii) import charges (transportation and insurance costs) between 1992 and 2007. We obtain data on both types of changes from the Census Bureau trade statistics made available by Schott (2008). For each IO industry and year, we measure the rate of tariffs t_j (or import charges c_j) as the share of total tariff duties (or total transportation/insurance costs) in total imports for personal consumption.

For each industry j, the shocks are given by the change in $\log(1+t_j)$ and $\log(1+c_j)$ between 1992 and 2007.

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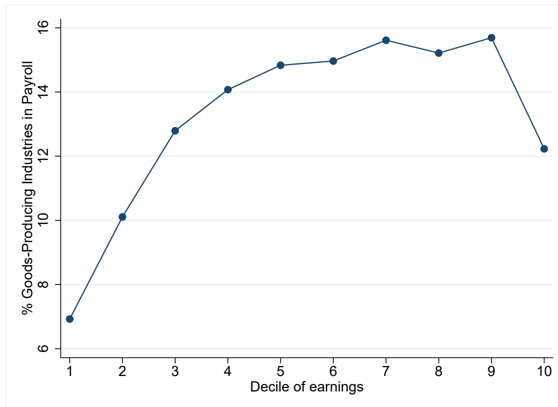
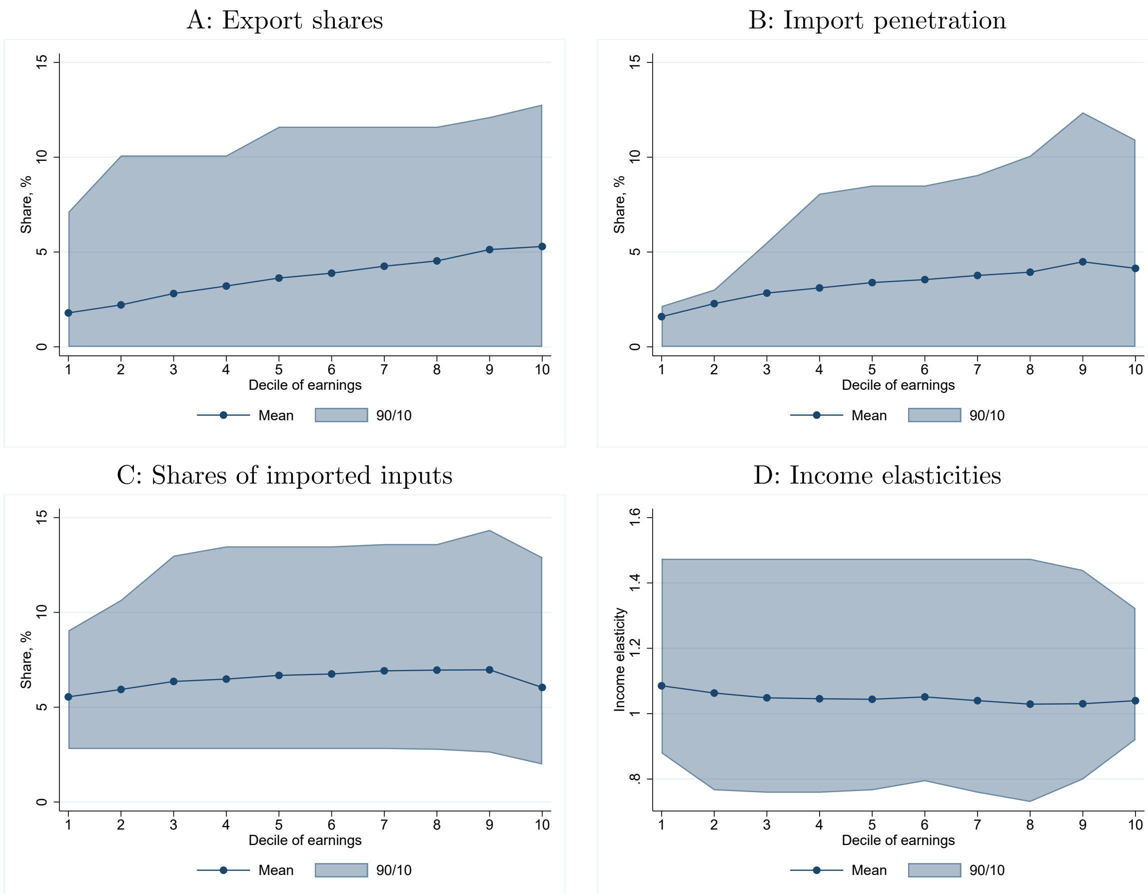
Appendix Figures and Tables

Figure S1: Goods-Producing Industries as Fraction of Payroll by Earnings Decile



Notes: This figure shows, for each decile of worker earnings, the fraction of goods-production industries in total payroll. The analysis is conducted in 2007 using the data from Section 3.1.

Figure S2: Raw Worker-Level Exposure to Trade



Notes: This figure plots "raw" exposure of workers to several margins of international trade, across and within deciles of initial earnings. Each worker's exposure is given by the corresponding industry variable, and no IO or other adjustments are applied. Each panel reports the average, the 10th percentile, and the 90th percentile across workers in each earnings bin.

Table S1: Accounting for the Wage Effects of Trade through Exposure

	Component of the effects on wages					
	All	Exports	Import competition	Intermediate inputs	Income effects	Substitution effects
	(1)	(2)	(3)	(4)	(5)	(6)
Exports	0.310	0.127	0.341	-0.112	-0.004	-0.042
	(0.026)	(0.013)	(0.016)	(0.004)	(0.001)	(0.008)
Import competition	0.800	0.332	0.355	0.073	0.003	0.036
	(0.030)	(0.013)	(0.014)	(0.005)	(0.002)	(0.006)
Intermediate inputs	0.694	0.287	-0.286	0.679	-0.006	0.020
	(0.098)	(0.042)	(0.045)	(0.019)	(0.007)	(0.027)
Income effects	0.986	0.412	-0.237	0.079	0.663	0.070
	(0.042)	(0.018)	(0.021)	(0.006)	(0.011)	(0.020)
Substitution effects	1.205	0.504	-0.246	0.068	0.036	0.843
	(0.085)	(0.038)	(0.026)	(0.006)	(0.006)	(0.041)
R^2	0.959	0.953	0.958	0.972	0.986	0.970

Notes: For the worker-level analysis of Section 4.1, this table regresses wage changes in general equilibrium (in column (1)) and their five underlying components (in columns (2) through (6)) on the exposure statistics capturing changes in labor demand, using Proposition 1 and equation (6). Specifically, we simulate a 10% fall in trade costs in our model, obtain wage changes across workers, and regress them on the five components of the labor demand response. Column (1) thus replicates column (4) of Table 2. The analysis is implemented using the 1,128,862 workers in the ACS data, with standard errors clustered by industry.