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On the Distributional Effects of International Tariffs[1]

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Abstract

We provide a quantitative analysis of the distributional effects of the 2018 increase in tariffs by the US and its major trading partners. We build a trade model with incomplete asset markets and households that are heterogeneous in their age, income, wealth, and labor skill. When tariff revenues are used to reduce labor and capital income taxes and increase transfers, the average welfare loss from the trade war is equivalent to a permanent 0.1 percent reduction in consumption. Much larger welfare losses are concentrated among retirees and low-wealth and low-income workers, while only wealthy households experience a welfare gain.

KEYWORDS: tariffs, inequality, consumption, welfare, taxation.
JEL CLASSIFICATION CODES: E21, F10, F62, H21.

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1 Introduction

There has been an increase in the number of trade-restricting policies since 2018. The United States imposed tariffs both on specific goods like aluminum, steel, solar panels, and washing machines from a wide range of countries and on a wide range of goods from specific countries (like China). Many of the tariffs resulted in retaliation. These actions were a significant reversal of a movement toward freer trade that had taken place over the last half-century.

What were the welfare consequences for US households of the 2018 trade war? Answering this question requires a careful quantitative analysis because tariffs affect households differently along many dimensions. Tariffs raise the prices of tradable goods and services, and poor households spend relatively more on these than the rich, as documented by Cravino and Levchenko (2017) and Carroll and Hur (2020). Tariffs also discourage capital accumulation by increasing the cost of capital production. This raises the return on capital relative to labor, benefiting wealthy households. Even among workers, welfare could differ by skill, since trade-induced changes in the capital stock can lead to changes in the skill premium, as shown by Parro (2013).

Tariffs also raise revenue. How the government spends these revenues can mitigate or amplify welfare differences across households, especially when markets are incomplete and broader fiscal policy already entails distortionary taxes. For example, using tariff revenue to reduce labor income taxes disproportionately compensates poor workers, while the opposite is true under capital income tax reform. Moreover, because the social provision of insurance is highly valued by the poor, using tariff revenue to increase transfers may result in an average welfare gain even if tariffs reduce aggregate efficiency. This highlights an important tension: the government can use tariffs to reduce the welfare costs from market incompleteness, but does so at the cost of less productive efficiency.

In this paper, we measure the distribution of welfare resulting from the trade war using a two-country Ricardian trade model with incomplete markets and rich heterogeneity across households: consumers differ by age, income, wealth, and labor skill. We calibrate the model so that it well approximates the high degree of wealth inequality in the US. The model captures the skill bias of trade emphasized by Parro (2013) by assuming that capital is more substitutable with unskilled labor than with skilled labor, as in Krusell et al. (2000). Because the welfare of the poor is important for determining overall welfare, we use nonhomothetic preferences to match the different tradable expenditure shares by wealth. For the same reason, it is critical that the model incorporates the US social safety net. Three features of the model accomplish this. First, we assume a progressive tax-and-transfer system as in Benabou (2000), which has been shown to be a good approximation to the US income tax system. Second, we estimate a stochastic income process on data that include other non-tax government support (e.g., unemployment insurance). Third, we model a social security retirement system with decreasing replacement rates by income.

Combining official government documents from the US and its major trading partners with disaggregated trade data, we calculate an average increase in US tariffs of 4.0 percent and a retaliatory response of 2.5 percent. Starting from a no-tariff steady state, we impose these tariff rates on the world economy and solve for the ensuing transition path to a higher tariff steady state. We use the Tax Cuts and Jobs Act of 2017 (TCJA) and farmer subsidies under the Market Facilitation Program (MFP) to guide our assumptions for the allocation of tariff revenues. In our baseline, about 12 percent of the revenue is distributed lump-sum to households and the remainder is split roughly equally to reduce labor income and capital income taxes. We estimate that the trade war reduced welfare by 0.1 percent on average, with larger welfare losses among the poor and the retired. Only rich households benefited from the tariff policy.

We decompose the welfare changes by source and find that low-wealth and low-income households are most harmed by the rise in the price of tradable consumption. Transfers and labor tax reductions, policies that relatively favor poor households, offset their losses only partially. Besides being impacted less by the price of tradables, rich households also benefit from the reduction in capital income taxes.

We compare these results to those from an alternative experiment under which all tariff revenue is used for wasteful government spending. This exercise isolates the effects of higher trade costs from the effects of fiscal policy reform, providing greater insight into the baseline results. In particular, under the baseline, the capital stock barely responds to the trade war. This is because the reduction of capital income taxes encourages saving and mostly offsets the negative effect from a higher investment price. When revenues are wasted instead, the economy experiences considerable capital shallowing, which drives down wages, magnifying the welfare losses of poor workers.[2] This illustrates that the allocation of tariff revenue is of first-order importance, not only for normative results, but also for understanding aggregate outcomes.

Recognizing that our measure of the distribution of welfare is strongly influenced by our assumptions about how tariff revenue is spent, we compute a series of alternative counterfactuals in which revenue is used entirely to adjust just one of the tax/transfer instruments. Spending all tariff revenue to reduce labor taxes compensates poor workers more relative to the rich and retired, offsetting some of the anti-poor welfare effects in the baseline. In contrast, a capital income tax reform boosts aggregate investment and prevents capital shallowing. This leads to greater long-run economic activity but exacerbates welfare inequality: rich households experience a larger welfare gain, while poor households suffer larger welfare losses, relative to the baseline. However, neither reform generates an average welfare gain. If instead the government distributes the tariff revenue in a lump-sum fashion, there is a rise in average welfare. This is due to large welfare increases among retirees, poor workers, and unskilled workers for whom the transfer provides a valuable source of income and, in the case of workers, social insurance against income fluctuations.

Despite the presence of a substantial social safety net, many households would support even higher tariffs in exchange for a larger transfer. We extend the lump-sum experiment by varying US tariff levels and the retaliatory response of its trading partners. Under the assumption that US trading partners retaliate in the same proportion as they do in the baseline, average welfare is maximized at a tariff rate of 11.8 percent, nearly three times the baseline value. If the rest of the world retaliates by imposing a tariff of equal size, the welfare-maximizing tariff declines significantly, though it remains larger than the baseline. Because we do not permit the government to adjust all tax rates simultaneously, this result should not be interpreted as a general solution to an optimal tariff and tax exercise. Since imposing tariffs to lower either the labor or the capital income tax rate does not generate average welfare gains, we doubt that the solution to such an optimal policy exercise would feature a positive tariff.

In fact, these findings align with the recent optimal trade and public finance literature that finds tariffs to be suboptimal in settings that differ considerably from ours. For example,

[2] The wage decline is particularly large for skilled households as they are more complementary with capital in production. This is consistent with evidence that *reducing* trade barriers increases the skill premium since tariff policy here *increases* trade costs.

Hosseini and Shourideh (2018) study optimal trade and tax policies under cooperation in a Ricardian trade model with rich input-output linkages and imperfect mobility of workers across sectors. They find that the gains from trade can be optimally redistributed using sector-specific value-added taxes and no tariffs. These results can be interpreted as an implementation of the classic "production efficiency" result from Diamond and Mirrlees (1971). In another example, Chari et al. (2019) augment the dynamic trade model of Backus et al. (1992) to include distortionary taxes and characterize the optimal trade and tax/transfer policies in a cooperative setting. They find that tariffs are suboptimal if inter-government transfers are allowed. In contrast, Costinot and Werning (2018) consider a tax structure that is sufficiently restrictive so that production efficiency is not ensured. While positive tariffs are an optimal response to increased trade with China, quantitatively they are close to zero.[3]

Our paper contributes to an emerging literature that studies the effects of trade in dynamic models with incomplete markets. For example, Lyon and Waugh (2019) use a Ricardian trade model with uninsurable income risk to study how labor market reallocation frictions affect the gains from trade. In a similar setup, Lyon and Waugh (2018) demonstrate how the gains from trade can be redistributed to import-exposed domestic workers by increasing the progressivity of labor income taxation. Ferriere et al. (2018) study how exposure to a negative trade shock drives intergenerational skill acquisition in an overlapping generations model with financial and reallocation frictions. Finally, Kohn et al. (2019) study how the severity of financial frictions moderates the gains from trade in a model with heterogeneous entrepreneurs.

We abstract from geographic and sectoral heterogeneity; however, recent papers have studied how the tariff war has impacted different locations and/or industries.[4] For example, Fajgelbaum et al. (2020) estimate a US demand system for imports to measure the short-run impact of US and retaliatory tariffs across regions and sectors. They find that import tariffs benefited regions that were politically competitive, while the costs of the retaliatory tariffs were concentrated in heavily Republican counties. Similarly, Waugh (2019) quantifies how retaliatory tariffs have impacted consumption across regions and finds that the negative

[3]Optimal tariffs may be positive in other settings. For instance, Costinot et al. (2015), Opp (2010), and Felbermayr et al. (2013) study optimal tariffs in a strategic context. Also see Newbery and Stiglitz (1984), who construct an example where autarky is Pareto superior to free trade.

[4]See Fajgelbaum and Khandelwal (2021) for an excellent review of this recent literature.

effects are concentrated among rural and Midwest counties. Finally, Santacreu et al. (2021) study the welfare implications of tariffs across US states using an Eaton-Kortum model (Eaton and Kortum 2002). They find that welfare varies considerably across US states based upon each state's composition of production. We complement these studies by focusing on the impact of tariffs along other dimensions of heterogeneity, specifically age, income, skill, and wealth. We also investigate how tariffs can be used to reduce other distortionary taxes in an environment in which the welfare theorems do not hold.

Our model has implications regarding trade and the wage skill premium, and is thus related to a large literature that studies this relationship.[5] Acemoglu (2003) and Yeaple (2005) develop models in which trade induces skill-biased technological change, resulting in an increase in the skill premium. Ripoll (2005) and Burstein and Vogel (2017) study Heckscher-Ohlin models in which trade can lead to an increase or decrease in the skill premium, depending on initial conditions and skill-biased productivity, respectively. The link in our model between trade and the skill premium is similar to Parro (2013), in which increased trade produces a decline in the price of investment and results in a relative increase in demand for skilled labor due to capital-skill complementarity.

While our model abstracts from the Stolper-Samuelson effects of trade on the skill premium that come from differences in relative factor endowments, our focus on capital-skill complementarity is consistent with Parro (2013). He finds that the Stolper-Samuelson effect is close to zero in a model that separately quantifies the impact of the Stolper-Saumelson effect, skill-biased trade with capital-skill complementarity, and skill-biased technical change on the skill premium. It is also consistent with Reyes-Heroles et al. (2020), who use a trade model with multiple countries, sectors, and factors of production to show that a global tariff increase results in a reduction in the US skill premium that is entirely driven by capital-skill complementarity.

This paper is organized as follows. Section 2 presents the model, defines general equilibrium, and characterizes the pattern of trade. Section 3 describes and evaluates the model calibration. Section 4 details our methodology for measuring the tariffs and the allocation of revenue and quantifies the aggregate and distributional consequences of the 2018 trade war. Section 5 concludes.

[5]See Goldberg and Pavcnik (2007) for an excellent review of this literature. More recent papers include Verhoogen (2008), Amiti and Cameron (2012), and Dix-Carneiro and Kovak (2015).

2 Model

We build on the heterogeneous-agent trade model developed in Carroll and Hur (2020)—which combines Ricardian trade as in Dornbusch et al. (1977), Stone-Geary nonhomothetic preferences as in Buera and Kaboski (2009), Herrendorf et al. (2013), Uy et al. (2013), and Kehoe et al. (2018), and incomplete markets as in Aiyagari (1994), Bewley (1986), Huggett (1993), and Imrohoroğlu (1989)—by adding overlapping generations, heterogeneous skills, tariffs, distortionary income taxes, endogenous labor, and capital-skill complementarities in the spirit of Stokey (1996), Krusell et al. (2000), and Parro (2013). In each country, denoted by $i = 1, 2$, a continuum of households consume tradable and nontradable goods, save, and if they are not retired, work. Households differ in their age, labor skill, productivity, and wealth. Similar to the Blanchard-Yaari perpetual youth model, workers retire and retirees die with constant probabilities. A government collects taxes on labor income, capital income, and consumption, and may impose a tariff on imports. In addition, the government operates a pay-go social security system for retired households. We assume that trade is balanced each period.[6]

2.1 Households

Demographics. Households have a life-cycle as in the perpetual youth model of Yaari (1965) and Blanchard (1985). A household is born as a worker with initial assets, k, labor productivity, ε, and permanent skill type, $s \in \{L, H\}$, denoting low (unskilled) and high (skilled). Over its working life, a household faces idiosyncratic labor productivity risk against which it can only self-insure by accumulating non-state-contingent assets. Each period, it has a constant probability, a, of becoming retired. Once the household has retired, its productivity level is fixed. This indexes its social security benefit. The retired household finances its consumption from its retirement benefit and the wealth it accumulated during its working life. Each period, it has a probability, d, of dying. When a retired household dies, its assets are transferred to a newborn worker household with the same skill level and an initial labor productivity drawn from the invariant distribution of skill-specific productivity.

[6] For an example of a recent paper that studies unilaterally optimal trade policy with trade imbalances, see Beshkar and Shourideh (2020).

Earnings. Worker households supply $\ell\varepsilon$ efficiency units of labor to a market corresponding to their skill type, where ℓ and ε denote hours supplied and labor productivity, respectively. We assume that ε follows a skill-specific Markov process with transition matrix $\Gamma_s(\varepsilon, \varepsilon')$, which gives rise to a unique invariant distribution, $\pi_s(\varepsilon)$. A household of skill s receives a wage w_{is} for each efficiency unit of labor. Let $y = w_{is}\ell\varepsilon$ denote a household's pre-tax earnings. The government collects taxes or provides transfers based on a household's earnings, according to $T_i(y)$. Additionally, earnings are taxed at a flat rate τ_{iSS}, which funds the social security benefits, $b_{is}(\varepsilon)$, for retirees.

Assets. There are no state-contingent claims, so households insure against labor productivity risk by accumulating capital. The law of motion for capital follows $k' = k(1-\delta) + x$, where δ is the depreciation rate of capital and x is investment, which is purchased at price P_{iX}. A unit of capital has a gross return of $r_i + (1-\delta) P_{iX}$. Capital income is taxed at a flat rate of τ_{ik}. We allow households to claim a depreciation allowance against their capital income.

