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# On the Distributional Effects of International Tariffs<sup>1</sup>

Daniel Carroll

Federal Reserve Bank of Cleveland  
[daniel.carroll@clev.frb.org](mailto:daniel.carroll@clev.frb.org)

Sewon Hur

Federal Reserve Bank of Dallas  
[sewonhur@gmail.com](mailto:sewonhur@gmail.com)

## Abstract

What are the distributional consequences of tariffs? We build a trade model with incomplete asset markets and households that are heterogeneous in their income, wealth, and labor skill. We provide a quantitative analysis of the distributional effects of an increase in tariffs and examine several budget-neutral fiscal policies for redistributing tariff revenue. As in other dynamic models with heterogeneous agents, we find that higher levels of long-run aggregate activity are not indicative of higher average welfare. Using tariff revenues to lower capital income taxes delivers the highest long run outcomes but the worst average welfare among the redistributionary policies. Meanwhile, increasing lumpsum transfers instead delivers the lowest long run outcomes but the best welfare. The welfare consequences of tariffs also depend on whether trading partners respond with retaliatory tariffs and on workers' mobility across sectors.

KEYWORDS: tariffs, inequality, consumption, welfare, taxation.

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# 1 Introduction

There has been an increase in the number of trade-restricting policies over the last few years. The United States has 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 these tariffs have resulted in retaliation. Furthermore, there have been threats of further tariffs. The specter of the United Kingdom leaving the European Union and facing higher tariffs also remains on the horizon.

The impact of tariffs is likely to be unequally distributed across households. For instance, tariffs raise the prices of tradable goods and services, and [Carroll and Hur \(2020\)](#) have documented that the share of household expenditures devoted to tradables declines with income and wealth, implying that poor households are particularly sensitive to increases in tradables prices. In the same way, tariffs increase the cost of capital inputs into production. Changes in the cost of capital goods from trade are thought to contribute to the changes in the skill premium ([Parro 2013](#)). Thus, tariffs should affect workers differently based on skill through wage effects.

In this paper, we study how households bear the economic costs of tariffs differently depending upon their labor skill, income, and wealth. The analysis is complicated by the fact that tariffs raise revenue, meaning that the distributional impacts are not independent of how that revenue is allocated. The analysis also depends on a country’s relative size and whether or not trading partners retaliate.

Our paper makes two main contributions to the literature. The first is theoretical in that we develop a framework for measuring the welfare consequences of tariffs across the income, wealth, and skill distribution. Our analytical expressions give intuition about how tariffs affect the prices of tradable and investment goods and factor prices, which in turn impact household welfare. The second is quantitative, as we use the calibrated model to quantify the welfare consequences of tariffs under different scenarios for redistributing tariff revenue as well as when trading partners do and do not retaliate. Our study is the first to quantify the welfare consequences of tariffs along the joint dimensions of income, wealth, and skill levels. This is important as we find large variation in welfare changes along these margins.

We build a heterogeneous-agent two-country Ricardian trade model in which households with permanent labor skill types face uninsurable income risk and borrowing constraints, and

where households have nonhomothetic preferences so that the poor have a higher tradable expenditure share. [Carroll and Hur \(2020\)](#) show that both of these features are quantitatively important for capturing the distributional consequences of trade. In addition, the model also features capital-skill complementarity, where capital is more substitutable with unskilled labor relative to skilled labor, as in [Krusell et al. \(2000\)](#). This permits the model to capture the skill bias of trade emphasized by [Parro \(2013\)](#).

Using the calibrated model, we compute the distribution of welfare changes arising from the US imposing a 5 percent import tariff on the rest of the world (ROW). We start by analyzing the case in which tariff revenue is used to finance wasteful government spending instead of redistribution. This isolates the economic costs of the tariff and its effects on the distribution. We find an average welfare loss equivalent to a permanent 1.1 percent reduction in consumption if ROW retaliates and a 0.5 percent reduction if it does not retaliate. In either case, all households lose from imposing tariffs, but two groups suffer disproportionately more: the poor and the skilled. The poor are harmed primarily because of the increase in the price of tradables, while the skilled are harmed primarily because tariffs lead to capital shallowing, which reduces the skilled wage by more than the unskilled wage.

Next, we consider three starkly different fiscal policies for distributing tariff revenue among households: a revenue-neutral labor income tax reform, a revenue-neutral capital income tax reform, and a lump-sum transfer. These three alternatives produce very different results, both in terms of aggregate dynamics and the distribution of welfare. The labor tax reform compensates poor households more relative to the rich, offsetting the anti-poor welfare effects in the baseline and leading to more equitable welfare costs across wealth. In contrast, the 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 welfare gain while poor households suffer welfare losses; however, neither reform can generate an average welfare gain when ROW retaliates. Finally, if the government distributes the tariff revenue in a lump-sum fashion, there is a small rise in average welfare. This is due to large welfare increases among poor and unskilled households for which the transfer is a valuable source of social insurance against income fluctuations. When ROW retaliates with an equal-size tariff, the average welfare change from tariffs is equivalent to a permanent change in consumption of  $-0.1$ ,  $-0.3$ , and  $0.1$  percent, respectively, when tariff revenue is redistributed by a reduction in the labor income tax, a

reduction in the capital income tax, and a lump-sum transfer.

65 When ROW does not retaliate, every redistributionary policy leads to an average welfare gain, although the ordering of average welfare across them is the same. The reason that unilateral tariffs can produce average gains when bilateral tariffs do not comes from an improvement in the terms-of-trade. When ROW does not respond, the US tariff tilts the terms-of-trade in the US's favor, passing some of the cost of the tariff to ROW. However, 70 because the US is smaller than ROW, when ROW retaliates with an equally sized tariff, there is a disproportionate effect that causes the US terms-of-trade to deteriorate.

The welfare consequences of tariffs can be decomposed into four channels. The first captures the effect of an increase in the tradables price, which tends to hurt poor households disproportionately. This *expenditure* channel is largely constant across fiscal policies but is 75 stronger when the trading partner retaliates. The second contains effects from the rise in the price of investment and changes to the net return to capital (the *investment* channel). Except when tariff revenue is used to lower capital income taxes, tariffs lead to a lower net return to capital along the transition path. In an environment with incomplete asset markets, the rise in investment prices benefits wealthy households because they are typically sellers of capital 80 despite the temporary fall in the net return to capital. The pro-wealth investment channel is especially strong when tariff revenue is used to reduce capital income taxes and the trading partner does not retaliate. The third captures the effect of changes to after-tax wages (the *wage* channel). Skilled after-tax wages rise when tariff revenue is used to reduce capital or labor income taxes and fall otherwise. Unskilled after-tax wages are roughly constant except 85 when labor income taxes are reduced. Generally, wealth-poor households, which derive most of their income from labor income, lose (benefit) the most from a decline (rise) in their after-tax wage. Finally, when tariff revenue is used to finance lump-sum transfers, poor and unskilled households benefit the most from this *transfer* channel.

We also study the effects of tariffs in an extension of the model where there is no mobility 90 across sectors. In the baseline model, tariffs reduce demand for tradable goods, which leads to a reallocation of labor from the tradable to the nontradable sector, equating wages across sectors for each skill. With immobility this reallocation of labor cannot occur, leading to a much larger decrease in tradable wages compared to the baseline. The fall in tradable wages reduces the marginal cost of production for tradables producers and this, in general 95 equilibrium, mutes the response of the prices of tradable consumption and investment goods.

