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

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Abstract

We develop a structural framework to identify the sources of cross-state heterogeneity in response to US tariff changes. A unilateral 25-percentage-point US tariff increase across sectors induces consumption changes ranging from -0.8% in Oregon to 2.1% in Montana. This variation stems from the interaction between states' internal comparative advantage and the nation's external comparative advantage. Factor mobility lowers aggregate consumption and reshapes the cross-state impacts by shifting resources towards more distorted states and sectors. Consequently, "preferred" tariff changes vary systematically across states, necessitating transfers to align regional policy incentives. Finally, foreign retaliation reduces aggregate gains while perpetuating cross-state variation.

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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, differences across states in geography, productivity, and endowments create winners and losers when tariffs change. Even if the union as a whole gains, cross-state transfers may be needed to align state preferences over those changes. Unlike other customs unions, such as the European Union, the United States is also a fiscal union, so, in principle, such transfers are feasible. It is therefore important to understand how cross-state heterogeneity influences the impact of trade policy in order to quantify both its distributional consequences and the transfers that may be required alongside trade policy proposals.

We develop a general equilibrium model of international and interstate trade where comparative advantage arises from differences in productivity and endowments. The model is calibrated to assess heterogeneous cross-state impacts of a uniform US import tariff increase. Tariffs protect *sectors* in which the United States has an external comparative disadvantage vis-à-vis foreign countries, and *states* with internal comparative advantage vis-à-vis other states in these sectors reap the largest gains. This mechanism explains states' differing preferences over trade policy and allows us to characterize tariff revenue transfers to mitigate cross-state impacts. Finally, factor mobility shapes the aggregate effects of tariffs and their distribution across states. Relative to immobile labor, allowing for sectoral mobility reduces aggregate US gains and increases the dispersion of cross-state gains. Allowing for both sectoral and interstate labor mobility further lowers aggregate US gains and significantly reduces the dispersion of cross-state gains.

Our analysis features a multi-location, multi-sector Eaton-Kortum model of trade. Each location differs in sectoral productivity and faces asymmetric iceberg 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 vis-à-vis 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 either remain in place or move across sectors and 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, allowing us to isolate changes in factor income.

We calibrate the model to 50 US states, 8 foreign locations, and a rest-of-world aggregate, using data for 2012 across 14 goods sectors and 2 services sectors. 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 lies in sectors like Computers and electronics and in Chemicals, while the United States has a comparative disadvantage in Mining and in Textiles. Within the United States, *internal* comparative advantage reflects primarily sectoral productivity differences. For example, Wyoming has a strong internal comparative advantage in Mining, and Oregon in Computers and electronics.

We first quantify the short-run effects of a uniform 25-percentage-point increase in US import tariffs across goods sectors, assuming immobile factors. At the aggregate level, US consumption rises modestly, as gains from tariff revenue slightly outweigh the efficiency losses from distorted spatial and sectoral allocations. However, this aggregate trend masks significant regional heterogeneity: real factor income changes range from -0.8% in Oregon to 2.1% in Montana. The tariff increases induce a shift in expenditures toward domestic producers, especially in sectors where the US lacks an external comparative advantage. Consequently, the primary beneficiaries are states with an internal comparative advantage in these protected sectors. Conversely, states whose internal strengths align with the US's external comparative advantage see the smallest gains or experience net losses.

We next demonstrate how alternative assumptions about factor mobility shape both aggregate welfare and the spatial distribution of gains. We find that labor mobility does not overturn the relative ranking of states; however, it significantly impacts both the magnitude of aggregate US gains and their cross-state dispersion. When labor is mobile across sectors within a state, it reallocates toward protected sectors, which are not necessarily the most productive, thereby amplifying misallocation and lowering US real income relative to the immobile-factor benchmark. Because states differ in their exposure, this intra-state reallocation increases the dispersion of outcomes. When mobility extends across both sectors and states, the distortion intensifies as labor follows tariff-induced wage premia across locations, concentrating activity where protection is strongest rather than where productivity is highest. While interstate reallocation partially equalizes cross-state impacts by shifting labor toward relatively advantaged states, it compresses dispersion but does not eliminate it. Thus, even in the long run, the interaction between internal and external comparative advantage remains the key determinant of regional heterogeneity.

We further extend our analysis in three dimensions. First, we characterize heterogeneous preferences over trade policy by tracing each state's most preferred tariff level. We show that these preferences are governed by the interaction between internal and external comparative advantage: states whose internal comparative advantage is negatively correlated with US external comparative advantage favor higher tariffs, as protection shifts demand toward sectors in which they are internally more productive. In contrast, states whose internal strengths align with the nation's external comparative advantage tend to prefer lower tariffs, as they benefit disproportionately from access to foreign markets and cheaper imported inputs. This divergence highlights how a common external tariff generates inherent conflicting policy preferences within the customs union. We find that greater factor mobility reduces the dispersion of preferred tariff rates across states, thereby mitigating tensions surrounding the design of a common external tariff.

Second, we explore whether it is possible to design a tariff revenue redistribution rule to achieve Pareto improvements. Under immobile factors, we show that the heterogeneous outcomes can be reconciled through a redistribution rule, fully financed by tariff revenue, that equalizes consumption gains across states, thereby delivering Pareto efficiency. The key feature of this rule is that transfers are tilted toward states experiencing the larger declines in real factor income, offsetting the uneven incidence of tariffs across locations. With mobility across sectors, the tariff increase still generates a positive aggregate surplus, allowing Pareto efficiency to be achieved through appropriate transfers. In contrast, when factors are mobile across both sectors and states, the decline in aggregate real factor income exceeds the increase in tariff revenue. As a result, no redistribution rule is capable of generating Pareto improvements.

Third, we consider a scenario in which foreign countries implement tit-for-tat retaliatory tariffs. Regardless of assumptions regarding factor mobility, retaliation neutralizes the US terms-of-trade advantage, reduces aggregate US consumption, and magnifies the cross-state dispersion in outcomes. Specifically, states with higher exposure to foreign markets—those whose internal comparative advantage aligns with the national external comparative advantage—experience disproportionate losses due to stifled export demand.

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 productivities, endowments, trade costs, and trade elasticities. US states' membership in a customs union—where they trade duty free with each other—further shapes these elasticities. While our framework does not yield explicit expressions for these elasticities, it captures their general-equilibrium implications by modeling how trade policy changes affect terms of trade, input-output linkages, trade flows, and factor prices across locations.

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 estimating internal trade costs despite missing state-level trade data. We address this by imputing 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, 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. Rodríguez-Clare et al. (2025) study the recent surge in U.S. tariffs using a dynamic trade model with cross-state heterogeneity and fiscal redistribution of tariff revenues. We complement this work by unpacking how cross-state heterogeneity in fundamentals shapes the distributional effects 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 weighting sectoral impacts with district-level sectoral employment shares. We show that when

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[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.

cross-location heterogeneity manifests predominantly in sectoral employment shares, this calculation provides a good approximation. Our findings align with studies showing that trade shocks, such as tariffs, have heterogeneous regional effects 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). To date, this literature has not quantitatively explored optimal trade policy in a multi-sector setting that incorporates 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 is tradable. Trade between locations is subject to physical iceberg costs, and trade across countries 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 4.2 to examine the medium-run with mobility across sectors, and the long-run with mobility across sectors and states implications.[2] In all specifications, we restrict labor from moving across countries.

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

Workers Workers make up to two sequential decisions. When allowed, they first choose a sector of employment either in their "home location" or, for US workers, in 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 across countries, but are common across worker types 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 an inelastic unit labor supply, with a location-sector-skill-specific wage. The other is a location-specific transfer of tariff revenue 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 We now aggregate the 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 location 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 location n.[3] The term $a_n^j(v)$ scales the gross output of variety v in sector j of location 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 distribution function in sector j is $F^j(a) = \exp(-a^{-\theta^j})$.

In each sector and location, a competitive firm aggregates all varieties with a 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 location 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.

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[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:

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

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 consumption units, i.e., in real terms. That is, in the United States, states have different consumption prices, so tariff rebates are adjusted to equalize their value in real consumption units across locations. 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 5.1.

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 the labor endowment. In the specification with sector labor mobility, the total demand for labor across sectors within a location equals the labor endowment of 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:

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

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.

Finally, we choose world GDP (factor income) as the numeraire, so that all nominal variables, such as factor income, wages, and prices, are expressed in units of world GDP. When referring to real variables, we deflate these objects by the local consumer price level.

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; collectively, they 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.

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[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.

We calibrate the model parameters in three steps. In Section 3.1, we describe the calibration of country-specific parameters that are directly observable in the data. In Section 3.2, we detail the imputation of 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 2012 data. We introduce the data sources and discuss the imputations performed to complete the coverage of our sample. We choose the 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 data 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 use the Census Bureau's American Community Survey (ACS) to obtain employment by skill type 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.

