What Determines State Heterogeneity in Response to US Tariff Changes?*

Ana Maria Santacreu† Michael Sposi‡ Jing Zhang§

February 27, 2025

Abstract

We develop a structural framework to identify the sources of cross-state heterogeneity in response to US tariff changes. We quantify the effects of unilaterally increasing US tariffs by 25 percentage points across sectors. Consumption changes range from −0.8 percent in Oregon to 2.1 percent in Montana. States gain more when their sectoral comparative advantage covaries negatively with that of the US. Consequently, "preferred" changes in tariffs vary systematically across states, indicating the importance of transfers in aligning state preferences over trade policy. Foreign retaliation reduces the gains across states, while perpetuating the cross-state variation.

Keywords: Interstate trade, Gains from trade, Customs union
JEL Classifications: F11, F62

*This paper supersedes a previous version titled "A Quantitative Analysis of Tariffs across US States." We thank George Alessandria, Lorenzo Caliendo, Joel David, Esteban Rossi-Hansberg, Fernando Parro, Kim Ruhl, Michael Waugh, and seminar and conference participants at Johns Hopkins SAIS, Sam Houston State University, Texas Christian University, University of Wisconsin, Midwest Macro conference, SEA conference, SED conference and SAET conference for their comments. The views expressed here are those of the authors and do not necessarily reflect those of the Federal Reserve Banks of Chicago and St. Louis, and the Federal Reserve System.

†Federal Reserve Bank of St. Louis, 1 Federal Reserve Bank Plaza, St. Louis, MO 63102. am.santacreu@gmail.com

‡Southern Methodist University, 3300 Dyer Street, Dallas, TX 75275. msposi1981@gmail.com

§Federal Reserve Bank of Chicago, 230 South LaSalle Street, Chicago, IL 60604. jzhangzn@gmail.com

1 Introduction

One defining characteristic of the United States is that it is a customs union with 50 member states, meaning that interstate trade occurs duty-free and all states face common external tariffs. However, heterogeneous characteristics among states, including geography, productivity, and endowments, generate winners and losers in response to common tariff changes. Even if the union benefits as a whole, cross-state transfers might be necessary to align state preferences over policy changes. Different from other customs unions, such as the European Union, the United States is also a fiscal union, so, in principle, such transfers are feasible. As such, it is essential to understand how cross-state heterogeneity influences the impact of trade policy in order to know the magnitudes of the transfers needed in conjunction with trade policy proposals.

We develop a general equilibrium model of international and interstate trade where comparative advantage arises from productivity and endowment differences. The model is calibrated to assess the cross-state heterogeneity in response to a uniform US import tariff increase. States gain (lose) when their sectoral productivity correlates negatively (positively) with that of the union. Protection favors *sectors* in which the US has external comparative disadvantage vis-à-vis foreign countries, and *states* with internal comparative advantage vis-à-vis other states in these sectors reap most gains. Hence, states have divergent preferences over common external tariffs. Foreign retaliation reduces consumption in most states while perpetuating the cross-state disparities. Our framework allows us to design tariff revenue transfers to mitigate these consumption differences.

Our analysis features a multi-location, multi-sector Eaton-Kortum model of trade. Each location differs in sectoral productivity and faces asymmetric physical trade costs and tariffs. A subset of locations—the US states—forms a customs union, enabling duty-free trade among themselves while facing common external tariffs with non-US locations. In every location, competitive firms in each sector produce output using high-skill and low-skill labor along with intermediate inputs from all sectors. Workers earn factor income and receive lump-sum transfers from tariff revenue, and they can move across sectors or states depending on the specified factor mobility scenario. As a fiscal union, the United States redistributes tariff revenue equally on a real per-capita basis across states, which allows us to focus on changes in factor income.

We calibrate the model to 50 US states, 8 foreign locations and a rest-of-world aggregate using 14 goods sectors and 2 services sectors for 2012. Following Levchenko and Zhang (2016), we infer bilateral trade costs and productivity for these sectors and locations from observed trade flows using a gravity approach. One challenge that we face is the lack of state-to-state trade data in agriculture, mining, and services, as well as state-to-country trade data in services. We construct sensible estimates for these missing trade flows using a gravity specification that links observed bilateral trade flows with observables, including production at the location-sector level, various measures of distance barriers, as well as sector, origin, and destination fixed effects. Finally, we scale these imputed trade flows to be consistent with state-sector production data and US-sector bilateral trade data with foreign countries.

Our calibration unveils patterns of comparative advantage across all locations. Relative to foreign countries, US *external* comparative advantage, determined by both productivity and endowment differences, lies in sectors like Computers and electronics and in Chemicals. Sectors with external comparative advantage are either those with high median productivity across states relative to foreign countries or those with high-skill labor intensity, since the US is relatively abundant in high-skill labor. The United States has a comparative disadvantage in Mining and in Textiles. Within the United States, *internal* comparative advantage of each state reflects primarily sectoral productivity differences. For example, Wyoming has a strong internal comparative advantage in Mining, and Oregon in Computers and electronics.

We begin by quantifying the effects of a uniform 25-percentage-point increase in US import tariffs across sectors. Most of the analysis imposes factor immobility to capture the short-run response to tariff changes. Overall US consumption rises by 0.54 percent, because the 1.04-percent loss in real factor income due to less efficient spatial allocation is outweighed by the 1.59-percent increase in tariff revenue. However, this aggregate effect masks substantial variation: factor income changes range from -0.8 percent to 2.3 percent. Higher tariffs cause US states to redirect expenditures from foreign to domestic producers, especially in sectors where the US has external comparative disadvantage (e.g., Mining). States that benefit more (e.g., Wyoming) are those with internal comparative advantage in such sectors, while states that benefit less (or lose more, e.g., Oregon) are those whose internal comparative advantage aligns with US external comparative advantage in sectors like Computers and electronics.

Heterogeneous impacts across states imply that states have different preferences over tariffs. To illustrate, we trace out each state's consumption change as uniform tariffs increase from zero to high values, and identify the tariff level that maximizes consumption. For example, states like Wyoming—which exhibits internal comparative advantage that is negatively correlated with US external comparative advantage—favor extreme high tariffs at the expense of other states. Even as tariffs become so high that tariff revenue nearly vanishes, Wyoming continues to benefit by gaining a larger share of the US mining market and by enjoying lower costs for computer and electronic goods imported from states like Oregon, where rising tariffs reduce production costs. Ultimately, this preference for higher tariffs stems from Wyoming's membership in the larger US customs union.

We also consider a scenario where foreign countries implement a tit-for-tat retaliation by increasing their tariffs on imports from the US by 25 percentage points across sectors. This shifts the terms of trade in favor of foreign countries and significantly reduces US consumption by 0.94 percent, reversing the 0.55 percent increase seen without retaliation. Meanwhile, foreign countries experience a smaller consumption decline of 0.13 percent, compared to 0.26 percent in the no-retaliation case. Retaliation also perpetuates the cross-state variation in consumption gains. States with internal comparative advantage aligned with the US tend to be large exporters and thus face greater losses.

Our baseline analysis demonstrates that there are winners and losers from changes in trade policy, even when the US gains on aggregate. We show that this is the case even when we restrict tariff changes to be sector specific. These outcomes satisfy the Kaldor-Hicks efficiency criteria, but clearly are not Pareto efficient among US states. This raises an important question: Is there a redistribution rule that, when paired with the tariff change, delivers Pareto efficiency? The answer is yes. We identify a redistribution rule that: (i) yields Pareto efficiency, (ii) is fully financed by the newly created tariff revenue, and (iii) equalizes consumption gains across states. This rule provides larger per-capita transfers to states experiencing greater declines in real factor income.

To study medium- and long-run effects, we introduce labor mobility by first allowing workers to move across sectors within states and then allowing movement between states as well as sectors. We find that factor mobility does not alter the relative ranking of states in terms of changes in real factor income. However, intra-state sectoral mobility slightly amplifies the variance of these impacts, while inter-state mobility reduces it. Thus, even in the long run when labor is mobile, the interaction between internal and external comparative advantage continues to shape the cross-state trade policy effects. Additionally, with sectoral factor mobility, Heckscher-Ohlin forces operate, allowing us to examine wage inequality across skill types. In response to a unilateral increase in tariffs, states with a relative abundance of low-skill labor see an increase in the skill premium, while those with a relative abundance of high-skill labor experience a decline.

Through the lens of standard trade theory, the extent to which a country can improve its terms of trade and benefit from imposing tariffs hinges on the export supply elasticity it faces (Broda, Limao, and Weinstein, 2008). Recent work has combined empirical estimates of trade elasticities with quantitative models to evaluate the impacts of tariff changes (Fajgelbaum et al., 2020). In our framework, export supply elasticities emerge endogenously from general-equilibrium interactions driven by productivity differences, endowments, trade costs, and trade elasticities. Moreover, US states' membership in a customs union—where they trade duty free with each other—shapes their export supply elasticities. While our framework does not yield explicit expressions for these elasticities, it captures their full complexity by modeling how trade policy changes affect terms of trade, input-output linkages, trade patterns, and factor prices across all states and countries in general equilibrium.

We contribute to recent literature that quantitatively integrates intranational and international trade (e.g. Caliendo et al., 2018; Caliendo, Dvorkin, and Parro, 2019; Coşar and Fajgelbaum, 2016).[1] A common challenge in this literature is to estimate internal trade costs despite missing state-level trade data. We impute the missing trade flows using a reduced-form gravity approach with limited state-to-state and state-to-country trade data, but with complete data on country-to-country trade, production and expenditure, and geographic information. Rodríguez-Clare, Ulate, and Vasquez (2024) use a similar approach to estimate internal trade costs when studying the impact of trade shocks on unemployment across US local labor markets. Both Eckert et al. (2019) and Gervais and Jensen (2019) impute internal trade flows using the difference between a location's expenditure and revenue. Similar to Ramondo, Rodríguez-Clare, and Saborío-Rodríguez (2016), they impose symmetric trade costs, which requires less data.

Recent research has explored the cross-state impacts of US trade policy changes. Caliendo and Parro (2022) quantify the impacts of the 2018 trade war and provide a comprehensive review of the trade policy literature. We complement their work by unpacking the cross-state heterogeneity in state-level fundamentals to characterize the determinants of the heterogeneous impacts of trade policy. Auer, Bonadio, and Levchenko (2020) quantify the impact of revoking NAFTA across US sectors and compute the welfare impact on each congressional district by weighing the US sectoral impacts by district-level sectoral employment shares. We show that when cross-location heterogeneity manifests predominantly in sectoral employment shares, this calculation is a good approximation. Our findings align with numerous studies that indicate that trade shocks, such as tariffs,

[1] Ramondo, Rodríguez-Clare, and Saborío-Rodríguez (2016) and Redding (2016) highlight the role of internal trade costs in international trade models. Coşar and Demir (2016), Donaldson (2018), and Allen and Arkolakis (2022) quantify the role of transportation infrastructure specifically.

can have varying effects on different regions within countries when labor mobility is limited (Kovak, 2013; Topalova, 2010). Similarly, Waugh (2019) studies the heterogeneous response of trade shocks across US counties in the context of the US-China trade war.

There exists a large literature, both theoretical and quantitative, that examines optimal trade policy in settings with many goods, sectors and countries (see for instance Ossa, 2011; Costinot, Donaldson, Vogel, and Werning, 2015; Beshkar and Lashkaripour, 2020; Bagwell, Staiger, and Yurukoglu, 2021; Lashkaripour and Lugovsky, 2022). So far, the literature has not quantitatively explored optimal trade policy in a multi-sector setting that involves the distributional impacts across, and political tensions among, members of a customs union. Although we do not tackle this question in this paper, our framework provides a foundation for such an analysis.

2 Model

We build on the workhorse Eaton-Kortum trade model. The world economy consists of US states and non-US (foreign) countries. Locations are indexed by $(n, i) = 1, \ldots, N$, and $\mathcal{US}$ denotes the set of locations within the United States. There are J sectors, indexed by $(j, k) = 1, \ldots, J$. Firm production in each sector requires high and low-skill labor, indexed by $s \in \{h, \ell\}$, as well as intermediate inputs in a roundabout format as in di Giovanni, Levchenko, and Zhang (2014) and Caliendo and Parro (2015). Output from each sector can be traded. Trade between locations is subject to physical iceberg costs (trade costs from now on), and trade across countries (e.g., not between US states) is also subject to tariffs, which are set at the country level by national governments. The tariff revenue collected is transferred back to workers.

We consider three specifications of worker mobility. Our first specification assumes labor is immobile across locations and sectors, allowing us to focus on the short-run implications of trade policy. This specification serves as the foundation for most of our quantitative analysis. We relax this assumption in Section 5.1 to examine medium-run (mobility across sectors) and long-run (mobility across sectors and states) implications.[2] In all the scenarios we restrict labor from moving across countries.

Workers Workers make potentially two sequential decisions. When allowed, they first choose a sector of employment either in their "home location" or, for US workers, in

[2] Existing evidence indicates that worker mobility is limited in response to trade shocks (Artuç, Chaudhuri, and McLaren, 2010; Dix-Carneiro, 2014).

any US state. Second, conditional on their location and sector, they make a consumption decision. A type-s worker employed in location n and sector j derives utility from consumption c_n^{sj} and from working b_n^{sj}. Specifically, the utility for this worker is given by

$$v_n^{sj} = c_n^{sj} + b_n^{sj},$$

where c_n^{sj} is a Cobb-Douglas aggregate over all sectoral goods, given by

$$c_n^{sj} = \prod_{k=1}^{J} c_n^{sj}(k)^{\omega_n^k},$$

and $c_n^{sj}(k)$ denotes this worker's consumption of the sector-k good. Preference weights, ω_n^k, can vary countries, but are common across worker type within a location. Utility from working, b_n^{sj}, is given by the amenity factor δ_n^{sj}, scaled by the worker's real wage:

$$b_n^{sj} = \delta_n^{sj} \frac{w_n^{sj}}{P_n^c},$$

where w_n^{sj} denotes the type-sector-location specific wage, and P_n^c denotes the location-specific consumption price. Importantly, the amenity factor δ_n^{sj} varies by worker type, location, and sector. For example, high- and low-skill workers in the same state and sector experience different amenities. Similarly, type-s workers face varying amenities across sectors within the same state, as well as across states within the same sector.

Workers earn two types of income. One is labor income, derived from inelastic unit labor supply, with a location-sector-skill-specific wage. The other is a location-specific indirect business tax transfer from the national government, denoted by t_n. Thus, each worker's total income is given by $w_n^{sj} + t_n$.

Conditional on being in a given location and sector, this worker optimally chooses sectoral consumption, $c_n^{sj}(k)$, subject to the budget constraint:

$$\underbrace{\sum_{k=1}^{J} p_n^k c_n^{sj}(k)}_{P_n^c c_n^{sj}} = w_n^{sj} + t_n,$$

where p_n^k is the price for the sector-k good in location n. The total consumption basket

c_n^{sj} has an ideal price index P_n^c:

$$P_n^c = \prod_{j=1}^{J} \left(\frac{p_n^j}{\omega_n^j} \right)^{\omega_n^j}.$$

Since all workers have identical preferences within a location, the ideal consumption price index is common to all workers in location n. The optimality condition prescribes that this worker allocates a fraction ω_n^j of their income on sector-j goods.

Using the optimal consumption decision together with the budget constraint, we can write this worker's utility conditional on being employed in sector j and location n as

$$v_n^{sj} = \frac{w_n^{sj}}{P_n^c} + \frac{t_n}{P_n^c} + \frac{w_n^{sj}}{P_n^c} \delta_n^{sj} = \frac{w_n^{sj}(1 + \delta_n^{sj})}{P_n^c} + \frac{t_n}{P_n^c}.$$

A type-s worker potentially decides the location and/or sector choice to maximize v_n^{sj}.

In the specification with immobile labor, there is no sector or location choice. In the specification with sectoral mobility, workers choose a sector within their "home location" n to maximize their utility. In the specification with both sectoral and state mobility, US workers choose a state, and a sector within that state, whereas foreign workers choose only a sector within their country, to maximize their utility.

Aggregation Now we aggregate workers' variables within location n. Let e_n^{sj} denote the number of type-s workers in sector j. The total number of type-s workers in location n is $E_n^s = \sum_{j=1}^J e_n^{sj}$, and the total workforce is $E_n = \sum_{s \in \{\ell,h\}} E_n^s$. The aggregate factor income in location n is $F_n = \sum_{j=1}^J \sum_{s \in \{\ell,h\}} w_n^{sj} e_n^{sj}$, and the aggregate transfer received by workers in location n is $T_n = E_n t_n$. Aggregate consumption in location n is $C_n = \sum_{j=1}^J \sum_{s \in \{\ell,h\}} c_n^{sj} e_n^{sj}$. The aggregate consumption expenditure in location n equals the aggregate factor income plus transfers:

$$P_n^c C_n = F_n + T_n. \tag{1}$$

Firms Each sector consists of a unit interval of tradable varieties indexed by $v \in [0, 1]$. Each variety can be produced by a competitive firm using two types of labor and composite intermediate inputs according to

$$y_n^j(v) = a_n^j(v) \left[A_n^j \prod_{s \in \{\ell,h\}} e_n^{sj}(v)^{\lambda^{sj}} \right]^{\nu^j} \left[\prod_{k=1}^{J} m_n^{jk}(v)^{\mu^{jk}} \right]^{1-\nu^j},$$

where $m_n^{jk}(v)$ denotes the quantity of the composite good from sector k used by country n to produce $y_n^j(v)$ units of variety v in sector j; $e_n^{sj}(v)$ denotes the amount of type-s workers employed. The share parameters are sector specific: ν^j is the share of value added in total output, λ^{sj} is the share of type-s workers in labor compensation, and μ^{jk} is the share of composite good k in intermediate spending by producers in sector j, with $\sum_{s \in \{\ell,h\}} \lambda^{sj} = 1$ and $\sum_{k=1}^{J} \mu^{jk} = 1$.