As a consequence, nearly all of the welfare losses in this case can be attributed to the wage channel. Both skilled and unskilled workers in the tradable sector suffer much larger welfare losses relative to those in the nontradable sector. Despite the high concentration of welfare losses among tradable workers, the average welfare change for all households is very close to that from the baseline model. Moreover, the result that poor and skilled households bear the brunt of the cost of tariffs is robust to this modification.

**Related literature.** Our paper draws from several strands of the literature. 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 [Imrohoroglu \(1989\)](#), by adding heterogeneous skills, tariffs, distortionary income taxes, and endogenous labor. We also adopt capital-skill complementarities in the spirit of [Stokey \(1996\)](#), [Krusell et al. \(2000\)](#), and [Parro \(2013\)](#).<sup>2</sup>

Our paper is closely related to recent works that have quantified the heterogeneous effects of trade and tariffs. [Fajgelbaum and Khandelwal \(2016\)](#) focus on heterogeneity across income, whereas [Artuç et al. \(2010\)](#), [Caliendo et al. \(2019\)](#), [Dix-Carneiro \(2014\)](#), [Dix-Carneiro and Kovak \(2017\)](#), [Fajgelbaum et al. \(2020\)](#), [Galle et al. \(2017\)](#), and [Kondo \(2018\)](#) focus on heterogeneity across labor markets. Our paper contributes to the emerging literature that studies the effects of trade in dynamic models with incomplete markets. [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. [Ferriere et al. \(2018\)](#) study the effects of trade on skill acquisition and [Kohn et al. \(2019\)](#) study the interaction of financial frictions and trade barriers in a model with heterogeneous entrepreneurs. In this paper, we focus on the heterogeneous impact of tariffs along the income, wealth, and skill distribution.

With capital-skill complementarity, trade in our model generates an increase in the wage skill premium. There is a large empirical literature that studies the relation between trade and the skill premium.<sup>3</sup> [Acemoglu \(2003\)](#) and [Yeaple \(2005\)](#) develop models in which trade

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<sup>2</sup>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.

<sup>3</sup>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 \(2015\)](#).

induces skill-biased technological change, resulting in an increase in the skill premium. [Ripoll](#)  
 (2005) and [Burstein and Vogel \(2017\)](#) develop 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 effects of trade on the skill premium  
 that come from differences in relative factor endowments as in Heckscher-Ohlin models, our  
 focus on capital-skill complementarity is 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 5 percent tariff increase results in a reduction in the US skill premium that is entirely  
 driven by capital-skill complementarity.

Finally, our paper is related to studies of the interaction between trade and fiscal policies.  
 While [Costinot et al. \(2015\)](#), [Opp \(2010\)](#), [Felbermayr et al. \(2013\)](#), and [Santacreu et al.](#)  
[\(2019\)](#) study optimal trade policy in a strategic context, [Hosseini and Shourideh \(2018\)](#) and  
[Chari et al. \(2018\)](#) focus on optimal trade and fiscal policy under cooperation. Both [Dixit](#)  
[and Norman \(1986\)](#) and [Lyon and Waugh \(2018\)](#) study how the gains from trade can be  
 redistributed through taxation. We depart from these papers by focusing on how tariffs  
 interact with labor and capital income taxes and how this affects households by income,  
 wealth, and skill.<sup>4</sup>

## 2 Model

We consider a two-country model with balanced trade and without labor or capital flows. We  
 build on the Ricardian trade model with incomplete markets and nonhomothetic preferences  
 developed in [Carroll and Hur \(2020\)](#) by adding heterogeneous skills, capital-skill complemen-  
 tarity, endogenous labor, and fiscal policies that include tariffs, distortionary income taxes,  
 and lump-sum transfers. For convenience we drop time subscripts.

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<sup>4</sup>There is also a large literature examining Ramsey optimal taxation in closed economies with incomplete  
 markets. See, for example, [Aiyagari \(1995\)](#), [Imrohoroglu \(1998\)](#), [Ventura \(1999\)](#), [Erosa and Gervais \(2002\)](#),  
[Domeij and Heathcote \(2004\)](#), [Nishiyama and Smetters \(2005\)](#), [Heathcote \(2005\)](#), [Conesa et al. \(2009\)](#), and  
[Carroll et al. \(2017\)](#).

## 150 2.1 Households

Each country, denoted by  $i = 1, 2$ , is populated by a mass  $\bar{H}_i$  of skilled households and a mass  $\bar{L}_i$  of unskilled households that consume a nontradable good,  $c_N$ , and a tradable good,  $c_T$ . We assume a separable period utility function

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

where  $\ell$  is labor supplied by the household. When  $\bar{c}_i \neq 0$ , the utility function represents Stone-Geary nonhomothetic preferences. Labor is perfectly substitutable across sectors, so there is a single efficiency wage rate,  $w_{ij}$ , for each skill  $j = H, L$  in country  $i = 1, 2$ .<sup>5</sup>

Households face uninsurable idiosyncratic productivity risk. Each period, a household  
 155 draws a realization of labor productivity  $\varepsilon$  from a finite set  $\mathcal{E}_j$ . Households earn a wage  $w_{ij}\varepsilon$ . We assume that  $\varepsilon$  follows a Markov process with transition matrix  $\Gamma_j(\varepsilon', \varepsilon)$ . There are no state-contingent claims so households can only self-insure through buying and accumulating capital,  $k$ . The law of motion for capital follows  $k' = k(1 - \delta) + x$  where  $\delta$  is the depreciation rate of capital and  $x$  is investment, which is purchased at price  $P_{iX}$ . A unit of capital has  
 160 a net return of  $r_i - \delta P_{iX}$  in the next period. Households pay taxes on labor income and on capital income at rates  $\tau_{i\ell}$  and  $\tau_{ik}$ , respectively. We allow households to claim a depreciation allowance against their capital income. For ease of exposition, define the *after-tax net return* as  $\tilde{r}_i = (1 - \tau_{ik}) \left( \frac{r_i}{P_{iX}} - \delta \right)$  and the *after-tax wage* as  $\tilde{w}_{ij} = (1 - \tau_{i\ell}) w_{ij}$ .

The problem of a household of skill  $j$  in country  $i$  can be stated as

$$\begin{aligned} V_{ij}(k, \varepsilon) = & \max_{c_T, c_N, \ell, k'} u(c_T, c_N, \ell) + \beta E_{\varepsilon'|\varepsilon, j} V_{ij}(k', \varepsilon') \\ \text{s.t. } & P_{iT} c_T + P_{iN} c_N + P_{iX} (k' - k) \leq \tilde{w}_{ij} \ell \varepsilon + \tilde{r}_i P_{iX} k + T_i \\ & k' \geq 0 \end{aligned} \tag{1}$$

where  $T_i$  is a lump-sum transfer. Solving this yields decision rules  $g_{ijT}(k, \varepsilon)$ ,  $g_{ijN}(k, \varepsilon)$ ,  
 165  $g_{ij\ell}(k, \varepsilon)$ , and  $g_{ijk}(k, \varepsilon)$  for tradable consumption, nontradable consumption, labor, and capital, respectively.

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<sup>5</sup>In Section 4.4, we discuss the results of an alternative model in which households cannot change their sector of employment.