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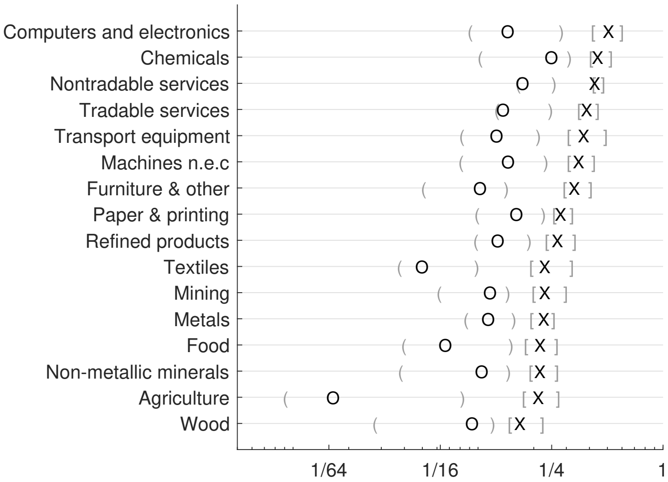
[5] Skill type is based on educational attainment. High-skill corresponds to at least some tertiary education, while low-skill corresponds to no tertiary education.

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 sectoral 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 aggregate US weights. The second column of Table 1 reports ω_n^j for the United States. Tradable services and

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[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.

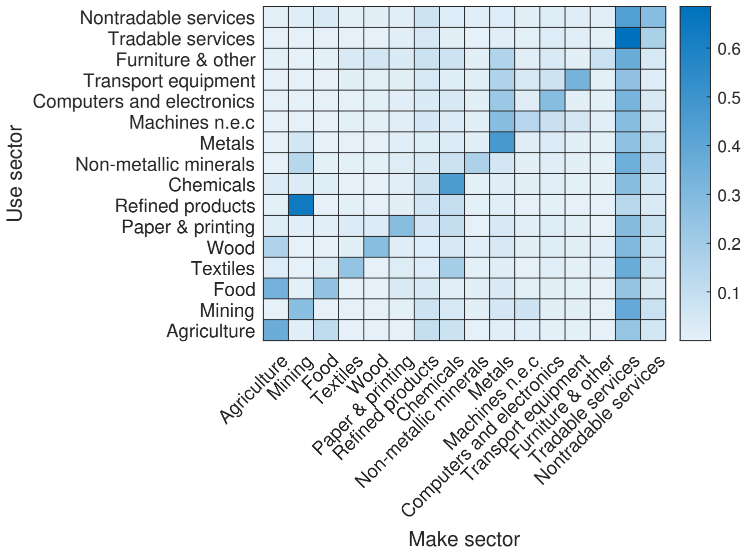
Nontradable services collectively account for more than 80 percent of US final demand. Outside of services, Food and Transport equipment are the next two largest components, accounting for 3.2% and 3.1%, respectively. Since they are constant across US states, they do not contribute to the heterogeneity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

Input and Factor Shares We now describe the sources for the production coefficients: the value-added share in gross output ν^j, the high-skill labor share of labor compensation λ^{hj}, and the intermediate use coefficients μ^{jk}. All of 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. Conversely, 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 important inputs 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 Machinery. These strong links transmit cost shocks resulting from tariff changes 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" sectors and each column represents "supply" sectors. 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 (MFN) 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 average of tariffs for *most imported products*. Specifically, the most imported

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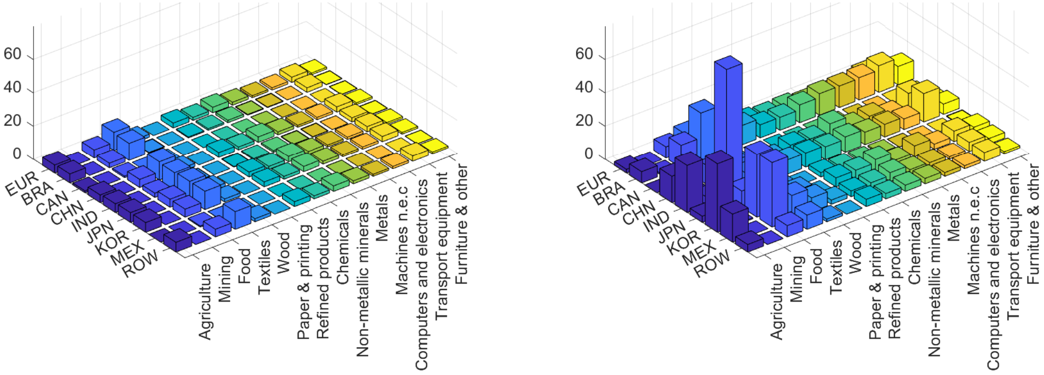
[8] We complement the product-level trade data using BACI—the world trade database developed by the CEPII—for missing values in the WITS database.

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 for 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; for services, we have country-with-country trade data. To our knowledge, no data exist for bilateral trade flows between US states in the agriculture, mining, or service sectors. In addition, there are no data for bilateral trade flows between states and foreign countries in the service sectors. In

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[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.

the appendix, we describe our procedure for constructing estimates for these missing trade flows by leveraging available trade and production data, alongside gravity variables, such as distance, common border, and common language. Our approach uses a gravity specification to predict missing trade flows and subsequently applies state-sector-level production data to impose adding-up constraints.

3.3 Parameters Estimated Using the Model

3.3.1 Productivity and Trade Costs

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

$$\ln\left(\frac{\mathrm{X}_{ni}^{j}}{\mathrm{X}_{nn}^{j}}\right)=\underbrace{\theta^{j}\ln\left(\frac{(A_{i}^{j})^{\nu^{j}}}{u_{i}^{j}}\right)}_{S_{i}^{j}}-\underbrace{\theta^{j}\ln\left(\frac{(A_{n}^{j})^{\nu^{j}}}{u_{n}^{j}}\right)}_{S_{n}^{j}}-\theta^{j}\ln\left(d_{ni}^{j}\right)-\theta^{j}\ln\left(1+\tau_{ni}^{j}\right),$$

where X_{ni}^{j} denotes location n's tariff-inclusive expenditure on sector-j goods from location i.[10] S_{n}^{j} captures location n's relative state of technology in sector j as a convolution of its unit input costs, u_{n}^{j}, and productivity, A_{n}^{j}. Any regional differences in relative trade shares that are not accounted for by tariffs or 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:

$$\ln\left(d_{ni}^{j}\right)=\mathrm{ex}_{i}^{j}+\sum_{r=1}^{6}\gamma_{d,r}^{j}\mathrm{dis}_{ni}^{r}+\gamma_{b}^{j}\mathrm{bdr}_{ni}+\gamma_{c}^{j}\mathrm{cur}_{ni}+\gamma_{l}^{j}\mathrm{lng}_{ni}+\gamma_{f}^{j}\mathrm{fta}_{ni}+\epsilon_{ni}^{j}. \tag{7}$$

The specification includes various symmetric terms. One is a distance indicator, dis_{ni}^{r}, 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 lan-

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[10] The trade data in WIOD are reported in "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.

guage, and whether they belong to a free trade agreement. The coefficients γ^j capture the 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 for the error term apply.

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

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

To improve precision in estimating the geographic effects $(\widehat{\beta}_{d,r}^j, \widehat{\beta}_b^j, \widehat{\beta}_c^j, \widehat{\beta}_l^j, \widehat{\beta}_f^j)$, 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: $\sum_{r=1}^{6} \widehat{\beta}_{d,r}^j \mathrm{dis}_{ni}^r + \widehat{\beta}_b^j \mathrm{bdr}_{ni} + \widehat{\beta}_c^j \mathrm{cur}_{ni} + \widehat{\beta}_l^j \mathrm{lng}_{ni} + \widehat{\beta}_f^j \mathrm{fta}_{ni}$.

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 $E_i^j = S_i^j - \theta^j \mathrm{ex}_i^j$. 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; measurement details are described in

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[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 $\gamma = -\beta/\theta$.

Appendix B.Because we do not have data on sectoral prices either across countries or states, we recover them based on Equation (4) using the estimated trade costs and states of technology:

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

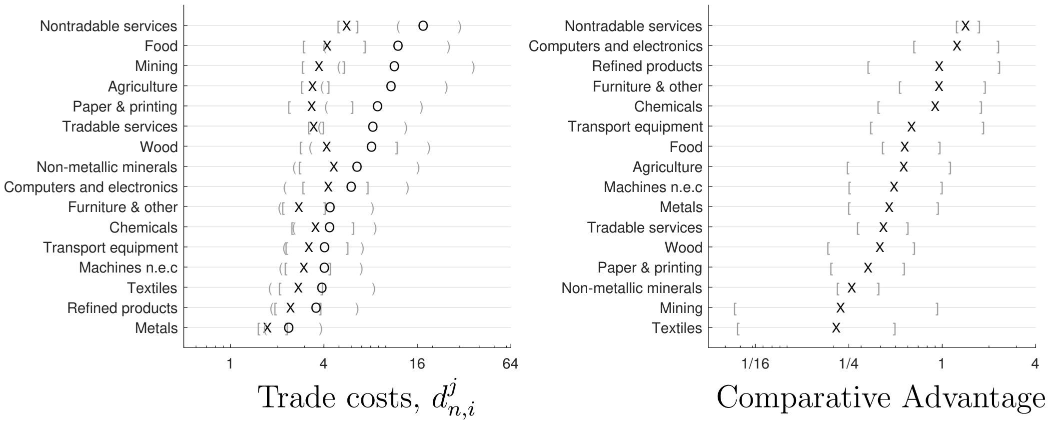
where $\gamma^j = \Gamma(1+\frac{1}{\theta^j}(1-\eta))^{1/(1-\eta)}$, and $\Gamma(\cdot)$ is the Gamma function. These inferred prices, together with factor prices, characterize the unit costs and identify the productivity from the state of technology using Equation (9).