Preferences. Households derive utility from consuming tradable and nontradable goods, c_T and c_N, and suffer disutility from labor. We assume a time separable utility function $u(c_T, c_N, \ell)$, which is differentiable and strictly concave in c_T and c_N and strictly convex in ℓ. Households discount future utility by β and receive no utility from leaving bequests.

Recursive problem. Let $j \in \{W, R\}$ denote whether a household is a worker or a retiree. A retiree household of skill s, wealth k, and productivity ε in country i solves

$$\begin{aligned} V_{is}^{R}(k,\varepsilon) = \max_{c_T, c_N, k'} \; & u(c_T, c_N, 0) + \beta(1-d) V_{is}^{R}(k', \varepsilon) \\ \text{s.t.} \;\; & (1+\tau_{ic})(P_{iT}c_T + c_N) + P_{iX}(k' - k) \leq \\ & \quad (1-\tau_{ik})(r_i - \delta P_{iX}) k + b_{is}(\varepsilon), \\ & k' \geq 0, \end{aligned} \tag{1}$$

where τ_{ic} is the tax on both types of consumption and P_{iT} is the tradable good price. Note that we normalize the price of the nontradable good to 1 in each country.

Similarly, the problem of a worker household of skill s, wealth k, and productivity ε in country i can be stated as

$$V_{is}^{W}(k,\varepsilon) = \max_{c_T,c_N,\ell,k'} u(c_T,c_N,\ell) + \beta\left[(1-a)E_{\varepsilon'|\varepsilon,s}V_{is}^{W}(k',\varepsilon') + aV_{is}^{R}(k',\varepsilon)\right] \tag{2}$$
$$\text{s.t.}\quad (1+\tau_{ic})(P_{iT}c_T + c_N) + P_{iX}(k'-k) \leq$$
$$(1-\tau_{iSS})w_{is}\ell\varepsilon - T_i(w_{is}\ell\varepsilon) + (1-\tau_{ik})(r_i - \delta P_{iX})k,$$
$$k' \geq 0$$

Solving these problems yields decision rules $\left\{g_{isT}^{j}(k,\varepsilon), g_{isN}^{j}(k,\varepsilon), g_{is\ell}^{j}(k,\varepsilon), g_{isk}^{j}(k,\varepsilon)\right\}_{j\in\{W,R\}}$ for tradable consumption, nontradable consumption, labor, and capital, respectively.

2.2 Firms

Three types of goods are produced for household consumption and investment: nontradables, tradables, and capital. Nontradable goods are produced using skilled and unskilled labor and capital. Tradable goods are produced using a continuum of intermediate goods: each variety can be produced in either country, using as inputs both types of labor and capital. Finally, capital is produced from tradable and nontradable goods. Capital and both types of labor can move freely across sectors within a country but do not flow across countries; only intermediates are traded.

Nontradables producer. A perfectly competitive representative firm in country i produces nontradable output Y_{iN} using skilled labor (H_{iN}) and unskilled labor (L_{iN}) and capital (K_{iN}) according to

$$Y_{iN} = G(L_{iN}, H_{iN}, K_{iN}). \tag{3}$$

We assume that G is a constant elasticity of substitution function. The nontradables producer solves a static profit maximization problem,

$$\max_{H_{iN},L_{iN},K_{iN}} Y_{iN} - w_{iH}H_{iN} - w_{iL}L_{iN} - r_iK_{iN} \tag{4}$$
$$\text{s.t. } (3).$$

Final tradables producer. As is common in Ricardian trade models, such as Dornbusch et al. (1977), a representative final tradables producer in country i bundles the varieties

$\omega \in [0,1]$ of intermediate tradable goods produced in the country of origin $o = 1, 2$, $q_{oi}(\omega)$, into a single tradable good, Y_{iT}, according to

$$Y_{iT} = \left(\int_0^1 \left[\sum_{o=1,2} q_{oi}(\omega) \right]^{\rho} d\omega \right)^{\frac{1}{\rho}} \tag{5}$$

and sells it to consumers at price, P_{iT}. The varieties in the bundle $q_{oi}(\omega)$ are purchased from intermediate tradable producers in country o at price $p_o(\omega)$. Given $\{p_o(\omega)\}$ for $o = 1, 2$ and $\omega \in [0,1]$ and P_{1T}, the producer in country $i = 1$ solves

$$\max_{\{q_{o1}(\omega)\}_{o,\omega}} P_{1T}Y_{1T} - \int_0^1 \left[p_1(\omega) q_{11}(\omega) + e\tau_1 p_2(\omega) q_{21}(\omega) \right] d\omega \tag{6}$$

$$\text{s.t. } (5)$$

where $\tau_1 - 1$ is the trade cost and e is the real exchange rate, which converts units of country 2's numeraire into units of country 1's numeraire. We assume that τ_i is composed of a technological cost, $\tau_{iT} \geq 1$, and a policy cost (i.e., tariff), $\tau_{iP} \geq 0$. The final tradable good producer in country 2 solves an analagous problem. Note that the producer in country i will purchase a variety ω from the lowest cost producer.[7]

Intermediate tradables producer. A representative intermediate tradables firm in country i produces a single variety, ω, of an intermediate tradable good and hires skilled ($h_i(\omega)$) and unskilled labor ($l_i(\omega)$) and capital ($k_i(\omega)$) to produce according to the production function

$$y_i(\omega) = z_i(\omega) G(l_i(\omega), h_i(\omega), k_i(\omega)). \tag{7}$$

Notice that we are assuming that the intermediate tradables sector uses the same production function as the nontradables sector. Taking prices $p_i(\omega)$ as given, the producer solves

$$\max_{h_i(\omega), l_i(\omega), k_i(\omega)} p_i(\omega) y_i(\omega) - w_{iH} h_i(\omega) - w_{iL} l_i(\omega) - r_i k_i(\omega) \tag{8}$$

$$\text{s.t. } (7).$$

[7] Without loss of generality, we assume that the producer sources domestically in the case where costs are equal.

We assume that the productivities for variety ω in each country are given by

$$z_1(\omega) = e^{\eta\omega}, \tag{9}$$

$$z_2(\omega) = e^{\eta(1-\omega)} \tag{10}$$

so that country $i = 1$ (2) has a higher productivity for high (low) ω varieties.

Capital producer. The representative capital producer in country i produces investment goods by combining tradable and nontradable goods according to

$$X_i = z_{iX} I_{iT}^{\kappa} I_{iN}^{1-\kappa}. \tag{11}$$

Taking prices P_{iT} and P_{iX} as given, the producer solves

$$\max_{I_T, I_N} P_{iX} X_i - P_{iT} I_{iT} - I_{iN} \tag{12}$$
$$\text{s.t. } (11).$$

2.3 Government

The government in country i pays for its expenditures, G_i, by collecting taxes on consumption, labor income, capital income, and revenue from tariffs. It operates a tax and transfer program for worker households through the labor income tax bill, $T_i(y)$, and a social security system for retirees by an additional flat tax on earnings of τ_{iSS}. The government pays each retired household a fixed benefit that depends on the household's skill level and productivity in the final period of its working life. We assume that the government budgets are balanced period by period.

2.4 Equilibrium

Define the state space over wealth and labor productivity as $S = K \times E$ and let a σ-algebra over S be defined by the Borel sets, $\mathcal{B}$, on S.

Definition. A *steady-state recursive equilibrium* given fiscal policies $\{G_i, T_i, \tau_{ic}, \tau_{ik}, \tau_{iP}, \tau_{iSS},$ $\{b_{is}\}_{s\in\{H,L\}}\}_{i\in\{1,2\}}$ is, for $i = 1, 2$, a collection of functions $\left\{V_{is}^j, g_{isT}^j, g_{isN}^j, g_{is\ell}^j, g_{isk}^j\right\}_{s,j\in\{W,R\}}$, prices $\left\{r_i, \{w_{is}\}_s, P_{iT}, P_{iX}, e, \{p_i(\omega)\}_{\omega\in[0,1]}\right\}$, nontradable producer plans $\{Y_{iN}, H_{iN}, L_{iN}, K_{iN}\}$, final tradable producer plans $\left\{Y_{iT}, \{q_{oi}(\omega)\}_{\omega,o\in\{1,2\}}\right\}$, intermediate tradable producer plans $\{y_i(\omega), h_i(\omega), l_i(\omega), k_i(\omega)\}_\omega$, capital producer plans $\{X_i, I_{iT}, I_{iN}\}$, and invariant measures $\left\{\lambda_{is}^j\right\}_{s,j}$ such that

1. For $j \in \{W, R\}$ and $s \in \{H, L\}$, given $\{r_i, w_{is}, P_{iT}, P_{iX}\}$, $\left\{V_{is}^j, g_{isT}^j, g_{isN}^j, g_{is\ell}^j, g_{isk}^j\right\}$ satisfy the household problems in (1) and (2).

2. Given $\{r_i, \{w_{is}\}_s\}$, $\{Y_{iN}, H_{iN}, L_{iN}, K_{iN}\}$ solve the problem in (4).

3. Given $\left\{P_{iT}, e, \{p_o(\omega)\}_{\omega,o}\right\}$, $\left\{Y_{iT}, \{q_{oi}(\omega)\}_{\omega,o}\right\}$ solve the problem in (6).

4. For $\omega \in [0, 1]$, given $\{r_i, \{w_{is}\}_s, p_i(\omega)\}$, $\{y_i(\omega), h_i(\omega), l_i(\omega), k_i(\omega)\}$ solve the problem in (8).

5. Given $\{P_{iT}, P_{iX}\}$, $\{X_i, I_{iT}, I_{iN}\}$ solve the problem in (12).

6. Markets clear:

   (a) $Y_{iN} = \sum_{j,s} \int_S g_{isN}^j(k,\varepsilon)\, d\lambda_{is}^j(k,\varepsilon) + I_{iN} + G_i$,

   (b) $Y_{iT} = \sum_{j,s} \int_S g_{isT}^j(k,\varepsilon)\, d\lambda_{is}^j(k,\varepsilon) + I_{iT}$,

   (c) $X_i = \delta \sum_{j,s} \int_S g_{isk}^j(k,\varepsilon)\, d\lambda_{is}^j(k,\varepsilon)$,

   (d) $y_1(\omega) = q_{11}(\omega) + \tau_2 q_{12}(\omega)$ and $y_2(\omega) = \tau_1 q_{21}(\omega) + q_{22}(\omega)$ for $\omega \in [0, 1]$,

   (e) $L_{iN} + \int_0^1 l_i(\omega)\, d\omega = \int_S \varepsilon g_{iL\ell}^W(k,\varepsilon)\, d\lambda_{iL}^W(k,\varepsilon)$,

   (f) $H_{iN} + \int_0^1 h_i(\omega)\, d\omega = \int_S \varepsilon g_{iH\ell}^W(k,\varepsilon)\, d\lambda_{iH}^W(k,\varepsilon)$.

7. Trade is balanced:

$$\int_0^1 \tau_2 p_1(\omega)\, q_{12}(\omega)\, d\omega = \int_0^1 e\tau_1 p_2(\omega)\, q_{21}(\omega)\, d\omega. \tag{13}$$

8. The government budget constraint holds, for $o \neq i$,

$$G_i = \sum_s \int T_i \left(w_{is} \varepsilon g^W_{is\ell}(k,\varepsilon) \right) d\lambda^W_{is}(k,\varepsilon) + \tau_{ik}(r_i - \delta P_{iX}) \sum_{j,s} \int k d\lambda^j_{is}(k,\varepsilon) \tag{14}$$
$$+ \tau_{ic} \sum_{j,s} \int (P_{iT} g^j_{isT}(k,\varepsilon) + g^j_{isN}(k,\varepsilon)) d\lambda^j_{is}(k,\varepsilon)$$
$$+ 1_{\{i=1\}} e \tau_{1P} \int p_2(\omega) q_{21}(\omega) d\omega + 1_{\{i=2\}} \frac{\tau_{2P}}{e} \int p_1(\omega) q_{12}(\omega) d\omega,$$
$$\sum_s \int b_{is}(\varepsilon) d\lambda^R_{is}(k,\varepsilon) = \sum_s \int \tau_{iSS} w_{is} \varepsilon g^W_{is\ell}(k,\varepsilon) d\lambda^W_{is}(k,\varepsilon). \tag{15}$$

9. For any subset $(\mathcal{K},\mathcal{E}) \in \mathcal{B}$, the invariant distribution λ^j_{is} satisfies, for $s \in \{H, L\}$

$$\lambda^W_{is}(\mathcal{K},\mathcal{E}) = (1-a) \int \sum_{\varepsilon' \in \mathcal{E}} 1_{\left\{ g^W_{isk}(k,\varepsilon) \in \mathcal{K} \right\}} \Gamma_s(\varepsilon,\varepsilon') d\lambda^W_{is}(k,\varepsilon) \tag{16}$$
$$+ d \int \sum_{\varepsilon \in \mathcal{E}} \pi_{is}(\varepsilon) 1_{\left\{ g^R_{isk}(k,\varepsilon) \in \mathcal{K} \right\}} d\lambda^R_{is}(k,\varepsilon)$$
$$\lambda^R_{is}(\mathcal{K},\mathcal{E}) = (1-d) \int 1_{\{\varepsilon \in \mathcal{E}\}} 1_{\left\{ g^R_{isk}(k,\varepsilon) \in \mathcal{K} \right\}} d\lambda^R_{is}(k,\varepsilon) \tag{17}$$
$$+ a \int 1_{\{\varepsilon \in \mathcal{E}\}} 1_{\left\{ g^W_{isk}(k,\varepsilon) \in \mathcal{K} \right\}} d\lambda^W_{is}(k,\varepsilon)$$

2.5 Properties of equilibrium

We now consider how tariffs alter the set of ω varieties that are traded, which determines the final tradable goods prices in both countries. Changes in the price of tradable goods affect not only the cost of consumption baskets, but also the price of investment and thus the dynamics of capital in the model. Because we allow for complementarities between labor types and capital, these capital dynamics can have important implications for the distribution of welfare.