## 2.2 Nontradables Production

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

$$Y_{iN} = z_{iN} \left[ (1 - \mu) L_{iN}^\zeta + \mu [(1 - \alpha) H_{iN}^\chi + \alpha K_{iN}^\chi]^\frac{\zeta}{\chi} \right]^\frac{1}{\zeta} \quad (2)$$

where  $z_{iN} > 0$  is a fixed level of productivity,  $1/(1-\zeta)$  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. It solves a static profit maximization problem

$$\begin{aligned} \max_{H_{iN}, L_{iN}, K_{iN}} \quad & P_{iN} Y_{iN} - w_{iH} H_{iN} - w_{iL} L_{iN} - r_i K_{iN} \\ \text{s.t.} \quad & (2). \end{aligned} \quad (3)$$

The optimality conditions are given by

$$w_{iL} = (1 - \mu) P_{iN} z_{iN} G(L_{iN}, H_{iN}, K_{iN})^{1-\zeta} L_{iN}^{\zeta-1}, \quad (4)$$

$$w_{iH} = \mu (1 - \alpha) P_{iN} z_{iN} G(L_{iN}, H_{iN}, K_{iN})^{1-\zeta} M(H_{iN}, K_{iN})^{\zeta-\chi} H_{iN}^{\chi-1}, \quad (5)$$

$$r_i = \mu \alpha P_{iN} z_{iN} G(L_{iN}, H_{iN}, K_{iN})^{1-\zeta} M(H_{iN}, K_{iN})^{\zeta-\chi} K_{iN}^{\chi-1}. \quad (6)$$

where

$$G(L_{iN}, H_{iN}, K_{iN}) = \left[ (1 - \mu) L_{iN}^\zeta + \mu M(H_{iN}, K_{iN})^\zeta \right]^\frac{1}{\zeta}, \quad (7)$$

$$M(H_{iN}, K_{iN}) = [(1 - \alpha) H_{iN}^\chi + \alpha K_{iN}^\chi]^\frac{1}{\chi}. \quad (8)$$

## 2.3 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

$$Y_{iT} = \left( \int_0^1 \left[ \sum_{o=1,2} q_{oi}(\omega) \right]^\rho d\omega \right)^{\frac{1}{\rho}} \quad (9)$$

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  $P_{iT}$ , the producer in country  $i$  solves

$$\begin{aligned} \max_{\{q_{oi}(\omega)\}_{o,\omega}} \quad & P_{iT} Y_{iT} - \int_0^1 \left( \sum_{o=1,2} \tau_{oi} p_o(\omega) q_{oi}(\omega) \right) d\omega \\ \text{s.t.} \quad & (9) \end{aligned} \quad (10)$$

where  $\tau_{oi} - 1$  is a trade cost and satisfies  $\tau_{oi} = 1$  for  $i = o$  and  $\tau_{oi} \geq 1$  for  $i \neq o$ . Note that the producer in country  $i$  will purchase a variety  $\omega$  from the lowest cost producer.<sup>6</sup> Then, the producer's optimality conditions are given by

$$q_{oi}(\omega) \leq \left( \frac{\tau_{oi} p_o(\omega)}{P_{iT}} \right)^{-\theta} Y_{iT}, \quad (11)$$

which holds with equality if  $q_{oi}(\omega) > 0$ . Furthermore, the tradables price is given by

$$P_{iT} = \left[ \int_0^1 \min_o \{ \tau_{oi} p_o(\omega) \}^{1-\theta} d\omega \right]^{\frac{1}{1-\theta}} \quad (12)$$

where  $\theta = \frac{1}{1-\rho}$  is the elasticity of substitution across varieties.

## 170 2.4 Intermediate Tradables Producer

A representative intermediate tradables firm in country  $i$  produces a single variety,  $\omega$ , 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

$$y_i(\omega) = z_i(\omega) \left[ (1-\mu) l_i(\omega)^\zeta + \mu[(1-\alpha) h_i(\omega)^\chi + \alpha k_i(\omega)^\chi]^{\frac{\zeta}{\chi}} \right]^{\frac{1}{\zeta}}. \quad (13)$$

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<sup>6</sup>Without loss of generality, we assume that the producer sources domestically in the case where costs are equal.

Notice that we are assuming that the intermediate tradables sector faces the same degree of capital-skill complementarity as in the nontradables sector.<sup>7</sup>

Taking prices  $p_i(\omega)$  as given, the producer solves

$$\begin{aligned} \max_{h_i(\omega), l_i(\omega), k_i(\omega)} & p_i(\omega) y_i(\omega) - w_{iH} h_i(\omega) - w_{iL} l_i(\omega) - r_i k_i(\omega) \\ \text{s.t.} & \text{ (13).} \end{aligned} \quad (14)$$

The intermediate firm's optimality conditions are given by

$$w_{iL} = (1 - \mu) p_i(\omega) z_i(\omega) G(l_i(\omega), h_i(\omega), k_i(\omega))^{1-\zeta} l_i(\omega)^{\zeta-1}, \quad (15)$$

$$w_{iH} = \mu (1 - \alpha) p_i(\omega) z_i(\omega) G(l_i(\omega), h_i(\omega), k_i(\omega))^{1-\zeta} M(h_i(\omega), k_i(\omega))^{\zeta-\chi} h_i(\omega)^{\chi-1}, \quad (16)$$

$$r_i = \mu \alpha p_i(\omega) z_i(\omega) G(l_i(\omega), h_i(\omega), k_i(\omega))^{1-\zeta} M(h_i(\omega), k_i(\omega))^{\zeta-\chi} k_i(\omega)^{\chi-1}. \quad (17)$$

We assume that the productivities for variety  $\omega$  in each country are given by

$$z_1(\omega) = e^{\eta\omega}, \quad (18)$$

$$z_2(\omega) = e^{\eta(1-\omega)} \quad (19)$$

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

## 2.5 Capital Producer

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

$$X_i = z_{iX} I_{iT}^\kappa I_{iN}^{1-\kappa}. \quad (20)$$

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

$$\begin{aligned} \max_{I_T, I_N} & P_{iX} X_i - P_{iT} I_{iT} - P_{iN} I_{iN} \\ \text{s.t.} & \text{ (20).} \end{aligned} \quad (21)$$

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<sup>7</sup>In light of the lack of good estimates for sector-specific elasticities, we made this assumption because it greatly simplifies the analytical expressions in our model (see Section 2.8)

The capital producer's optimality conditions are given by

$$P_{iT} = \kappa P_{iX} z_{iX} I_{iT}^{\kappa-1} I_{iN}^{1-\kappa}, \quad (22)$$

$$P_{iN} = (1 - \kappa) P_{iX} z_{iX} I_{iT}^{\kappa} I_{iN}^{-\kappa}. \quad (23)$$

Furthermore, using equations (20), (22), and (23), we obtain

$$I_{iN} = \frac{X_i}{z_{iX}} \left( \frac{1 - \kappa}{\kappa} \frac{P_{iT}}{P_{iN}} \right)^{\kappa} \quad (24)$$

$$I_{iT} = \frac{X_i}{z_{iX}} \left( \frac{1 - \kappa}{\kappa} \frac{P_{iT}}{P_{iN}} \right)^{1-\kappa} \quad (25)$$

## 175 2.6 Government

The government in country  $i$  finances government expenditures,  $G_i$ , and transfers,  $T_i$ , by collecting taxes on labor and capital income and revenue from tariffs. We assume that trade costs,  $\tau_{oi}$ , are composed of a technological cost,  $\tau_{oiT} \geq 1$ , and a policy cost (i.e., tariff),  $\tau_{oiP} \geq 0$ .