Fundamental productivity, A_n^j, scales value-added for all varieties in sector j of country n.[3] The term $a_n^j(v)$ scales gross-output of variety v in sector j of country n. Following Eaton and Kortum (2002), gross-output productivity in sector j for each variety is drawn independently from a Fréchet distribution with sector-specific shape parameter θ^j. The cumulative density function in sector j is $F^j(a) = \exp(-a^{-\theta^j})$.

In each sector and location a competitive firm aggregates all varieties with constant elasticity to construct a nontradable composite good:

$$Q_n^j = \left[\int_0^1 q_n^j(v)^{1-1/\eta} dv \right]^{\eta/(\eta-1)},$$

where η is the elasticity of substitution between varieties, and $q_n^j(v)$ is the quantity of sector-j variety v used by country n, which consists potentially of both locally produced and imported varieties. The composite good, Q_n^j, is used domestically for intermediate and final use.

Trade Trade between different locations is subject to two types of barriers. One barrier is a trade cost whereby location n must purchase $d_{ni}^j \geq 1$ units of any variety of sector j from location i in order for one unit to arrive. As a normalization, $d_{nn}^j = 1$ for all (n, j). The second type of barrier is an ad-valorem tariff (tariff from now on), whereby τ_{ni}^j is the net tax rate that location n levies on the value of imports from location i in sector j. Domestically produced varieties incur zero tariffs. Every location sources each variety from its respective least-cost supplier.

[3]The fundamental productivity encompasses unmeasured physical capital endowments, which are potentially important especially for Mining and agriculture.

As in Eaton and Kortum (2002), the fraction of location n's expenditures sourced from location i in sector j is given by:

$$\pi_{ni}^j = \frac{\left((A_i^j)^{-\nu^j} u_i^j d_{ni}^j (1+\tau_{ni}^j)\right)^{-\theta^j}}{\sum_{i'=1}^{N} \left((A_{i'}^j)^{-\nu^j} u_{i'}^j d_{ni'}^j (1+\tau_{ni'}^j)\right)^{-\theta^j}}, \tag{2}$$

where the unit cost for a bundle of inputs for producers in sector j in location i is:

$$u_i^j = B^j \left[\prod_{s\in\{\ell,h\}} \left(w_i^{sj}\right)^{\lambda^{sj}}\right]^{\nu^j} \left[\prod_{k=1}^{J} \left(p_i^k\right)^{\mu^{jk}}\right]^{(1-\nu^j)}. \tag{3}$$

The price of the sector-j composite good in country n is given by:

$$p_n^j = \gamma^j \left[\sum_{i=1}^{N} \left((A_i^j)^{-\nu^j} u_i^j d_{ni}^j (1+\tau_{ni}^j)\right)^{-\theta^j}\right]^{-\frac{1}{\theta^j}}. \tag{4}$$

The terms B^j and γ^j are constants.

Governments In each country, there is a government that collects tariff revenue and transfers the proceeds to households. To calculate location n's tariff revenue on imports from location i in sector j, we first divide the sectoral imports measured at tariff-inclusive prices, $p_n^j Q_n^j \pi_{ni}^j$, by the gross tariff rate $1+\tau_{ni}^j$. The tariff-exclusive imports are then multiplied by the net tariff rate to yield the tariff revenue. The total tariff revenue generated in location n is therefore

$$R_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \left(\frac{p_n^j Q_n^j \pi_{ni}^j}{1+\tau_{ni}^j}\right) \tau_{ni}^j.$$

We assume that governments rebate tariff revenue to all workers equally in terms of real consumption. Because foreign countries are single locations and all workers in each foreign country face the same consumption price, the tariff revenue is distributed evenly also in nominal terms within those locations. In the United States, however, states have different consumption prices, so the tariff rebate in nominal terms is adjusted to compensate for the consumer price differences. There is no empirical guidance on how to model tariff transfers across states and workers. Our assumption, in addition to being intuitive, is convenient in the scenario with labor mobility, because tariff transfers have no influence on workers' location choices. We also consider other reasonable transfer rules in Section 4.3.

In foreign countries, $t_n = R_n/E_n$. In the United States the tariff revenue is distributed so that every worker, regardless of location, receives the same value in real terms:

$$\frac{t_n}{P_n^c} = \frac{\sum_{i \in \mathcal{US}} R_i}{\sum_{i \in \mathcal{US}} P_i^c E_i}.$$

The entirety of tariff revenue collected by each country's customs authority is transferred to workers, so the national government's budget is balanced. Notably, within the US, this allows net transfers between states equal to $R_n - T_n$, such that $\sum_{n \in \mathcal{US}} R_n = \sum_{n \in \mathcal{US}} T_n$.

Equilibrium A competitive equilibrium under a tariff policy regime $\{\tau_{ni}^j\}$ satisfies the following: i) taking prices as given, workers maximize utility subject to their budget and mobility constraints; ii) taking prices as given, firms maximize profits subject to the available technologies; iii) varieties are purchased from their lowest-cost provider subject to the trade costs and tariffs; iv) national government budgets are balanced; (v) labor and goods markets clear; and (vi) trade is balanced at the country level.

Appendix A lists the complete set of equilibrium conditions. It is important to note that labor market clearing conditions differ based on the assumptions on factor mobility. In the scenario without any factor mobility, labor demand in each sector-location pair equals to the labor endowment. In the specification with sector labor mobility, the total demand for labor across sectors within a location equals the labor endowed to that location. Finally, in the specification allowing for both sector and state mobility, the total demand for labor in each country across all sectors and states within a country (such as the US) equals the country-specific labor endowment.

In the absence of factor mobility, sector-location-specific wage w_n^{sj} adjusts to equate labor demand with fixed labor supply, as workers cannot move across sectors or across locations to exploit amenity-adjusted wage differentials. In the case with sector mobility, amenity-adjusted equilibrium wages equalize across sectors within each location, because workers can move across sectors to exploit any existing differentials. This equilibrium condition is described by:

$$\frac{w_n^{sj}}{w_n^{sk}} = \frac{1 + \delta_n^{sk}}{1 + \delta_n^{sj}}, \text{ for } n \in \{1, \ldots, N\}, (j, k) \in \{1, \ldots, J\}, \text{ and } s \in \{h, \ell\}. \tag{5}$$

In the case with both sector and state factor mobility, the equilibrium wages for US workers—adjusted for sector and state amenities as well as the state-specific cost of living—are equalized across locations and sectors. This equilibrium condition for US workers is described by:

$$\frac{w_n^{sj}/P_n^c}{w_i^{sk}/P_i^c} = \frac{1+\delta_i^{sk}}{1+\delta_n^{sj}}, \text{ for } (n,i) \in \mathcal{US}, (j,k) \in \{1,\ldots,J\}, \text{ and } s \in \{h,\ell\}. \tag{6}$$

Notably, equation (6) does not apply to foreign workers since they are not allowed to choose their location.

3 Calibration

The quantitative exercise is applied to 59 locations: 50 US states, 8 non-US locations (Brazil, Canada, China, the European Union, India, Japan, Mexico, and South Korea), and a rest-of-world aggregate. These non-US locations were selected based on the criteria that they each accounted for at least one percent of US trade in 2012; They collectively account for about 70 percent of US trade. All remaining trading partners of the US are part of a rest-of-world aggregate.

Economic activity consists of 16 sectors of the economy: (1) Agriculture; (2) Mining; (3) Food, beverages, and tobacco; (4) Textiles and apparel; (5) Wood; (6) Paper and printing; (7) Refined petroleum, plastics, and rubbers; (8) Chemicals and pharmaceuticals; (9) Non-metallic minerals; (10) Primary and fabricated metals; (11) Machinery n.e.c.; (12) Computers, electronics, and electrical equipment; (13) Transportation equipment; (14) Furniture and other; (15) Tradable services; and (16) Nontradable services.

It is important to include services, which account for about one-third of US exports and 80 percent of US employment. We split the services sectors into two groups: *Tradable services* and *Nontradable services*. A service industry belongs to Tradable services if the ratio of its global exports to global gross output is above 5 percent, and to Nontradable services otherwise.[4] This level of disaggregation of the services sectors facilitates the imputation of services trade data across US states.

We calibrate the model parameters in three steps. In section 3.1, we describe the

[4] Service industries in Tradable services, beginning with the most tradable, are (i) Transport & warehouse, (ii) Wholesale & retail (iii) Information, (iv) Business services, and (v) Finance & insurance. Service industries in Nontradable services, beginning with the most tradable, are (i) Entertainment, (ii) Utilities, (iii) Education, (iv) Other services, (v) Construction, (vi) Health, and (vii) Real estate.

calibration of country-specific parameters that are directly observable in the data. In section 3.2, we impute missing trade flows across US states using gravity methods together with observable trade flows, geography, and state-sector level production. In section 3.3, we calibrate the remaining parameters using the model's structure.

3.1 Parameters Taken Directly from the Data

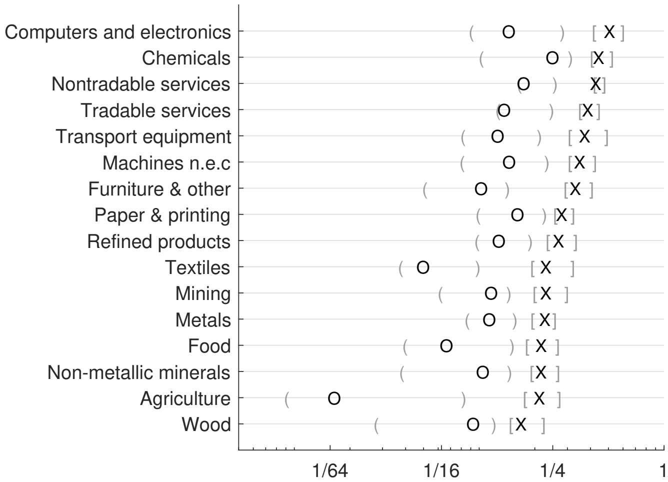
This subsection describes the parameters that are directly sourced from the data in 2012. We introduce the data sources and discuss the imputations that are done to complete the coverage of our sample. We choose year 2012, because it is the most recent available year for bilateral trade between US states provided by the Census Bureau's Commodity Flow Survey. Appendix B provides the detailed description of the data.

Labor Endowments Each location is endowed with sector-specific high-skill labor e_n^{hj} and low-skill labor $e_n^{\ell j}$. Country-level employment comes from the Penn World Table (Feenstra, Inklaar, and Timmer, 2015, (PWT)). The 2016 release of the Socio Economic Accounts in the World Input Output Database (WIOD) (Timmer, Dietzenbacher, Los, Stehrer, and de Vries, 2015; Timmer, Los, Stehrer, and de Vries, 2016) provides the sectoral shares of total employment for each country, and the 2014 release reports sectoral skill composition for each country.[5] This information allows us to compute high and low-skill labor endowments at the sector level for each country. Finally, for US states, we appeal to the Census Bureau's American Community Survey (ACS) to obtain employment by skill types at the state-sector level. Details are provided in Appendix B.

Figure 1 illustrates that the high-skill share of workers in the United States exceeds that of most foreign countries across sectors. On the vertical axis, the sectors are ranked by the median share of high-skill workers in the US, marked by "X", with square brackets reflecting the interquartile range. The top two sectors are Computers and electronics and Chemicals. The two bottom sectors are Wood and Agriculture. The median ratios for foreign countries are illustrated by "O," with round brackets reflecting the interquartile range. The shares of high-skill workers in foreign countries are highly correlated with those in the US across sectors.

[5]Skill type is based on educational attainment. High-skill corresponds to at least some tertiary education, while low-skill corresponds to no tertiary education.

Figure 1: High-Skill Labor Share by Sector



Notes: X denotes the median high-skill share in employment in the US, and square brackets reflect the interquartile range; O denotes the median high-skill share in foreign countries, and round brackets reflect the interquartile range. Sectors are ordered by the high-skill share in the US from the lowest on the bottom to the highest on the top.

Trade elasticities Trade elasticities for manufacturing sectors are sourced from Giri, Yi, and Yilmazkuday (2021).[6] They do not provide estimates for four of our sectors (Agriculture; Mining; Tradable services; Nontradable services). For these sectors, we assume a value of 4 as estimated for manufacturing by Simonovska and Waugh (2014). The first column of Table 1 reports the trade elasticities. Metals and Refined products have high values, consistent with the fact that goods in those sectors are more homogeneous than goods in other sectors. On the other hand, Paper & printing and Computers and electronics have low values, as goods in those sectors are more differentiated than goods in other sectors.[7]

Consumption Weights Sectoral weights in total consumption, ω_n^j, are computed for each country using the nominal shares in final demand (public and private consumption and investment) from the WIOD. We do not observe final demand at the US state level, so we assume that the weights for each state are the same as for the United States aggregate. The second column of Table 1 reports ω_n^j for the United States. Tradable ser-

[6]Their sector classification is not identical to ours. For the sectors where our classification coincides with theirs, we use their value directly. In the case where their classification is finer than ours, we take an average of the values they report for the underlying sub-sectors. In the case where our classification is finer, we use the same elasticity for the sub-sectors.

[7]The elasticity of substitution between varieties in the composite goods is set to $\eta = 2$, which plays no quantitative role.

Table 1: Sector-Specific Parameters

	θ^j	ω^j_{US}	ν^j	λ^{hj}
Agriculture	4.00	0.004	0.445	0.204
Mining	4.00	0.009	0.712	0.355
Food	3.57	0.032	0.259	0.291
Textiles	4.82	0.010	0.313	0.261
Wood	4.17	0.001	0.301	0.166
Paper & printing	2.97	0.002	0.350	0.441
Refined products	5.75	0.019	0.251	0.300
Chemicals	3.75	0.016	0.442	0.577
Non-metallic minerals	3.87	0.001	0.400	0.233
Metals	7.01	0.003	0.314	0.216
Machines n.e.c	3.87	0.013	0.368	0.298
Computers and electronics	3.27	0.021	0.623	0.490
Transport equipment	4.47	0.031	0.292	0.339
Furniture & other	4.47	0.010	0.452	0.283
Tradable services	4.00	0.275	0.599	0.464
Nontradable services	4.00	0.554	0.643	0.393

Notes: θ^j is the trade elasticity, ω^j_n is sector j's share in locations n's consumption spending (we report US values), ν^j is the share of value added in gross output, and λ^{hj} is the share of high-skill labor in the wage bill.

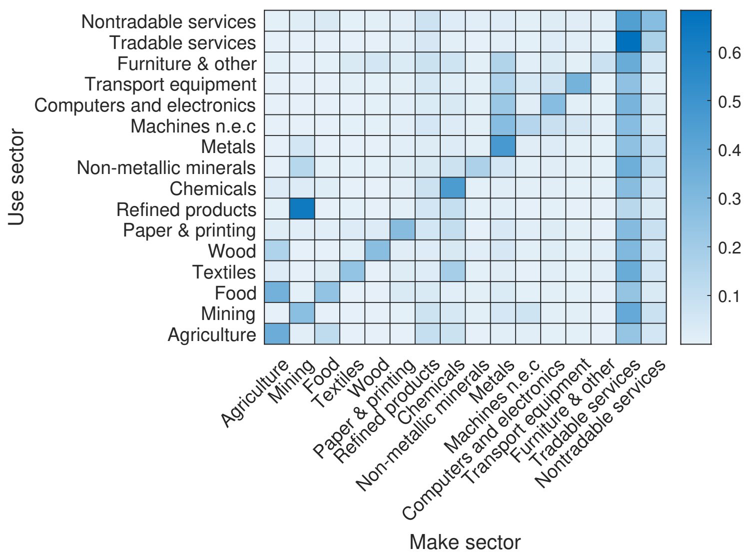
vices and Nontradable services collectively account for more than 80 percent of US final demand. Outside of services, Food and Transport equipment are the next two largest components, accounting for 3.2 and 3.1 percent, respectively. Since they are constant across US states, they do not contribute to the heterogeneity in consumption impacts from tariff changes.

Input and Factor Shares We now describe the sources for the production coefficients: the intermediate input share in gross output ν^j, the high-skill labor share λ^{hj}, and the intermediate use coefficients μ^{jk}. All these parameters are directly computed using 2012 values from the WIOD for the United States.