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 recovering values for ROW using its respective GDP per capita and GDP.

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." As expected, 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, while *Metals* has the lowest. For all sectors, trade costs vary substantially not only across countries but also across states, as shown by the square and round brackets reflecting the respective interquartile ranges. Non-metallic minerals exhibits the greatest interstate dispersion in trade costs, while Mining exhibits the greatest international dispersion.

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 a comparative advantage in Computers and electronics, Refined products, Furniture & other, and Chemicals; it has a comparative disadvantage in Textiles, Mining, and Non-metallic minerals.

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: $\exp(S^j_{\text{median-USA}})/\exp(S^j_{\text{median-foreign}})$.

States also differ in their competitiveness within each sector.[12] This heterogeneity is evidenced by the square brackets, which depict the interquartile range across states for each sector. In 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 $\exp(S^j_n)$ to the median $\exp(S^j_n)$ of US states. The pattern of state internal comparative advantage plays a critical role in explaining the differential impact of trade policy changes across states.

3.3.2 Skill-Sector-Location Amenities

So far, we have obtained all parameters for the model with immobile labor, where high- and low-skill labor endowments at the state-sector level are taken directly from 2012 data. Using these parameters, we can solve the baseline model with immobile labor to obtain real wages that are specific to each state, sector, and skill group. We then calibrate amenity factors δ^{sj}_n to rationalize the real wage differentials across states, sectors, and skills implied by the baseline model with immobile labor. Specifically, we derive the ratios of amenities as the inverse of the ratios of real wages across sectors and states, expressed

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

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 for sector 1 is normalized to zero in state 1 of the United States and in each foreign country.

This calibration ensures that, prior to any tariff change, the equilibrium allocations of labor and associated factor prices are identical under the three mobility regimes: (i) immobile factors, (ii) factors mobile across sectors only, and (iii) factors mobile across both states and sectors. Consequently, when tariff rates are varied in the policy experiments, the divergence in outcomes across regimes directly reflects the influence of labor mobility on the transmission of tariff shocks, rather than differences in initial conditions.

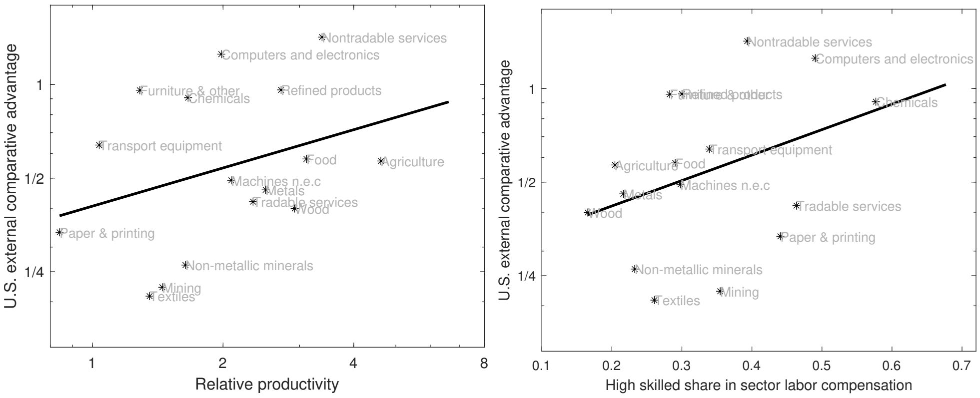
3.4 Sources of Comparative Advantage

We now shed light on the sources of US external comparative advantage and state internal comparative advantage. US external comparative advantage arises 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 underlie its external comparative advantage in sectors in high-skill-intensive sectors.

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 electronics 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 determine its near-median position across sectors in terms of external comparative advantage.

We now consider state internal comparative advantage. Quantitatively, the internal comparative advantage of a state is mainly determined by relative productivity differences rather than relative labor endowment differences. Figure 6 demonstrates that when a state's sectoral productivity relative to the median US sectoral productivity,

Figure 5: Sources of US External Comparative Advantage



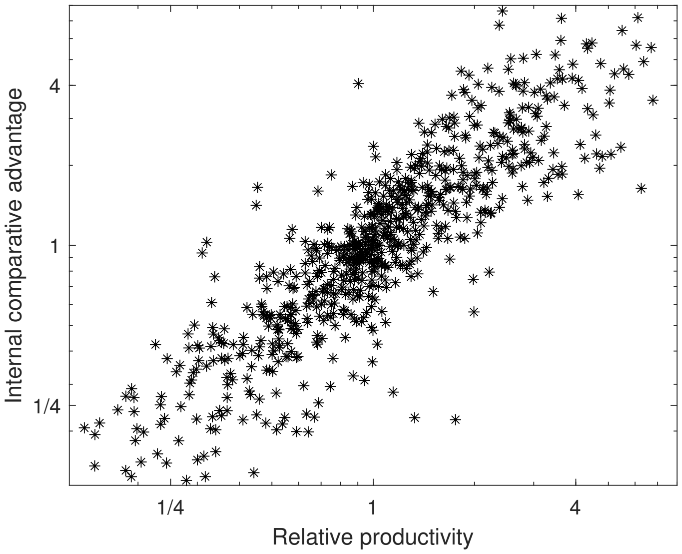
Notes: US external comparative advantage is defined as the ratio of the median US state's competitiveness to median foreign competitiveness: $\exp(S^j_{\text{median-USA}})/\exp(S^j_{\text{median-foreign}})$. Relative productivity is defined as the ratio of the median US state's fundamental productivity 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}.

$A^j_n/A^j_{\text{median-USA}}$, is high, its internal comparative advantage, $\exp(S^j_n)/\exp(S^j_{\text{median-USA}})$, is also high. The slope of the relationship is close to unity, and deviations from this relationship are due to heterogeneous factor prices across states resulting from general equilibrium effects driven by geography and heterogeneous trade costs.

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 the highest in Refined products. These inferred productivity levels reflect the patterns of trade, particularly as expressed 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 possesses 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 attracts a large share of tourism and, in turn, maintains a relatively large hospitality industry.

We conclude the calibration by checking the model fit along several dimensions. The correlation between model-predicted and data-observed 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.

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: $\exp(S_n^j)/\exp(S_{\text{median-USA}}^j)$. Relative productivity is defined as the ratio of state n's fundamental productivity to the median US state's fundamental productivity: $A_n^j/A_{\text{median-USA}}^j$.

4 Impacts of Unilateral Tariff Changes

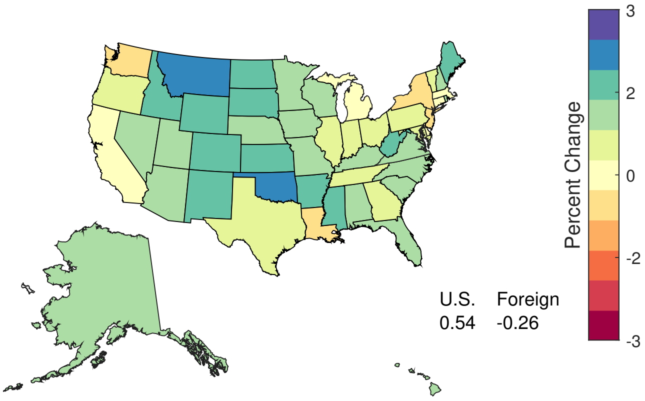
In this section, we quantify the consumption effects of a uniform increase in US import tariffs across goods sectors and identify the state-level characteristics that account for heterogeneity in consumption responses. We consider a 25-percentage-point increase in US import tariffs in all goods sectors, while holding foreign tariff rates fixed at the baseline levels. Specifically, the US import tariff schedule increases from τ to $\widetilde{\tau} = \tau + 0.25$. In this counterfactual exercise, we vary tariffs while holding productivities, preferences, and input-output coefficients fixed. We then solve for the new general equilibrium, allowing wages, prices, trade flows, and labor allocation to adjust endogenously.

We analyze the impacts of this policy under three alternative assumptions about factor mobility. In the baseline case, factors are immobile, capturing the short-run response to higher tariffs. We next allow factors to move across sectors within a state, reflecting medium-run adjustment. Finally, we allow factors to move across both sectors and states, capturing the long-run effects of the tariff increase.