Patterns of trade. The final tradable producer's demand function in country $i = 1$ for a domestically produced intermediate ω is given by

$$q_{11}(\omega) \leq \left(\frac{p_1(\omega)}{P_{1T}} \right)^{-\theta} Y_{1T}, \tag{18}$$

which holds with equality if $q_{11}(\omega) > 0$. The demand function for an imported intermediate ω is given by

$$q_{21}(\omega) \leq \left(\frac{e\tau_1 p_2(\omega)}{P_{1T}}\right)^{-\theta} Y_{1T}, \tag{19}$$

which holds with equality if $q_{21}(\omega) > 0$. Combining these with (5) and assuming that the firm sources from the lowest price variety net of any trade costs, it can be shown that the tradables price is

$$P_{1T} = \left[\int_0^1 \min\{p_1(\omega), e\tau_1 p_2(\omega)\}^{1-\theta} d\omega\right]^{\frac{1}{1-\theta}} \tag{20}$$

where $\theta = \frac{1}{1-\rho}$ is the elasticity of substitution across varieties. Country 2 has analogous expressions.

Given the CES structure assumed for the production function, the price of a tradable variety produced in country $o = 1, 2$ can be obtained by combining the first-order conditions of both the intermediate and nontradable producers:

$$p_o(\omega) = \frac{1}{z_o(\omega)}. \tag{21}$$

In equilibrium, two thresholds, $\bar{\omega}_1$ and $\bar{\omega}_2$, determine the production of the intermediate tradable goods. These thresholds can be obtained by substituting equation (21) into the conditions $e\tau_1 p_2(\bar{\omega}_1) = p_1(\bar{\omega}_1)$ and $ep_2(\bar{\omega}_2) = \tau_2 p_1(\bar{\omega}_2)$. That is, these are the thresholds where a final tradables producer is indifferent between sourcing domestically or from abroad. Given the distribution of productivities in (9) and (10), we obtain

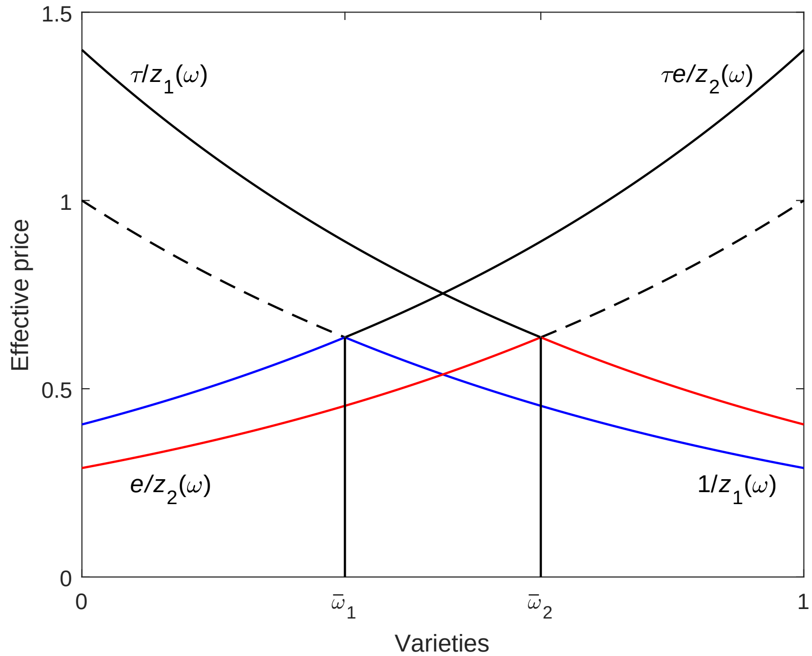
$$\bar{\omega}_1 = \max\left\{0, \frac{1}{2\eta}\left[\eta - \log(e\tau_1)\right]\right\}, \tag{22}$$

and

$$\bar{\omega}_2 = \min\left\{1, \frac{1}{2\eta}\left[\eta - \log\left(\frac{e}{\tau_2}\right)\right]\right\}. \tag{23}$$

Figure 1 illustrates the pattern of production, trade, and specialization. Both countries produce the varieties $\omega \in [\bar{\omega}_1, \bar{\omega}_2]$. Note that when $\tau_1 = \tau_2 = 1$, we obtain $\bar{\omega}_1 = \bar{\omega}_2$, which corresponds to free trade and full specialization, and when $\tau_1 e > \exp(\eta)$ or $\tau_2 > \exp(\eta)e$, we obtain $\bar{\omega}_1 = 0$ or $\bar{\omega}_2 = 1$, which corresponds to autarky.

Figure 1: Pattern of production, trade, and specialization



Tradable and investment prices. Substituting the prices in (21) into the tradable price aggregator in (20) and imposing the pattern of trade above, we obtain the equilibrium final tradable good prices in each country,

$$P_{1T} = \left[\int_0^{\bar{\omega}_1} \left(\frac{\tau_1 e}{z_2(\omega)} \right)^{1-\theta} d\omega + \int_{\bar{\omega}_1}^1 \left(\frac{1}{z_1(\omega)} \right)^{1-\theta} d\omega \right]^{\frac{1}{1-\theta}} \tag{24}$$

and

$$P_{2T} = \left[\int_0^{\bar{\omega}_2} \left(\frac{1}{z_2(\omega)} \right)^{1-\theta} d\omega + \int_{\bar{\omega}_2}^1 \left(\frac{\tau_2}{e z_1(\omega)} \right)^{1-\theta} d\omega \right]^{\frac{1}{1-\theta}}. \tag{25}$$

Equations (24)–(25) show that the tradable price in each country is a function of the productivity of the intermediate tradable producers, $z_o(\omega)$, in country $o = 1, 2$, the real exchange rate, e, the trade costs of country i, and the set of goods that are imported, which is determined by $\bar{\omega}_i$.

Using the capital producer's first-order conditions, we can derive the equilibrium investment price,

$$P_{iX} = \frac{1}{z_{iX}} \left(\frac{P_{iT}}{\kappa} \right)^{\kappa} \left(\frac{1}{1-\kappa} \right)^{1-\kappa}. \tag{26}$$

This demonstrates that increases in the price of tradables lead to an increase in the investment price, by a factor of κ.

Comparative statics. The effect of an increase in country 1's trade costs on its tradable price can be written as

$$\frac{dP_{1T}}{d\tau_1} = \frac{\partial P_{1T}}{\partial \tau_1} + \frac{\partial P_{1T}}{\partial e}\frac{de}{d\tau_1}. \tag{27}$$

The first term, $\partial P_{1T}/\partial \tau_1 > 0$, is the direct effect, which reflects the increase in costs of imported intermediates. Note that if the two symmetric countries impose identical tariffs, then $e = 1$ and therefore only this direct effect is present. More generally, however, changes in tariffs can affect the real exchange rate, either amplifying or mitigating the direct effect. This indirect effect is captured in the second term. $\partial P_{1T}/\partial e$ is clearly positive since a deterioration in the terms of trade (i.e., a rise in e) again increases the cost of imports. The sign of the overall effect, however, is ambiguous because $de/d\tau_1$ depends on factors such as the relative size of each country and the degree to which country 2 retaliates. While we cannot derive a closed-form expression for $de/d\tau_1$, across our numerical experiments, we find that a unilateral tariff always leads to an improvement in the terms of trade, mitigating the direct effect of the tariff. The reverse can be true when the trading partner's size or its retaliatory tariff is relatively large.

As discussed above, higher tradables prices pass through to the price of investment, and this promotes capital shallowing. Ultimately, the extent of the capital shallowing—or whether it occurs at all—depends on factors such as the tariff response of country 2 and how country 1's government redistributes tariff revenue. We quantitatively analyze these cases in the following sections.

3 Calibration

We now discuss our functional form assumptions and parameterize the model so that the steady-state equilibrium matches several features of the US economy. In what follows, country $i = 1$ refers to the United States (US) and country $i = 2$ refers to the rest of the world (ROW), representing the main trading partners.[8] We assume that both countries have identical parameters, with the exception of population size.

[8] The set of countries is: Canada, China, Japan, Mexico, South Korea, and EU member countries.

Household demographics and earnings. The measures of skilled and unskilled households are set to 0.33 and 0.67, respectively, to match the fraction of college graduates among household heads between the ages of 23 and 64, 33 percent (2004–2014, *Panel Survey of Income Dynamics*, PSID, Institute for Social Research 2021). Holding fixed the proportion of skilled and unskilled labor, we then scale the measure in ROW by a factor of 2, since ROW is roughly twice as large as the US economy.

The labor productivity shocks, ε_s, take values from one of two finite sets depending on a household's skill. We assume that each set is made up of six elements. The first five elements are "normal" worker states and are assumed to follow an order-one auto-regressive process as follows:

$$\log \varepsilon' = \rho_s \log \varepsilon + \nu, \nu \sim N\left(0, \sigma_{s\nu}^2\right) \tag{28}$$

with persistence ρ_s and standard deviation $\sigma_{s\nu}$ of the persistent shock ν. For the purpose of estimating this process using household data from the PSID, we also add transitory shocks to allow for measurement error (see Appendix A for details). We compute household wages, defined as the sum of household labor earnings and transfers (excluding social security) divided by the sum of hours worked and hours unemployed. We include transfers and hours unemployed because our model does not include unemployment or transfers that are not part of the income tax system. We then remove fixed effects for time and the household head's age and education, and uncover estimates of $\rho_H = 0.91$ and $\sigma_{H\nu} = 0.23$ for skilled households (defined as households whose head has a bachelor's degree or higher) and $\rho_L = 0.94$ and $\sigma_{L\nu} = 0.20$ for unskilled households.[9] These processes are approximated by a five-state Markov chain using the Rouwenhorst procedure described in Kopecky and Suen (2010).

The sixth and final productivity element is a "superstar" state, which is reached with very low probability. Superstar households have much higher productivity than the average worker. Following Kindermann and Krueger (2014), we assume that a household that exits the superstar state falls to the median worker's productivity level. We calibrate the model so that superstars (of either skill type) are the top 1 percent of earners. Using Social Security Administration data from 1978–2004, Kopczuk et al. (2010) find that a worker in the top 1 percent of earners has a 75 percent probability of remaining there after one year. Therefore,

[9] The sample selection and estimation procedures closely follow Krueger et al. (2016). See Appendix A for details. Notice that our estimates are similar to those of Floden and Lindé (2001), who estimate a similar process for wages across all skill groups.

we set $\Gamma_s(\varepsilon_s(6), \varepsilon_s(3)) = 0.25$ and $\Gamma_s(\varepsilon_s(6), \varepsilon_s(6)) = 0.75$[10] and set the entry probability (from any normal state) to 0.28 percent so that the total mass of superstars in the economy is equal to 1 percent of all workers. Finally, the productivity values of the superstar states, $\varepsilon_L(6) = \varepsilon_H(6)$, are calibrated so that the steady-state 95-to-50 wealth ratio matches the data counterpart of 19.4 (2004–2014, PSID).[11]

We set the probability that a worker retires, a, to 0.025 and the probability that a retiree dies, d, to 0.067, so that the average working life and retirement are 40 years and 15 years, respectively. The social security benefit is assumed to depend on a household's skill level and on the household's last working-age productivity level. We follow Huggett and Parra (2010), who use marginal replacement rates of 0.9 for labor income less than 0.21 times average earnings, 0.32 for labor income between 0.21 and 1.29 times average earnings, and 0.15 for labor income between 1.29 and 2.42 times average earnings. Since social security is capped, we fix the benefit of the retired superstars to the maximum value among the normal workers.

Household preferences. The utility function takes the form

$$u(c_T, c_N, \ell) = \frac{\left[c_T^{\gamma}(c_N + \bar{c})^{1-\gamma}\right]^{1-\sigma}}{1-\sigma} - \psi \frac{\ell^{1+\nu}}{1+\nu}$$

with $\bar{c} > 0$, representing Stone-Geary nonhomothetic preferences.[12] We choose the tradable share parameter, γ, and the nonhomothetic preference parameter, $\bar{c}$, so that the model matches the average tradable expenditure shares in the US of 35 percent and that of the top 25 percent of the wealth distribution, 31 percent (2004–2014, Carroll and Hur 2020). Matching these heterogeneous expenditure shares is important because it allows the model to better quantify the distributional effects from increases in the tradables price across the income and wealth distributions.

The household's disutility from labor, ψ, is set so that the model generates a share of disposable time spent working of 0.33. The household's discount factor, β, is chosen so that the model matches the net-worth-to-GDP ratio in the US, 4.8 (2014, *US Financial*

[10] The persistence of the superstar state is considerably lower than any of the normal worker states. Castaneda et al. (2003) show that this high risk of an extreme disruption in earnings can generate wealth inequality close to that in the data by pushing the precautionary savings motive into the right tail.

[11] The skill-specific productivity values and transition matrices are provided in Appendix A.

[12] We discuss the implications of departing from homothetic preferences in Section 4.7.

Accounts). Finally, we set the household's risk aversion, σ, to be 2 and the Frisch elasticity, $1/\nu$, to be 0.5, which are standard values in the literature (for example, see Chetty et al. 2011).

Production and trade. The production function for the nontradable good and tradable intermediate good producers is assumed to take the form:

$$G(H, L, K) = \left[(1-\mu) L^{\zeta} + \mu[(1-\alpha) H^{\chi} + \alpha K^{\chi}]^{\frac{\zeta}{\chi}}\right]^{\frac{1}{\zeta}} \tag{29}$$

where $1/(1-\zeta)$ is the elasticity of substitution between unskilled labor and capital and $1/(1-\chi)$ is the elasticity of substitution between skilled labor and capital. This functional form, similar to ones used in Stokey (1996), Krusell et al. (2000), and Parro (2013), allows for the elasticities between skill types and capital to be different. In particular, by setting $\chi < \zeta$, we assume that there is capital-skill complementarity.[13] The elasticities of substitution between unskilled labor and capital and between skilled labor and capital are set to 1.67 and 0.67, respectively, following Krusell et al. (2000) and Parro (2013).[14] We set the weight on capital and unskilled labor in tradables and nontradables production, α and μ, to match the aggregate capital income share of 36 percent and the skilled wage premium of 85 percent (2004–2014, PSID).[15]

The parameter that governs the curvature of the productivity distribution, η, is set so that the employment share of the top 17 percent of intermediate producers is 32.1 percent.[16] For the empirical counterpart, we compute the employment share of the top 17 percent

[13]See Violante (2008) for an overview of skill-biased technical change, including the literature on technology-skill complementarity, and Lewis (2011) and Duffy et al. (2004), who provide empirical evidence for capital-skill complementarity across US regions and across a wide range of countries, respectively.