## 180 2.7 Equilibrium

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

**Definition.** A *steady-state recursive equilibrium* given fiscal policies  $\{\tau_{il}, \tau_{ik}, \tau_{oiP}, T_i, G_i\}_{i=1,2}$  is, for  $i = 1, 2$ , a collection of functions  $\{V_{ij}, g_{ijT}, g_{ijN}, g_{ijl}, g_{ijk}\}_{j \in \{H, L\}}$ , prices  $\{r_i, \{w_{ij}\}_j$ ,  
185  $P_{iT}, P_{iN}, P_{iX}, \{p_i(\omega)\}_{\omega \in [0,1]}\}$ , nontradable producer plans  $\{Y_{iN}, H_{iN}, L_{iN}, K_{iN}\}$ , final tradable producer plans  $\{Y_{iT}, \{q_{oi}(\omega)\}_{\omega, o \in \{1,2\}}\}$ , 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  $\{\lambda_{ij}^*\}_j$  such that

1. For  $j = H, L$ , given  $\{r_i, w_{ij}, P_{iT}, P_{iN}, P_{iX}\}$ ,  $\{V_{ij}, g_{ijT}, g_{ijN}, g_{ijl}, g_{ijk}\}$  satisfy the household problem in (1).
- 190 2. Given  $\{r_i, w_{iH}, w_{iL}, P_{iN}\}$ ,  $\{Y_{iN}, H_{iN}, L_{iN}, K_{iN}\}$  solve the problem in (3).
3. Given  $\{P_{iT}, \{p_o(\omega)\}_{\omega, o}\}$ ,  $\{Y_{iT}, \{q_{oi}(\omega)\}_{\omega, o}\}$  solve the problem in (10).

4. For  $\omega \in [0, 1]$ , given  $\{r_i, w_{iH}, w_{iL}, p_i(\omega)\}$ ,  $\{y_i(\omega), h_i(\omega), l_i(\omega), k_i(\omega)\}$  solve the problem in (14).

5. Given  $\{P_{iT}, P_{iN}, P_{iX}\}$ ,  $\{X_i, I_{iT}, I_{iN}\}$  solve the problem in (21).

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6. Markets clear:

$$(a) \ Y_{iN} = \sum_{j=H,L} \int_S g_{ijN}(k, \varepsilon) d\lambda_{ij}^*(k, \varepsilon) + I_{iN} + G_i,$$

$$(b) \ Y_{iT} = \sum_{j=H,L} \int_S g_{ijT}(k, \varepsilon) d\lambda_{ij}^*(k, \varepsilon) + I_{iT},$$

$$(c) \ X_i = \delta \sum_{j=H,L} \int_S g_{ijk}(k, \varepsilon) d\lambda_{ij}^*(k, \varepsilon),$$

$$(d) \ y_i(\omega) = \tau_{i1} q_{i1}(\omega) + \tau_{i2} q_{i2}(\omega) \text{ for } \omega \in [0, 1],$$

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

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

7. Trade is balanced:

$$\int_0^1 \tau_{12} p_1(\omega) q_{12}(\omega) d\omega = \int_0^1 \tau_{21} p_2(\omega) q_{21}(\omega) d\omega \quad (26)$$

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

$$G_i = \sum_{j=H,L} \int_S [\tau_{i\ell} w_{ij} \varepsilon g_{ij\ell}(k, \varepsilon) + \tau_{ik} (r_i - \delta P_{iX}) k] d\lambda_{ij}^*(k, \varepsilon) + \int_0^1 \tau_{oi} P p_o(\omega) q_{oi}(\omega) d\omega.$$

9. For any subset  $(\mathcal{K}, \mathcal{E}) \in \mathcal{B}$  and for  $j = H, L$ ,  $\lambda_{ij}^*$  satisfies

$$\lambda_{ij}^*(\mathcal{K}, \mathcal{E}) = \int_S \sum_{\varepsilon' \in \mathcal{E}} 1_{\{g_{ijk}(k, \varepsilon) \in \mathcal{K}\}} \Gamma(\varepsilon', \varepsilon) d\lambda_{ij}^*(k, \varepsilon).$$

## 2.8 Characterization of Equilibrium

In what follows, we use the nontradable good in country 1 as the global numeraire and normalize its price to one, i.e.,  $P_{1N} = 1$ . In this case, the real exchange rate, defined as the price of the nontradable good in country 2 relative to that in country 1, is simply given by  $e = P_{2N}$ . Furthermore, without loss of generality, we set  $z_{1N} = z_{2N} = 1$ .

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By combining equations (4) and (5), we can solve for the optimal composite of skilled labor and capital in the nontradable sector,  $M(H_{iN}, K_{iN})$ , which we can plug into equation (6) to obtain

$$P_{iN} = \left[ (1 - \mu) \left[ \frac{w_{iL}}{(1 - \mu)} \right]^{\frac{\zeta}{\zeta-1}} + \mu \left( (1 - \alpha) \left[ \frac{w_{iH}}{\mu(1 - \alpha)} \right]^{\frac{\chi}{\chi-1}} + \alpha \left[ \frac{r_i}{\alpha\mu} \right]^{\frac{\chi}{\chi-1}} \right)^{\frac{\chi-1}{\chi} \frac{\zeta}{\zeta-1}} \right]^{\frac{\zeta-1}{\zeta}} \quad (27)$$

which also represents the marginal cost faced by nontradable producers. Similarly, we can solve for the optimal mix of skilled labor and capital for each intermediate producer,  $M(h_i(\omega), k_i(\omega))$ , by combining equations (15) and (16), and substitute into (17) to obtain the price of variety  $\omega$  produced in country  $i$ ,

$$p_i(\omega) = \frac{P_{iN}}{z_i(\omega)}. \quad (28)$$

In equilibrium, two thresholds determine the production of the intermediate tradable goods. Country  $i = 1$  imports the varieties  $\omega < \bar{\omega}_1$ , where

$$\bar{\omega}_1 = \max \left\{ 0, \frac{1}{2\eta} \left( \eta - \log \tau_{21} - \log \frac{P_{2N}}{P_{1N}} \right) \right\}, \quad (29)$$

which can be obtained from the condition  $\tau_{21}p_2(\bar{\omega}_1) = p_1(\bar{\omega}_1)$ . Similarly, country  $i = 2$  imports the varieties  $\omega > \bar{\omega}_2$ , where

$$\bar{\omega}_2 = \min \left\{ 1, \frac{1}{2\eta} \left( \eta + \log \tau_{12} - \log \frac{P_{2N}}{P_{1N}} \right) \right\}. \quad (30)$$

Both countries produce the varieties  $\omega \in [\bar{\omega}_1, \bar{\omega}_2]$ . Figure 1 illustrates the pattern of production, trade, and specialization. Note that when  $\tau_{12} = \tau_{21} = 1$ , we obtain  $\bar{\omega}_1 = \bar{\omega}_2$ , which corresponds to free trade and full specialization, and when  $\tau_{21}P_{2N} > \exp(\eta)$  or  $\tau_{12} > \exp(\eta)P_{2N}$ ,

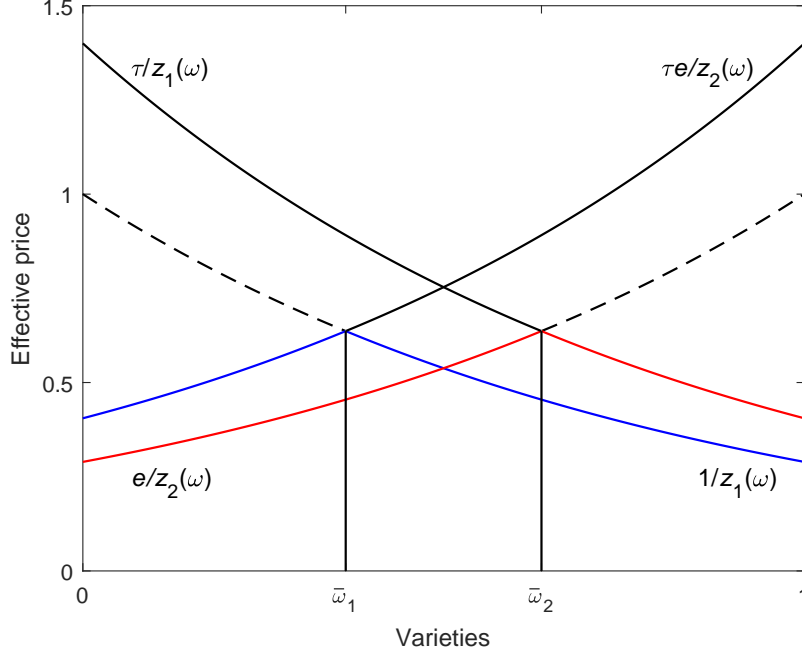
we obtain  $\bar{\omega}_1 = 0$  or  $\bar{\omega}_2 = 1$ , which corresponds to autarky.