The third column of Table 1 reports the share of value added in the sectoral output for the United States. The most value-added intensive (least intermediate intensive) sectors are Mining, Computers and electronics, and Nontradable services. The least value-added intensive sectors are Refined products and Food. The last column reports the share of high-skill workers in labor compensation (high-skill intensity) across sectors for the United States. The most high-skill intensive sectors are Chemicals, Computers and electronics, and Tradable services, while Wood, Agriculture, and Metals are the least high-skill intensive.

The input-output structure is an important transmission mechanism. Figure 2 illustrates the linkage between "use" sectors in rows and "supply" sectors in columns, where shares in each row sum to unity. Three patterns emerge from this figure. First, each sector tends to use output from its own sector intensively, as indicated by darker diagonal blocks. Second, Tradable services (including professional & business services) are an important input in most other sectors' production. Third, certain sectors are key inputs to specific sectors, such as the use of Mining in Refined products, the use of Agriculture in Food, and the use of Metal in Machines. These strong links transmit cost shocks due to changes in tariffs disproportionately across sectors. For example, a tariff-induced increase in the price of Mining disproportionately impacts the price of Refined products.

Figure 2: Input-Output Shares



Notes: Each row represents "use" sector and each column represents "supply" sector. Each row sums to one.

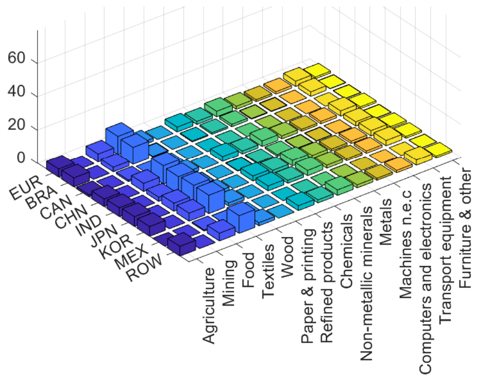
Tariffs We obtain applied effective tariff rates from the World Integrated Trade Solution (WITS) database. For missing values, we use the most-favored nation tariff rate. We use the accompanying product-level trade data from WITS to aggregate the tariffs from the HS–6 digit level to our 14 goods-producing sectors (there are no tariffs for service sectors) as follows.[8] For each importing country and each sector, we use a simple

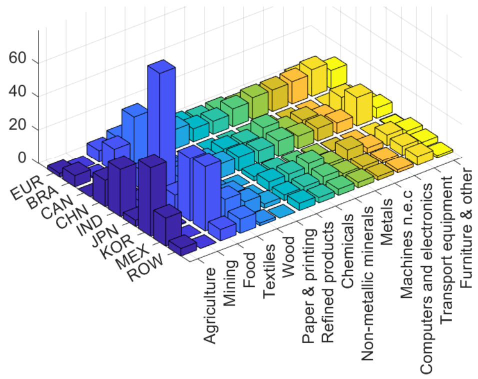
[8]We complement the product-level trade data using BACI—the world trade database developed by the CEPII—for missing values in the WITS database.

average of tariffs for *most imported products*. Specifically, the most imported products meet two conditions: (i) they cumulatively account for at least 80 percent of total sectoral imports for the importer, and (ii) they individually account for at least 0.005 percent of total sectoral imports.[9]

Figure 3 plots US tariff rates by sector and trading partner. The United States imposes lower import tariffs (left panel) than it faces on its exports (right panel). In terms of the simple average across countries, the tariff rate ranges from 0 percent in Paper and printing and 0.04 percent in Mining to 4.33 percent in Agriculture and 8.37 percent in Textiles. When averaged across sectors, the US tariff rate ranges from 0.07 percent for Mexico and 0.16 percent for Canada to about 2.5 percent for each of South Korea, Japan, and the EU. US exports face relatively high tariffs in Agriculture and Food, particularly in emerging markets such as Brazil, China, and India.

Figure 3: US Tariff Rates, Percentage Points





Notes: The left panel shows the tariff rates that the US imposes on imports from foreign countries. The right panel shows the tariff rates that US exports face in foreign markets.

3.2 Missing Trade Flows across US States

We have complete bilateral trade flows in manufacturing sectors (state-with-state, state-with-country, and country-with-country). For agriculture and mining we have state-with-country and country-with-country trade data, and for services we have country-with-country trade data. To our knowledge, there is no data on bilateral trade flows between US states for the agriculture, mining, or service sectors. In addition, there are no data on

[9] We do not use trade weights to average the product-level tariff rates, to ensure that the sector-level tariffs that each member of the European Union imposes is the same.

bilateral trade flows between states and foreign countries for the service sectors. In the appendix, we describe our procedure to construct estimates for the missing trade flows using available data on bilateral trade flows and production, as well as gravity variables, such as distance, common border and common language. The idea is to use gravity to predict missing trade flows and then make use of state-sector-level production data to impose adding-up constraints.

3.3 Parameters Estimated Using the Model

We use the model's gravity structure to estimate fundamental productivity and physical trade costs, as in Levchenko and Zhang (2016). Similarly to many common workhorse models of trade, the model's gravity structure from equation (2) links bilateral trade shares to comparative advantage forces and trade barriers as follows:

$$\ln\left(\frac{\mathrm{X}^j_{ni}}{\mathrm{X}^j_{nn}}\right) = \underbrace{\theta^j \ln\left(\frac{(A^j_i)^{\nu^j}}{u^j_i}\right)}_{S^j_i} - \underbrace{\theta^j \ln\left(\frac{(A^j_n)^{\nu^j}}{u^j_n}\right)}_{S^j_n} - \theta^j \ln\left(d^j_{ni}\right) - \theta^j \ln\left(1+\tau^j_{ni}\right),$$

where X^j_{ni} denotes location n's expenditure on location i's sector-j goods inclusive of the tariff.[10] S^j_n captures location n's relative state of technology in sector j as a convolution of its unit input costs, u^j_n, and productivity, A^j_n. Any regional differences in relative trade shares that are not accounted for by tariffs or by regional differences in states of technology are attributed to bilateral trade costs.

Since bilateral trade costs are unobservable, we impose a parsimonious relationship with observable gravity variables as follows:

$$\ln\left(d^j_{ni}\right) = \mathrm{ex}^j_i + \sum_{r=1}^{6} \gamma^j_{d,r}\mathrm{dis}^r_{ni} + \gamma^j_b \mathrm{bdr}_{ni} + \gamma^j_c \mathrm{cur}_{ni} + \gamma^j_l \mathrm{lng}_{ni} + \gamma^j_f \mathrm{fta}_{ni} + \epsilon^j_{ni}. \quad (7)$$

The specification includes various symmetric terms. One is a distance indicator, dis^r_{ni}, indexed by $r = 1, \ldots, 6$, capturing whether the distance (in miles) between locations n and i falls in certain intervals: $[0, 350)$, $[350, 750)$, $[750, 1500)$, $[1500, 3000)$, $[3000, 6000)$, and $[6000, \infty)$. The remaining symmetric terms—bdr_{ni}, cur_{ni}, lng_{ni}, and fta_{ni}—indicate whether locations share a common border, a common currency, a common official language, and whether they belong to a free trade agreement. The coefficients γ^j capture the

[10] The trade data in WIOD are "Free on Board producer prices," so we multiply these trade flows by the corresponding gross tariff rate to convert to purchaser prices, in line with the theory.

effects of symmetric indicators on bilateral trade costs in sector j. Asymmetry in trade costs is captured by an exporter-fixed effect, ex_i^j, based on Waugh (2010). Standard independence assumptions of the error term apply.

Combining the previous two equations and imposing the observed tariff rates together with calibrated θ^js yield a gravity equation in reduced form:

$$\ln\left(\frac{\mathrm{X}_{ni}^j}{\mathrm{X}_{nn}^j}\right) + \theta^j \ln\left(1+\tau_{ni}^j\right) = M_n^j + E_i^j + \left(\sum_{r=1}^{6}\beta_{d,r}^j \text{dis}_{ni}^r + \beta_b^j \text{bdr}_{ni} + \beta_c^j \text{cur}_{ni} + \beta_l^j \text{lng}_{ni} + \beta_f^j \text{fta}_{ni}\right) + \varepsilon_{ni}^j. \tag{8}$$

To improve precision in estimating the effect of geography $(\widehat{\beta}_{d,r}^j, \widehat{\beta}_b^j, \widehat{\beta}_c^j, \widehat{\beta}_l^j, \widehat{\beta}_f^j)$ we exploit as much geographic variation as we can. We first estimate equation (8) using data on bilateral trade between all 50 states and 42 non-US countries.[11] To avoid imposing an ad-hoc aggregation of the fixed effects (M_n^j, E_i^j) across the EU-28 countries, we revert to our original sample of 50 US states, the EU-28 aggregate, and 7 other foreign countries to re-estimate these regions' fixed effects, using the predicated symmetric components of their trade costs: $\sum_{r=1}^{6}\widehat{\beta}_{d,r}^j \text{dis}_{ni}^r + \widehat{\beta}_b^j \text{bdr}_{ni} + \widehat{\beta}_c^j \text{cur}_{ni} + \widehat{\beta}_l^j \text{lng}_{ni} + \widehat{\beta}_f^j \text{fta}_{ni}$.

We follow Levchenko and Zhang (2016) to recover the sectoral productivity and trade costs from the estimated fixed effects. The reduced-form estimates map into structural parameters as follows: $M_n^j = -S_n^j$, and $E_i^j = S_i^j - \theta^j \text{ex}_i^j$. We then construct bilateral trade costs between each location using the specification in equation (7).

The available degrees of freedom imply that in each sector the state of technology, S_n^j, is identified up to a normalization; we take Alabama as the reference location based on alphabetical ordering: $S_{AL}^j = 0$ for all sectors j. Information on sector-specific relative productivity levels across locations, A_n^j, is contained in the estimated relative states of technology, S_n^j. Recall that the state of technology is:

$$S_n^j = \ln\left(\left(A_n^j\right)^{\nu^j\theta^j}\left(u_n^j\right)^{-\theta^j}\right), \tag{9}$$

where the unit cost of an input bundle u_n^j is given by equation (3).

Factor prices (both wage rates) are computed as the compensation to the appropriate factor divided by the endowment of that factor; the measurement of each of these variables is described in Appendix B. We do not have data on sectoral prices either across countries

[11] These estimates map to $(\widehat{\gamma}_{d,r}^j, \widehat{\gamma}_b^j, \widehat{\gamma}_c^j, \widehat{\gamma}_l^j, \widehat{\gamma}_f^j)$ as $\gamma = -\beta/\theta$.

or states. We therefore recover sectoral prices based on equation (4) using the estimated trade costs and states of technology:

$$\left(p_n^j\right)^{-\theta^j} = \gamma^j \sum_{i=1}^{N} \exp\left(S_i^j\right)\left(d_{ni}^j(1+\tau_{ni}^j)\right)^{-\theta^j},$$

where $\gamma^j = \Gamma(1+\frac{1}{\theta^j}(1-\eta))^{1/(1-\eta)}$, and $\Gamma(\cdot)$ is the Gamma function. These inferred prices, together with factor prices, characterize the unit costs and identify the productivity from the state of technology using equation (9).

We impute the exporter fixed effect coefficient, ex_n^j, and the states of technology, S_n^j, for the ROW aggregate by regressing the respective estimates for all other locations against their log GDP per capita and log GDP, then recover a value for ROW using its GDP per capita and GDP.

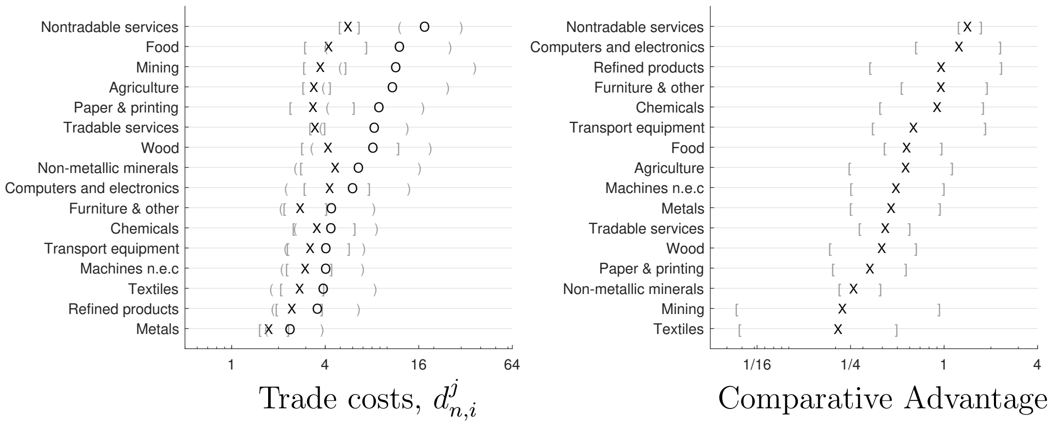
Skill-Sector-Location Amenities Finally, we calibrate amenity factors δ_n^{sj} to rationalize real state-sector-skill specific wage differentials that emerge from the baseline model with immobile factors, where the numbers of workers at the state-sector-skill level are taken from the data. In particular, we derive the ratios of amenities as the inverse of the ratios of real wages across sectors and states, expressed as follows:

$$\frac{1+\delta_i^{sk}}{1+\delta_n^{sj}} = \frac{w_n^{sj}/P_n^c}{w_i^{sk}/P_i^c}.$$

Without loss of generality, the amenity factor of sector 1 and state 1 is normalized to zero in the United States. Likewise, the amenity factor of sector 1 is normalized to zero in each foreign country. This calibration of amenities ensures that before any tariff change occurs, the equilibrium allocations of labor and associated factor prices remain identical under all three mobility assumptions: immobile factors, factors mobile across sectors only, and factors mobile across both states and sectors.

Estimated Trade Costs We first present the estimated iceberg trade costs in the left panel of Figure 4. The median state-to-state trade cost in each sector is illustrated with "X," and the median state-to-country trade cost with "O." Not surprisingly, in every sector the median state-to-state trade cost is lower than the median state-to-country trade cost. Moreover, the median state-to-state trade cost covaries with median state-to-country trade costs across sectors, with a correlation of 0.76. *Nontradable services* has the highest median trade cost, and *Metals* has the lowest median trade cost. For any sector, trade costs vary substantially not only across countries but also across states, as shown by square and round brackets reflecting the respective interquartile ranges. Non-metallic minerals have the greatest interstate dispersion in trade costs, and Mining has the greatest international dispersion.

Figure 4: Median Trade Costs and Comparative Advantage



Notes: In the left panel, "X" denotes the median state-to-state trade cost and square brackets reflect the interquartile range; "O" denotes the median state-to-country trade cost and round brackets reflect the interquartile range. Sectors are ordered by the median state-to-country trade cost from lowest (bottom) to highest (top). In the right panel, "x" denotes the median US state external comparative advantage and square brackets reflect the interquartile range across states. Sectors are ordered by US external comparative advantage from lowest (bottom) to highest (top). Comparative advantage is defined as the ratio of the median US state's competitiveness to median foreign competitiveness: $\exp(S^j_{\text{median-USA}})/\exp(S^j_{\text{median-foreign}})$.

Estimated Comparative Advantage We next show the patterns of estimated comparative advantage. We first look at the overall competitiveness of the United States relative to trading partners across sectors. To do so, we define *US external comparative advantage* as the ratio of the median competitiveness $\exp(S_n^j)$ of US states relative to the median of foreign countries, which is marked as "X" for each sector in the right panel of Figure 4. Among the goods-producing sectors, the United States has comparative advantage in Computers and electronics, Refined products, Furniture & other, and Chemicals, and it has comparative disadvantage in Textiles, Mining, and Non-metallic minerals.

States also differ in their competitiveness within each sector.[12] This can be seen from the square brackets, which depict the interquartile range across states for each sector. In

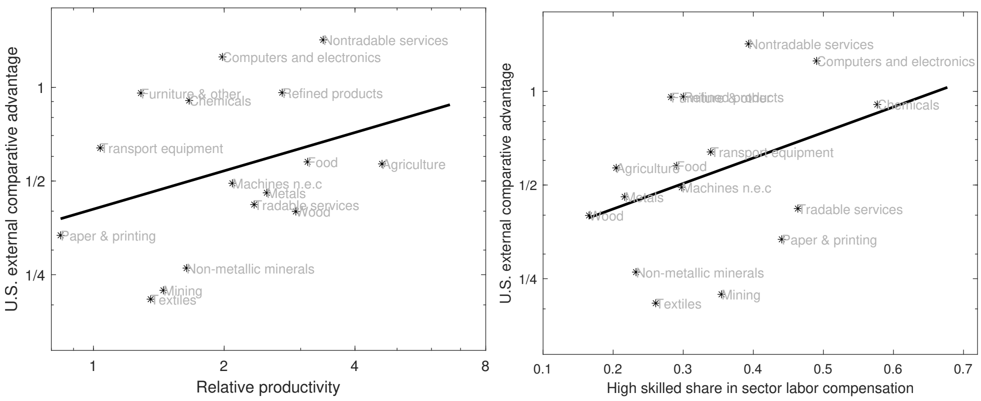
[12]Our competitiveness measure incorporates both fundamental productivity and factor input costs. The former boosts competitiveness, while the latter reduces it.