[14]Notice that, following Krusell et al. (2000) and Parro (2013), we are assuming that the elasticity of substitution between unskilled labor and skilled labor is the same as that between unskilled labor and capital goods. See Krusell et al. (2000), who argue that the alternative assumption of restricting the elasticity of substitution between capital goods and skilled labor to be the same as that between skilled labor and unskilled labor is inconsistent with empirical estimates. Section 4.7 discusses how assuming a Cobb-Douglas form instead affects our results.

[15]Note that we assume that the production functions and their parameters are the same across tradable intermediate and nontradable production. We do so for two reasons. First, this assumption keeps the model more tractable, both analytically and computationally. Second, to our knowledge, there are no existing empirical estimates on sector-specific elasticities of substitution between skilled and unskilled labor and capital, for tradable and nontradable sectors. Estimating these elasticities is beyond the scope of this paper, and we leave this to future research.

[16]Each ω variety is treated as being produced by a separate establishment. So the employment share is calculated as $\int_{\hat{\omega}_1}^{1} (l_1(\omega) + h_1(\omega))\, d\omega / \int_{\bar{\omega}_1}^{1} (l_1(\omega) + h_1(\omega))\, d\omega$, where $1 - \hat{\omega}_1 = 0.17(1 - \bar{\omega}_1)$.

of large US manufacturing establishments (at least 100 employees), which is 32.1 percent (2014, US Census, *Business Dynamics Statistics*). To calibrate the elasticity of substitution between tradable varieties, θ, we solve the long-run response of our model to a 1 percent rise in trade costs and verify that it generates a trade elasticity of 4.1, the preferred estimate of Simonovska and Waugh (2014). We set the tradable share in capital production, κ, to match the tradable share of capital production inputs calculated from the US input-output table, 56 percent (2014, *Bureau of Economic Analysis*). We assume that the initial steady-state tariff is set to zero, and set the technological trade cost $\tau_T - 1$ to match the US import share of GDP, 17 percent (2014, *World Bank*).

Finally, the depreciation rate of capital, δ, is set to 5 percent, a standard value in the literature.

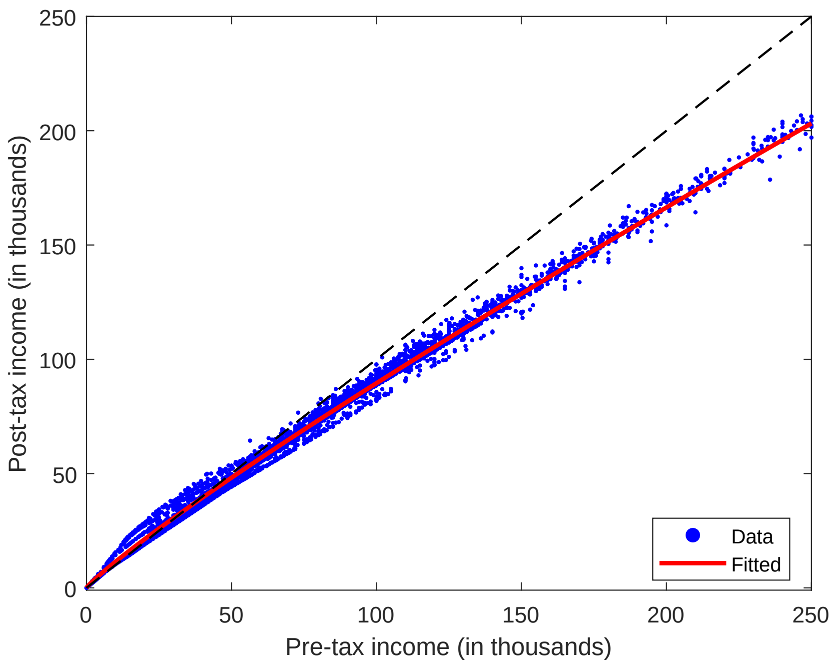
Government. The nonlinear tax schedule over labor income takes the following form:

$$T(y) = y - (1 - \tau_y)\frac{y^{1-\nu_y}}{1 - \nu_y} - Tr_y. \tag{30}$$

This form (with $Tr_y = 0$) was introduced by Feldstein (1973) and used by Benabou (2000). The parameter τ_y adjusts the average level of labor income taxes, while ν_y controls the degree of progressivity. Heathcote et al. (2017) estimate the parameters τ_y and ν_y and find that the function well-approximates the labor income tax and transfer system in the US. To improve fit at the ends of the earnings distribution, we follow Daruich and Fernández (2020) and Boar and Midrigan (2020) and include the tax credit parameter, $Tr_y > 0$.

To estimate these parameters, we first compute a measure of household earnings from the 2017 PSID (which covers the 2016 tax year) that also includes transfers (minus social security) as in the earnings process estimation. Then we pass these values to TAXSIM32 (Feenberg and Coutts 1993) to find after-tax earnings and estimate $\nu_y = 0.11$ using nonlinear least squares (Figure 2). Because our earnings measure already includes some transfers, our estimate of the progressivity parameter is somewhat lower than those from Heathcote et al. (2017), Daruich and Fernández (2020), and Boar and Midrigan (2020). The labor tax transfer, Tr_y, is set so that the bottom 10 percent of the earnings distribution receives a net tax equal to -0.9 percent of average labor income (2016, PSID). Finally, τ_y is calibrated so that the average net tax rate is 13.1 percent.

Figure 2: Tax function



Notes: Each data observation is a household in the PSID for the tax year 2016. Pre-tax income includes household labor income plus transfer income, excluding social security. Post-tax income is pre-tax income minus taxes estimated by TAXSIM32.

The tax rates on consumption and capital income, τ_c, τ_k, are set to 6.4 and 27.3 percent, respectively, following Carey and Rabesona (2002), who estimate national tax rates from OECD data.[17] τ_{SS} is set to 10.5 percent so that in the initial steady state, social security tax revenue equals total benefits paid to retirees.[18]

Summary. We summarize the parameters and targets in Table 1. In total, there are 13 parameters that are internally calibrated (i.e., require solving the model): discount factor, β, tradable share parameter, γ, non-homotheticity parameter, $\bar{c}$, labor disutility, ψ, capital weight, α, skilled weight, μ, productivity curvature, η, elasticity of substitution between intermediates, θ, trade cost, τ, average tax parameter, τ_y, tax credit parameter, Tr_y, social security tax, τ_{SS}, and superstar productivity, $\varepsilon_L(6) = \varepsilon_H(6)$. The remaining 19 parameters are either set from external sources or calibrated externally (i.e., before solving the model).

3.1 Model validity

Before continuing to our model's evaluation of the tariff war and its welfare consequences, we first examine how well it approximates moments of the distribution of wealth, income, and consumption, including those that we did not target in the calibration. Table 2 compares the values of some nontargeted moments in the model and the data. Overall, the model does a good job, particularly in terms of inequality. The model generates tradable expenditure shares that match the data at the median but that are slightly higher than those in the data for the lower 25 percent of the wealth distribution. The Gini coefficients as well as the inter-percentile ratios are very close to their data counterparts.[19] The model also approximates well the fraction of households with nonpositive wealth in the data. The model produces considerable wealth inequality between skill groups, though not to the same degree as in the data.[20]

[17] These rates are very close to those estimated by McDaniel (2007), who conducts an exercise similar to that of Carey and Rabesona (2002) but using national accounts data.

[18] In all of our numerical exercises, we leave social security benefits and the tax rate fixed along the transition path. Any social security surplus or deficit is added to the general government budget. In all cases, these imbalances in social security are extremely small.

[19] Note that we use the PSID data to compute all of these moments, including those related to wealth. Because the PSID is a random sample, it does not do as good a job of capturing the high degree of wealth concentration in the US as does the Survey of Consumer Finances, particularly if the SCF is augmented with the Forbes 400 data and measures of defined benefits (Bricker et al. 2021).

[20] The model relies primarily on labor income differences to generate wealth inequality by skill. One plausible reason the gap might be larger in the data is that there may be differences in returns on saving by

Table 1: Calibration

Parameters	Values	Targets / Source
Discount factor, β	0.97	Wealth-to-GDP: 4.8
Risk aversion, σ	2	Standard value
Tradable share, γ	0.28	Tradable expenditure share: 35 percent
Nonhomotheticity, $\bar{c}$	0.05	Tradable expenditure share of wealthiest 25 percent: 31 percent
Disutility from labor, ψ	83	Average hours: 33 percent
Frisch elasticity, $1/\nu$	0.5	Standard value
Retirement probability, a	0.025	Expected working years: 40
Death probability, d	0.067	Expected retirement years: 15
Skilled fraction, $\bar{H}_1$	0.33	Skilled labor force: 33 percent
Capital weight, α	0.81	Capital income share: 36 percent
Skilled weight, μ	0.55	Skill premium: 85 percent
Elasticity of substitutions,		
unskilled–capital, $1/(1-\zeta)$	1.67	Krusell et al. (2000)
skilled–capital, $1/(1-\chi)$	0.67	Krusell et al. (2000)
tradable intermediates, θ	6.00	Trade elasticity: 4.1
Factor elasticity, κ	0.56	Tradable input share in capital production
Capital depreciation rate, δ	0.05	Standard value
Productivity distribution, η	0.69	Employment share of top 17% of large manufacturing establishments: 32%
Iceberg cost, $\tau - 1$	0.07	Import share: 17 percent
Fiscal parameters		
average, τ_y	0.27	Average net tax rate: 13 percent
tax credit, Tr_y	0.002	Average net tax of bottom 10 percent of earnings: –0.9% of average labor income
progressivity, ν_y	0.11	Authors' estimates
consumption, τ_c	0.06	Carey and Rabesona (2002)
capital, τ_k	0.27	Carey and Rabesona (2002)
social security, τ_{SS}	0.11	Government budget constraint
benefits, b		See text
Persistence of wage process,		
unskilled, $\rho_{L,\varepsilon}$	0.94	Authors' estimates
skilled, $\rho_{H,\varepsilon}$	0.91	Authors' estimates
Standard deviation,		
unskilled, $\sigma_{L,\nu}$	0.20	Authors' estimates
skilled, $\sigma_{H,\nu}$	0.23	Authors' estimates
Superstar parameters		
highest productivity, $\varepsilon_L(6) = \varepsilon_H(6)$	39	Wealth p95/p50: 19.4
persistence, $\Gamma_s(\varepsilon_s(6), \varepsilon_s(6))$	0.75	persistence of top 1 percent: 75 percent
exit, $\Gamma_s(\varepsilon_s(6), \varepsilon_s(3))$	0.25	$1 - \Gamma_s(\varepsilon_s(6), \varepsilon_s(6))$
entry, $\Gamma_s(\varepsilon_s(1:5), \varepsilon_s(6))$	0.0028	Mass of superstars: 1 percent of workers

Table 2: Model and data

Targeted moments	Data	Model
Wealth-to-GDP	4.8	4.8
Trade elasticity	–4.1	–4.1
Import share	0.17	0.17
Tradable expenditure shares:		
average	0.35	0.35
top 25 percent (wealth)	0.31	0.31
Wealth p95/p50	19.4	19.4
Nontargeted moments		
Tradable expenditure shares:		
median	0.34	0.34
bottom 25 percent (wealth)	0.38	0.41
Gini coefficients:		
wealth (k)	0.75	0.77
consumption (c)	0.35	0.35
disposable labor income* (y)	0.41	0.47
Correlations between*:		
$\log k, \log y$	0.44	0.20
$\log k, \log c$	0.55	0.81
$\log c, \log y$	0.67	0.42
Wealth distribution:		
p90/p50	11.2	9.3
p95/p90	1.7	2.1
p99/p95	2.7	2.6
frac. w/ nonpositive wealth	0.17	0.19
skilled p50/unskilled p50	4.0	2.7
Wealth mobility: 2-year persistence of		
top 25 percent	0.83	0.71
bottom 25 percent	0.70	0.96

*: conditional on working age

In terms of wealth mobility, the model broadly captures the high persistence at the top and bottom 25 percent. The persistence of the bottom 25 percent is higher in the model than in the data: this is mainly because *all* low-wealth retirees remain poor during retirement in the model—it is an absorbing state. Finally, the model correlation between consumption and disposable labor income (measured in logs) and that between income and wealth are smaller than in the data and the model correlation between consumption and wealth is larger than in the data. The latter is to be expected in a model where households use wealth to smooth income fluctuations.

4 Quantitative Exercises

In this section, we use our calibrated model to analyze the impacts of the 2018 trade war. We allow the government to redistribute tariff revenue through a combination of labor income tax and capital income tax reductions and lump-sum transfers. We use the reductions in tax revenues enacted in the Tax Cuts and Jobs Act of 2017 (TCJA) and the Market Facilitation Program of 2018 (MFP) to inform our redistribution exercise.

4.1 Measuring the tariffs of 2018

We focus on tariffs that were officially announced in 2018 by the US and its major trading partners (Canada, China, EU, Japan, Korea, and Mexico). Our goal is to calculate an aggregate tariff rate increase that reflects the *perceived* increase in trade costs in 2018. Since tariffs can differ across time, commodities, and country of origin, we now describe how we obtain an aggregated measure.

For differences across time, we consider the maximum of any scheduled increases or decreases that were *officially announced* in 2018. For example, in the case of the US tariff on solar panel imports, which starts at 30 percent in 2018 and is scheduled to decrease by 5 percent annually, we use 30 percent. In the case of the US tariff on washing machine imports, which is 20 percent for the first 1.2 million units and 50 percent thereafter, with both rates scheduled to decrease by 5 percent annually, we use 50 percent. In another example, the third round of tariff increases on imports from China started at 10 percent on September

skill. For instance, college-educated households are more likely to hold stocks in their portfolio or to employ a financial advisor (Bertaut and Haliassos 1997; Lusardi et al. 2017).