Substituting the price in (28) into the tradable price aggregator in (12), we obtain

$$P_{iT} = \left[ \int_0^{\bar{\omega}_i} \left( \frac{\tau_{2i}P_{2N}}{z_2(\omega)} \right)^{1-\theta} d\omega + \int_{\bar{\omega}_i}^1 \left( \frac{\tau_{1i}P_{1N}}{z_1(\omega)} \right)^{1-\theta} d\omega \right]^{\frac{1}{1-\theta}}. \quad (31)$$

Equation (31) shows that the tradable price in country  $i$  is a function of the marginal costs

Figure 1: Pattern of production, trade, and specialization



faced by the intermediate tradable producers,  $P_{oN}/z_o(\omega)$ , in country  $o = 1, 2$ , the trade costs of country  $i$ , and the set of goods that are imported which is determined by  $\bar{\omega}_i$ .

Combining the capital producer's optimality conditions in equations (22) and (23), we obtain

$$P_{iX} = \frac{1}{z_{iX}} \left( \frac{P_{iT}}{\kappa} \right)^\kappa \left( \frac{P_{iN}}{1 - \kappa} \right)^{1-\kappa}. \quad (32)$$

In the case of symmetry, in which case  $P_{1N} = P_{2N} = 1$ ,  $P_{1T} = P_{2T} = P_T$ ,  $P_{1X} = P_{2X} = P_X$ , and  $\tau_{12} = \tau_{21} = \tau$ , it is straightforward to show that

$$\frac{d \log(P_T)}{d\tau} > 0 \quad (33)$$

and

$$\frac{d \log(P_X)}{d\tau} > 0 \quad (34)$$

That is, higher trade costs increase the price of tradables and, to a lesser extent, increase the price of investment. The higher price of investment induces capital shallowing, which leads to lower wages, particularly skilled wages, since capital is more complementary with skilled than with unskilled labor. In general, the effects of tariffs on the tradable price, investment price, and factor prices are complicated by movements in the real exchange rate. We will

quantitatively analyze the effects of a change in trade costs in the next section.

### 3 Calibration

We choose parameters so that the model’s 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), roughly defined as the OECD economies (excluding the US) and China. We assume that both countries have identical parameters, with the exception of population size. We summarize the parameters in Table 1.

We normalize the aggregate labor endowment of the US,  $\bar{H}_1 + \bar{L}_1$ , to one, and set  $\bar{H}_1$  to match the fraction of college graduates among household heads that are between the ages of 25 and 64, 33 percent (2004–2013, *Survey of Consumer Finances*).<sup>8</sup> Holding fixed the proportion of skilled and unskilled labor, we then scale the labor endowments in ROW by a factor of 2, since ROW is roughly twice as large as the US economy. We set the household’s discount factor  $\beta$ , so that the model matches the net-worth-to-GDP ratio in the US, 4.8 (2014, *US Financial Accounts*). We choose the tradable share parameter,  $\gamma$ , 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](#)). The household’s disutility from labor,  $\psi$ , is set so that the model generates a share of disposable time spent working of 0.33.

We set the weight on capital and unskilled labor in tradables and nontradables production,  $\alpha$  and  $\mu$ , to match the aggregate capital income share of 36 percent and the skilled wage premium of 82 percent (2004–2014, *Panel Survey of Income Dynamics*, PSID). The parameter that governs the curvature of the productivity distribution,  $\eta$ , is set so that, conditional on exporting, the employment share of the top 17 percent of exporters is 32.1 percent. For the empirical counterpart, we compute the employment share of the top 17 percent of large US manufacturing establishments (at least 100 employees), which is 32.1 percent (2014, US Census, *Business Dynamics Statistics*).<sup>9</sup> We calibrate the elasticity of substitution between tradable varieties  $\theta$  to generate a trade elasticity of 4, which is in the range of estimates in

<sup>8</sup>For  $i = 1, 2$ , let  $\bar{H}_i = \int_S d\lambda_{iH}^*(k, \varepsilon)$  and  $\bar{L}_i = \int_S d\lambda_{iL}^*(k, \varepsilon)$ .

<sup>9</sup>Ideally, we would target the size distribution of exporting establishments. Without access to those data, we are using the set of large manufacturing establishments as a proxy for the set of exporting establishments, as in [Carroll and Hur \(2020\)](#).

the literature.<sup>10</sup> We set the tradable share in capital production,  $\kappa$ , 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*). We assume that the tax rate on labor income,  $\tau_\ell$ , is equal to that on capital income,  $\tau_k$ , and they are set so that the model matches the US government's consumption share of GDP, 15 percent (2014, OECD). Lump-sum transfers are assumed to be zero in the initial steady state.

The labor productivity shocks  $\varepsilon$  are assumed to follow an order-one auto-regressive process as follows:

$$\log \varepsilon_t = \rho_{j,\varepsilon} \log \varepsilon_{t-1} + \nu_t, \nu_t \sim N(0, \sigma_{j,\nu}^2). \quad (35)$$

We estimate this process using wages from the PSID to find a persistence  $\rho_{H,\varepsilon} = 0.935$  and a standard deviation  $\sigma_{H,\nu} = 0.195$  for skilled households and a persistence  $\rho_{L,\varepsilon} = 0.938$  and a standard deviation  $\sigma_{L,\nu} = 0.182$  for unskilled households.<sup>11</sup> These processes are approximated with five-state Markov processes using the Rouwenhurst procedure described in [Kopecky and Suen \(2010\)](#). We set the household's risk aversion,  $\sigma$ , 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](#)). 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. \(2000\)](#).<sup>12</sup> Finally, the depreciation rate of capital,  $\delta$ , is set to 5 percent, a standard value in the literature.

We show in Table 2 that the calibrated model matches not only the targeted moments but also moments that were not targeted reasonably well. The model generates tradable expenditure shares that match the data at the median wealth level but that are slightly higher than the data for the lower 25 percent of the wealth distribution. In general, the model generates reasonable, albeit lower, levels of inequality than in the data for wealth, consumption,

<sup>10</sup>For example, see [Simonovska and Waugh \(2014\)](#).

<sup>11</sup>The sample selection and estimation procedures closely follow [Krueger et al. \(2016\)](#). See Appendix A for details. Notice that our estimates are similar to [Floden and Lindé \(2001\)](#), who estimate a similar process for wages across all skill groups.

<sup>12</sup>Though [Krusell et al. \(2000\)](#) estimate these elasticities under a slightly different production function specification, they also provide a summary of estimates of these elasticities under various specifications in the literature in [Krusell et al. \(1997\)](#), which are consistent with their own estimates. In Appendix D.2, we show that our main results are robust to changes in these elasticities.