Mining, the state at the 75th percentile is 20 times more competitive than the state at the 25th percentile. This dispersion determines *state internal comparative advantage*, or the ratio of a state's $\exp(S_n^j)$ to the median $\exp(S_n^j)$ of US states. The pattern of state internal comparative advantage plays a critical role in understanding the differential impact of changes in trade policy across states.

3.4 Sources of Comparative Advantage

We now shed light on the sources of US external comparative advantage and state internal comparative advantage. US external comparative advantage comes from both productivity and endowments. Sectoral relative productivity—the ratio of the median US state productivity to the median foreign productivity— is positively correlated with US external comparative advantage across sectors, as shown in the left panel of Figure 5. The correlation is 0.24. Sectoral skill intensity, λ^{hj}, is also positively correlated with US external comparative advantage across sectors, as illustrated in the right panel of Figure 5; the correlation is 0.41. Given that the United States is relatively abundant in high-skill labor, endowment differences give rise to its external comparative advantage in sectors in high-skill intensive sectors.

Figure 5: Sources of US External Comparative Advantage

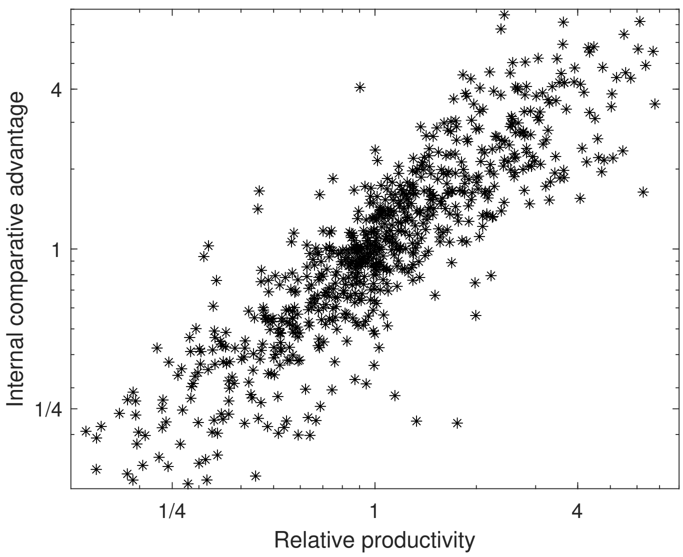


Notes: US external comparative advantage is defined as the ratio of the median US state's competitiveness to median foreign competitiveness: $\exp(S^j_{\text{median-USA}})/\exp(S^j_{\text{median-foreign}})$. Relative productivity is defined as the ratio of the median US state's fundamental productivity to median foreign fundamental productivity: $A^j_{\text{median-USA}}/A^j_{\text{median-foreign}}$. High-skill share in sector labor compensation is defined as λ^{hj}.

Consider two sectors where the US has a comparative advantage (Computers and Chemicals) and two where it has a comparative disadvantage (Mining and Textiles). Computers and Chemicals have higher relative productivity and also higher high-skill intensities than Mining and Textiles. Specifically, the high-skill intensity is 0.58 for Chemicals and 0.49 for Computers and electronics compared with 0.36 for Mining and 0.26 for Textiles. Agriculture stands out with the highest relative productivity but the second-to-lowest high-skill intensity, which jointly determines its near-median position across sectors in terms of external comparative advantage.

Now we consider state internal comparative advantage. Quantitatively, the internal comparative advantage of a state is mainly determined by relative productivity differences instead of relative labor endowment differences. Figure 6 demonstrates that when a state's sectoral productivity, relative to the median US sectoral productivity, $A_n^j/A^j_{\text{median-USA}}$, is high, its internal comparative advantage, $\exp(S_n^j)/\exp(S^j_{\text{median-USA}})$, is also high. The slope of the relationship is close to one, and deviations from this relationship are due to heterogeneous factor prices across states resulting from general equilibrium effects based on geography and heterogeneous trade costs.

Figure 6: Sources of State Internal Comparative Advantage



Notes: State internal comparative advantage is defined as the ratio of state n's competitiveness to the median US state's competitiveness: $\exp(S_n^j)/\exp(S^j_{\text{median-USA}})$. Relative productivity is defined as the ratio of state n's fundamental productivity to the median US state's fundamental productivity: $A_n^j/A^j_{\text{median-USA}}$.

The cross-state ranking of fundamental productivity within each sector is intuitive. For example, Michigan has the highest fundamental productivity in Transport equipment, Oregon the highest in Wood, and Louisiana in Refined products. These inferred productivity levels reflect the patterns of trade, particularly through export intensity. We also obtain sensible predictions for the service sectors. In Tradable services, New York has the highest fundamental productivity, followed by Massachusetts and Connecticut, each of which has a high concentration of finance and insurance activity. In Nontradable services, the three states with the highest fundamental productivity are Hawaii, Nevada, and Alaska, each of which attract a large share of tourism and in turn maintain relatively large hospitality industries.

We conclude the calibration by checking the model fit along several dimensions. The correlation between model and data bilateral trade shares ranges from 0.76 to 0.98 across sectors. The cross-country correlation between the model and data for sectoral shares in value added ranges from 0.51 to 0.99, and the cross-state correlation from 0.85 to 1.00.

4 Impacts of Tariff Changes with Immobile Factors

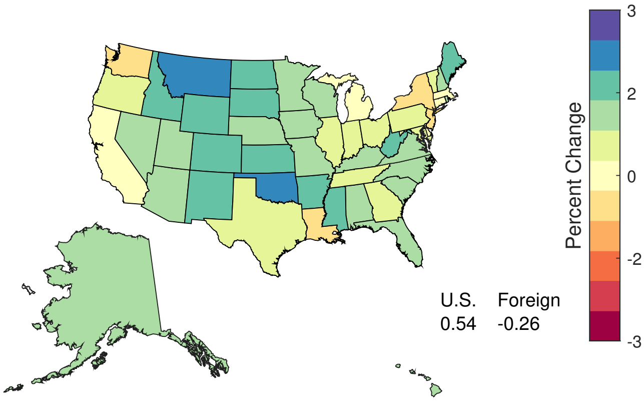
In this section, we begin by quantifying the consumption effects of a uniform increase in US import tariffs across sectors and identify the key state-level characteristics that drive cross-state heterogeneity in consumption changes. We then analyze the implications when foreign countries implement a tit-for-tat retaliation. Next, we study the effects of sector-specific tariff changes and alternative methods of redistributing tariff revenue across states. Throughout this section, factors remain immobile across sectors and states—a restriction we relax in the following section.

4.1 US Unilateral Tariff Increases

In the main counterfactual, we increase the US import tariff rates in goods sectors by 25 percentage points, while the tariff rates levied by foreign countries remain unchanged at the baseline levels. Specifically, the US import tariff schedule increases from τ to $\widetilde{\tau} = \tau + 0.25$. On a population-weighted average, this policy results in a 0.54 percent increase in US consumption, while foreign countries experience a 0.26 percent decline. The higher US import tariffs significantly reduce US imports, which fall from 11.2 percent to 6.7 percent of GDP.

The aggregate impact of the tariff increase masks the sizable dispersion of its impact across states. Figure 7 highlights this dispersion, with consumption changes ranging from a 0.8 percent decline in Washington to a 2.3 percent increase in Montana. To understand the mechanisms behind cross-state heterogeneity, we decompose the consumption change

Figure 7: Percent Change in Consumption Across US States



Notes: Changes in consumption associated with increasing US import tariffs in each sector uniformly by 25 percentage points. In terms of population-weighted averages, the United States gains 0.54 percent in consumption, while foreign countries collectively lose 0.26 percent.

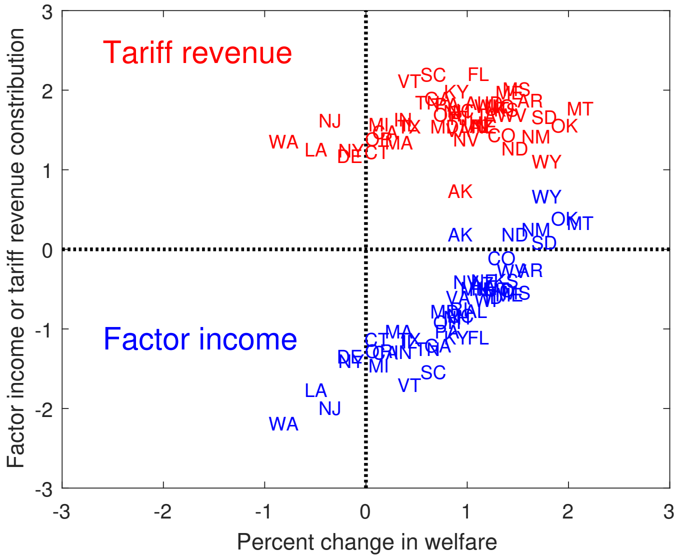
for each US state using the following expression, derived from equation (1):

$$\frac{\widetilde{C}_n}{C_n} - 1 = \overbrace{\underbrace{\left(\frac{F_n}{P^c_n C_n}\right)}_{\substack{\text{Initial factor}\\ \text{income share}}} \underbrace{\left(\frac{\widetilde{F}_n/\widetilde{P}^c_n}{F_n/P^c_n} - 1\right)}_{\substack{\%\Delta \text{ in real}\\ \text{factor income}}}}^{\text{Factor income contribution}} + \overbrace{\underbrace{\left(\frac{T_n}{P^c_n C_n}\right)}_{\substack{\text{Initial tariff}\\ \text{revenue share}}} \underbrace{\left(\frac{\widetilde{T}_n/\widetilde{P}^c_n}{T_n/P^c_n} - 1\right)}_{\substack{\%\Delta \text{ in real}\\ \text{tariff revenue}}}}^{\text{Tariff revenue contribution}}, \tag{10}$$

where variables with $\widetilde{}$ are outcomes under the counterfactual tariff schedule $\widetilde{\tau}$, and those without $\widetilde{}$ are outcomes from the baseline. The consumption change has two components: the factor income contribution and the tariff revenue contribution. Specifically, the factor income contribution is the percent change in real factor income, weighted by the initial share of factor income in consumption. Similarly, the tariff revenue contribution is the percent change in real tariff revenue, weighted by the initial share of tariff revenue in consumption. Given that tariff revenue is redistributed to equate real tariff income across states, the tariff revenue contribution differs across states only due to their initial tariff revenue shares.

Figure 8 plots the factor income contributions (blue) and the tariff revenue contributions (red) against the consumption changes for each state. The first thing to notice from Figure 8 is that the factor income contribution is negative in most states, with an average loss of 0.74 percent. Mechanically, nominal factor returns increase in the US, relative to abroad, following the unilateral tariff increase as a result of increased demand for domestically produced goods. The loss in real factor income thus reflects higher con-

Figure 8: Consumption Change Across US states: Factor Income and Tariff Revenue



Notes: The decomposition of consumption changes into factor income contributions (blue), and the tariff revenue contributions (red) are based on equation (10). The two contributions sum to the percent change in consumption.

sumer prices. Specifically, nominal factor returns across US states increase by about 8 percent, on average; the consumer price level increases more than 9 percent. The price increase is substantially less than the 25 percent tariff increase for two reasons. One is that imports constitute only part of the final consumption basket. The other is through the terms-of-trade effect: the US is a large economy, so when it raises tariffs, world demand for foreign goods declines, reducing the free-on-board prices of US imports; that is, the higher tariff rate is applied to a lower pre-tariff price.

The second prominent feature is that the tariff revenue contribution is positive in all states, with an average of 1.7 percent. We unpack this number using a back-of-the-envelope calculation at the US level. Prior to raising tariffs, the average US tariff rate is 2 percent across sectors, with imports amounting to 11.2 percent of GDP, implying that the tariff revenue is about 0.2 percent of GDP. In the counterfactual, the average tariff rate rises to about 27 percent across sectors, while imports drop to 6.7 percent of GDP and tariff revenue rises to about 1.8 percent of GDP—a nine-fold increase. At the same time, the average final consumption price increases by 9 percent. This implies that real tariff revenue changes by about $1,000$ percent. Given an initial share of the tariff revenue in GDP of 0.2 percent, the tariff revenue contribution for the US is 0.2 percent of 1000 percent, which is just above 1.7 percent.

Regarding cross-state heterogeneity, we find substantial variation in the factor income contribution and limited variation in the tariff revenue contribution. The cross-state variance of factor income contributions is 0.40, close to the variance of consumption changes of 0.46. In contrast, the variance of tariff revenue contributions is only 0.08. Moreover, as Figure 8 shows, consumption changes across states positively co-vary with factor income contributions far more than with tariff revenue contributions; the respective correlations are 0.91 and 0.36. For instance, Wyoming gains 1.91 percent in consumption compared with 0.30 percent for Oregon. This difference primarily reflects the disparity in the factor income contributions: 0.68 percentage points for Wyoming and −1.25 percentage points for Oregon. Meanwhile, the difference in tariff revenue contributions is less stark: 1.23 percentage points for Wyoming and 1.55 for Oregon. This is an implication of how tariff revenue is distributed across states. Hence, to understand heterogeneity in consumption changes across states, we need to unpack the variation in real factor income contribution.

Variation in Factor Income Contribution: State versus Sector We define sectoral real factor income in state n, sector j as f_n^j/P_n^c, where f_n^j is the factor income and P_n^c is the consumer price level. The total real factor income in a location is the sum of real sectoral factor income, weighted by sector shares in nominal factor income. In response to changes in tariffs, both high- and low-skill workers within a location realize proportionate changes in wages, while these changes vary across sectors.[13] Moreover, all workers in a location consume the same basket of goods and thus experience the same change in the consumer price level. The change in real factor income in a location is:

$$\frac{\widetilde{F}_n/\widetilde{P}_n^c}{F_n/P_n^c} - 1 = \sum_{j=1}^{J} \underbrace{\left(\frac{f_n^j}{F_n}\right)}_{\text{sectoral share}} \underbrace{\left(\frac{\widetilde{f}_n^j/\widetilde{P}_n^c}{f_n^j/P_n^c} - 1\right)}_{\text{sectoral change}}. \tag{11}$$

We first focus on the "sectoral change" component of equation (11) and decompose the variation of sectoral changes in real factor income across states into state and sector fixed

[13] Since there are no differential impacts across high- and low-skill workers, our model with factor immobility does not speak to distributional impacts across skill/income levels. In a later section, we introduce factor mobility, giving rise to Heckscher-Ohlin forces that induce changes in the skill premium in response to changes in tariffs. As an alternative, Carroll and Hur (2022) study a model where consumers have different expenditure shares in their baskets across income levels and thus are impacted differently from changes in trade costs.

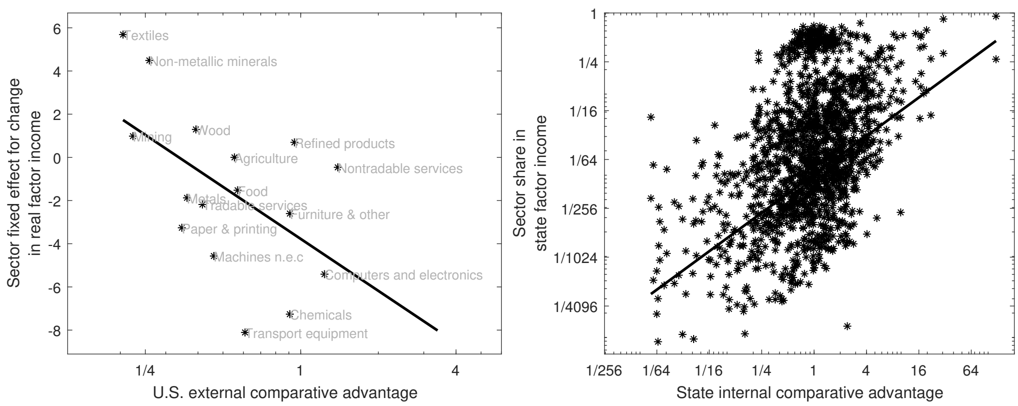
effects by running the following regression:

$$\frac{\widetilde{f}_n^j / \widetilde{P}_n^c}{f_n^j / P_n^c} - 1 = \mathbf{FE}^j + \mathbf{FE}_n + \epsilon_n^j. \tag{12}$$

where $\mathbf{FE}^j$ are sector fixed effects and $\mathbf{FE}_n$ are state fixed effects. The regression yields an R^2 of 0.77, with sector fixed effects accounting for 79 percent of the total variance and state fixed effects accounting for only 3 percent. These results indicate the presence of a significantly strong sector component and a relatively weak state component. Intuitively, the impact of tariff changes on a typical worker depends primarily on the sector of employment and less on the location of the worker.

We find that the sector fixed effects are largely governed by US external comparative advantage. The left panel of Figure 9 shows that sectors in which the United States has a comparative advantage exhibit lower sector fixed effects (i.e., smaller gains or larger losses). Similarly, sectors in which the United States has a comparative disadvantage present larger fixed effects (i.e., larger gains or smaller losses). Intuitively, protection benefits sectors for which the United States has a comparative disadvantage, since production increases in these sectors boosting the factor income to workers in those sectors.