4.1 Immobile Factors

We first consider the case with immobile labor, both across sectors and locations. On a population-weighted average, the policy we consider 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.

Figure 7: Percent Change in Consumption Across US States



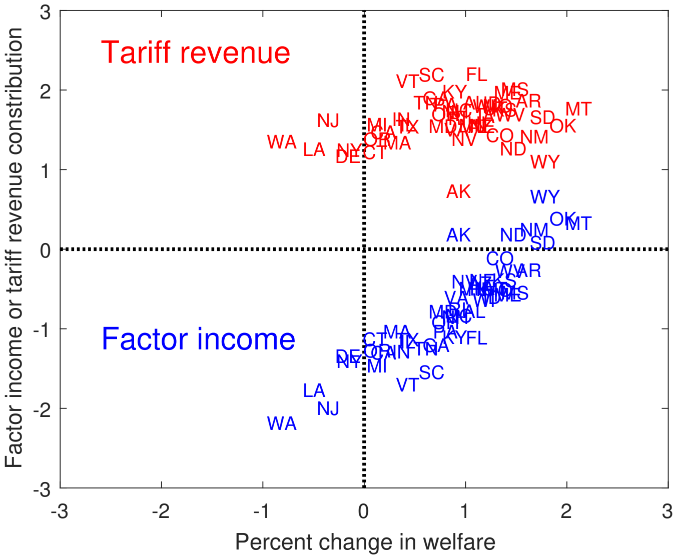
Notes: Changes in consumption associated with increasing US import tariffs in each sector uniformly by 25 percentage points. In terms of population-weighted averages, the United States gains 0.54 percent in consumption, while foreign countries collectively lose 0.26 percent.

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

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

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: 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.

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, 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 consumer prices. Specifically, 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 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

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[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

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:

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

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 effects by running the following regression:

$$\frac{\widetilde{f}^j_n/\widetilde{P}^c_n}{f^j_n/P^c_n} - 1 = \mathbf{FE}^j + \mathbf{FE}_n + \epsilon^j_n. \tag{12}$$

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.

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

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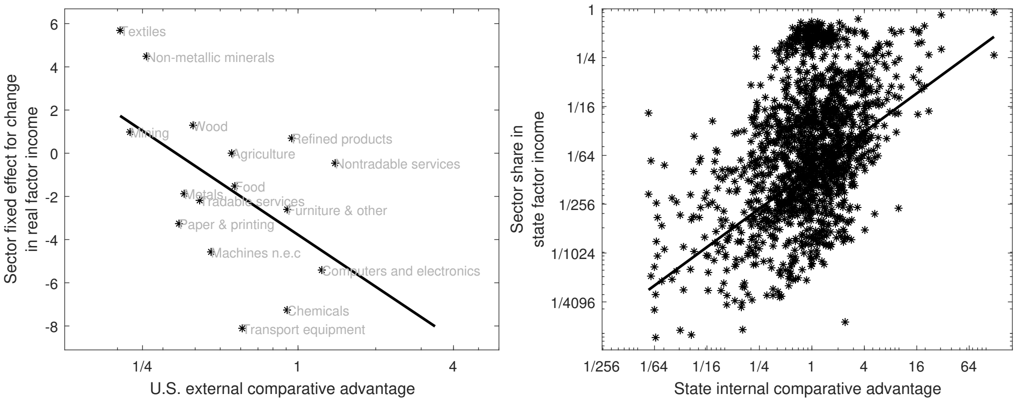
differently from changes in trade costs.

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



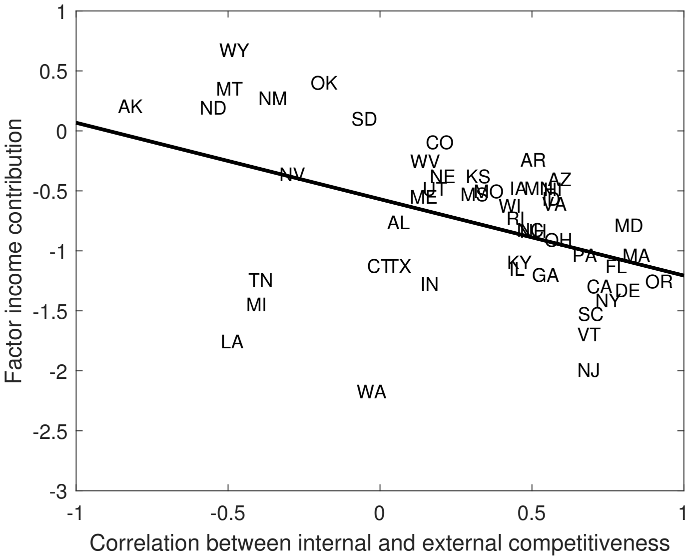
Notes: The sector fixed effect for change in real factor income is defined as the fixed effect $\mathbf{FE}^j$ in equation (12). US external comparative advantage is defined as the ratio of the median US state's competitiveness to median foreign competitiveness: $\exp(S^j_{\text{median-USA}})/\exp(S^j_{\text{median-foreign}})$.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

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.

Figure 10: Factor Income Changes vs. Similarity in Competitiveness



Notes: The y-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 x-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.

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 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 Factor Mobility

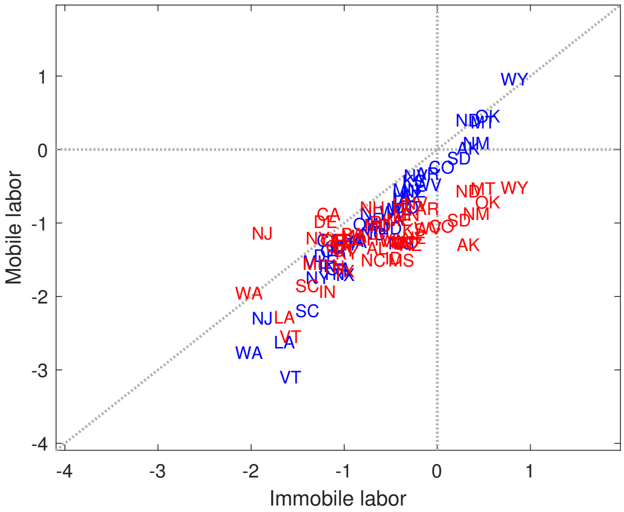
The previous analysis examined the short-run responses to higher tariffs under the assumption of factor immobility. We now extend the analysis to study the medium- and long-run implications of tariff changes by allowing for factor mobility. Specifically, we consider two scenarios: (i) factors move freely across sectors within a state, capturing medium-run adjustment; and (ii) factors move freely across both sectors and states, capturing long-run adjustment. In both cases, factors remain immobile across countries.

Figure 11 illustrates how factor mobility shapes the impact of a unilateral 25 percent tariff increase on state-level real factor income by comparing outcomes under factor mobility (y-axis) with those under immobility (x-axis). The blue points represent mobility across sectors within a state, while the red points represent mobility across both sectors and states. Allowing sectoral mobility leaves the relative ranking of states largely unchanged, as indicated by the high correlation of 0.96, but increases the dispersion of impacts across states: the cross-state standard deviation of changes in real factor income rises from 0.63 under immobility to 0.82. Allowing mobility across both states and sectors also leaves state rankings broadly similar, with a correlation of 0.82, but substantially compresses the distribution of impacts: the cross-state standard deviation falls to 0.41.

We report the aggregate effects of tariffs on the US economy under alternative factor-mobility scenarios in Table 2. The table shows that the adverse aggregate effects of tariffs are amplified by factor mobility. Real factor income falls by 1.04 percent with immobile factors, by 1.30 percent when factors can move across sectors within a state, and by 1.62 percent when factors can move across both sectors and states. As factor mobility rises, real tariff revenue declines slightly, and aggregate consumption gains shrink, eventually becoming negative in the long run when factors can move across both sectors and states.

The intuition is that factor mobility amplifies the distortions created by tariffs. When labor is immobile, adjustment is constrained, and the resulting misallocation is partially contained. In this case, the increase in tariff revenue outweighs the decline in real factor income, leading to a modest increase in consumption. When labor can move across sectors within a state, it responds to tariff-induced changes in relative wages by reallocating

Figure 11: Tariff Impact on State Factor Income: The Role of Labor Mobility



Notes: The figure compares factor-income changes from unilateral tariff increases, with the x-axis representing the case of immobile factors and the y-axis representing the cases of mobile factors across sectors within a state (blue) and mobile factors both across sectors and states (red). The diagonal dotted line represents the 45-degree line.