Table 1: Calibration

Parameters	Values	Targets / Source
Discount factor, $\beta$	0.97	Wealth-to-GDP: 4.8
Risk aversion, $\sigma$	2	Standard value
Tradable share, $\gamma$	0.26	Tradable expenditure share: 35 percent
Non-homotheticity, $\bar{c}$	0.11	Tradable expenditure share of wealthiest 25 percent: 31 percent
Disutility from labor, $\psi$	440	Average hours: 33 percent
Frisch elasticity, $1/\nu$	0.5	Standard value
Skilled fraction, $\bar{H}_1$	0.33	Skilled labor force: 33 percent
Capital weight, $\alpha$	0.85	Capital income share: 36 percent
Skilled weight, $\mu$	0.51	Skill premium: 82 percent
Elasticity of substitutions, unskilled-capital, $1/(1 - \zeta)$	1.67	<a href="#">Krusell et al. (1997)</a>
skilled-capital, $1/(1 - \chi)$	0.67	<a href="#">Krusell et al. (1997)</a>
tradable intermediates, $\theta$	6.54	Trade elasticity: 4.0
Factor elasticity, $\kappa$	0.56	Tradable input shares in capital production
Productivity distribution, $\eta$	1.29	Employment share of top 17 percent of large manufacturing establishments: 32 percent
Iceberg cost, $\tau - 1$	0.09	Import share: 17 percent
Income tax, $\tau_\ell = \tau_k$	0.20	Government consumption: 15 percent of GDP
Capital depreciation rate, $\delta$	0.05	Standard value
Persistence of wage process, unskilled, $\rho_{L,\varepsilon}$	0.94	Authors' estimates (PSID)
skilled, $\rho_{H,\varepsilon}$	0.94	Authors' estimates (PSID)
Standard deviation, unskilled, $\sigma_{L,\nu}$	0.20	Authors' estimates (PSID)
skilled, $\sigma_{H,\nu}$	0.18	Authors' estimates (PSID)

Table 2: Model and data

Targeted moments	Data	Model
Wealth-to-GDP	4.8	4.8
Trade elasticity	-4.0	-4.0
Import share	0.17	0.17
Tradable expenditure shares:		
average	0.35	0.35
top 25 percent (wealth)	0.31	0.31
Nontargeted moments		
Gini coefficients:		
wealth ( $k$ )	0.79	0.59
consumption ( $c$ )	0.36	0.24
disposable labor income ( $y$ )	0.41	0.35
Correlation between:		
$k, y$	0.32	0.32
$k, c$	0.39	0.83
$c, y$	0.69	0.69
Tradable expenditure shares:		
median	0.34	0.34
bottom 25 percent (wealth)	0.38	0.41

and disposable labor income. It is common for standard infinitely lived models to generate  
270 less skewness in the wealth distribution relative to the data. There is a large quantitative  
literature that explores mechanisms that can produce higher levels of wealth concentration  
in incomplete-markets models.<sup>13</sup> The model also generates exactly the correlation between  
wealth and disposable labor income and between consumption and disposable labor income.  
However, the model predicts a much higher level of correlation between consumption and  
275 wealth than in the data. We suspect that some of the mechanisms that would help generate  
more dispersion in wealth would also help generate lower correlations between wealth and  
consumption.

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<sup>13</sup>Some examples are “awesome” labor earnings states (Castaneda et al. 2003), entrepreneurship (Cagetti and De Nardi 2006), life-cycle bequest motives (De Nardi 2004), discount factor heterogeneity (Krusell and Smith 1998), or return risk (Benhabib et al. 2011).

## 4 Quantitative Exercises

Next, we use our calibrated model to analyze the impacts of trade disruptions caused by an increase in tariffs. Starting in period one, before any agent's decisions are made, the US imposes an unanticipated tariff of 5 percent on imports from ROW, which corresponds to the change in the average effective tariff rate on US imports from ROW, when including both legislated and proposed tariffs since 2017.

As a reference, we start with the case where tariff revenue is used to finance additional wasteful government spending. This fiscal policy most closely correlates with a common thought experiment from the trade literature where iceberg trade costs change.<sup>14</sup> This provides a lower bound for average welfare by separating the costs of tariffs from the compensation from redistribution.

We highlight how the results change based on whether or not ROW retaliates with an equally sized tariff on US exports and based on how the US redistributes the tariff revenues. We consider three redistributive policies: two revenue-neutral tax reductions, one on labor income and the other on capital income, and lump-sum transfers.<sup>15</sup>

### 4.1 Solving for Transition Paths

The problem of the household with skill type  $j \in \{L, H\}$  can be stated recursively as

$$\begin{aligned} V_{ijt}(k, \varepsilon) &= \max_{c_T, c_N, \ell, k'} u(c_T, c_N, \ell) + \beta E_{\varepsilon' | \varepsilon, j} V_{ij, t+1}(k', \varepsilon') \\ \text{s.t. } & P_{iTt}c_T + P_{iNt}c_N + P_{iXt}(k' - k) \leq \tilde{w}_{ijt}\ell\varepsilon + \tilde{r}_{it}P_{iXt}k + T_{it}, \\ & k' \geq 0 \end{aligned} \tag{36}$$

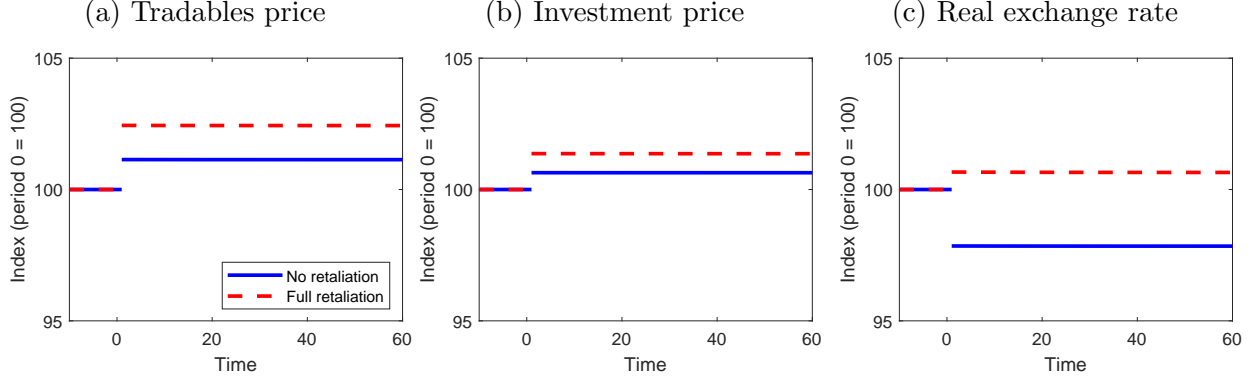
Solving this yields time-dependent decision rules  $g_{ijTt}(k, \varepsilon)$ ,  $g_{ijNt}(k, \varepsilon)$ ,  $g_{ij\ell t}(k, \varepsilon)$ , and  $g_{ijkt}(k, \varepsilon)$  for tradables consumption, nontradables consumption, labor, and saving, respectively.

To solve the transition, we begin with the stationary wealth distribution in the initial steady state,  $\lambda_{ij0}^*$ , at  $t = 0$ . We then introduce a permanent increase in trade costs in  $t = 1$ , and solve for a sequence of value functions  $\{V_{ijt}\}_{t=1}^\infty$ , decision rules  $\{g_{ijTt}, g_{ijNt}, g_{ij\ell t}, g_{ijkt}\}_{t=1}^\infty$ ,

<sup>14</sup>See, for example, [Arkolakis et al. \(2012\)](#).

<sup>15</sup>Because we focus on US welfare, we simplify our results by assuming that ROW always balances its budget by adjusting government spending.