Figure 9: Sectoral Implications of the Tariff Increase, Percent Change



Notes: The sector fixed effect for change in real factor income is defined as the fixed effect $\mathbf{FE}^j$ in equation (12). US external comparative advantage is defined as the ratio of the median US state's competitiveness to median foreign competitiveness: $\exp(S^j_{\text{median-USA}})/\exp(S^j_{\text{median-foreign}})$. State internal comparative advantage is defined as the ratio of state n's competitiveness to the median US state's competitiveness: $\exp(S^j_n)/\exp(S^j_{\text{median-USA}})$.

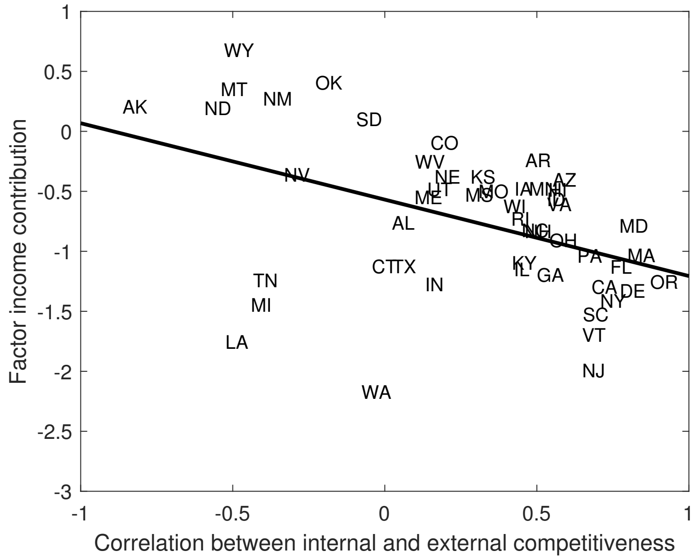
Since the majority of the variance in real sectoral factor income changes is due to sector effects, variation in total real factor income at the state level ultimately reflects cross-state variation in *exposure* to different sectors. This exposure is captured by the sectoral share in factor income, as in equation (11). In theory, comparative advantage drives sectoral shares across locations. For US states, both external and internal comparative advantage influence these shares, with their relative importance depending on the magnitudes of external versus internal trade costs. Our calibration shows that external trade costs are significantly higher than internal trade costs across all sectors, implying that sectoral shares within states are largely driven by internal comparative advantage. As shown in the right panel of Figure 9, state-sector pairs realize greater increases in real factor income when a sector accounts for a large share of that state's factor income. In other words, states tend to be more concentrated in, and thus exposed to, sectors for which they are relatively more competitive, internally.

Sources of Cross-State Variation in Factor Income Contribution According to equation (11), the change in a state's real factor income is equal to the inner product between its initial sectoral shares in factor income and the change in its sectoral factor income. State sectoral shares reflect states' internal competitiveness: states concentrate more in, and thus are exposed more to, sectors that they are internally competitive in. Sector fixed effects account for most of the variation in the state-level sectoral changes in factor income, which reflects US external competitiveness across sectors. Specifically, sectors in which the US is more externally competitive suffer larger losses with a higher import tariff. Overall, these findings suggest that a state suffers more from high tariffs when its internal competitiveness highly correlates with US external competitiveness.

Figure 10 demonstrates this point: a state's factor income contribution is negatively correlated with the "similarity" of its sectoral competitiveness to that of the US. Our preferred measure of "similarity" is a weighted correlation between each state's sectoral competitiveness and the median state's sectoral competitiveness. The state-specific weights are defined as each state's sectoral shares in factor income. For instance, Oregon's sectoral competitiveness profile correlates positively with that of the US since its relative competitiveness is high in Computers and electronics and low in Mining. Conversely, Wyoming's competitiveness profile correlates negatively with that of the US since its relative competitiveness is low in Computers and electronics and high in Mining.

The similarity of a state's competitiveness with US competitiveness plays a first-order role in determining the impact of higher tariffs on factor income across states. Nonetheless, heterogeneity in external trade costs across states also plays a role. As shown in Figure 10, some states, such as Louisiana and Michigan, have a negative correlation between internal competitiveness and US external competitiveness, but experience negative

Figure 10: Factor Income Changes vs. Similarity in Competitiveness



Notes: The vertical axis is the factor income contribution to each state's consumption change when US tariffs are unilaterally increased by 25 percentage points in all sectors. The horizontal axis is the weighted correlation between a state's sectoral competitiveness and the median US state's competitiveness across sectors. The state-specific weights are defined as the sector shares in factor income.

factor income contributions. These states tend to have lower-than-average foreign import costs (weighted by sector and foreign trading partner). That is, deviations from the predicted line in the figure have a strong positive correlation with foreign import costs.

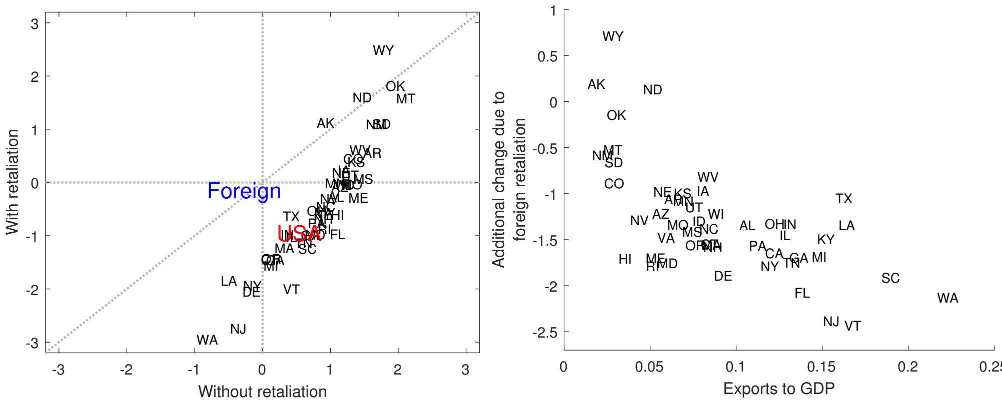
In sum, cross-state heterogeneity in consumption changes depends mainly on the variation in the factor income contribution and less on variation in the tariff revenue contribution. The factor income contribution of a state hinges on its sectoral concentration because the tariff increase has significantly differential impacts across sectors rather than across geographic locations. US external comparative advantage determines how each sector is impacted, whereas internal comparative advantage determines how exposed each state is to each sector. As a result, states whose sectoral productivity profile differs most from the median US state tend to benefit more from increased tariff rates.

4.2 Retaliatory Tariffs

So far we have examined unilateral tariff increases imposed by the United States. In practice, foreign countries respond through disputes with the World Trade Organization (WTO) or by imposing retaliatory tariffs. We now study the effects when foreign countries impose tit-for-tat retaliation, whereby foreign countries increase their tariff by 25 percentage points on their imports from the US across all goods sectors. We assume that all tariffs between non-US country pairs remain unchanged.

Relative to the baseline, the US population-weighted consumption decreases by 0.94 percent, in contrast to an increase of 0.54 percent without retaliation. Population-weighted consumption for foreign countries decreases by 0.13 percent with retaliation, compared with a decrease of 0.26 percent with no retaliation. Indeed, retaliation mitigates the losses for foreign countries as the US' terms of trade advantage diminishes.

Figure 11: Consumption Change Across US States with Foreign Retaliation



Notes: The left panel plots the consumption change from unilateral tariff increases on the horizontal axis and the consumption change from a trade war with retaliation on the vertical axis. The diagonal dotted line is the 45-degree line. The right panel plots the difference in gains with and without retaliation against exports to GDP. Exports to GDP for a state are defined as a state's exports to foreign countries as a share of its GDP at the baseline tariffs.

At the state level, most states gain less, or lose more, when there is retaliation than under a unilateral tariff increase, as shown in the left panel of Figure 11. The right panel illustrates that the additional consumption loss from retaliation, relative to a unilateral tariff increase, is smaller for states that export less to foreign countries.[14] We also find that the additional change in real factor income from retaliation, relative to a unilateral tariff increase, is positive for Wyoming, North Dakota, and Alaska. These states export very little to foreign countries and also benefit from lower wages and lower goods prices in other states such as Oregon, from which they source a large portion of their goods.

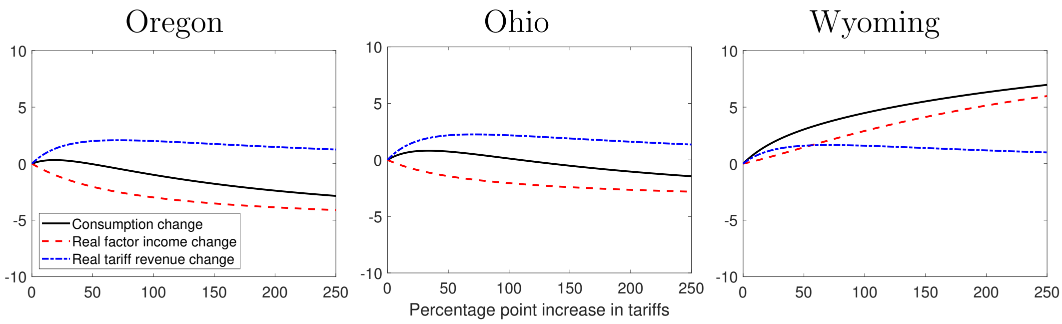
[14]Santacreu and Peake (2020) find empirically that states that were more exposed to trade experienced lower output and employment growth following the US-China trade war.

4.3 Heterogeneous Tariff Preferences across States

The cross-state heterogeneity documented above highlights that a uniform 25 percent increase in the US tariff rate impacts states differently, creating tensions in setting a common external tariff for the US customs union. In this subsection, we first characterize state-level preferences across a range of tariff increases and demonstrate the substantial variation in each state's preferred tariff rate. Second, we demonstrate that even sector-specific tariffs do not eliminate these tensions, as there will always be winners and losers. Importantly, these results depend on the baseline tariff revenue redistribution rule. In the next section, we will discuss how these tensions can be mitigated by adjusting tariff revenue redistribution in conjunction with the tariff changes.

Uniform Tariff Increases across Sectors To highlight heterogeneous preferences over tariff changes, we ask the following question: If each state could individually raise US tariffs uniformly across sectors, how much would it choose to increase? To answer this question, we construct a Laffer-like curve for each state by tracing out its consumption change, relative to the baseline tariff schedule, as the tariffs in all sectors increase uniformly without foreign retaliation. Figure 12 plots the consumption curves for three selected states: Oregon, Ohio, and Wyoming. The solid black lines describe the percentage change in consumption over a wide range of tariff increases. The contributions from both real factor income and real tariff revenue are depicted by the red-dashed lines and the blue-dotted lines, respectively.

Figure 12: Percent Change in Consumption Relative to Baseline Tariffs



Notes: The horizontal axis depicts the range of percentage-point increases in tariffs across all sectors. The solid black line represents the consumption change for each percentage point increase in tariffs, relative to the baseline tariff schedule. The dashed red line represents the factor income contribution, and the dash-dotted blue line represents the tariff revenue contribution.

For all three states, the tariff revenue contribution exhibits similar hump shapes across the tariff changes. However, the pattern for the factor income contribution differs. For Oregon and Ohio, the factor income contribution declines monotonically as the tariff increases. For Wyoming, the factor income contribution increases monotonically with the tariff. As a result, for states like Oregon and Ohio, there exists a finite optimal tariff rate that maximizes their consumption, whereas states like Wyoming prefer an infinite tariff rate.[15] Overall, we find that the states that prefer high tariff rates are those that gain the most in consumption from a uniform 25 percentage point tariff increase.

Wyoming's preference for an ever-higher common external tariff is shaped by two key factors: the negative correlation between its internal comparative advantage and US external comparative advantage, and its membership in a large customs union. When the US increases tariffs on foreign imports, domestic spending shifts toward Wyoming's products, driven by this negative correlation. For example, a 25-percentage-point tariff hike increases Wyoming's share in US value added increases by 2.6 percent. At the same time, duty-free trade within the union limits the impact of higher external tariffs on local prices. Wyoming relies heavily on trade with other US states, importing eight times more from other US states than from abroad, compared to the national average of five times. Consequently, Wyoming's price level rises by only 0.2 percent relative to the median US state following the tariff increase.

To illustrate the quantitative importance of being part of a customs union, we consider two alternative scenarios. In the first scenario, Wyoming is part of a free trade agreement (FTA) with the rest of the US rather than a customs union member. Wyoming unilaterally increases its tariffs on imports from foreign countries while maintaining duty-free trade with other US states. However, the remaining US states do not adjust their tariffs on imports from foreign countries. Under these conditions, Wyoming gains no economic advantage from increasing its tariffs by any magnitude. In particular, a 25-percentage-point tariff increase results in a 0.95-percent decline in consumption, contrasting sharply with the 1.91-percent increase observed when the entire customs union imposes the same tariff increase on foreign countries. Furthermore, Wyoming's share in US value added is effectively unchanged because the other US states do not significantly shift their expenditures from foreign goods to Wyoming's products. Its price level rises by 9 percent relative to the median US state.

In the second scenario, Wyoming secedes from the US customs union and no longer benefits from duty-free trade with other US states. Wyoming imposes uniform tariffs on

[15]Three other states—Alaska, North Dakota, Oklahoma—similarly prefer infinite tariffs. Notably, these states rank among the top four in terms of the share of mining in their state-level GDP.

all sectors and trading partners, including other US states, while the remaining US states maintain their existing tariff policies. Operating effectively as a small open economy, Wyoming does not benefit from higher tariffs on its trading partners. A 25-percentage-point tariff increase results in a 11.35-percent decline in consumption. While its share in US value added rises marginally by 0.7 percent, Wyoming's price level surges by 13.7 percent compared to the median US state. This drastic increase in its relative price level reflects the fact that a small open economy cannot improve its terms of trade by raising tariffs. This is consistent with the classic result that the optimal tariff for a small open economy is zero, even in the absence of retaliation.

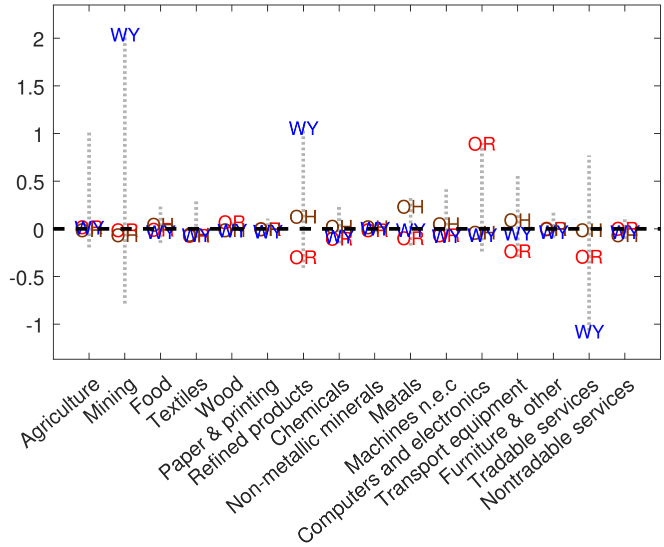
Sector-Specific Tariff Increases So far we have emphasized how states are impacted differentially by a uniform tariff change across all sectors. We now explore the heterogeneity across states in response to sector-specific tariff changes. To do this, we increase the US import tariff rate by 25 percentage points in one sector at a time, keeping the tariff rates in all other sectors at their baseline values. In each case, the tariff change is implemented unilaterally by the United States with no foreign retaliation. Figure 13 shows the range of consumption changes across US states for each sector-specific tariff increase. It also indicates the position of three states in the distributions: Wyoming, Ohio, and Oregon.

One result is that there is no sector where every state either simultaneously gains or simultaneously loses from an increase in that sector's tariff rate. Wyoming gains substantially from higher tariffs in two sectors: Mining and Refined products. Meanwhile, tariff increases in any other sector result in consumption losses for Wyoming. In a similar vein, Oregon is the biggest gainer among US states when the tariff increases for Computers and electronics, but it tends to lose with tariff increases in other sectors. The effects of raising the tariff in any given sector are mild for Ohio, because Ohio has neither a strong comparative advantage nor disadvantage in any sector, as the number of states exceeds the number of sectors.

4.4 Importance of Redistribution for Efficiency

In all the analyses above, we assume that US tariff revenue is redistributed equally across states as real transfers to all workers. Empirically, there is no specific budgeting rule to leverage, as the federal government does not earmark tariff revenue for particular expenditure. However, because the US is a fiscal union, there are no inherent restrictions

Figure 13: Percent Change in Consumption From Sector-Specific Tariff Changes



Notes: The vertical dotted lines depict the range of consumption changes across US states when the US import tariff is increased by 25 percentage points in each sector, on sector at a time. The positions of Wyoming, Ohio, and Oregon are shown in each case.

on how tariff revenue is allocated. We can therefore design tariff revenue redistribution rules, in conjunction with tariff schedules, to achieve efficiency of trade policy changes for the US. A policy change is Kaldor-Hicks efficient if the US as a whole gains, even if some states lose, as long as redistribution from winners to losers could, in theory, ensure a net positive aggregate gain. A stricter notion, Pareto efficiency, requires that any policy change makes at least one state better off without making any state worse off. Additionally, we insist that transfers to each state must be funded exclusively through newly generated tariff revenue, meaning non-negative transfers to each state.