Table 2: Tariff Impact on US Aggregates: The Role of Labor Mobility

	Immobility	Sector mobility	Sector & State mobility
Real factor income	-1.04	-1.30	-1.62
Real tariff revenue	1.59	1.53	1.51
Consumption	0.54	0.23	-0.11

Notes: The table reports the percentage changes in consumption, real factor income, and real tariff revenue, in response to a uniform 25-percentage-point increase in US import tariffs across sectors under alternative scenarios of factor mobility.

toward artificially protected sectors. Because these sectors are not the most productive ones, this reallocation moves resources further away from the efficient pre-tariff allocation and amplifies misallocation. As a result, real factor income declines more significantly relative to the immobile benchmark. When mobility extends across both sectors and states, this distortion becomes even stronger, as labor flows not only toward protected sectors but also toward locations that benefit relatively more from tariff protection. As a result, aggregate consumption falls in this case.

This mechanism also shapes cross-state heterogeneity. States that are relatively specialized in protected sectors experience smaller losses or even gains, as labor reallocates toward those sectors. In contrast, states that are relatively concentrated in sectors with lower protection or stronger external competitiveness—such as Washington—experience larger declines. Consistent with this mechanism, Figure 11 shows that sectoral mobility increases the dispersion of tariff impacts across states. By contrast, allowing mobility across both sectors and states compresses cross-state differences in outcomes, as labor also reallocates toward locations that benefit relatively more from tariff protection. However, interstate mobility does not fully eliminate dispersion because differences in amenities continue to sustain equilibrium wage differentials.

5 Further Analysis

In this section, we examine three key questions related to the consequences of US tariff increases. First, what is the preferred unilateral tariff rate for each state relative to the national benchmark? This exercise highlights the substantial heterogeneity in trade policy preferences across states and shows that greater factor mobility dampens this heterogeneity by facilitating adjustment across sectors and locations. Second, can Kaldor-Hicks or Pareto efficiency be achieved through the redistribution of tariff revenue across states? This analysis emphasizes the importance of jointly designing tariff policy and revenue allocation mechanisms, as well as the pivotal role of factor mobility. Third, what are the aggregate and cross-state effects when foreign countries respond with tit-for-tat retaliation? We find that trade wars generate aggregate consumption losses for all countries and reduce the number of US states that experience gains, particularly as factor mobility increases. Throughout this section, we compare results across the three factor-mobility cases.

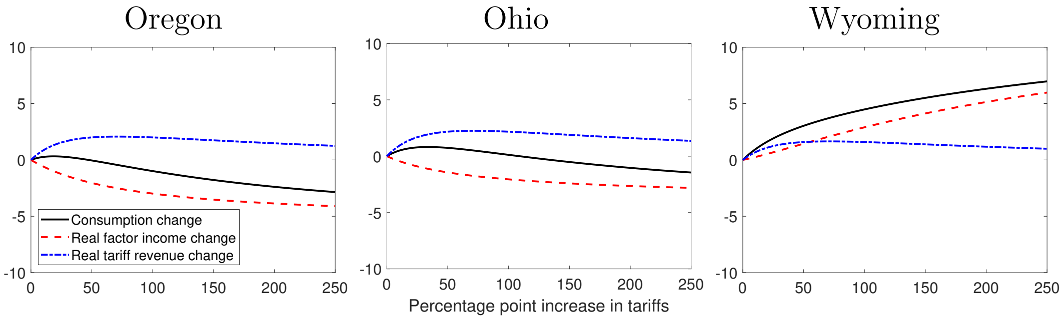
5.1 Heterogeneous Tariff Preferences across States

The cross-state heterogeneity documented in the previous section shows that a uniform 25-percentage-point increase in the US tariff rate has uneven effects across states, generating tensions in the choice of a common external tariff for the US customs union. In this subsection, we characterize state-level responses to alternative tariff increases and show that there is substantial heterogeneity in states' preferred unilateral tariff rates. This heterogeneity depends on factor mobility: spatial factor mobility reduces the dispersion in preferred tariff rates across states, while sector factor mobility does not.

To illustrate these differences in policy preferences, we ask the following question: if each state could individually choose a uniform increase in US tariffs across sectors, how large an increase would it prefer? To answer this question, we construct a Laffer-like curve for each state by tracing out the change in its consumption, relative to the baseline tariff schedule, as tariffs rise uniformly and unilaterally in all goods sectors. We conduct this exercise under the three factor mobility scenarios.

We start with the case with immobile factors. For the US as a whole, the preferred unilateral tariff increase is 26 percentage points, which delivers an increase in consumption of 0.54 percent relative to the baseline tariff schedule. 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 x-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 a similar hump-shaped pattern as the tariff rate increases. In contrast, the factor income contribution differs markedly across states. For Oregon and Ohio, real factor income declines monotonically with the tariff rate, while for Wyoming, it rises monotonically. As a result, states such as Oregon and Ohio have a finite optimal tariff rate that maximizes consumption, whereas states such as Wyoming prefer an infinite tariff rate.[14] The first column of Table 3 reports the optimal tariff rates and the associated consumption gains. Oregon prefers a 19-percentage-point increase in US tariff rates, Ohio prefers a 34-percentage-point increase, and Wyoming prefers an infinite tariff rate. More broadly, states that favor high tariff

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[14] Three other states—Alaska, North Dakota, Oklahoma—also prefer infinite tariffs. Notably, these states, together with Wyoming, rank among the top four in terms of the mining share in state GDP.

rates are precisely those that experience the largest consumption gains from a uniform 25-percentage-point tariff increase.

Table 3: Heterogeneity in Tariff Preferences

	Immobility	Sector mobility	Sector & State mobility
	Preferred Change in US Tariffs (ppts)		
US	26	18	8
Oregon	19	14	18
Ohio	34	28	21
Wyoming	∞	∞	45
	Consumption Gains under Preferred Change (%)		
US	0.54	0.23	0.07
Oregon	0.32	0.19	0.27
Ohio	0.81	0.62	0.40
Wyoming	~ 7	~ 6	0.75

Notes: A state's preferred change in US tariffs is the percentage-point increase in the unilateral, uniform U.S. external tariff—common across sectors and non-US trade partners—that maximizes consumption in that state.

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 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.

We now consider how factor mobility impacts preferred tariff rates. Table 3 reports the preferred tariff changes for US and three representative states (Oregon, Ohio and Wyoming) under the three alternative assumptions about factor mobility.[15] Allowing for sectoral mobility generally lowers the preferred tariff rate at both the national and state levels. For instance, the US preferred tariff increase declines from 26 percent under factor immobility to 18 percent when factors are mobile across sectors. Permitting mobility across both sectors and states has an even stronger effect: the preferred US tariff increase falls further to 8 percent. Greater mobility also reduces the dispersion of preferred tariff rates across states, thereby mitigating tensions surrounding the design of a common external tariff. Moreover, the consumption gains from moving from the status quo to the preferred rate are smaller under either form of factor mobility than under factor immobility.

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[15] The corresponding Laffer curves for these states under the mobility scenarios are presented in Figure C.1 in the appendix.

5.2 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 workers. Empirically, there is no specific budgeting rule governing tariff revenue, as the federal government does not earmark it for particular expenditures. However, because the US is a fiscal union, there are no inherent restrictions on how tariff revenue can be allocated across states. This allows us to jointly design tariff schedules and redistribution rules to assess the efficiency of trade policy.

We evaluate policy changes using two standard criteria. A policy is *Kaldor-Hicks efficient* if aggregate consumption increases, so that winners could in principle compensate losers. A stronger notion, *Pareto efficiency*, requires that all states weakly gain. We additionally impose that transfers must be fully financed by newly generated tariff revenue, implying non-negative net transfers across states.

We begin with the case of immobile labor. Under the baseline redistribution rule, the US as a whole gains from higher tariffs, but some states experience losses. This raises the question of whether redistribution can eliminate these losses. We find that because the increase in tariff revenue exceeds the aggregate decline in real factor income, there exists a positive surplus that can be redistributed. We construct a redistribution rule that achieves Pareto efficiency, is fully financed by tariff revenue, and that equalizes consumption gains across states.[16] Under this rule, states that experience larger declines in real factor income receive larger per-capita transfers. For example, the transfer to Washington is more than 15 times that to Wyoming on a per-capita basis.

To assess robustness, we consider three alternative redistribution rules under immobile labor. First, under *state-level retention*, each state keeps the tariff revenue generated by its own imports, so no cross-state transfers occur. Second, under *population-based transfers*, revenue is allocated proportionally to population, which is more progressive than the baseline. Third, under *GDP-based transfers*, revenue is distributed according to states' shares in US value added. While these rules generate different distributions of gains across states, they yield similar aggregate outcomes. In particular, each is Kaldor-Hicks efficient but not Pareto efficient, and aggregate consumption remains nearly unchanged across rules. Redistribution affects how tariff revenue is allocated across states, but not total factor income or the overall size of the gains.