24, 2018 and the tariffs were scheduled to increase to 25 percent on January 1, 2019. In this case, we use 25 percent (the rate increase was postponed multiple times and eventually implemented on May 10, 2019). In a similar example, on August 3, 2018, China announced tariffs ranging from 5 to 25 percent on $60 billion worth of US imports, lowered them to 5–10 percent on September 24, 2018, and raised them to 5–25 percent on June 1, 2019. In this case, we use the originally announced tariffs of 5–25 percent. We do not include further increases in tariffs that were officially announced after 2018, such as additional escalations in tariffs by the US and China in 2019 and those by the US and EU in 2019 and 2020. We also do not include tariffs that were only unofficially announced, such as the 25 percent tariff on automobile imports and the 5–25 percent tariffs on all Mexican imports.[21]

To aggregate across commodities, we use as weights the 2017 import volumes. Whenever possible, we use the weights that are provided in the official documentation. For example, we use a weight of $16 billion on the 25 percent tariff on Chinese imports that was announced on June 20, 2018, based on United States Trade Representative (2018), which states that the tariffs are to be applied on commodities that "have an approximate annual trade value of $16 billion." In another example, for the retaliatory tariffs levied by the EU, which range from 10 to 50 percent, we use a tariff rate of 23 percent and a weight of $7 billion. This is based on the World Trade Organization (2018), which estimated $1.6 billion in tariff duty over $7.1 billion worth of imports from the US ($23 = 100 \times 1.6/7.1$). When the official documentation only provides the tariff schedule, we match it with disaggregated trade data to compute both the average tariff and the weight.[22] For example, in the case of the Mexican tariffs of 7–25 percent on US imports, we match the tariff schedule with Mexico's US imports and compute a weighted average of 20.6 percent, applied on $3.5 billion worth of US imports.

Finally, to compute the aggregate tariff change for the US on its major trading partners, we multiply the tariff rates by their respective weights, shown in Table 3, sum them up, and divide by total US imports from its major trading partners in 2007, $1.8 trillion, to arrive at 4.0 percent. To get a sense of the magnitude, given that the import share of US GDP is roughly one-half of the capital income share of US GDP, a 4 percent increase in tariffs roughly raises the same amount of tax revenue as a 2 percent increase in the capital income tax rate, holding fixed the revenue base.

[21] See, for example, https://www.bbc.com/news/world-us-canada-48469408.

[22] For US imports, we use DataWeb (United States International Trade Commission 2021). For US exports, we use Trade Map (International Trade Centre 2021).

Table 3: Tariffs of 2018

Date officially announced	Date effective	Country	Products	Official tariff (percent)	Effective tariff (percent)	Weight ($ bil)	Source
Tariffs on US imports							
Jan 23, 2018	Feb 7, 2018	all	Solar panels	30	30	4	US Proclamation 9693
Jan 23, 2018	Feb 7, 2018	all	Washing machines	20–50	50	1	US Proclamation 9694
Mar 8, 2018	Mar 23, 2018	all	Aluminum	10	10	12	US Proclamation 9704
Mar 8, 2018	Mar 23, 2018	all	Steel	25	25	19	US Proclamation 9705
Jun 20, 2018	Jul 6, 2018	China	List 1	25	25	34	USTR 2018-13248
Aug 16, 2018	Aug 23, 2018	China	List 2	25	25	16	USTR 2018-17709
Sep 21, 2018	Sep 24, 2018	China	List 3	10–25	25	200	USTR 2018-20610
Total imports from EU, Canada, China, Japan, Korea, Mexico (2017)						1751	
Weighted average tariff (percent)					**4.0**		
Retaliatory tariffs on US exports							
May 6, 2018	Jun 5, 2018	Mexico	Various	7–25	20	4	Mexican government[a]
May 18, 2018	Jun 20, 2018	EU	Various	10–50	23	7	WTO G/L/1237
Jun 4, 2018	Jul 1, 2018	Canada	Various	10–25	14	17	Canadian government[b]
Mar 29, 2018	Apr 3, 2018	China	Various	15–25	22	3	WTO G/L/1218
Jun 16, 2018	Jul 6, 2018	China	List 1	25	25	34	USTR 2018-15090
Jun 16, 2018	Aug 23, 2018	China	List 2	25	25	16	USTR 2018-15090
Aug 3, 2018	Sep 24, 2018	China	List 3	5–25	14	60	Chinese government[c]
Total exports to EU, Canada, China, Japan, Korea, Mexico (2017)						1056	
Weighted average tariff (percent)					**2.5**		

[a]: Diario Oficial de la Federación (http://www.dof.gob.mx/nota_detalle.php?codigo=5525036&fecha=05/06/2018)
[b]: Department of Finance (https://www.canada.ca/en/department-finance/programs/consultations/2018/notice-intent-impose-countermeasures-action-against-united-states-response-tariffs-canadian-steel-aluminum-products.html)
[c]: Taxation Commission Announcement 2018-6 (http://gss.mof.gov.cn/gzdt/zhengcefabu/201808/t20180803_2980950.htm)

Restricting the set of tariffs to only those that were effective in 2018 (by replacing the 25 percent US tariff on $200 billion worth of Chinese imports with 10 percent), we arrive at a more conservative estimate of 2.3 percent. On the other hand, by including all of the tariffs levied in 2018–2020 as well as those that were only unofficially announced, we arrive at a more liberal estimate of 11.7 percent. We believe that 4.0 percent is a good middle-of-the-road estimate that reflects the *perceived* increase in trade costs at the end of 2018.

Retaliatory tariffs by the major trading partners are calculated analogously, which we calculate to be 2.5 percent. Table 3 lists all of the retaliatory tariffs that are included in this calculation. As is the case for US tariffs, we consider the maximum of the tariff schedules officially announced by the major trading partners in 2018. We do not include any tariffs that were announced after 2018, such as those by the EU and China. We also do not include retaliatory tariffs that were proposed (but never formally announced) such as those by Japan in 2018 and Mexico in 2019. Restricting our calculation to only tariffs that were effective in 2018, we arrive at a conservative estimate of 2.1 percent. Including tariffs levied after 2018 as well as those that were only unofficially announced, we arrive at a liberal estimate of 3.1 percent. Again, we believe that 2.5 percent is a good middle-of-the-road estimate of the perceived increase in retaliatory tariffs.

4.2 Allocating tariff revenue to fiscal reforms in the model

As we will demonstrate in our quantitative exercises, the welfare consequences of tariffs crucially depend on how tariff revenue is spent. This presents a challenge, however, because the US government did not earmark tariff revenues to any specific fiscal reform. The closest example of spending being related to tariffs was the USDA's Market Facilitation Program (MFP), which was enacted in 2018 and "aimed at assisting farmers suffering from damage due to unjustified trade retaliation by foreign nations."[23]

The USDA made about $8.6 billion in transfer payments to producers who applied for the

[23]See, for example, https://www.usda.gov/media/press-releases/2020/02/03/usda-issues-third-tranche-2019-mfp-payments. The USDA also implemented two additional programs: the Food Purchase and Distribution Program (FPDP), which purchased commodities determined to have been affected by trade retaliation, and the Agricultural Trade Promotion Program (ATP), which subsidized private efforts to expand export markets. For our analysis, we only use the direct transfers in the MFP. However, because the FPDP and the ATP were much smaller than the MFP, our quantitative results would be unchanged by their inclusion.

MFP in 2018,[24] or approximately 12.3 percent of estimated tariff revenue. In the model, there are no "farmer" households, so we approximate these payments with a universal lump-sum transfer.[25] We treat the remaining revenue as being incorporated into the general budget to be allocated in support of other fiscal expenditures. We assume that these revenues were used to partially offset the revenue losses from the Tax Cuts and Jobs Act of 2017, which lowered labor income tax rates and reduced the taxes on capital gains and investment income. Analyses published around the time of enactment estimate that the TCJA would reduce revenues from labor income by \$1.9 trillion and from capital income by \$1.7 trillion over 10 years.[26] Clearly, these revenue losses—in magnitudes—are much larger than the estimated tariff revenue. However, we use the proportion of tax revenue changes related to labor and those related to capital in the TCJA to guide the tax reforms in our model. This equates to allocating 52.8 and 47.2 percent of the remaining tariff revenue toward reducing labor and capital income taxes, respectively.

4.3 The trade war of 2018

We initialize the economy in a steady state with no tariffs. Then, at the beginning of period $t = 1$, the US imposes an unanticipated tariff of 4.0 percent on imports from ROW, and ROW responds with a retaliatory tariff of 2.5 percent. These values correspond to the effective tariff changes documented in Section 4.1. In our baseline, the US redistributes tariff revenue in the following manner: 12.3 percent is given back to households lump-sum; 46.3 percent is used to reduce the labor income tax rate; and the remaining 41.4 percent reduces the capital income tax rate. This corresponds to the proportions of tax revenue changes for labor income, capital income, and transfers documented in Section 4.2. Specifically, the government reduces labor income tax rates by decreasing τ_{yt} in (30) and the capital income tax rate by lowering τ_{kt} and provides a lump-sum transfer, Tr_{it}, to all households.[27]

[24] https://www.usda.gov/media/press-releases/2019/07/25/usda-announces-details-support-package-farmer

[25] In Appendix C.3, we explore the implications of targeting the lump-sum transfer to worker households only.

[26] For example, see Table 5 in Tax Foundation (2017), which attributes \$1.9 trillion to the adjustment to individual income tax rates and thresholds and \$1.7 trillion to lower corporate income taxes and the deduction for pass-through business income.

[27] Notice that Tr_{it} is distinct from the additive constant labor income tax parameter, Tr_y, which remains at its calibrated value in all our exercises. Tr_y only applies to households that pay labor income taxes (i.e., workers), while Tr_{it} benefits *all* households.

We solve for the perfect foresight transition path to the new steady state. At each time period, t, a retired household with skill type $s \in \{L, H\}$ solves:

$$
\begin{aligned}
V^R_{ist}(k,\varepsilon) = \max_{c_T, c_N, k'} \; & u(c_T, c_N, 0) + \beta(1-d)V^R_{is,t+1}(k',\varepsilon) \\
\text{s.t.} \quad & (1+\tau_{ic})(P_{iTt}c_T + c_N) + P_{iXt}(k'-k) \leq \\
& \quad b_{is}(\varepsilon) + (1-\tau_{ikt})(r_{it} - \delta P_{iXt})k + Tr_{it}, \\
& k' \geq 0,
\end{aligned} \tag{31}
$$

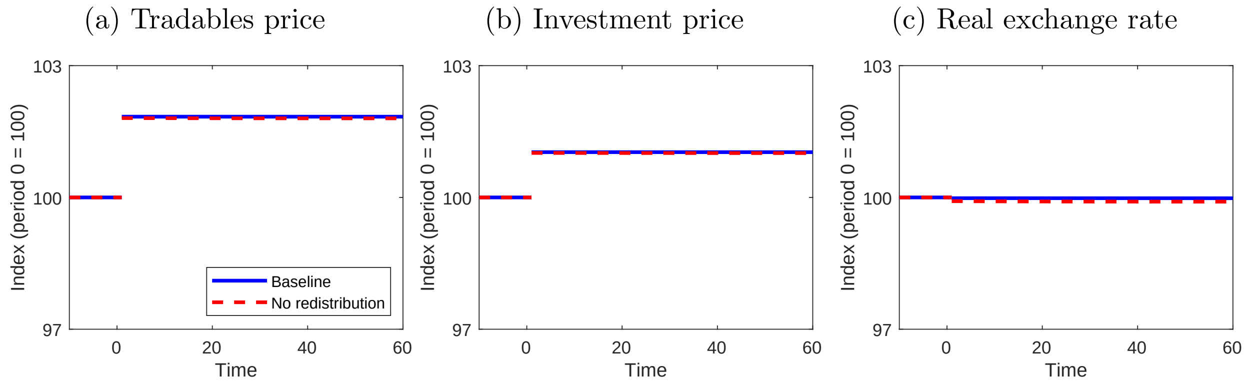
and a worker household with skill type $s \in \{L, H\}$ solves:

$$
\begin{aligned}
V^W_{ist}(k,\varepsilon) = \max_{c_T, c_N, \ell, k'} \; & u(c_T, c_N, \ell) + \beta\left[(1-a)E_{\varepsilon'|\varepsilon,s}V^W_{is,t+1}(k',\varepsilon') + aV^R_{is,t+1}(k',\varepsilon)\right] \\
\text{s.t.} \quad & (1+\tau_{ic})(P_{iTt}c_T + c_N) + P_{iXt}(k'-k) \leq \\
& \quad (1-\tau_{iSS})w_{ist}\ell\varepsilon - T_{it}(w_{ist}\ell\varepsilon) + (1-\tau_{ikt})(r_{it} - \delta P_{iXt})k + Tr_{it}, \\
& k' \geq 0.
\end{aligned} \tag{32}
$$

The solution to (31)–(32) yields a sequence of time-dependent value functions $\{V^j_{ist}\}^\infty_{t=1}$ and decision rules $\{g^j_{isTt}, g^j_{isNt}, g^j_{is\ell t}, g^j_{iskt}\}^\infty_{t=1}$ for $i = 1, 2$, $s \in \{H, L\}$, and $j \in \{W, R\}$. The definition of competitive equilibrium is then given by value functions and decision rules, prices $\left\{r_{it}, w_{iHt}, w_{iLt}, P_{iTt}, P_{iXt}, e_t, \{p_{it}(\omega)\}_{\omega\in[0,1]}\right\}^\infty_{t=1}$, wealth distributions $\{\lambda^j_{ist}\}^\infty_{t=1}$, and fiscal policies $\{\tau_{i\ell t}, \tau_{ikt}, \tau_{iPt}, T_{it}, \tau_{iSS}, \{b_{is}\}_{s\in\{H,L\}}, Tr_{it}\}$ for $i = 1, 2$, $s \in \{H, L\}$, and $j \in \{W, R\}$, such that given prices, households and firms make optimal decisions, markets clear, trade is balanced, the government budget constraint holds,[28] and distributions are consistent with household savings decisions. As in the steady-state analysis, we use the nontradable good as the numeraire in each country and the real exchange rate is given by e_t. We assume that in country $i = 2$, all taxes and transfers remain at their initial steady-state values and any changes in revenue are reflected in government expenditures. Appendix B provides the algorithm used to solve the model.

[28] Because the social security tax rate and the retiree benefit schedule are fixed at their initialized values, changes in aggregate labor income can produce imbalances in the social security budget along the transition path. In all of our exercises, these imbalances are extremely small. For simplicity, we let any surpluses or deficits in the retirement system be subsumed into the overall government budget constraint.