We find that the 25-percentage-point tariff increase, combined with the baseline redistribution rule, achieves Kaldor-Hicks efficiency but falls short of Pareto efficiency. As discussed earlier, while the US as a whole gains, some states lose under the baseline redistribution rule. This raises an important question: Is there a redistribution rule that, when paired with the tariff change, delivers Pareto efficiency? The answer is yes. We find one such rule that yields Pareto efficiency, is fully financed by the newly created tariff revenue, and also equalizes consumption gains across states.[16] Intuitively, since the increase in US tariff revenue exceeds the loss in US factor income, every state can re-

[16]There are multiple redistribution rules that could deliver Pareto efficiency. Solving for such a redistribution rule involves a fixed-point problem as, in principle, the size of the US pie and the change in real factor income across states are endogenous to the redistribution rule.

ceive a positive transfer. Furthermore, under this rule, states experiencing larger declines in real factor income receive greater per-capita transfers. For example, the transfer to Washington is more than 15 times that to Wyoming on a per-capita basis.

To assess the robustness of our results surrounding redistribution rules, we consider three sensible alternatives. The first is state-level retention, where each state keeps the tariff revenue generated by its own imports. That is, each state has its own customs agency with no cross-state transfers. The second is population-based distribution, where each state receives a transfer proportionate to its population shares. This rule is more progressive, as high income per capita states receive less than in the baseline. The third is GDP-based distribution, where transfers are allocated based on each state's nominal GDP shares. In this rule, states with lower price levels receive less than in the baseline.

Each of these cases is Kaldor-Hicks efficient in response to tariff changes, but not Pareto efficient. Furthermore, in each case, the overall change in US consumption remains nearly identical, and factor income contributions at the state level are unaffected by the particular redistribution rule. The difference among these rules lies in the tariff revenue contribution across states, which in turn affects consumption changes across states. These findings suggest that transfers can be designed to improve efficiency without altering overall factor income contributions or total economic gains (the "size of the US pie").

5 Further Analysis

In this section, we extend our quantitative analysis in several dimensions. First, we allow labor mobility across sectors and states to examine the longer-term implications of tariff increases. Second, we analyze how the skill premium responds to tariff changes under different labor mobility scenarios. Third, we conduct robustness checks on trade elasticities. Finally, we provide a quantitative analysis of the trade war during the first Trump administration.

5.1 Factor Mobility

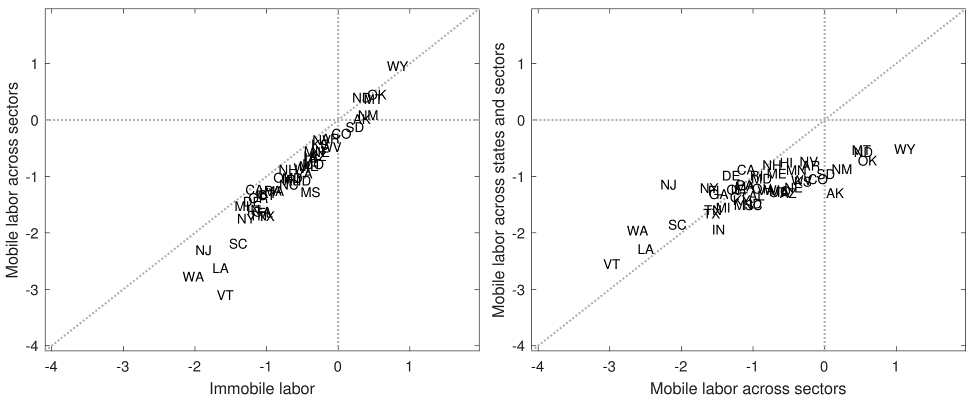
The previous section studied the short-term effects of trade policy changes under the assumption of factor immobility. Here, we extend the analysis to examine the longer-term implications of tariff changes by introducing factor mobility. We consider two degrees of factor mobility. First, factors are allowed to move freely across sectors within a given location, reflecting medium-term responses to tariff changes. Second, we allow factors to move freely across both sectors and states, capturing long-term responses. In both cases, factors remain immobile across countries. Our finding indicates that factor mobility does not change the relative ranking of the heterogeneous impacts of tariff increases on changes in real factor income across states. However, factor mobility within states slightly amplifies the variance of these impacts. Only when factors are mobile across states does the variance in these impacts decline.

Figure 14 illustrates how factor mobility shapes the impact of tariffs on real factor income across states. The left panel compares changes in consumption following a unilateral 25 percent tariff increase under two scenarios: sectoral mobility (y-axis) and factor immobility (x-axis). Although sectoral factor mobility does not substantially alter the relative ranking of these changes across states, as evidenced by the high correlation between the two scenarios (0.96), it does amplify the standard deviation in changes across states (0.82 under sectoral mobility versus 0.63 under immobility). Under factor immobility, sectors like Mining experience significant wage increases, while sectors like Computers experience large wage declines, consistent with US external comparative advantage patterns following tariff increases. When labor can move across sectors, workers move from low-wage-growth sectors like Computers to high-wage-growth ones like Mining within a state.[17] However, the internal comparative advantage structure differs across states: Mining is a relatively high-wage sector in Wyoming but a relatively low-wage sector in Washington. Consequently, labor mobility increases real factor income in Wyoming, where workers benefit from moving to high-wage sectors, but reduces it in Washington, where the opposite occurs.

The right panel of Figure 14 compares changes in real factor income in response to a unilateral 25 percent tariff increase under state and sectoral mobility (y-axis) with those under sectoral mobility only (x-axis). While state mobility barely changes the relative rankings of these changes across states, as shown by the high correlation between the two scenarios (0.82), it substantially reduces the standard deviation in these changes (0.41 under state and sector factor mobility compared to 0.82 under sectoral mobility alone). The reduction in the variance occurs because workers relocate to states with initially higher real factor income gains, leading to more equalized changes in factor income across states when only sectoral mobility is allowed. However, due to differences in amenities across states and sectors, wage levels continue to vary even under state and sector mobility. As states differ in their factor share across sectors, the disparity in tariff

[17] In the presence of sectoral mobility, wage differences across sectors are equal to the exogenous amenities: relatively low wage sectors have relatively high amenity values.

Figure 14: Impact of Tariff on Real Factor Income with Factor Mobility



Notes: The left panel compares factor-income changes from unilateral tariff increases, with the horizontal axis representing the case of immobile factors and the vertical axis representing the case of mobile factors across sectors within a state. The right panel illustrates real factor income changes under sectoral mobility within a state (horizontal axis) versus mobility across both sectors and states (vertical axis). In both panels, the diagonal dotted line represents the 45-degree line.

impacts persists across states.

5.2 Wage Inequality and the Skill Premium

Up to this point, our results focused on wage inequality either across sectors or across states. This subsection explores wage inequality across skill types and defines the skill premium as the ratio of high-skill to low-skill wages. In the model, the skill premium in location n and sector j equals the product of (i) the ratio of high-skill to low-skill labor share in production and (ii) the ratio of the high-skill to low-skill labor in the sector-location:

$$\frac{w_n^{hj}}{w_n^{\ell j}} = \left(\frac{\lambda_n^{hj}}{\lambda_n^{\ell j}}\right)\left(\frac{e_n^{\ell j}}{e_n^{hj}}\right). \tag{13}$$

When workers are immobile and the elasticity of substitution between high-skill and low-skill labor is one, the skill premium in each sector and location is invariant to changes in tariffs, i.e., the right-hand side of equation (13) does not vary with the tariff.

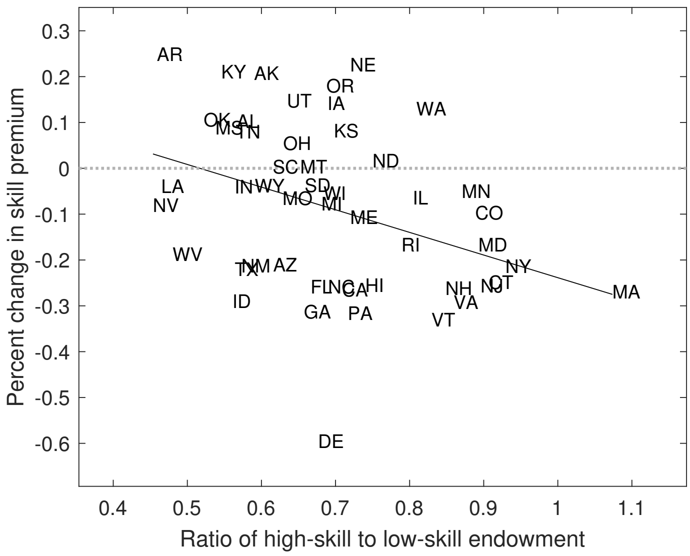
With sectoral factor mobility, the changes in the wage premium in equation (13) differ across states, as long as the changes in the ratio of $e_n^{\ell j}$ to e_n^{hj} in sector j are not identical across states, in response to the tariff increases.[18] The changes in the skill premium are the same across sectors in each state, because factor mobility across sectors equates

[18] Another way to introduce responses of the skill premium to the tariff change is to adopt a non-unitary elasticity of substitution between the skill types, such as in Parro (2013).

sectoral wages up to exogenous amenity differences regardless of tariff changes.

Figure 15 depicts the change in the skill premium across US states following a unilateral 25 percentage point increase in tariffs. The change in the skill premium ranges from −0.6 percent in Delaware to 0.3 percent in Arkansas, with a median of −0.1 percent in Michigan and Missouri. Indeed, most states realize a decrease in the skill premium, because the US has a relative abundance of high-skill workers compared to the rest of the world. Moreover, the decline in the skill premium tends to be larger in states with a relatively greater abundance of high-skill workers. These results are consistent with the classic Heckscher-Ohlin mechanism, in which the return to the relatively abundant factor of production tends to decrease compared to that of the relatively scarce factor after increased trade protections.

Figure 15: Changes in Skill Premium with Sectoral Factor Mobility



Notes: The x-axis is the endowment ratio of high-skill to low-skill workers in each state. The y-axis is the percentage change in the wage premium for the Agriculture sector in each state in response to a unilateral 25-percentage-point unilateral increase in tariffs. The change in the wage premium is identical across sectors within each location.

When workers can move between states, the skill premium equalizes across states, as wages converge, adjusted for exogenous amenity differences in each sector. However, the skill premium changes differentially across countries. In the United States, it declines by about 0.5 percent, while most of foreign countries experience increases: 0.04 percent in EU-28, 0.10 percent in South Korea, 0.23 percent in Brazil, 0.27 percent in Canada, 0.27 percent in India, 0.31 percent in China, and 0.35 percent in the rest of the world, consistent with the Heckscher-Ohlin theory.

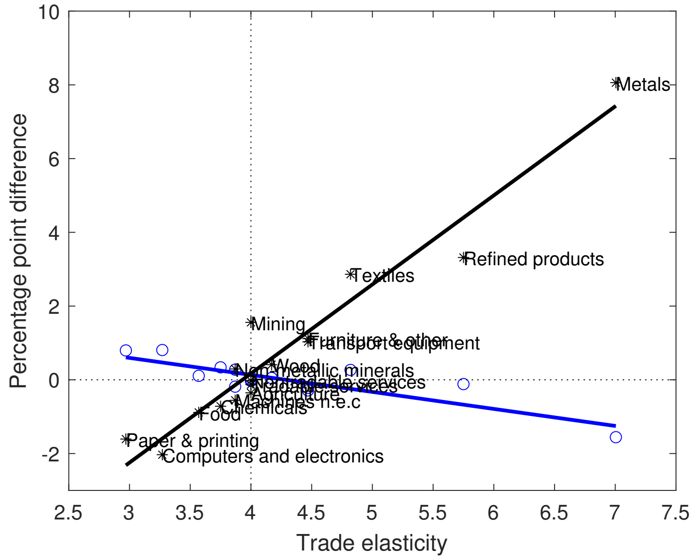
5.3 Trade Elasticities

The trade elasticity plays an important role in analyzing the effects of tariff changes. In our model, sectoral trade elasticities, θ^j, are calibrated to range from 2.97 to 7.01, with a median value of 4 and a mean of 4.24. Higher θ^j values correspond to greater sensitivity of trade flows to tariff changes. This section illustrates the role of the sectoral heterogeneity in trade elasticities by implementing two additional experiments. In the first experiment, we assign a uniform trade elasticity of four across all sectors, while keeping all other parameters unchanged. This adjustment to θ^j alone implies different model moments, particularly sectoral trade flows. In the second experiment, we also impose a common trade elasticity of four across all sectors but re-calibrate the bilateral trade costs and fundamental productivity to align with the baseline model's moments.

The outcomes in both experiments reveal that changes in real consumption, in response to tariff changes, across states are quantitatively similar to those in the baseline model. In particular, following a 25 percentage point increase in US-imposed tariffs, the median percent change in state-level consumption is 1.13 percent in the first experiment and 1.02 percent in the second one, compared to 1.09 percent in the baseline model. The cross-state correlation of these changes is 1 between the first experiment and the baseline model, and is 0.94 between the second experiment and the baseline model.

We now analyze the sectoral impact of tariff changes as heterogeneity in sectoral trade elasticities are removed in these two experiments, as plotted in Figure 16. The x-axis plots the sectoral trade elasticities from the baseline model. The y-axis plots the percentage point difference in the median change of real factor income across states between the baseline model and each of the two experiments with uniform trade elasticities. The first experiment, shown by the black line, reveals that sectors with higher trade elasticities experience significantly great gains (or smaller losses) in real factor income, all else equal. This is because higher trade elasticities allow for more substitution away from higher-priced imports caused by increased tariffs, mitigating the overall price impact. The second experiment, shown by the blue line, indicates that re-calibration of the trade costs and productivity offsets this effect. Sectors with higher trade elasticities in the baseline require higher physical trade costs to align with the observed trade flows. These higher trade costs reduce the sensitivity of trade flows and consumption to tariff changes. Consequently, the net effect is minimal in sectoral real factor income changes.

Figure 16: Two Experiments with Uniform Trade Elasticity Across Sectors



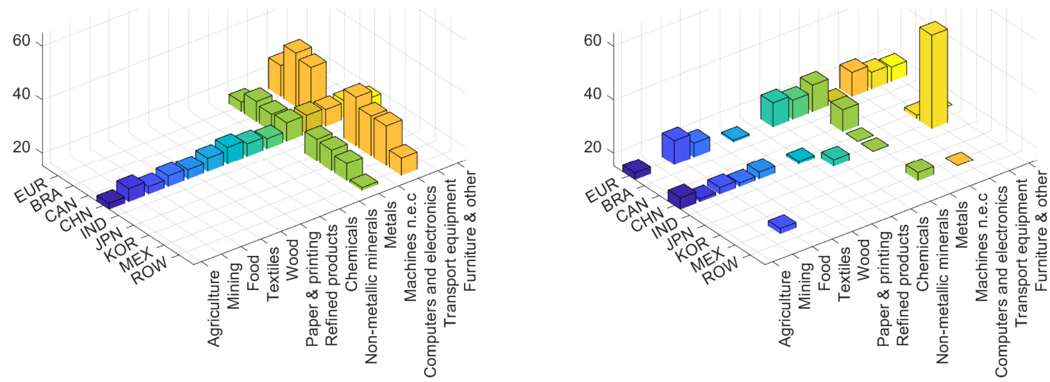
Notes: The x-axis is the sectoral trade elasticities from the baseline model. The y-axis is the percentage point difference in the median sectoral real factor income changes across states in response to a 25-percentage-point increase in tariffs between the baseline model and each of the two experiments setting a uniform trade elasticity of 4 across sectors. The black line is for the first experiment, where $\theta^j = 4$ under the baseline calibration. The blue line is for the second experiment, where the model is re-calibrated with $\theta^j = 4$.

5.4 Trade War

To investigate the economic impact of the first Trump administration's trade war, we extend our baseline analysis of a uniform 25-percentage-point tariff increase across sectors by conducting two additional counterfactual experiments.The first experiment studies the effects of unilateral tariff increases imposed by the Trump administration on foreign countries. The second experiment includes, in addition, retaliatory tariff measures implemented by those foreign countries. We use detailed HS10-level tariff data from Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2020) and Fajgelbaum, Goldberg, Kennedy, Khandelwal, and Taglioni (2024), who compiled both US tariff impositions and foreign retaliatory measures in 2018 and 2019. We aggregate these tariff changes to the sectoral level using the same methodology as in our baseline calibration.

The left panel of Figure 17 shows the tariff increases imposed by the US on foreign countries across sectors in 2018 and 2019. China faced the largest increase across nearly all sectors, increasing from about 3.8 to 24 percent (using pre-tariff sectoral trade weights). India experienced the second-highest increase, with tariffs climbing from about 3.1 to 7.6 percent. Notably, all trading partners faced significant tariff increases in the Metals sector, increasing from about 0.2 to 3 percent (using pre-tariff country trade weights), and in the Computers and electronics sector, increasing from about 0.2 to 4.2 percent. The right panel illustrates the tariff increases imposed by foreign countries on US goods in the same period. China implemented broad tariff increases across all sectors, ranging from about 8 to 23 percent. Similarly, the EU imposed tariff increases in most sectors, ranging from about 3.5 to 23 percent.