Factor mobility fundamentally alters these conclusions. With mobility across sectors,

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[16] There are multiple redistribution rules that can deliver Pareto efficiency. Solving for such a rule involves a fixed-point problem, as both the size of the aggregate surplus and the distribution of real factor income across states are endogenous to the redistribution scheme.

the tariff increase still generates a positive aggregate surplus, so Pareto efficiency can be achieved through appropriate transfers. In contrast, when factors are mobile across both sectors and states, aggregate real factor income declines by more than tariff revenue increases. As a result, no redistribution rule can generate Pareto improvements. More generally, once tariffs reduce the aggregate surplus, redistribution cannot offset the losses, and even Kaldor-Hicks efficiency fails.

5.3 Retaliatory Tariffs

So far, we have focused on unilateral tariff increases imposed by the United States. In practice, however, foreign countries often respond either through disputes with the World Trade Organization (WTO) or by imposing retaliatory tariffs. We now study a symmetric tit-for-tat retaliation scenario in which foreign countries raise their tariffs by 25 percentage points on imports from the US across all goods sectors. Tariffs between non-US country pairs are assumed to remain unchanged. Table 4 compares the resulting consumption outcomes for the US and foreign countries, with and without retaliation, under three alternative assumptions about factor mobility.

Table 4: Consumption Impact of US Tariff Increases: With and Without Retaliation

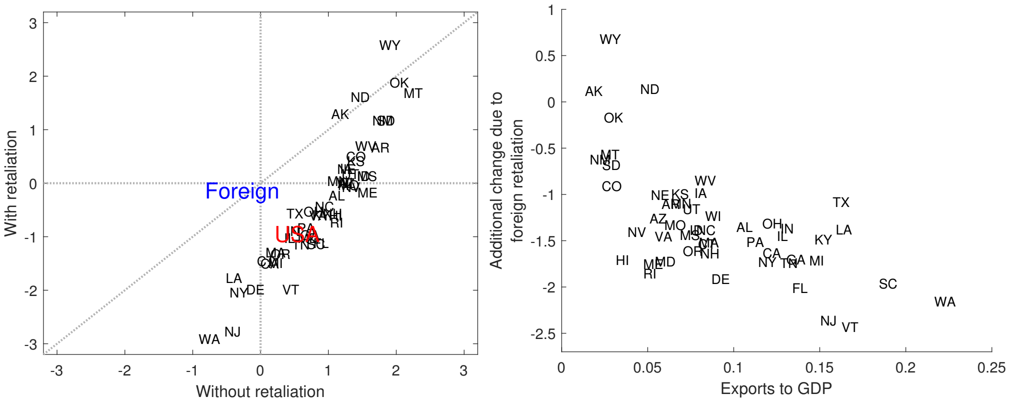
	Immobility	Sector mobility	Sector & State mobility
US			
No retaliation	0.54	0.23	−0.11
Retaliation	−0.94	−1.15	−1.73
Foreign countries			
No retaliation	−0.26	−0.27	−0.28
Retaliation	−0.13	−0.18	−0.20

Notes: The table reports the percentage changes in consumption in response to a uniform 25-percentage-point increase in US import tariffs across sectors under alternative scenarios of factor mobility, with and without tit-for-tat retaliation.

We start with the baseline case of factor immobility. A 25-percentage-point increase in US tariffs reduces the US population-weighted consumption by 0.94 percent under foreign retaliation, instead of generating a gain of 0.54 percent under unilateral policy. For foreign countries, population-weighted consumption falls by 0.13 percent with retaliation, compared with a 0.26-percent decline without retaliation. Thus, retaliation partially offsets foreign losses by eroding the US terms of trade advantage, but does not overturn the overall negative consumption effect abroad.

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 13. Moreover, the cross-state effects under retaliation are highly correlated with those under no retaliation, indicating that retaliation largely magnifies existing distributional patterns rather than reshuffling them. Retaliation also increases the dispersion of consumption effects across states. The cross-state standard deviation of percent changes in consumption is 0.7 percent in the the absence of retaliation, compared to 1.4 percent with retaliation. The right panel illustrates that the additional consumption loss from retaliation, relative to a unilateral tariff increase, is smaller for states with lower export exposure to foreign countries.[17] We also find that the additional change in real factor income from retaliation is positive for Wyoming, North Dakota, and Alaska. These states export very little to foreign countries and benefit indirectly from lower wages and lower goods prices in other states, such as Oregon, from which they source a large share of their goods.

Figure 13: Consumption Change Across US States with Foreign Retaliation



Notes: The left panel plots the consumption change from unilateral tariff increases on the x-axis and the consumption change from a trade war with retaliation on the y-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.

We now turn to the cases with sector mobility and with mobility across both states and sectors. Factor mobility does not overturn the central message regarding foreign retaliation. Across all mobility scenarios, retaliation substantially worsens US outcomes relative to the no-retaliation benchmark. Under factor immobility, a 25-percentage-point

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[17] 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.

tariff increase raises U.S. consumption by 0.54 percent in the absence of retaliation, but leads to a loss of 0.94 percent when foreign countries retaliate. With sectoral mobility, the initial gain of 0.23 percent turns into a loss of 1.15 percent under retaliation. When factors are mobile across both sectors and states, the U.S. already experiences a loss of 0.11 percent without retaliation, and retaliation deepens this loss to 1.73 percent. Hence, greater domestic adjustment margins amplify the aggregate costs of a trade war, as mobility strengthens the transmission of export contractions across sectors and locations.[18]

For foreign countries, by contrast, the degree of U.S. factor mobility has only a modest quantitative effect. Without retaliation, foreign consumption declines by roughly between 0.26 and 0.28 percent across all mobility scenarios. Retaliation partially mitigates these losses by reducing them to between 0.13 and 0.20 percent, though the overall effect remains negative.

Taken together, the results show that retaliation eliminates any potential gains from unilateral tariffs and that greater domestic factor mobility magnifies the aggregate consumption costs of trade wars. While retaliation dampens foreign losses by compressing US terms-of-trade gains, it transforms unilateral tariff gains into sizable losses for the United States and intensifies cross-state inequality in outcomes.

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 com-

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[18] Retaliation also increases the dispersion of consumption effects across states (see Figure C.2) under either form of factor mobility, as export-oriented and highly integrated states suffer disproportionately larger losses.

parative 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.

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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 every j.

The value of sector-j output produced by location n is equal to the total (pre-tariff) value of sector-j goods that all locations purchase from location 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 location n's (pre-tariff) gross absorption. The right-hand side is the sum of gross output and the net government transfers $T_n - R_n$.

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 a state's 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 of type-s labor in sector j and location n.

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

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

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

B Data

The primary data sources include the Bureau of Economic Analysis (BEA) Regional Economic Accounts; the Census Bureau American Community Survey (ACS); the Census Bureau Commodity Flow Survey (CFS); the Census Bureau Foreign Trade Database (FTD); version 10.0 of the Penn World Table (Feenstra, Inklaar, and Timmer, 2015, (PWT)); the 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); the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII), and the World Integrated Trade Solution (WITS) database. We merge these different data sources into 16 sectors and 59 locations. Unless stated otherwise, all data are for the 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 seven individual countries (each accounting for at least 1% of US imports and 1% of US exports), an 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 the 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, within each sector, the ratio of value added to gross output is the same as the ratio for the US.

Data on intermediate inputs are obtained 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-skill and low-skill) from various sources. High-skill workers are those who have completed a post-secondary degree, while low-skill

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.

workers are those who have not completed a post-secondary degree.

Data on aggregate employment (measured as the number of persons engaged) at the country level come from the PWT. Sectoral employment data for each non-US country come from the SEA16. We scale sectoral employment to match total employment from the 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 provide the high-

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

skill 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-skill share in employment in that state-sector to be the average across the 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 for the two primary factors of production (high- and low-skill 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-skill share in labor is measured as the ratio of high-skill labor compensation times total labor compensation, relative to compensation of employees. This share is then multiplied by labor compensation to obtain high-skill labor compensation. Low-skill 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 are reported on a Free on Board (FOB) basis.

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

State-to-country trade Bilateral trade between US states and non-US countries is taken from the FTD 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 total US exports to that country in the WIOD, and (ii) the sum of all states' imports from any non-US country equals US imports from that country in the WIOD.

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

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the share of hours worked by high-skill workers to be the share of employment for high-skill workers.

amount.[20] 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 occurs either because exports are over-reported due to re-export issues or because gross output is under-constructed due to our assumption of a constant gross-output-to-value-added ratio across states. To address this issue, we adjust downward 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 between 0.8 and the maximum ratio. For the problematic states, we scale down their foreign exports to equal 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 maintain consistency 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 surveyed entities 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 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:

$$\begin{aligned}\ln(\mathrm{Trd}_{ni}^{j}) = {} & \alpha_j + \delta_n + \gamma_i + \rho_0 \ln(1+\tau_{n,i}^{j}) + \rho_1 \ln(\mathrm{GO}_i^{j}) + \rho_2 \ln(\mathrm{FD}_n^{j}) \\ & + \rho_3 \mathbb{I}_{n\in\mathcal{US},i\notin\mathcal{US}} \ln(\mathrm{Trd}_{\mathrm{US},i}^{j}) + \rho_4 \mathbb{I}_{n\notin\mathcal{US},i\in\mathcal{US}} \ln(\mathrm{Trd}_{n,\mathrm{US}}^{j}) \\ & + \sum_{r=1}^{6} \beta_{d,r}^{j} \mathrm{dis}_{ni}^{r} + \beta_b^{j} \mathrm{bdr}_{ni} + \beta_c^{j} \mathrm{cur}_{ni} + \beta_l^{j} \mathrm{lng}_{ni} + \beta_f^{j} \mathrm{fta}_{ni} + \beta_h^{j} \mathrm{hbs}_{ni} + \epsilon_{ni}^{j}.\end{aligned} \tag{B.1}$$

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[20] There are eight 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.