Figure 2: Prices (no redistribution)



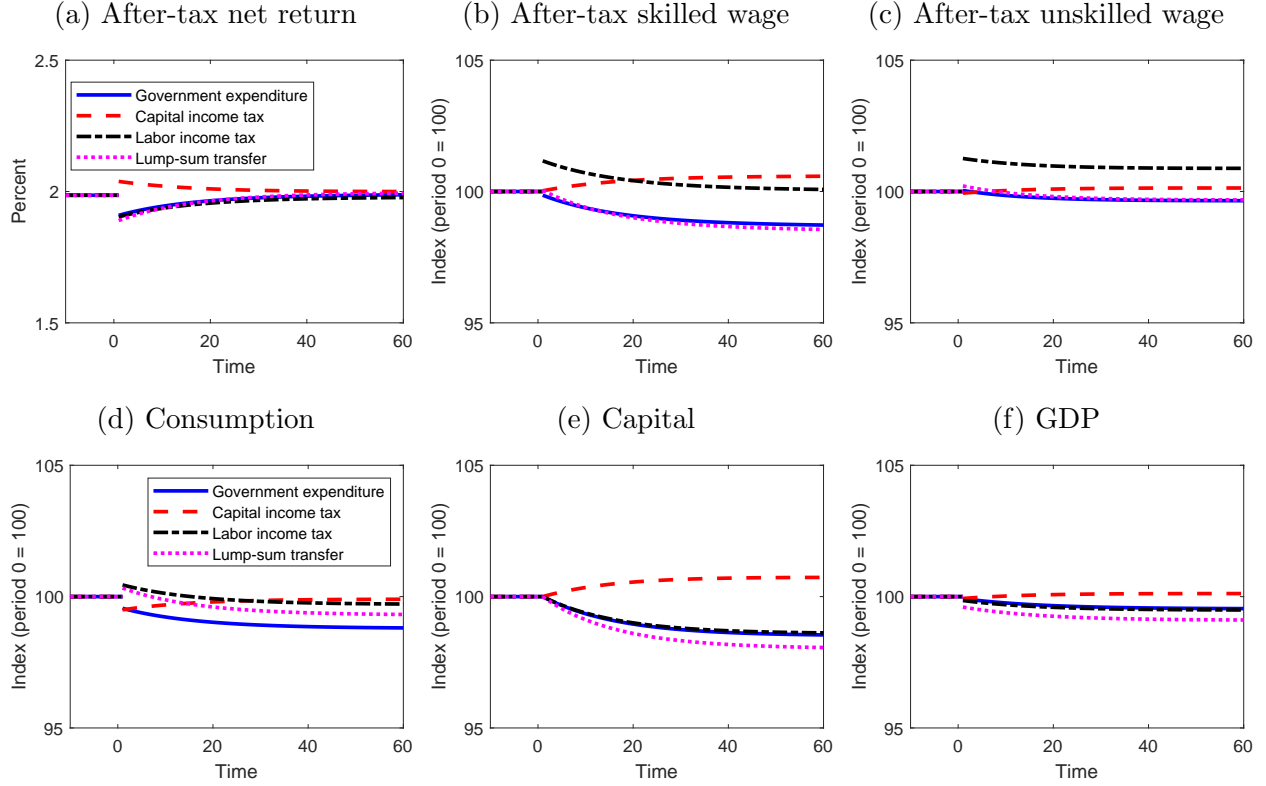
300 wealth distributions  $\{\lambda_{ijt}\}_{t=1}^{\infty}$ , prices  $\left\{r_{it}, w_{ijt}, P_{iTt}, P_{iXt}, P_{iNt}, \{p_{ot}(\omega)\}_{\omega,o}\right\}_{t=1}^{\infty}$ , and fiscal policies  $\{\tau_{ilt}, \tau_{ikt}, \{\tau_{oit}\}_o, T_{it}\}$  for  $i = 1, 2$  and  $j \in \{H, L\}$ , such that given prices, households and firms make optimal decisions, markets clear, trade is balanced, and distributions are consistent with household savings decisions. As in the steady-state analysis, we use as the global numeraire the nontradable good in country 1, and normalize its price to one, i.e.,  
 305  $P_{1Nt} = 1$ . Thus, the real exchange rate is given by  $e_t = P_{2Nt}$ .

## 4.2 Equilibrium Effects of Tariffs

The US tariff induces several immediate and permanent effects that are virtually identical regardless of how tariff revenue is spent. First, because of the increased cost of imports and because tariffs result in a less efficient pattern of production and trade,  $P_{US,T}$  rises, as  
 310 shown in Figure 2. Since tradables are an input into new capital, some of the  $P_{US,T}$  increase passes through to the investment price so  $P_{US,X}$  also rises. If ROW retaliates by enacting an equal-sized tariff on US exports, these effects are magnified.

The effect on the real exchange rate depends upon how ROW reacts. If it does not retaliate, the real exchange rate appreciates, improving the terms-of-trade. That is, US  
 315 exports become more expensive relative to US imports, excluding tariffs. On the other hand, if ROW does retaliate, because the US is smaller, the exchange rate moves in the opposite direction and its terms-of-trade deteriorate. Because the no retaliation case looks like an attenuated version of the full retaliation case, in the remainder of this section, we restrict attention to the results under retaliation. Results from the no retaliation case are  
 320 provided in Appendix D.1 (Figures 12 through 17).

Figure 3: Factor prices and aggregates (full retaliation)



How tariffs affect factor prices depends on how the US government uses the tariff revenue. The basic dynamics are most clearly seen for the case of wasteful government expenditure shown in the solid blue lines in Figure 3. The rise in  $P_X$  discourages investment and induces capital shallowing. This exerts downward pressure on wages, especially on the skilled wage, since skilled labor is more complementary with capital. The net return on capital drops immediately, since it becomes more costly to purchase investment units, but over time, capital shallowing drives  $\tilde{r}$  back up near its pre-tariff value. Real GDP and average consumption are permanently lower as a result of tariff policy.

Most redistribution alternatives lead to similar dynamics along most dimensions. When revenues are redistributed through a lump-sum transfer, the price dynamics are virtually identical to those without redistribution, but average consumption is a little higher. Moreover, the lump-sum transfer policy produces the lowest long-run capital and GDP. This is because the lump-sum transfer reduces the pre-cautionary saving motive, leading to even lower levels of investment and capital.

Redistributing through a reduction in the labor income tax leads to dynamics of the return

to capital and aggregate capital and output that are similar to those without redistribution, but with higher consumption. After-tax wages of both skill types rise initially due to lower taxes, but the skilled wage eventually returns to its pre-tariff level because the increase from the tax reduction is fully offset by the decrease due to capital shallowing.

340 If the government instead uses tariff revenue to reduce capital income taxes, thereby propping up the after-tax net return, it can overcome the negative effects on investment and spur a modest capital deepening. The wages for both skill types rise, though the increase is larger for skilled labor, since it is more complementary with capital. In the long run, GDP is slightly higher, and average consumption is roughly unchanged.