Figure 3: Prices



Aggregate effects. When the trade war begins, the price of tradables consumption jumps 1.8 percent to a new permanent level, reflecting the increased cost of imports and the less efficient pattern of production and trade. The pass-through from tradables prices moves the investment price, P_X, up by 1.0 percent. The exchange rate is essentially unchanged, as shown in Figure 3.

Despite a sizeable and permanent increase in the price of investment, there are scant signs of capital dynamics in the baseline transition path, shown in Figure 4. The long-run capital stock declines by only 0.4 percent, and output falls by only 0.2 percent. Households adjust their consumption bundles, substituting nontradables for tradables, but on balance the path of aggregate consumption is virtually flat. Imports fall from 17.0 to 15.3 percent of GDP.

This subdued response of capital is the result of competing general equilibrium effects. On the one hand, the pure effect of the tariff suppresses the return to capital, discouraging investment and inducing capital shallowing in the economy. On the other hand, the reduction in the capital income tax rate—made feasible by the new tariff revenue—increases the after-tax return to capital. These two opposing forces have a very negligible net effect on the capital stock.

The pure tariff effect is shown in Figures 3–5 by the dashed line. This line traces a counterfactual transition path resulting from the government using tariff revenue to increase G instead of reducing taxes.[29] Although the path of P_X is nearly identical in the two cases (Figure 3b), without redistribution the long-run capital stock declines by 1.2 percent. GDP

[29]This fiscal policy closely correlates with a common thought experiment from the trade literature where iceberg trade costs change. See, for example, Arkolakis et al. (2012).

Figure 4: Aggregate quantities

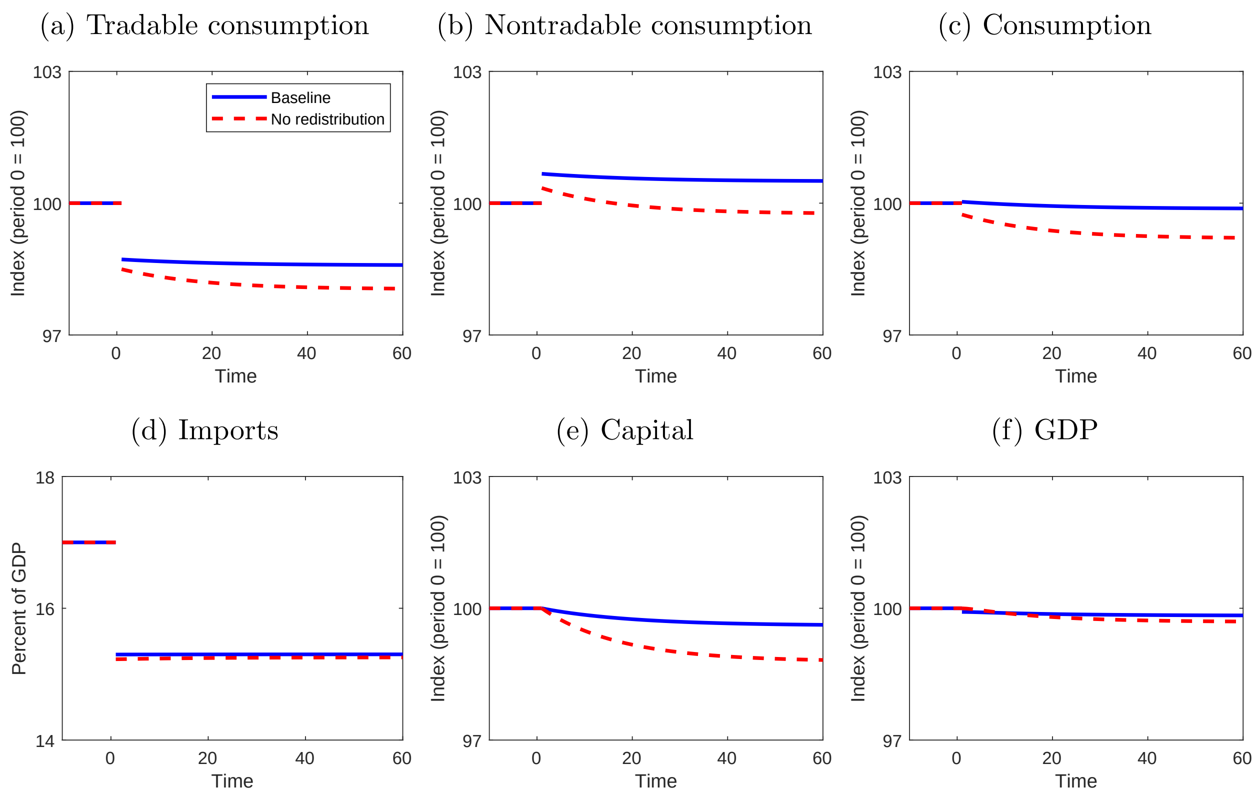
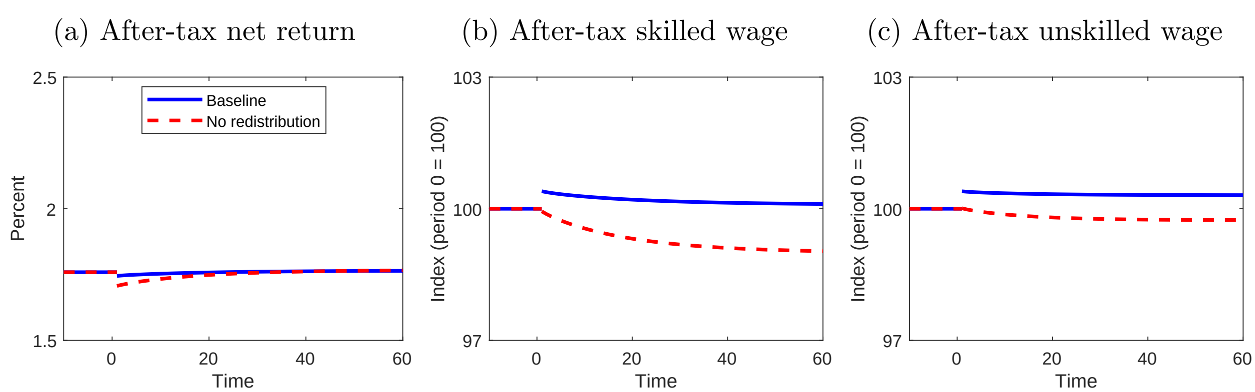


Figure 5: Factor prices



and especially total consumption are also lower following the implementation of tariffs. We view this finding as evidence that assumptions about the allocation of tariff revenue are consequential, not only for normative analysis but also for positive analysis.

In our baseline, the long-run average after-tax wages of the skilled and the unskilled increase by 0.1 and 0.3 percent, respectively (Figure 5). Because capital exhibits very little response, these increases are almost entirely due to the decrease in average labor income taxes. If revenue is instead used for wasteful government spending, after-tax wages fall for both skill groups because of capital shallowing. In this case, the decline is larger for skilled workers as they are more complementary with capital in production. In the baseline, the reduction in the capital income tax cancels out the rise in the investment price so the after-tax return barely changes.

4.4 Welfare consequences

The dynamic response of prices arising from the imposition of tariffs leads to differential welfare effects on households depending upon their wealth, income, skill type, and age. We quantify these welfare effects in this subsection.

We calculate the distribution of welfare using consumption equivalence. For each household, we compute the value, $1+\Delta$, by which initial steady-state consumption of tradables and nontradables would both have to be permanently increased in order to make a household indifferent to the policy change.[30] Negative values of Δ indicate that a household is harmed by raising tariffs, since it would be willing to permanently sacrifice consumption to avoid the transition to a higher tariff environment. Formally, given the household value functions at the beginning of the transition, $V^{j}_{is,t=1}(k,\varepsilon)$, and the initial steady-state decision rules, g^{j}_{isT}, g^{j}_{isN}, $g^{j}_{is\ell}$, and g^{j}_{isk}, we solve for $\Delta^{j}_{is}(k,\varepsilon)$, such that

$$V^{j\Delta}_{is}(k,\varepsilon) = V^{j}_{is,t=1}(k,\varepsilon)$$

[30]Because preferences are nonhomothetic, one may be concerned that we are mismeasuring welfare by restricting compensation to be equally proportioned across both types of consumption goods. We have explored the consequences of using each household's ideal composition, however, and found that the differences were quantitatively negligible.

Table 4: Welfare

	Total	Decomposition				Support
		wage	investment	expenditure	transfer	
All	–0.1	0.2	0.2	–0.7	0.2	16
Skilled	–0.1	0.2	0.2	–0.6	0.1	17
Unskilled	–0.0	0.3	0.2	–0.7	0.2	20
Retired	–0.3	0.0	0.1	–0.7	0.3	8
High wealth	0.2	0.1	0.6	–0.6	0.1	97
Low wealth	–0.3	0.1	0.0	–0.8	0.3	0
High income	–0.0	0.2	0.2	–0.4	0.1	23
Low income	–0.1	0.2	0.1	–0.7	0.3	15

Units: percent. High and low wealth correspond to the top and bottom deciles of wealth, respectively. High and low income correspond to the top and bottom deciles of labor income, respectively, conditional on working age. Support reports the percent of each (sub)population that has a positive welfare gain.

where

$$
\begin{aligned}
V_{is}^{R\Delta}(k,\varepsilon) =& u\left(\left(1+\Delta\right) g_{isT}^{R}, \left(1+\Delta\right) g_{isN}^{R}, 0\right) + \beta(1-d) V_{is}^{R\Delta}\left(g_{isk}^{R}, \varepsilon\right) \\
V_{is}^{W\Delta}(k,\varepsilon) =& u\left(\left(1+\Delta\right) g_{isT}^{W}, \left(1+\Delta\right) g_{isN}^{W}, g_{is\ell}^{W}\right) \\
&+ \beta\left[(1-a) E_{\varepsilon'|\varepsilon,s} V_{is}^{W\Delta}\left(g_{isk}^{W}, \varepsilon'\right) + a V_{is}^{R\Delta}\left(g_{isk}^{W}, \varepsilon\right)\right].
\end{aligned}
$$

According to the model, the combined effect of a rise in tariffs and the fiscal reforms resulted in a decline in average welfare of 0.1 percent. Just as with the aggregate responses, average welfare depends greatly on how tariff revenue is used. If tariff revenue is used entirely to increase G, the average welfare loss is more than five times larger (Table 5). There are also clear winners and losers in the baseline. The first column of Table 4 reports the average welfare change for different groups of households. Only the high-wealth subgroup, defined as households in the top wealth decile, experiences an average welfare gain, while those in the bottom decile of wealth and retirees experience much larger losses in welfare than the average.

We decompose the source of the average welfare change for each group into four channels. These channels isolate the effect coming from changes in a specific subset of prices, and they highlight the tradeoffs faced along each dimension of household heterogeneity. The wage channel measures the welfare effect from changes in the after-tax wages from both the labor income tax cut and the general equilibrium changes in w_U and w_S. The investment channel captures the effect from changes in the after-tax return on investment due to P_X, r, and τ_k.

The expenditure channel measures the welfare loss attributable to a higher tradables price, P_T. Finally, the transfer channel measures the welfare gain from the lump-sum transfer.

To create this decomposition, we compute the welfare for each household from undergoing a partial equilibrium exercise where all prices stay constant except those associated with a particular channel. For example, for the expenditure channel, only P_T follows its equilibrium path, while tax rates, wages, returns, and transfers stay at their pre-tariff values. We then solve for the value function arising under this alternative price path.

The sign and strength of each channel can vary by household type. Because tariffs always increase tradables prices and all households consume some tradables, the expenditure channel is unambiguously negative. The strength of the expenditure channel diminishes as a household's income and wealth rises. Likewise, the transfer channel is unambiguously positive, though all else equal, higher transfers favor the unskilled over the skilled, retirees over workers, poor over rich, and low earners relative to high earners. The wage channel obviously has no effect on retirees, but is positive for working-age households, and is stronger for low-income and unskilled workers.

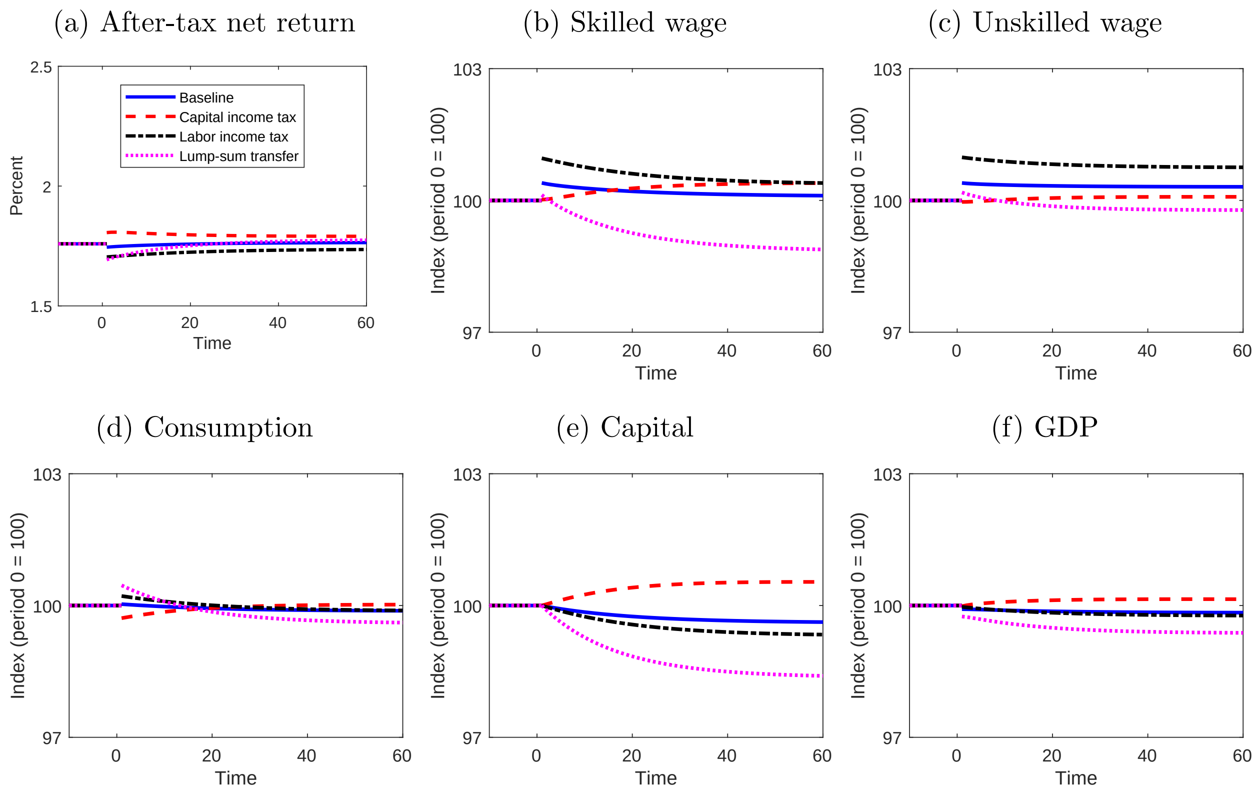
Finally, the investment channel captures the combined effect of the rise in investment prices, changes in capital income taxes, and the change in r. Generally, it favors the wealthy since under capital tax reform, these households benefit from paying less taxes on a primary source of income. Even in cases where τ_k is unchanged, however, they still tend to benefit more because the pass-through of a higher tradables price to P_X generates a one-time capital gain.