[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.

The trade flow Trd_{ni}^{j} is the FOB value. The specification includes sector, importer, and exporter fixed effects (α_j, δ_n, and γ_i), the bilateral tariff associated with the trade flow, sectoral gross output of the exporter ($\ln(\text{GO}_i^j)$), and sectoral final demand by the importer ($\ln(\text{FD}_n^j)$).[22] Sectoral final demand for each state is calculated by assuming its ratio of final demand to GDP is the same as the national US ratio. Furthermore, 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 from country i are denoted by $\ln(\text{Trd}_{\text{US},i}^{j})$, and US exports in sector j to country i are denoted by $\ln(\text{Trd}_{n,\text{US}}^{j})$. Finally, we include sector-specific geographic effects captured by dummy variables: distance, shared border, common currency, common language, participation in a free-trade agreement, and a home-bias dummy indicating 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 coefficients are statistically significant.

We impute the missing bilateral trade flows given the observed predictors on the right-hand side of Equation (B.1). For the 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 total US exports to (imports from) that country in the 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 obtained 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 eight 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 the values with the maximum tariff value applied by the reporter in that 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. 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% of an importer's sectoral imports and that individually accounts for at least 0.005% of imports. The HS-6 trade data come from the BACI dataset developed by CEPII for 2012.

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[22] Ideally, we would use gross absorption rather than final demand, but data on gross absorption for US states in agriculture, mining, and service sectors are unavailable.

[23] Belgium and Luxembourg are merged due to trade data availability.

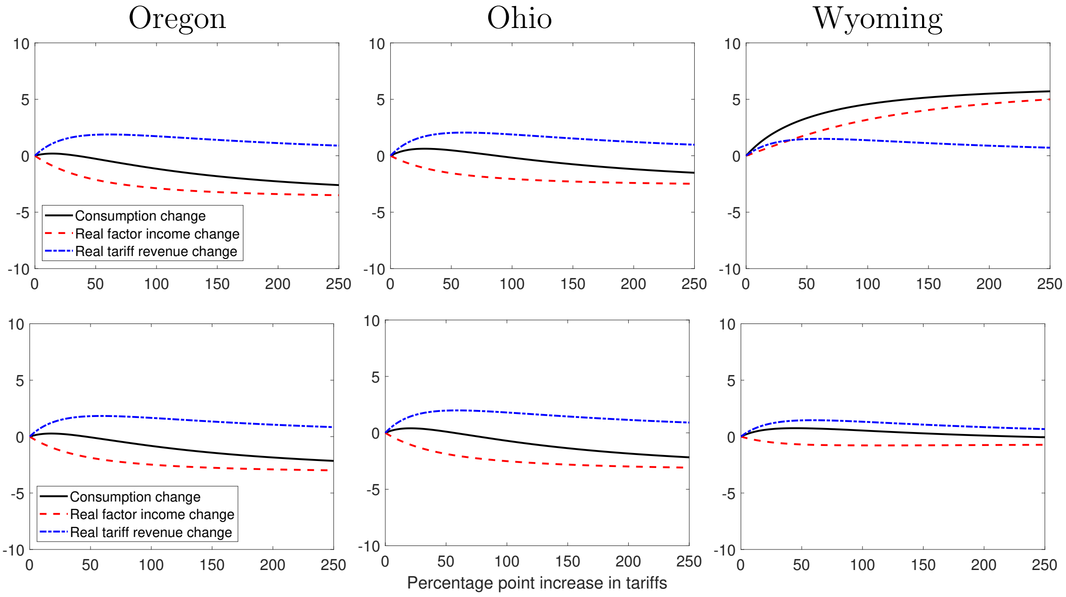
Table B.3: Estimates for Missing Trade Flows

			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.

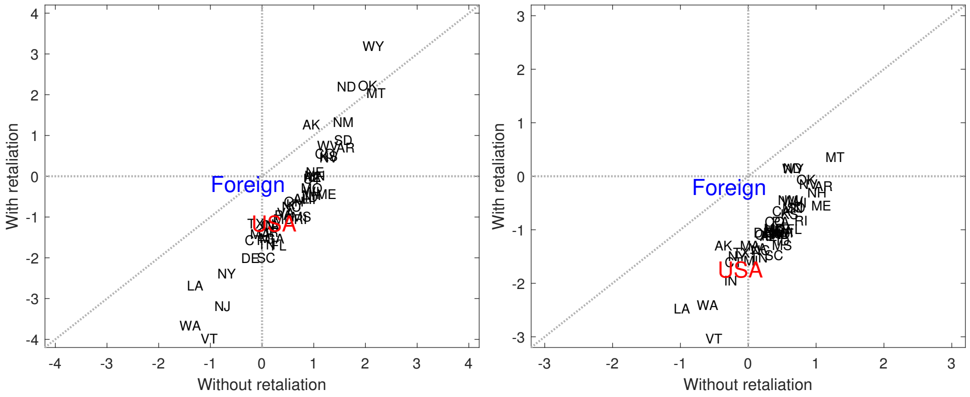
C Additional Figures

Figure C.1: 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. The first row depicts the case with sector mobility. The bottom row depicts the case with cross-state (within US) and sector mobility, and in this case each variable is expressed in per-capita terms.

Figure C.2: Consumption Change Across US States with Foreign Retaliation



Notes: Both panels plots the consumption change from unilateral tariff increases on the x-axis and the consumption change from a trade war with retaliation on the y-axis. The diagonal dotted line is the 45-degree line. The left panel depicts the case with sectoral labor mobility. The right panel depicts the case with cross-state (within US) and sectoral mobility, and captures changes in consumption per capita within each state.

D Additional Analysis

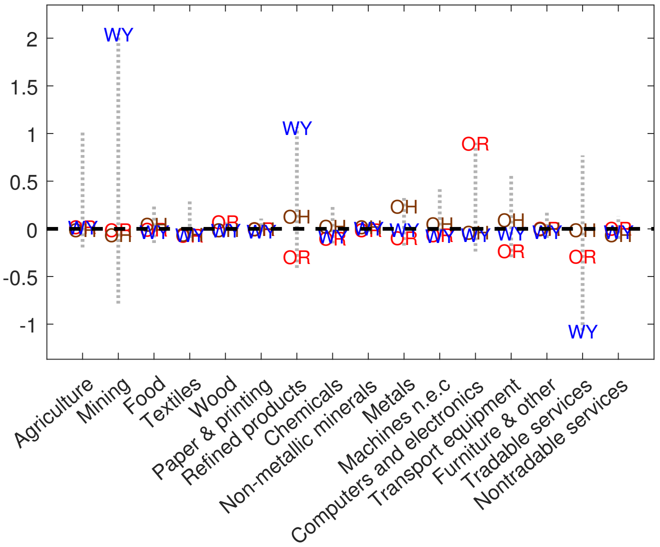
In this section, we extend our quantitative analysis in several dimensions. First, we examine the implications of sector-specific tariff changes. Second, we analyze how the skill premium responds to tariff changes under different labor mobility scenarios. Third, we conduct robustness checks on trade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

D.1 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 under immobile labor. To do so, 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 D.1 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.

A notable 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 petroleum 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 relatively mild for Ohio, because Ohio has neither a strong comparative advantage nor disadvantage in any sector. Note

Figure D.1: 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.

that the number of states exceeds the number of sectors, which naturally leads to such cross-state heterogeneity.

D.2 Wage Inequality and the Skill Premium

Up to this point, our results have 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 is determined by the product of (i) the ratio of the high-skill to low-skill labor shares in production and (ii) the inverse ratio of high-skill to low-skill labor employment in the sector-location:

$$\frac{w_n^{hj}}{w_n^{\ell j}} = \left(\frac{\lambda_n^{hj}}{\lambda_n^{\ell j}}\right)\left(\frac{e_n^{\ell j}}{e_n^{hj}}\right). \tag{D.1}$$

When workers are immobile and the elasticity of substitution between high-skill and low-skill labor is unitary (as in our Cobb-Douglas specification), the skill premium in each sector and location is invariant to changes in tariffs; that is, the right-hand side of equation (D.1) does not vary with the tariff.