Figure 17: Changes in Tariff Rates in 2018 and 2019, Percentage Points



(a) US Import Tariff

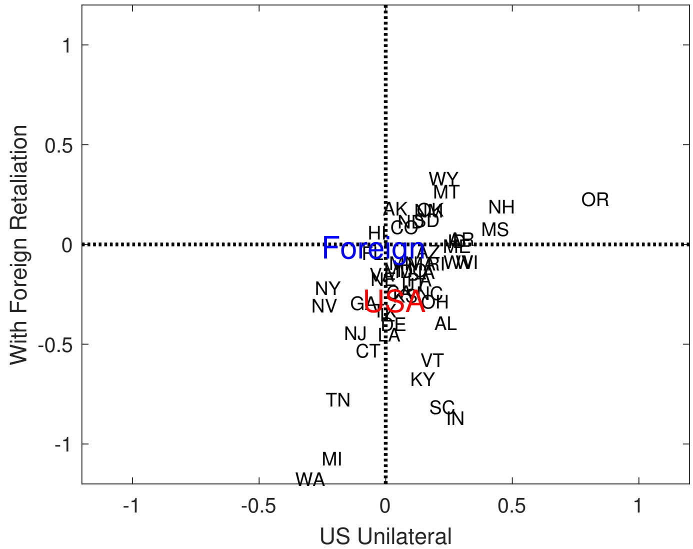
(b) Foreign Import Tariff

Notes: The left panel shows the changes in tariff rates that the US imposes on imports from foreign countries. The right panel shows the changes in tariff rates that foreign countries impose on their imports from the US.

Figure 18 presents the impact of the trade war. The horizontal axis represents the percent change in consumption relative to the baseline case under unilateral US tariff increases, while the vertical axis shows the corresponding changes with foreign retaliation. When US imposes unilateral tariff increases, the overall economic benefits for the US are minimal. Meanwhile, targeted countries incur moderate losses—China, for example, sees a 0.22 percent decline in consumption as US imports from China decline from 1.33 percent to 0.65 percent of US GDP. In terms of sectoral impacts, US real factor income rises the most in the following industries (in decreasing order): Metals, Textiles, Non-metallic minerals, and Wood. These sectors either have a large share of US absorption attributed to China or are subject to broad-based tariffs imposed by US on many trading partners.

Next, we examine the implications of foreign retaliation against US tariff hikes. In this case, the US experiences a 0.3 percent loss in consumption. Meanwhile, the retaliating countries either see economic gains or mitigate their losses relative to the unilateral US tariff case. At the US state level, the impact of foreign retaliation is wide spread with 36

Figure 18: Percent Change in Consumption Relative to Baseline Tariffs



Notes: The horizontal axis represents the percent change in consumption due to unilateral US tariff increases relative to the baseline case, while the vertical axis shows the corresponding changes when foreign retaliation is included.

states experiencing consumption losses, compared to just 13 states under the unilateral tariff case. The sectors experiencing the largest decline in real factor income are Transport equipment, Chemicals, and Machines.

6 Conclusion

US trade policy has heterogeneous impacts across US states. We seek to identify the sources of heterogeneity underpinning such spatial variation. We develop a multi-sector, multi-location model of international and interstate trade. Locations differ in terms of their factor endowments, sectoral productivity, and trade costs, each of which shapes the pattern of trade and sectoral specialization across locations. Starting from observed tariff schedules, we consider a unilateral increase in the US import tariff of 25 percentage points across all sectors in an environment with immobile factors. In spite of higher consumer prices the US as a whole experiences, on net, consumption increases because of a favorable shift in its terms of trade. However, the gains are not distributed equally across states, ranging from from -0.8 percent in Washington to 2.3 percent in Montana. This variation depends on how labor income changes in response to the higher tariffs.

The impact of higher tariffs on a state's labor income depends on how its internal comparative advantage interacts with US external comparative advantage. US external comparative advantage—driven by both productivity and endowment differences—governs the sectoral effects across US states. State internal comparative advantage—driven primarily by productivity differences—determines each state's exposure to different sectors. States with internal comparative advantage in sectors in which the US has an external comparative disadvantage realize large gains, and so prefer high tariffs.

We also analyzed the cross-state impact of trade policy changes under mobile factors. We find that factor mobility does not change the relative ranking of the heterogeneous impacts of tariff increases on changes in real factor income across states. However, factor mobility within states slightly amplifies the variance of these impacts. Only when factors are mobile across states does the variance in these impacts decline.

We have studied the heterogeneous impact of changes in trade policy in a static environment. Recent studies have extended standard trade models to incorporate intertemporal aspects of labor mobility and capital accumulation (see Caliendo, Dvorkin, and Parro, 2019; Ravikumar, Santacreu, and Sposi, 2019; Kleinman, Liu, and Redding, 2023). We leave these extensions for further research.

Heterogeneity within a customs union complicates the design of optimal trade policy to influence tariff selection and political tensions between member states. Our quantitative model provides a starting point to this analysis. Abstracting from strategic considerations, our analysis suggests that the US can choose a tariff to maximize the "size of its pie" and then use transfers to distribute tariff revenue so as to balance the gains across states, as redistribution has minimal impact on the size of the pie. Further work should explore strategic interactions across countries and other dimensions of trade policy, such as export subsidies or sector-specific taxes.

References

Allen, Treb and Costas Arkolakis. 2022. "The Welfare Effects of Transportation Infrastructure Improvements." *Review of Economic Studies* 89:2911–2957.

Artuç, Erhan, Shubham Chaudhuri, and John McLaren. 2010. "Trade Shocks and Labor Adjustment: A structural Empirical Approach." *American Economic Review* 100 (3):1008–45.

Auer, Raphael A, Barthélémy Bonadio, and Andrei A Levchenko. 2020. "The economics and politics of revoking NAFTA." *IMF Economic Review* 68:230–267.

Bagwell, Kyle, Robert W. Staiger, and Ali Yurukoglu. 2021. "Quantitative Analysis of Multiparty Tariff Negotiations." *Econometrica* 89:1595–1631.

Beshkar, Mostafa and Ahmad Lashkaripour. 2020. "Interdependence of Trade Policies in General Equilibrium." Tech. rep., Indiana University.

Broda, Christian, Nuno Limao, and David E Weinstein. 2008. "Optimal tariffs and market power: the evidence." *American Economic Review* 98 (5):2032–2065.

Caliendo, Lorenzo, Maximiliano Dvorkin, and Fernando Parro. 2019. "Trade and Labor Market Dynamics: General Equilibrium Analysis of the China Trade Shock." *Econometrica* 87 (3):741–835.

Caliendo, Lorenzo and Fernando Parro. 2015. "Estimates of the Trade and Welfare Effects of NAFTA." *Review of Economic Studies* 82 (1):1–44.

———. 2022. "Trade Policy." chap. 4. Elsevier, 219–295.

Caliendo, Lorenzo, Fernando Parro, Esteban Rossi-Hansberg, and Pierre-Daniel Sarte. 2018. "The Impact of Regional and Sectoral Productivity Changes on the U.S. Economy." *The Review of Economic Studies* 85 (4):2042–2096.

Carroll, Daniel and Sewon Hur. 2022. "On the distributional effects of international tariffs." *Globalization Institute Working Paper* (413).

Coşar, A Kerem and Banu Demir. 2016. "Domestic road infrastructure and international trade: Evidence from Turkey." *Journal of Development Economics* 118:232–244.

Coşar, A Kerem and Pablo D Fajgelbaum. 2016. "Internal geography, international trade, and regional specialization." *American Economic Journal: Microeconomics* 8 (1):24–56.

Costinot, Arnaud, Dave Donaldson, Jonathan Vogel, and Iván Werning. 2015. "Comparative Advantage and Optimal Trade Policy." *The Quarterly Journal of Economics* 130 (2):659–702.

di Giovanni, Julian, Andrei Levchenko, and Jing Zhang. 2014. "The Global Welfare Impact of China: Trade Integration and Technological Change,." *American Economic Journal: Macroeconomics* 6 (3):153–183.

Dix-Carneiro, Rafael. 2014. "Trade liberalization and labor market dynamics." *Econometrica* 82 (3):825–885.

Donaldson, Dave. 2018. "Railroads of the Raj: Estimating the impact of transportation infrastructure." *American Economic Review* 108 (4-5):899–934.

Eaton, Jonathan and Samuel Kortum. 2002. "Technology, Geography, and Trade." *Econometrica* 70 (5):1741–1779.

Eckert, Fabian et al. 2019. "Growing apart: Tradable services and the fragmentation of the us economy." *mimeograph, Yale University* .

Fajgelbaum, Pablo D, Pinelopi K Goldberg, Patrick J Kennedy, and Amit K Khandelwal. 2020. "The return to protectionism." *The Quarterly Journal of Economics* 135 (1):1–55.

Fajgelbaum, Pablo D, Pinelopi K Goldberg, Patrick J Kennedy, Amit K Khandelwal, and Daria Taglioni. 2024. "The US-China Trade War and Global Reallocations." *American Economic Review: Insights* 6 (2):295–312.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. 2015. "The Next Generation of the Penn World Table." *American Economic Review* 105 (10):3150–3182.

Gervais, Antoine and J Bradford Jensen. 2019. "The tradability of services: Geographic concentration and trade costs." *Journal of International Economics* 118:331–350.

Giri, Rahul, Kei-Mu Yi, and Hakan Yilmazkuday. 2021. "Gains from trade: Does sectoral heterogeneity matter?" *Journal of International Economics* 129:103429.

Kleinman, Benny, Ernest Liu, and Stephen J Redding. 2023. "Dynamic spatial general equilibrium." *Econometrica* 91 (2):385–424.

Kovak, Brian K. 2013. "Regional effects of trade reform: What is the correct measure of liberalization?" *American Economic Review* 103 (5):1960–1976.

Lashkaripour, Ahmad and Volodymyr Lugovsky. 2022. "Profits, Scale Economies, and the Gains from Trade and Industrial Policy." Tech. rep., Indiana University.

Levchenko, Andrei and Jing Zhang. 2016. "The Evolution of Comparative Advantage: Measurement and Welfare Implications,." *Journal of Monetary Economics* 78:96–111.

Ossa, Ralph. 2011. "A new trade theory of GATT/WTO negotiations." *Journal of Political Economy* 119 (1):122–152.

Parro, Fernando. 2013. "Capital-Skill Complementarity and the Skill Premium in a Quantitative Model of Trade." *American Economic Journal: Macroeconomics* 2 (5):72–117.

Ramondo, Natalia, Andrés Rodríguez-Clare, and Milagro Saborío-Rodríguez. 2016. "Trade, domestic frictions, and scale effects." *American Economic Review* 106 (10):3159–84.

Ravikumar, B, Ana Maria Santacreu, and Michael Sposi. 2019. "Capital accumulation and dynamic gains from trade." *Journal of International Economics* 119:93–110.

Redding, Stephen J. 2016. "Goods Trade, Factor Mobility and Welfare." *Journal of International Economics* 101:148–167.

Rodríguez-Clare, Andrés, Mauricio Ulate, and Jose P. Vasquez. 2024. "Trade with Nominal Rigidities: Understanding the Unemployment and Welfare Effects of the China Shock." Tech. rep.

Santacreu, Ana Maria and Makenzie Peake. 2020. "The Economic Effects of the 2018 US Trade Policy: A State-Level Analysis." *Federal Reserve Bank of St. Louis Review* 102 (4):385–412.

Simonovska, Ina and Michael E. Waugh. 2014. "The Elasticity of Trade: Estimates and Evidence." *Journal of International Economics* 92 (1):34–50.

Timmer, Marcel P., Erik Dietzenbacher, Bart Los, Robert Stehrer, and Gaaitzen J. de Vries. 2015. "An Illustrated Guide to the World Input-Output Database: The Case of Global Automotive Production." *Review of International Economics* 23 (3):575–605.

Timmer, Marcel P., Bart Los, Robert Stehrer, and Gaaitzen J. de Vries. 2016. "An Anatomy of the Global Trade Slowdown based on the WIOD 2016 Release." GGDC research memorandum 162, Groningen Growth and Development Center.

Topalova, Petia. 2010. "Factor immobility and regional impacts of trade liberalization: Evidence on poverty from India." *American Economic Journal: Applied Economics* 2 (4):1–41.

Waugh, Michael E. 2010. "International Trade and Income Differences." *American Economic Review* 22 (5):2093–2124.

Waugh, Michael E. 2019. "The consumption response to trade shocks: Evidence from the US-China trade war." Tech. rep., National Bureau of Economic Research.

A Equilibrium conditions

This appendix describes the equilibrium conditions in each of the three model specifications: immobile factors, factor mobility across sectors, and factor mobility across sectors and US states.

Household consumption optimization The optimal sectoral consumption expenditure of the representative household in location n is

$$p_n^j c_n^j = \omega_n^j P_n^c C_n.$$

Firm optimization At the sector level, factor expenses exhaust the value of output, which implies:

$$w_n^{sj} e_{nt}^{sj} = \lambda^{sj} \nu^j p_n^j y_n^j, \quad p_n^k m_{nt}^{jk} = (1 - \nu^j) \mu^{jk} p_n^j y_n^j.$$

Goods market clearing conditions Within each location n, markets for the composite sectoral good must clear: $c_n^j + \sum_{k=1}^{J} m_n^{kj} = Q_n^j$, for any j.

The value of sector-j output produced by location n is equal to the (pre-tariff) value of sector j goods that all countries purchase from country n:

$$p_n^j y_n^j = \sum_{i=1}^{N} \left[\left(p_i^j c_i^j + \sum_{k=1}^{J} p_i^j m_i^{kj} \right) \left(\frac{\pi_{in}^j}{1 + \tau_{in}^j} \right) \right].$$

Finally, the aggregate resource constraint must hold in each location:

$$\sum_{j=1}^{J} \sum_{i=1}^{N} \left(\frac{p_n^j Q_n^j \pi_{ni}^j}{1 + \tau_{ni}^j} \right) = \sum_{j=1}^{J} p_n^j y_n^j - R_n + T_n,$$

where the left-hand side is country n's (pre-tariff) gross absorption. The right-hand side is the sum of gross output and the net government transfer $T_n - R_n$.

Government budget balance Tariff revenue collected at the national level is

$$R_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \left(\frac{p_n^j Q_n^j \pi_{ni}^j}{1 + \tau_{ni}^j} \right) \tau_{ni}^j.$$

The transfer dispersed to workers at the national level is $R_n = T_n$. At the US state level the transfers received need not equal the revenue generated by its imports, but the cross-state transfers must balance:

$$\sum_{n \in \mathcal{US}} R_n = \sum_{n \in \mathcal{US}} T_n.$$

Labor market clearing with factor immobility

$$e_n^{sj} = \bar{e}_n^{sj}$$

where $\bar{e}_n^{sj}$ denotes the exogenous endowment type-s labor in sector j location n.

Labor market clearing with factor mobility across sectors The factor market clearing conditions in this model specification become

$$\sum_{j=1}^{J} e_n^{sj} = \bar{E}_n^s,$$

where $\bar{E}_n^s$ denotes the exogenous endowment of type-s labor in location n.

Labor market clearing with factor mobility across sectors and across US states The factor market clearing conditions for non-US locations are the same as in the model with factor mobility across sectors. For the US market, the factor market clearing conditions become

$$\sum_{j=1}^{J} \sum_{n \in \mathcal{US}} e_n^{sj} = \bar{E}_{\mathcal{US}}^s,$$

where $\bar{E}_{\mathcal{US}}^s$ and denotes the exogenous endowment of type-s labor in the United States.

B Data

The primary data sources include Bureau of Economic Analysis Regional Economic Accounts (BEA); Census Bureau American Community Survey (ACS); Census Bureau Commodity Flow Survey (CFS); Census Bureau Foreign Trade Database (FTB); version 10.0 of the Penn World Table (Feenstra, Inklaar, and Timmer, 2015, (PWT)); World Input-Output Database (Timmer, Dietzenbacher, Los, Stehrer, and de Vries, 2015; Timmer, Los, Stehrer, and de Vries, 2016, (WIOD)), including the July 2014 and November 2016 releases of the WIOD Socio Economic Accounts (SEA14 and SEA16, respectively); Centre d'Etudes Prospectives et d'Informations Internationales (CEPII), and World Integrated Trade Solution (WITS) database. We merge the different data sources into 16 sectors and 59 locations. Unless stated otherwise, all data are for year 2012, which is the latest year available for the state-to-state trade data.

B.1 Location and sector aggregation

We construct our 16 sectors by aggregating 3-digit NAICS (2012) classifications as shown in Table B.1. The 59 locations consist of 50 US states and 9 non-US locations, which are listed in Table B.2. Among the 9 non-US locations there are 7 individual non-US countries, each of which accounts for at least 1 percent of US imports and 1 percent of US exports, a EU-28 aggregate, and a Rest-of-world aggregate. Our Rest-of-World aggregate includes the "rest-of-world" aggregate, as constructed in the WIOD, plus the following individual countries: Indonesia, Norway, Russia, Switzerland, Taiwan, and Turkey.