Wealth is one of the dimensions along which welfare differences are most pronounced. Nearly all households in the top decile of wealth support the tariff-financed tax reform, while those in the bottom decile universally oppose it. The difference in average welfare between these two groups is mostly explained by the investment channel. Comparing the breakdown of welfare changes shown in Table 4, the additional harm to the poor from the expenditure channel is roughly offset by the welfare gain from the transfer channel.

4.5 Alternative redistribution policies

Fiscal reform is a mixture of changes to three tax instruments: the progressive labor income tax, the flat capital income tax, and the lump-sum transfer. We compute three additional revenue-neutral counterfactual transitions. In each transition, only one of the instruments

Figure 6: Factor prices and quantities (counterfactuals)



clears the government budget constraint, while the other two remain unchanged from their initial values. These exercises serve two purposes. First, they provide intuition for our baseline results by isolating the effect of each tax instrument. Second, when evaluated jointly, they form a robustness exercise for thinking about the welfare consequences of tariffs if tariff revenue is allocated according to different proportions from our baseline.

Figure 6 plots the responses of factor prices and aggregate quantities for these counterfactual transitions and the baseline.

Reduce labor income taxes only. If the entirety of tariff revenues is used to lower labor income tax rates, the transition is qualitatively similar to the baseline, but the magnitude of the effects is amplified. This is most apparent in the paths of after-tax wages (Figures 6b–6c), which mechanically follow from the larger size of the labor tax reform. In the absence of a capital income tax reform to offset the rise in the investment price, the net return on capital drops further than in the baseline (Figure 6a), generating a lower path for the capital stock (Figure 6e). Because retirees do not earn labor income, they do not directly

Table 5: Welfare (redistributive policies)

	Baseline	Counterfactuals			
		no redistribution	capital income tax	labor income tax	lump-sum transfer
Average	–0.1	–0.7	–0.3	–0.2	0.6
Skilled	–0.1	–0.8	–0.1	–0.1	–0.1
Unskilled	–0.0	–0.6	–0.3	–0.0	0.6
Retired	–0.3	–0.6	–0.5	–0.6	1.1
High wealth	0.2	–0.3	0.7	–0.2	0.2
Low wealth	–0.3	–0.8	–0.7	–0.5	1.2
High income	–0.0	–0.5	0.1	–0.1	–0.0
Low income	–0.1	–0.7	–0.4	–0.0	0.9
Support	16	0	18	35	84

Units: percent. High and low wealth correspond to the top and bottom deciles of wealth, respectively. High and low income correspond to the top and bottom deciles of labor income, respectively, conditional on working age. Support reports the percent of the population that has a positive welfare gain.

benefit from lower taxes but still face a rise in the tradables price and their consumption falls. Working-age households have higher disposable income after the reform and respond by boosting their consumption. Because these households make up a larger population share than retirees, aggregate consumption jumps slightly initially (Figure 6d). GDP is roughly unchanged relative to the baseline (Figure 6f) as a result of the slightly higher labor supply offsetting the slightly larger capital decline.

Table 5 reports the percentage change in average welfare for each alternative policy along with average welfare for sub-populations in the economy. The overall welfare loss from only reducing labor income taxes is 0.2 percent, slightly larger than in the baseline.

Across worker households, welfare is nearly the same as in the baseline, since the higher after-tax wages compensate them for higher tradables prices and lower capital returns. On the other hand, retirees, for whom there is no direct transfer of revenues, suffer an average welfare loss (0.6 percent) that is as large as the one they suffer when the government does not redistribute at all (0.6 percent). High-wealth households are also considerably worse off relative to the baseline because they no longer gain from the capital income tax cut.

Reduce capital income taxes only. The transition path under capital income tax reform is qualitatively very different from the baseline. A lower tax rate on capital income more than offsets the post-tariff rise in the investment price, leading to a substantial increase in the after-tax net return to capital. This is the only scenario in which there is capital deepening and a higher long-run level of GDP. Despite no change in the labor income tax schedule, after-tax wages rise for both skill types. The increase is larger for the skilled workers because they are more complementary with capital. Aggregate consumption drops in the early periods of the transition as the economy builds up capital, but it increases over time. Among the four redistribution policies, this is the only one with a higher long-run level of total consumption.

Despite having higher long-run aggregate activity, this policy has the lowest average welfare. This holds more broadly across our quantitative exercises: the ranking of long-run output or consumption is not indicative of average welfare.[31]

Lump-sum transfer. If all of the tariff revenue is redistributed through the lump-sum transfer, the path for the after-tax return on capital is lower, as in the labor income reform case. However, in addition, the transfer produces an income effect that further reduces households' desire to work and save. As a result, this case generates the largest declines in the capital stock and GDP. Capital shallowing leads to an erosion in wages, especially for the skilled. The combination of these forces causes the path of aggregate consumption to jump initially and then decline gradually toward a long-run level that is 0.4 percent lower than in the original steady state.

Of the three alternatives, this is the only policy under which imposing tariffs generates an average welfare gain. It is also a very popular policy: 84 percent of households support it (compared to 16 percent in the baseline). Of course, this takes as given the degree to which the rest of the world retaliates. Nevertheless, despite the negative expenditure consequences from tariffs and the substantial amount of social insurance built into the initial equilibrium, low-income and low-wealth households still strongly favor positive tariffs. This motivates our next exercise.

4.6 Constrained optimal tariff with lump-sum transfer policy

Thus far, we have studied the consequences of a 4.0 percent tariff imposed on US imports and a 2.5 percent tariff imposed on ROW imports, with various ways of redistributing tariff revenue. In this subsection, we broadly address two additional questions. First, what tariff

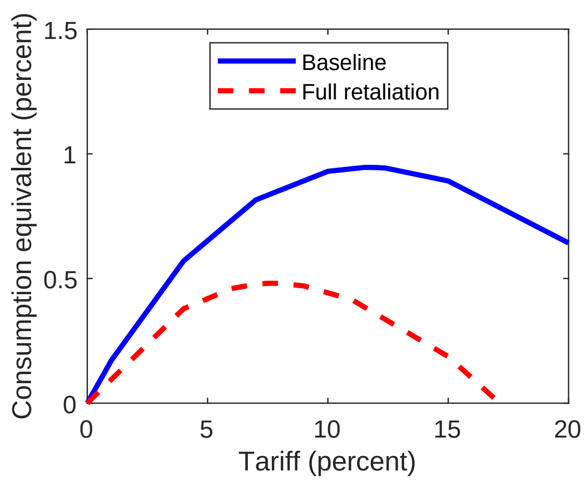
[31]This tradeoff between average welfare and output is consistent with results from other papers that use macroeconomic models with incomplete markets to study fiscal reform (see, for example, Domeij and Heathcote 2004 and Conesa et al. 2009).

level maximizes average welfare in the model if the raised revenue is restricted to being spent on lump-sum transfers? We refer to this as the constrained optimal tariff in the sense that we are not solving for a general optimal tariff and tax policy that allows all of the policy instruments to be changed. And second, is this positive optimal tariff outcome just an artifact of the ROW only partially retaliating? If ROW instead matched the US tariff one-for-one, would the US, as the smaller economy, find it optimal not to impose a tariff?

Figure 7 plots average welfare for the US at different tariff levels, assuming that all of the revenue raised is redistributed lump-sum. For values on the solid line, ROW always retaliates in the same proportion as the baseline ($\tau_{2P} = 0.625 \times \tau_{1P}$). Under partial retaliation, the US average welfare is maximized at 11.8 percent. These welfare gains are driven by poor workers and retirees, for whom the transfers are most beneficial.

To answer the second question, we repeat the exercise but assume that ROW retaliates in full (i.e., $\tau_{2P} = \tau_{1P}$). The results are shown by the dashed line. First, the maximal average welfare level is much lower when ROW retaliates in full. Nevertheless, at 7.8 percent, the constrained optimal tariff is still far from zero. Relative to the partial retaliation case, under full retaliation wages are lower, investment and tradables prices are higher, and the transfer is slightly lower. For the low-income and low-wealth workers and retirees—the critical groups in our model for driving average welfare—the increased severity of losses from these channels is more than compensated for by the transfer.

Figure 7: Welfare gains from tariffs and lump-sum transfers



4.7 Implications of alternative model assumptions

The model calibration imposes two conditions which—though well-motivated by the literature and data—may nevertheless strike the reader as non-standard: Stone-Geary non-homothetic preferences and capital-skill complementarity in production. Here we briefly discuss the importance of these model ingredients for our results. For exposition, we relegate tables of alternative results to Appendix C. For the overall welfare effect of the trade war, these assumptions make no significant difference, but they matter a great deal for the distribution of welfare, particularly under alternative redistributive policies.

Why is the average welfare effect unchanged by these different assumptions? In the case of homothetic preferences, the average expenditure share remains the same as in the baseline and the price of tradables increases by the same amount. Therefore, the welfare costs, which were higher for poor households and lower for rich households in the baseline, get distributed evenly among the entire population with homothetic preferences. Although the average is the same, failing to account for the heterogeneous consumption patterns of the poor mismeasures their welfare loss by 0.1 percent, representing 0.5 standard deviations of the welfare changes from the trade war in the baseline model.

Abstracting from capital-skill complementarity matters little for average welfare in the baseline because the effects of the trade war on the capital stock are very small under baseline policy. As discussed in Section 4.3, the investment-suppressing effects of higher tariffs are offset by the fiscal reforms the tariffs finance. This greatly limits the scope for the skill premium to affect average welfare. The importance of capital-skill complementarity is more evident in the alternative redistribution exercises, which have more pronounced impacts on the capital stock. For instance, when the government does not redistribute tariff revenue—the case that leads to the most capital shallowing—the welfare loss of the unskilled is 0.2 percent greater under Cobb-Douglas relative to the baseline model with capital-skill complementarity, roughly equivalent to one standard deviation of the baseline trade war welfare change distribution.

5 Conclusion

The rise in anti-trade policies and retaliatory actions in recent years has motivated us to ask the question, "What are the distributional consequences of global tariffs?" To this end, we have studied the distributional effects of the 2018 tariff increases in an overlapping-generations Ricardian trade model with uninsurable income risk, incomplete asset markets, capital-skill complementarity, and nonhomothetic preferences. Tariffs reduce allocative efficiency and increase the prices of tradable goods and investment, but the revenue generated from tariffs can be used to reduce distortionary taxes and increase transfers. Using the Tax Cuts and Jobs Act and the Market Facilitation Program to guide our assumptions on how the tariff revenue is allocated, we find that the increase in tariffs by the US and its trading partners reduced US average welfare by 0.1 percent, with larger losses concentrated among retirees and low-income and low-wealth workers. When we isolate the pure consequences of the tariffs, we find that they lead to substantial declines in aggregate capital and consumption; however, when we use tariff revenue to reduce taxes these negative effects are largely offset. While our baseline model abstracts from labor market frictions or geographical heterogeneity, we leave these potentially fruitful extensions for future research.

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A Estimation of Wage Processes

The sample selection and estimation procedure closely follows the procedure described in Krueger et al. (2016) and Hur (2018). We use annual household income data from the PSID core sample (1970–1997), selecting all households whose head is between ages 23 and 64. For each household, we compute total household labor income as the sum of labor income of the head and spouse, 50 percent of income from farm and from business, plus transfers (excluding social security). Next, we construct household wages by dividing total household labor income by total hours, where total hours is the sum of hours worked and hours unemployed. We then deflate wages using the CPI. We drop observations with missing education, with wages that are less than one quarter of the minimum wage, with topcoded income, and with total hours less than 500 hours per year. On this sample, we regress the log real wage on age and education dummies, their interaction, and year dummies. We then exclude all household wage sequences that are shorter than 8 years, leaving final samples of 915 skilled households (college graduates) and 2,394 unskilled households, with an average length of 18 years. On these separate samples, we compute the autocovariance matrix of the residuals. The stochastic process in equation (28) is modified to allow for measurement error. Specifically, we use the modified stochastic equation:

$$\begin{aligned} \log \varepsilon_t &= p_t + \epsilon_t, \epsilon_t \sim N(0, \sigma^2_{s\epsilon}) \\ p_t &= \rho_s p_{t-1} + \nu_t, \nu_t \sim N\left(0, \sigma^2_{s\nu}\right). \end{aligned} \tag{33}$$

This modified process is estimated using GMM, targeting the covariance matrix, where the weighting matrix is the identity matrix. We find estimates of $\rho_H, \sigma_{H\nu}, \sigma_{H\epsilon}$ equal to 0.914, 0.229, and 0.186, respectively, for skilled households and $\rho_L, \sigma_{L\nu}, \sigma_{L\epsilon}$ equal to 0.941, 0.197, and 0.223, respectively, for unskilled households. Finally, we treat the transitory shocks as measurement error (that is, we set $\sigma_{H\epsilon} = \sigma_{L\epsilon} = 0$), and construct the skill-specific five-state Markov processes using the Rouwenhorst procedure described in Kopecky and Suen (2010).