With sectoral factor mobility, changes in the skill premium in equation (D.1) differ across states, as long as the changes in the ratio of low-skill to high-skill labor in sector j are not identical across states in response to the tariff increases.[24] The changes in

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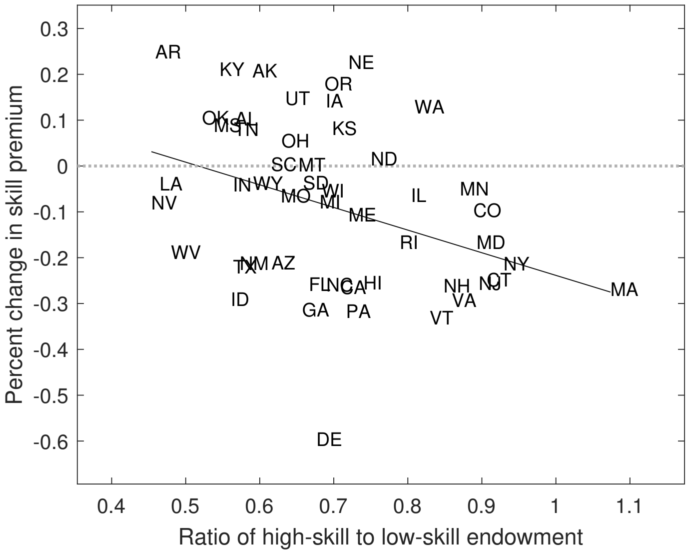
[24] Another way to introduce responses of the skill premium to tariff changes is to adopt a non-unitary

the skill premium are the same across sectors within each state, because factor mobility across sectors equates sectoral wages up to exogenous amenity differences regardless of tariff changes.

Figure D.2 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 experience 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 increased protection tends to reduce the relative return of the abundant factor (high-skill labor) as the economy shifts away from comparative-advantage sectors.

Figure D.2: 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 skill premium for the Agriculture sector in each state in response to a unilateral 25-percentage-point unilateral increase in tariffs. The change in the skill premium is identical across sectors within each location.

When workers are mobile between states, the skill premium equalizes across the United 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 is estimated to decline by about 0.5%, while most foreign countries experience increases: 0.04% in EU-28, 0.10% in South Korea, 0.23% in Brazil, 0.27% in Canada, 0.27% in India, 0.31% in China, and 0.35% in the rest of the world. These cross-country patterns are consistent with the Heckscher-Ohlin theory; as a skill-abundant country, the United

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elasticity of substitution between skill types, such as in Parro (2013).

States sees a reduction in the relative return to its abundant factor when trade barriers increase, whereas skill-scarce regions experience the opposite effect.

D.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 sectoral heterogeneity in trade elasticities by implementing two additional experiments. In the first experiment, we assign a uniform trade elasticity of $\theta = 4$ across all sectors, while keeping all other parameters unchanged. This adjustment to θ^j alone implies different model moments, particularly regarding sectoral trade flows. In the second experiment, we similarly impose a common trade elasticity of 4 across all sectors, but we re-calibrate the bilateral trade costs and fundamental productivity to ensure the model remains consistent with the baseline model's moments.

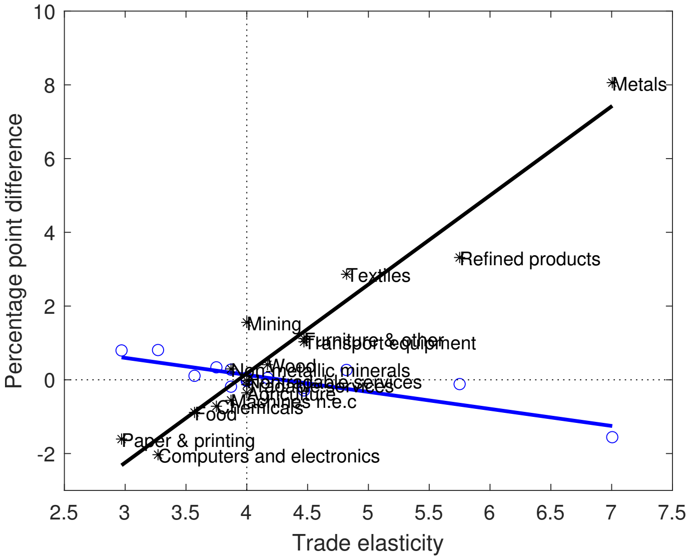
The outcomes in both experiments reveal that state-level changes in real consumption in response to tariff changes are quantitatively similar to those in the baseline model. In particular, following a 25-percentage-point increase in US-imposed tariffs, the median percent change in state-level consumption is 1.13% in the first experiment and 1.02% in the second one, compared to 1.09% in the baseline model. The cross-state correlation of these changes is 1.00 between the first experiment and the baseline model, and is 0.94 between the second experiment and the baseline.

We now analyze the sectoral impact of tariff changes when heterogeneity in sectoral trade elasticities is removed in these two experiments, as plotted in Figure D.3. 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 greater 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 the re-calibration of the trade costs and productivity offsets this effect. Sectors with higher trade elasticities in the baseline require higher implied 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.

D.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

Figure D.3: Two Experiments with Uniform Trade Elasticity Across Sectors



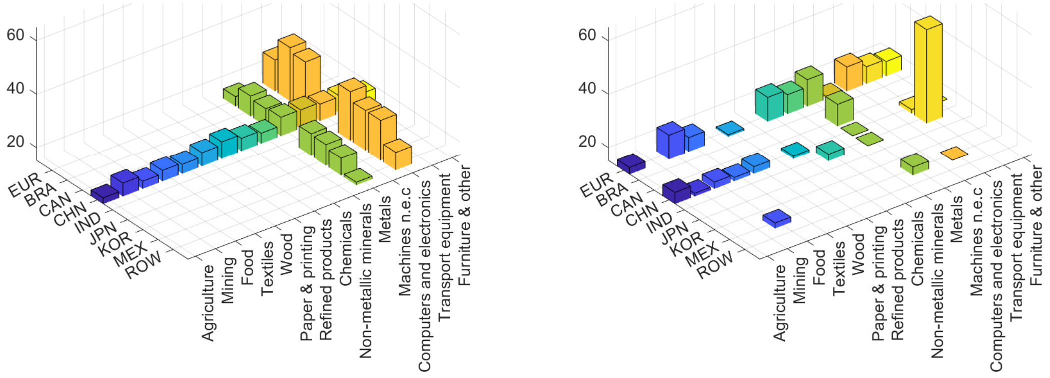
Notes: The x-axis is the sectoral trade elasticities from the baseline model. The y-axis is the percentage point difference in the median sectoral real factor income changes across states in response to a 25-percentage-point increase in tariffs between the baseline model and each of the two experiments 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 $\theta^j = 4$.

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 D.4 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% (using pre-tariff sectoral trade weights). India experienced the second-highest increase, with tariffs climbing from about 3.1% to 7.6%. Notably, all trading partners faced significant tariff increases in the Metals sector, increasing from about 0.2% to 3% (using pre-tariff country trade weights), and in the Computers and electronics sector, increasing from about 0.2% to 4.2%. 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%. Similarly, the EU imposed tariff increases in most sectors, ranging from about 3.5% to 23%.

Figure D.5 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.

Figure D.4: Changes in Tariff Rates in 2018 and 2019, Percentage Points



(a) US Import Tariff

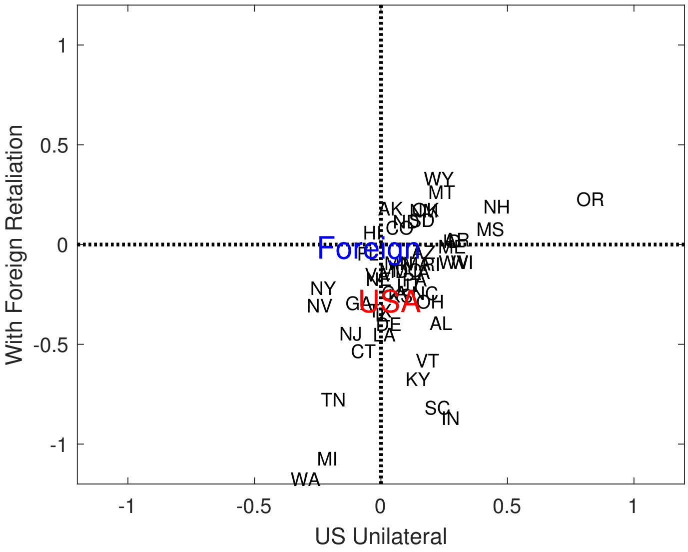
(b) Foreign Import Tariff

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.

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% decline in consumption as US imports from China decline from 1.33% to 0.65% 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% loss in consumption. This aggregate loss is consistent with the findings of Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2020). In contrast, Reyes-Heroles, Traiberman, and Van Leemput (2020) find a larger consumption loss (approximately 1%). This difference likely stems from their modeling of the capital-investment channel and long-run steady-state effects. 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 widespread with 36 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.

Figure D.5: Percent Change in Consumption Relative to Baseline Tariffs



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