Table B.1: Sector Classification

Sector name	3-digit NAICS code
Agriculture	11*
Mining	211–213
Food, beverages, and tobacco	311, 312
Textiles and apparel	313–316
Wood	321
Paper and printing	322, 323
Refined petroleum, plastics, and rubbers	324, 326
Chemicals and pharmaceuticals	325
Non-metallic minerals	327
Primary and fabricated metals	331, 332
Machinery n.e.c.	333
Computers, electronics, and electrical equipment	334, 335
Transportation equipment	336
Furniture and other	337, 339
Tradable services	42*, 44*, 45*, 48*, 49*, 51*, 52*, 54*–56*
Nontradable services	22*, 23*, 53*, 61*, 62*, 71*, 72*, 81*, 92*

Note: *ab** refers to three-digit categories beginning with digits *ab*. For example, 11* refers to three-digit codes 110, 111, 112, etc.

B.2 Input-output data

For each country, data on sectoral value added and gross output (in current US dollars) are obtained from WIOD. We define value added as the difference between gross output and intermediate spending to abstract from taxes, subsidies, and international transport margins. Data on sectoral value added in each US state come from the BEA. In each sector, we scale the state-level value added data so that the sum across states equals US value added. We construct sectoral gross output for each state by assuming that in each sector the ratio of value added to gross output is the same as the ratio for the US.

Data on intermediate inputs come directly from the WIOD at the country level. Final demand is the sum of private and public consumption and investment expenditure. Data on country-level final demand across sectors also come from the WIOD.

B.3 Factor endowments

We construct data on the two types of labor (high- and low-skilled) from various sources. High-skilled workers are those who completed a post-secondary degree, while low-skilled workers are those who have not completed a post-secondary degree.

Table B.2: Location Names and Codes

US states			
Alabama	AL	Montana	MT
Alaska	AK	Nebraska	NE
Arizona	AZ	Nevada	NV
Arkansas	AR	New Hampshire	NH
California	CA	New Jersey	NJ
Colorado	CO	New Mexico	NM
Connecticut	CT	New York	NY
Delaware	DE	North Carolina	NC
Florida	FL	North Dakota	ND
Georgia	GA	Ohio	OH
Hawaii	HI	Oklahoma	OK
Idaho	ID	Oregon	OR
Illinois	IL	Pennsylvania	PA
Indiana	IN	Rhode Island	RI
Iowa	IA	South Carolina	SC
Kansas	KS	South Dakota	SD
Kentucky	KY	Tennessee	TN
Louisiana	LA	Texas	TX
Maine	ME	Utah	UT
Maryland	MD	Vermont	VT
Massachusetts	MA	Virginia	VA
Michigan	MI	Washington	WA
Minnesota	MN	West Virginia	WV
Mississippi	MS	Wisconsin	WI
Missouri	MO	Wyoming	WY

Non-US countries and regions	
European Union (EU-28)	EUR
Brazil	BRA
Canada	CAN
China	CHN
India	IND
Japan	JPN
South Korea	KOR
Mexico	MEX
Rest-of-world	ROW

Notes: The Rest-of-World aggregate includes the “rest-of-world” aggregate as constructed in the WIOD, plus Indonesia, Norway, Russia, Switzerland, Taiwan, and Turkey.

Data on aggregate employment (measured as the number of persons engaged) at the country level come from PWT. Sectoral employment data for each non-US country come from the SEA16. We scale sectoral employment to match total employment from PWT. Sectoral employment for each country is further broken down into high- and low-skill employment using data from the SEA14.[19] The SEA14 does not have the high-skill

[19]The SEA14 provides data on the share of high skill working hours in total hours by sector. We take the share of hours by high-skill workers to be the share of employment by high-skill workers.

labor share for all countries and sectors. We impute the missing shares by regressing the observed values across countries on aggregate real income per capita within a sector.

Sectoral employment data for US states by skill type come from the ACS 2010–2014 sample. Some states report zero employment in certain sectors with positive value added. For these observations, we impute sectoral employment such that the ratio of value added to employment is equal to the median value across states in that sector. In addition, some state-sector pairs have missing information on skill composition. In these cases, we set the high skilled share in employment in that state-sector to be the average across remaining states in that same sector. Finally, we scale the state-sector employment by to match employment at the US level in each sector.

B.4 Factor compensation

We obtain country-level compensation to the two primary factors of production (high- and low-skilled labor) from the SEA14. (The SEA14 release reports data from 1995-2011, so we compute each number as the median value over time.) The high-skilled share in labor is measured as the ratio of high-skilled labor compensation times total labor compensation, relative to compensation of employees. This share is then multiplied by labor compensation to obtain high-skilled labor compensation. Low-skilled labor compensation is the residual labor compensation. We do not observe state-sector-skill type shares in value added. Therefore, we assume that for each state-sector, the proportion of value added that compensates each skill type is identical to that of the US.

B.5 Bilateral trade

We construct bilateral trade flows across regions at the sector level by combining multiple sources of trade data to achieve the most comprehensive coverage possible. We then use a gravity specification to impute missing trade flows. All data reported Free on Board.

Country-to-country trade Bilateral trade data across countries for all sectors are taken from WIOD.

State-to-country trade Bilateral trade between US states and non-US countries is taken from the FTB for agriculture, mining, and all 12 manufacturing sectors. For each of these sectors, we scale the trade flows proportionately across states so that in each sector (i) the sum of all states' exports to any non-US country equals US exports to that country in WIOD and (ii) the sum of all states' imports from any non-US country equals US imports from that country in WIOD.

We make two adjustments to the data. First, in some sectors, all states have zero reported trade with some countries, while the aggregate US data report a positive amount.[20]

[20]There are 8 such instances in total: imports from Luxembourg in Agriculture; imports from Luxembourg, Malta, Bulgaria, and Slovakia in Mining; imports from Malta in Paper and printing; and imports from Slovakia and Slovenia in Chemicals and pharmaceuticals.

We impute state-level trade as US trade multiplied by each state's share in US value added in the relevant sectors. Second, in some sectors, the sum of a state's exports to all foreign countries exceeds its gross output due to measurement problems.[21] This is either because exports are over-reported due to re-export issues or because gross output is constructed below the actual levels due to our assumption of a constant gross-output-to-value-added ratio across states. To address this problem, we adjust down these states' exports using the following procedures.

For each sector, we categorize a state into a problematic group if its ratio of foreign exports to gross output exceeds 0.8, or into a non-problematic group otherwise. Using the non-problematic group, we compute the maximum ratio of foreign exports to gross output. We define an adjustment ratio as the midpoint of 0.8 and the maximum ratio. For the problematic states, we scale down their foreign exports to be the product of their gross output and the adjustment ratio. We construct "lost exports" as the difference between the observed exports and the scaled exports. To be consistent with US exports data, we reallocate the lost exports to non-problematic states in proportion to their observed shares in US exports in a given sector.

State-to-state trade The CFS provides survey-based trade data between US cities for manufacturing. We aggregate these manufactured products into our 12 manufacturing sectors and aggregate the cities to the state level. We then scale these flows so that each state's gross output in each manufacturing sector equals its sales to foreign countries plus its sales to all US states (including to itself).

Inferring missing bilateral trade flows As noted above, there are no data for state-to-foreign-country trade in services or for state-to-state trade in agriculture, mining, or services. We use a gravity specification informed by observed trade flows, along with sector, state, and country characteristics and geography to impute these missing bilateral trade flows as follows:

$$\begin{aligned}\ln(\mathrm{Trd}^j_{ni}) = {} & \alpha_j + \delta_n + \gamma_i + \rho_0 \ln(1+\tau^j_{n,i}) + \rho_1 \ln(\mathrm{GO}^j_i) + \rho_2 \ln(\mathrm{FD}^j_n) \\ & + \rho_3 \mathbb{I}_{n\in\mathcal{US},i\notin\mathcal{US}} \ln(\mathrm{Trd}^j_{\mathrm{US},i}) + \rho_4 \mathbb{I}_{n\notin\mathcal{US},i\in\mathcal{US}} \ln(\mathrm{Trd}^j_{n,\mathrm{US}}) \\ & + \sum_{r=1}^{6} \beta^j_{d,r}\mathrm{dis}^r_{ni} + \beta^j_b \mathrm{bdr}_{ni} + \beta^j_c \mathrm{cur}_{ni} + \beta^j_l \mathrm{lng}_{ni} + \beta^j_f \mathrm{fta}_{ni} + \beta^j_h \mathrm{hbs}_{ni} + \epsilon^j_{ni}.\end{aligned} \tag{B.1}$$

The trade flow Trd^j_{ni} is the Free on Board value. First, we include sector, importer, and exporter fixed effects: α_j, δ_n, and γ_i. Second, we include the bilateral tariff associated with the particular trade flow. Third, we include sectoral gross output of the exporter,

[21] These cases are Alaska and Louisiana in Agriculture; Delaware, Michigan, Maine, and North Dakota in Paper and printing; Delaware, Montana, North Dakota, and Oregon in Chemicals and pharmaceuticals; Florida, Hawaii, Nevada, and Vermont in Computers and electronics; Alaska, Delaware, and Florida in Machinery n.e.c.; and Alaska, Delaware, Hawaii, and New Jersey in Transportation equipment.

$\ln(\mathrm{GO}_i^j)$, and sectoral final demand by the importer, $\ln(\mathrm{FD}_n^j)$.[22] Sectoral final demand for each state is calculated by assuming its ratio of final demand to GDP is the same as the ratio for the United States. Fourth, we include the sectoral bilateral trade flows between the US and each foreign country when predicting each US state's sectoral bilateral trade with that foreign country. Specifically, US imports in sector j to country i are denoted by $\ln(\mathrm{Trd}_{\mathrm{US},i}^j)$, and US exports in sector j to country i are denoted by $\ln(\mathrm{Trd}_{n,\mathrm{US}}^j)$. Finally, we include sector-specific geographic effects captured by dummy variables. The first five terms are the same as those we used in our estimation in Section 3.3 (distance, shared border, common currency, common language, and belonging to a free-trade agreement). The sixth term is a home-bias dummy that indicates whether the exporter is the same as the importer. Estimates are reported in table B.3. The R^2 is 0.74, and almost all he coefficients are statistically significant.

We impute the missing bilateral trade flows given the observed predictors on the right-hand side of the estimated equation (B.1). For two service sectors, we scale the state-to-country trade flows proportionately so that in each sector, the sum of exports (imports) across states with any foreign country equals US exports to (imports from) that country in WIOD. For agriculture, mining, and the two service sectors we proportionately scale the state-to-state trade flows so that each state's gross output equals its sales to foreign countries plus its sales to all 50 states.

B.6 Tariffs

Tariff data are from the WITS database. We use the HS-2012 classification, which contains products at the 6-digit level. We focus on a sample of regions and countries (the United States, 27 EU countries,[23] Brazil, Canada, China, India, Japan, South Korea, and Mexico). For reporters, we have 8 individual countries along with one aggregated entity for the European Union (EU). For partners, the EU is disaggregated into 27 member countries. If the tariff rate for a partner of a reporting country is missing, we fill in the missing values with the maximum tariff value by this reporter in this product. We use effectively applied rates reported in the database.

We construct the bilateral tariff rates in two steps. First, we build the bilateral rate matrix at the 6-digit level. Particularly, we need to disaggregate the EU into its 27 individual countries. For each EU country, we set tariff at zero if the partner is also a EU member, and the reported tariff rate otherwise. Second, we aggregate these matrices up to our sectoral level. We find the "most traded" HS-6 products for each importer within each sector and compute the simple average tariff across these products. These most-traded products are defined as the smallest set that cumulatively accounts for at least 80 percent of an importer's sectoral imports and that individually account for at least 0.005 percent of imports. The HS-6 trade data come from the BACI dataset developed by CEPII for 2012.

[22]Ideally we would use gross absorption rather than final demand, but we do not have data on gross absorption for US states in agriculture, mining, and service sectors.

[23]Belgium and Luxembourg are merged because of trade data availability.

Table B.3: Estimates for Missing Trade Flows

			dis^2_{ni}	dis^3_{ni}	dis^4_{ni}	dis^5_{ni}	dis^6_{ni}	bdr_{ni}	cur_{ni}	lng_{ni}	fta_{ni}	hbs_{ni}
$\ln(1+\tau^j_{n,i})$	-0.61	Agriculture	-0.55	-1.38	-1.81	-4.65	-4.99	1.01	0.52	1.45	-0.27	2.79
	(0.21)		(0.14)	(0.14)	(0.16)	(0.17)	(0.17)	(0.14)	(0.08)	(0.09)	(0.10)	(0.22)
$\ln(\text{GO}^j_i)$	1.01	Mining	-1.15	-1.89	-2.69	-4.38	-5.29	1.50	0.46	1.23	0.09	2.12
	(0.01)		(0.12)	(0.12)	(0.13)	(0.15)	(0.16)	(0.12)	(0.08)	(0.09)	(0.10)	(0.21)
$\ln(\text{FD}^j_n)$	0.10	Food	-0.86	-1.68	-2.31	-3.98	-4.30	1.22	0.83	1.05	0.70	2.15
	(0.01)		(0.12)	(0.12)	(0.13)	(0.14)	(0.15)	(0.12)	(0.07)	(0.09)	(0.09)	(0.21)
$\mathbb{I}_{n\in\mathcal{US},i\notin\mathcal{US}}\ln(\text{Trd}^j_{\text{US},i})$	0.03	Textiles	-0.40	-0.85	-1.07	-3.28	-3.34	0.77	0.90	0.82	0.62	1.51
	(0.00)		(0.12)	(0.12)	(0.13)	(0.14)	(0.15)	(0.12)	(0.07)	(0.09)	(0.09)	(0.21)
$\mathbb{I}_{n\notin\mathcal{US},i\in\mathcal{US}}\ln(\text{Trd}^j_{n,\text{US}})$	0.04	Wood	-1.02	-1.75	-2.34	-4.61	-4.99	1.54	0.71	0.82	-0.06	2.26
	(0.01)		(0.12)	(0.12)	(0.13)	(0.15)	(0.16)	(0.12)	(0.08)	(0.09)	(0.10)	(0.21)
Origin Fixed Effects	Y	Paper & printing	-0.46	-1.11	-1.60	-3.64	-3.88	0.89	0.97	1.18	0.40	1.64
Destination Fixed Effects	Y		(0.12)	(0.12)	(0.13)	(0.14)	(0.15)	(0.12)	(0.07)	(0.08)	(0.09)	(0.21)
Sector Fixed Effects	Y	Refined products	-0.72	-1.68	-2.45	-4.34	-4.81	1.31	0.40	0.49	0.49	2.03
			(0.12)	(0.12)	(0.13)	(0.15)	(0.15)	(0.12)	(0.07)	(0.09)	(0.09)	(0.21)
		Chemicals	-0.73	-1.37	-2.02	-3.77	-3.95	1.11	0.33	0.12	0.49	1.93
			(0.12)	(0.12)	(0.13)	(0.14)	(0.14)	(0.12)	(0.07)	(0.09)	(0.09)	(0.21)
		Non-metallic minerals	-0.83	-1.68	-2.19	-3.66	-4.26	1.25	0.62	0.96	0.54	2.40
			(0.12)	(0.12)	(0.13)	(0.15)	(0.15)	(0.12)	(0.07)	(0.09)	(0.09)	(0.21)
		Metals	-0.57	-1.27	-1.75	-3.73	-4.16	0.94	0.58	0.83	0.65	1.78
			(0.12)	(0.12)	(0.13)	(0.14)	(0.15)	(0.12)	(0.07)	(0.09)	(0.09)	(0.21)
		Machines n.e.c	-0.48	-0.93	-1.31	-2.76	-3.24	1.08	0.55	0.31	0.59	1.87
			(0.12)	(0.12)	(0.13)	(0.14)	(0.14)	(0.12)	(0.07)	(0.08)	(0.09)	(0.21)
		Computers and electronics	-0.35	-0.69	-1.02	-2.61	-2.94	0.56	0.53	0.33	0.84	1.47
			(0.12)	(0.12)	(0.13)	(0.14)	(0.15)	(0.12)	(0.07)	(0.08)	(0.09)	(0.21)
		Transport equipment	-0.44	-1.13	-1.67	-3.24	-3.61	1.32	0.27	0.30	0.79	2.22
			(0.12)	(0.12)	(0.13)	(0.14)	(0.15)	(0.12)	(0.07)	(0.09)	(0.09)	(0.21)
		Furniture & other	-0.66	-1.31	-1.65	-3.25	-3.47	0.92	0.38	0.98	0.71	2.17
			(0.12)	(0.12)	(0.12)	(0.14)	(0.14)	(0.12)	(0.07)	(0.08)	(0.09)	(0.21)
		Tradable services	-0.93	-1.38	-1.71	-4.01	-4.85	0.12	0.59	0.51	0.19	3.58
			(0.21)	(0.21)	(0.25)	(0.24)	(0.25)	(0.22)	(0.21)	(0.13)	(0.13)	(0.36)
		Nontradable services	-1.04	-1.81	-2.50	-4.85	-5.87	-0.10	0.89	0.42	-0.30	5.33
			(0.21)	(0.21)	(0.25)	(0.24)	(0.25)	(0.22)	(0.21)	(0.13)	(0.13)	(0.36)

Notes: Standard errors are in parentheses.