Incorporating the "superstar" state as the sixth productivity element as described in

Section 3, the skill-specific productivity values are given by

$$\varepsilon_L = \{0.3121, 0.5587, 1, 1.7899, 3.2036, 39.0674\}$$
$$\varepsilon_H = \{0.2831, 0.5320, 1, 1.8796, 3.5329, 39.0674\}$$

with transition matrices

$$\Gamma_L = \begin{bmatrix} 0.88465 & 0.10756 & 0.00490 & 0.00010 & 0.00000 & 0.00278 \\ 0.02689 & 0.88710 & 0.08075 & 0.00245 & 0.00002 & 0.00278 \\ 0.00082 & 0.05383 & 0.88792 & 0.05383 & 0.00082 & 0.00278 \\ 0.00002 & 0.00245 & 0.08075 & 0.88710 & 0.02689 & 0.00278 \\ 0.00000 & 0.00010 & 0.00490 & 0.10756 & 0.88465 & 0.00278 \\ 0.00000 & 0.00000 & 0.25000 & 0.00000 & 0.00000 & 0.75000 \end{bmatrix}$$
$$\Gamma_H = \begin{bmatrix} 0.83644 & 0.15033 & 0.01013 & 0.00030 & 0.00000 & 0.00278 \\ 0.03758 & 0.84151 & 0.11298 & 0.00507 & 0.00008 & 0.00278 \\ 0.00169 & 0.07532 & 0.84320 & 0.07532 & 0.00169 & 0.00278 \\ 0.00008 & 0.00507 & 0.11298 & 0.84151 & 0.03758 & 0.00278 \\ 0.00000 & 0.00030 & 0.01013 & 0.15033 & 0.83644 & 0.00278 \\ 0.00000 & 0.00000 & 0.25000 & 0.00000 & 0.00000 & 0.75000 \end{bmatrix}.$$

B Computational Appendix

Broadly, we use value function iteration to solve for the initial and final steady states and a shooting method to solve the transition between them.

1. Let $\lambda^0(k,\varepsilon) = \{\lambda_s^{j,0}(k,\varepsilon)\}_{j=W,R,s=L,H}$ be an initial guess over a finely spaced wealth grid, k_{fine}, and $\mathcal{E}$.

2. Given tariff policy $\mathcal{T} = \{\tau_1, \tau_2\}$, solve for the equilibrium rental rate, $r_i^\star$, in each country.

   (a) Indexing iterations by n, guess $\upsilon^n = \{r_i^n, w_{iH}^n, e^n, B_i^n\}$ where B_i is the value of the fiscal policy instrument that clears the government budget constraint in country i (e.g., τ_{ik}).

(b) From e^n and $\mathcal{T}$ calculate $\{P^n_T, P^n_X\}_i$ using equations (24) and (26).

(c) The market clearing interest rate can now be solved for each country separately, so we suppress the subscript i. Given r^n and w^n_H, compute w^n_L by combining the nontradables firm's first-order conditions.

(d) Iterate on the household value function until convergence to get the decision rules for each skill type, $g^n = \left\{g^j_{sT}, g^j_{sN}, g^j_{s\ell}, g^j_{sk}\right\}_{j,s}$.

(e) Begin with λ^0, iterate forward using g^n to find the invariant distribution, λ^*_n.

(f) Aggregate by combining g^n with λ^*_n to get $\{C^n_T, C^n_N, X^n, H^n, L^n, K^n\}$.

(g) Use the first-order conditions of the capital producer to obtain $\{I^n_T, I^n_N\}$.

(h) Impose market clearing conditions for tradable and nontradable final goods to obtain $\{Y^n_T, Y^n_N\}$.

(i) Substitute $G^n_N = Y^n_N$ into equation (3) to obtain L^n_N and then $L^n_T = L^n - L^n_N$.

(j) From the first-order conditions of the intermediate tradable producers

$$H^n_T = \left(\frac{1-\mu}{\mu}\frac{1}{(1-\alpha)\,\Omega}\frac{w^n_H}{w^n_L}\right)^{\frac{1}{\zeta-1}} L^n_T, \tag{34}$$

$$K^n_T = \left(\frac{\alpha}{1-\alpha}\frac{w^n_H}{r^n}\right)^{\frac{1}{\chi-1}} H^n_T, \tag{35}$$

where

$$\Omega = \left[\alpha\left(\frac{\alpha}{1-\alpha}\frac{w^n_H}{r^n}\right)^{\frac{\chi}{1-\chi}} + 1 - \alpha\right]^{\frac{\zeta-\chi}{\chi}}. \tag{36}$$

(k) Use the market clearing conditions for skilled labor and capital to obtain $\{H^n_N, K^n_N\}$.

(l) Calculate r^{new} using the first-order conditions of the nontradable producer.

(m) We use Brent's method to solve for $r^\star$ over a fixed interval.

(n) With $r^\star$ computed for each country, update the remaining elements of υ. The implied skilled wage in each country can be solved from each country's nontradables producer's first-order condition for skilled labor. The implied exchange rate, e^{new}, can be computed from the trade balance equation (see equation (13) in the definition of a steady state), and the implied value of the fiscal instrument, B^{new}, can be found directly by rearranging the government budget constraint.

(o) Finally, for $\nu \in (0,1)$, update guess with

$$\upsilon^{n+1} = \nu \upsilon^{new} + (1-\nu)\,\upsilon^{n}$$

and iterate until convergence.

C Sensitivity Analysis

In this section, we investigate the sensitivity of our baseline quantitative results to our choice of functional forms for preferences and production.

C.1 Cobb-Douglas production

First, we eliminate the assumption of capital-skill complementarity in production. Instead, we assume that production takes place according to:

$$G(K, N) = K^{\alpha} N^{1-\alpha} \tag{37}$$

where N is efficiency units of labor. There is now a uniform wage w_i for each efficiency unit of labor. The market clearing condition for labor is then changed to

$$N_{iN} + \int_0^1 n_i\,(\omega)\, d\omega = \sum_{s=L,H} \int_S \varepsilon g_{is\ell}^{W}\,(k, \varepsilon)\, d\lambda_{is}^{W}\,(k, \varepsilon) \tag{38}$$

where the ε levels are appropriately scaled up to reflect the difference in skill premium. Here, the skill premium reflects differences in the relative endowments of efficiency units of labor. The model is then recalibrated according to the same strategy outlined in Section 3. We present Tables 6 and 7, which are the Cobb-Douglas analogues to Tables 4 and 5, respectively.

There are three points to make. First, most of the main results are broadly robust to this assumption (Table 6). That is, the total welfare loss associated with the 2018 trade war is identical at 0.1 percent, the policy is supported by a small minority (20 percent, compared to 16 percent in the baseline), and welfare losses are concentrated among low-wealth and low-income households. Why does this seemingly large change in the elasticities of substitution across factors deliver overall similar results? The answer comes from the fact that in the

Table 6: Welfare decomposition (Cobb-Douglas production)

	Total	Decomposition				Support
		wage	investment	expenditure	transfer	
All	–0.1	0.1	0.3	–0.7	0.2	19
Skilled	–0.1	0.1	0.3	–0.6	0.1	28
Unskilled	–0.1	0.1	0.3	–0.7	0.2	19
Retired	–0.3	0.0	0.2	–0.7	0.3	12
High wealth	0.5	0.0	1.0	–0.6	0.1	100
Low wealth	–0.4	0.0	0.0	–0.8	0.3	0
High income	0.0	0.1	0.4	–0.5	0.1	35
Low income	–0.2	0.1	0.2	–0.7	0.3	14

Units: percent. High and low wealth correspond to the top and bottom deciles of wealth, respectively. High and low income correspond to the top and bottom deciles of labor income, respectively, conditional on working age. Support reports the percent of each (sub)population that has a positive welfare gain.

baseline exercise, changes in the capital stock are small, resulting in a muted response in the skill premium.

Second, even though the decline in the capital stock and the associated decline in the skill premium are small, they still have noticeable distributional effects. For example, the unskilled and low income (the latter also being more likely to be unskilled) suffer slightly larger welfare losses than in the model with production complementarities. That is, unskilled and low-income households suffer a welfare loss of 0.1 and 0.2 percent, respectively (compared to 0.0 and 0.1 percent, respectively, in the baseline). This is because wage declines are smaller in the baseline for the unskilled—due to capital-skill complementarity—relative to the Cobb-Douglas case.

Third, these differences are magnified when we consider the counterfactual redistributive policies (Table 7). For instance, when tariff revenue is not redistributed, leading to the largest declines in aggregate capital, the unskilled and low-income suffer even larger welfare losses relative to the baseline model with capital-skill complementarity. Specifically, when tariff revenue is not redistributed, unskilled and low-income households suffer a welfare loss of 0.8 and 0.9 percent, respectively (compared to 0.6 and 0.7 percent, respectively, in the baseline).

Table 7: Welfare (redistributive policies with Cobb-Douglas production)

	Baseline	Counterfactuals			
		no redistribution	capital income tax	labor income tax	lump-sum transfer
Average	–0.1	–0.7	–0.3	–0.2	0.5
Skilled	–0.1	–0.7	–0.1	–0.0	0.1
Unskilled	–0.1	–0.8	–0.3	–0.1	0.4
Retired	–0.3	–0.6	–0.5	–0.6	1.1
High wealth	0.5	–0.1	0.9	0.0	0.4
Low wealth	–0.4	–0.9	–0.8	–0.6	1.1
High income	0.0	–0.5	0.1	–0.0	–0.0
Low income	–0.2	–0.9	–0.5	–0.2	0.7

Units: percent. High and low wealth correspond to the top and bottom deciles of wealth, respectively. High and low income correspond to the top and bottom deciles of labor income, respectively, conditional on working age.

C.2 Homothetic preferences

Second, we consider the case in which household preferences are represented by homothetic Cobb-Douglas aggregation over tradeables and nontradables. That is, we set $\bar{c} = 0$ and recalibrate the other parameters of the model in the same manner as described in Section 3.

Ignoring the fact that households have different consumption baskets will understate the welfare losses of low-income and low-wealth households. Indeed, Table 8 shows that the welfare losses of these groups are smaller than in the baseline model with non-homothetic preferences. That is, low-income households are welfare neutral (compared to a 0.1 percent welfare loss in the baseline) and low-wealth households suffer a welfare loss of 0.2 percent (compared to 0.3 percent in the baseline). A similar pattern can be found in the counterfactual redistributive policies (Table 9).

C.3 Lump-sum transfers to worker households only

Finally, we consider the case where lump-sum transfers are provided to worker households only. Unsurprisingly, retirees suffer larger welfare losses in this case, relative to the baseline model, where lump-sum transfers are provided universally (Table 10). Somewhat surprisingly, even though the size of the lump-sum transfer provided to worker households is now larger, worker households do not gain in welfare relative to the baseline. This is because worker households anticipate that they will not receive any transfers (related to tariff rev-

Table 8: Welfare decomposition (homothetic preferences)

	Total	Decomposition				Support
		wage	investment	expenditure	transfer	
All	–0.1	0.2	0.2	–0.6	0.2	28
Skilled	–0.1	0.2	0.2	–0.6	0.1	14
Unskilled	0.0	0.2	0.2	–0.6	0.2	44
Retired	–0.2	0.0	0.1	–0.6	0.3	13
High wealth	0.2	0.1	0.6	–0.6	0.1	92
Low wealth	–0.2	0.1	0.0	–0.6	0.3	14
High income	–0.0	0.2	0.2	–0.5	0.1	21
Low income	0.0	0.2	0.1	–0.6	0.3	66

Units: percent. High and low wealth correspond to the top and bottom deciles of wealth, respectively. High and low income correspond to the top and bottom deciles of labor income, respectively, conditional on working age. Support reports the percent of each (sub)population that has a positive welfare gain.

Table 9: Welfare (redistributive policies with homothetic preferences)

	Baseline	Counterfactuals			
		no redistribution	capital income tax	labor income tax	lump-sum transfer
Average	–0.1	–0.6	–0.2	–0.1	0.7
Skilled	–0.1	–0.8	–0.1	–0.1	0.0
Unskilled	0.0	–0.6	–0.2	0.0	0.7
Retired	–0.2	–0.5	–0.4	–0.5	1.2
High wealth	0.2	–0.3	0.6	–0.3	0.2
Low wealth	–0.2	–0.6	–0.6	–0.4	1.5
High income	–0.0	–0.5	0.0	–0.1	–0.0
Low income	0.0	–0.6	–0.3	0.0	1.1

Units: percent. High and low wealth correspond to the top and bottom deciles of wealth, respectively. High and low income correspond to the top and bottom deciles of labor income, respectively, conditional on working age. Support reports the percent of the population that has a positive welfare gain.

Table 10: Welfare decomposition (transfers to workers only)

	Total	Decomposition				Support
		wage	investment	expenditure	transfer	
All	–0.2	0.2	0.2	–0.7	0.1	14
Skilled	–0.1	0.2	0.2	–0.6	0.1	15
Unskilled	–0.1	0.3	0.2	–0.7	0.2	17
Retired	–0.6	0.0	0.1	–0.7	0.0	5
High wealth	0.2	0.1	0.6	–0.6	0.1	92
Low wealth	–0.5	0.1	0.0	–0.8	0.1	0
High income	–0.0	0.2	0.2	–0.5	0.1	20
Low income	–0.1	0.3	0.1	–0.7	0.2	13

Units: percent. High and low wealth correspond to the top and bottom deciles of wealth, respectively. High and low income correspond to the top and bottom deciles of labor income, respectively, conditional on working age. Support reports the percent of each (sub)population that has a positive welfare gain.

Table 11: Welfare (redistributive policies with transfers to workers only)

	Baseline	Counterfactuals			
		no redistribution	capital income tax	labor income tax	lump-sum transfer
Average	–0.2	–0.7	–0.3	–0.2	0.0
Skilled	–0.1	–0.8	–0.1	–0.1	–0.1
Unskilled	–0.1	–0.6	–0.3	–0.0	0.5
Retired	–0.6	–0.6	–0.5	–0.6	–0.6
High wealth	0.2	–0.3	0.7	–0.2	–0.0
Low wealth	–0.5	–0.8	–0.7	–0.5	–0.2
High income	–0.0	–0.5	0.1	–0.1	–0.1
Low income	–0.1	–0.7	–0.4	–0.0	0.7

Units: percent. High and low wealth correspond to the top and bottom deciles of wealth, respectively. High and low income correspond to the top and bottom deciles of labor income, respectively, conditional on working age.

enue) when they retire in the future. This is also the reason that the counterfactual policy in which tariff revenue is fully redistributed lump-sum to worker households is not associated with an average welfare gain, as can be seen in Table 11.