### 345 4.3 Welfare

The dynamics of prices resulting from tariffs lead to differential effects on household welfare across wealth, income, and skill type. We calculate the distribution of welfare using consumption equivalence. That is, we compute, for each household, by what common factor,  $\Delta$ , would initial steady-state consumption of tradables and nontradables have to be permanently increased in order to make a household indifferent to the policy change.<sup>16</sup> Negative values of  $\Delta$  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 trade cost environment. Formally, given the household value functions at the beginning of the transition,  $V_{ij,t=1}(k, \varepsilon)$ , and the initial steady-state decision rules,  $g_{ijT}^{ss}$ ,  $g_{ijN}^{ss}$ ,  $g_{ij\ell}^{ss}$ , and  $g_{ijk}^{ss}$ , we solve for  $\Delta_{ij}(k, \varepsilon)$ , such that

$$V_{ij}^{\Delta}(k, \varepsilon) = V_{ij,t=1}(k, \varepsilon)$$

where

$$V_{ij}^{\Delta}(k, \varepsilon) = u\left((1 + \Delta)g_{ijT}^{ss}, (1 + \Delta)g_{ijN}^{ss}, g_{ij\ell}^{ss}\right) + \beta E_{\varepsilon'|\varepsilon,j} V_{ij}^{\Delta}(g_{ijk}^{ss}, \varepsilon').$$

Table 3 reports the change in average welfare and the percent of households that gain from tariffs across different fiscal policies with and without retaliation. When tariff revenue is not redistributed to households, tariffs generate a negative welfare effect on all households with an average loss of 1.1 and 0.5 percent, respectively, with and without retaliation. Also,

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<sup>16</sup>Because preferences are nonhomothetic, one may be concerned that we are mismeasuring welfare by restricting that 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 3: Welfare

	Average welfare change	Percent with welfare gain
<i>Full retaliation</i>		
no redistribution	−1.1	0.0
lump-sum transfer	0.1	67.0
labor income tax	−0.1	26.7
capital income tax	−0.3	21.4
<i>No retaliation</i>		
no redistribution	−0.5	0.0
lump-sum transfer	0.9	99.1
labor income tax	0.6	100.0
capital income tax	0.4	70.5

Units: percent.

despite generating higher levels of long-run economic activity, the capital income tax reform is the least popular means of redistribution, suggesting that aggregate outcomes do not represent the welfare of the typical household. When there is full retaliation, redistributing tariff revenue through lump-sum transfers is the only case that generates an average welfare gain.

Figure 4 plots the average welfare of households across the initial steady-state wealth distribution, normalized by per capita output.<sup>17</sup> On average, the welfare losses from the labor tax reform are more evenly spread across households. In contrast, the capital income tax reform generates very unequal welfare gains by wealth. The reason for the positive welfare result under lump-sum redistribution is also apparent: poor households greatly value the extra social insurance the transfer provides.

To understand the pattern for average welfare from each policy, we examine the welfare channels for each policy in turn, starting with wasteful government expenditure. Figure 5(a) plots average welfare across the initial steady-state wealth distribution for both skill types for this case, normalized by per capita output. Without redistribution, welfare losses from tariffs fall more heavily on the poor relative to the wealthy and on the skilled relative to the unskilled. We decompose the total welfare change for each household into three channels: the *expenditure* channel, the *investment* channel, and the *wage* channel.<sup>18</sup>

The expenditure channel measures the welfare cost associated with a rise in tradable

<sup>17</sup>For reference, median wealth is 2.6, and the 90th percentile of wealth is 12.6.

<sup>18</sup>This decomposition exercise is similar to the one described in [Carroll and Hur \(2020\)](#). Details can be found in Appendix C.

Figure 4: Welfare change

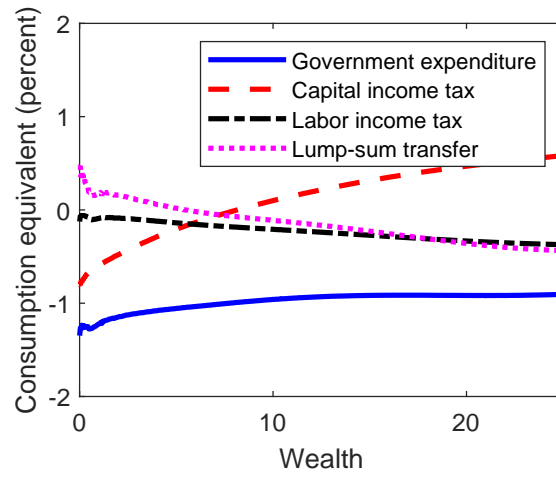
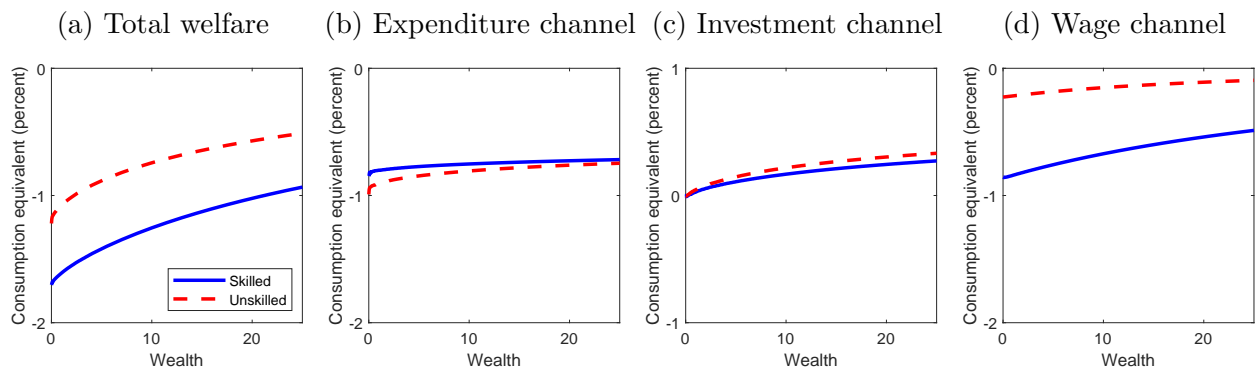


Figure 5: Welfare decomposition (no redistribution and full retaliation)





goods prices. As shown in Panel (b) of Figure 5, this channel has a larger effect on low-wealth households because they spend a larger share of their consumption expenditures on tradable goods. The investment channel nests two opposing effects: a capital gain realized from the immediate rise in  $P_X$  and a lower future discounted stream of net returns. In this case, the capital gain dominates so that on average households with positive wealth benefit (Panel (c)).<sup>19</sup> Finally, the wage channel isolates the welfare costs from lower wages. Because rich households derive less of their income from wages, they are less affected by a decline in their wage (Panel (d)). The wage channel, by far, is the largest determinant of the welfare differences across skill levels, reflecting the differential effects that tariffs and capital shallowing have on wages across skill types. Notice that all three channels favor wealthy households relative to poor households.

If the government redistributes tariff revenue through a lump-sum transfer, the expenditure, investment, and wage channels are nearly identical to the wasteful government spending baseline, as can be seen in Figure 6. However, the total welfare gain is much higher for the poor, particularly the poor unskilled, and is due to the transfer channel (Panel (e)). By increasing the amount of feasible consumption available to poor and low-productivity households, this policy reduces the need to privately insure. Although the magnitude of the transfer is equal, the value of the transfer in terms of marginal utility is much greater for the poor, and this produces higher average welfare. Interestingly, the case where the government redistributes tariff revenue through a lump-sum transfer leads to a dichotomy across skills: all skilled households oppose the tariff and transfer policy and all unskilled households support it. This is because skilled wages fall by more than unskilled wages and the fact that skilled households value the transfer less than unskilled households because of their higher average income.

If the government uses tariff revenue to reduce the labor income tax, the welfare changes are more equally distributed, as can be seen in Panel (a) of Figure 7. This is because the labor income tax reduction raises after-tax wages, which benefits low-wealth households (Panel (d)), offsetting the pro-wealthy expenditure and investment channels (Panels (b) and (c)), which are roughly unchanged from the no redistribution and lump-sum transfer policies.

In contrast, using tariffs to reduce capital income taxes generates the most unequal

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<sup>19</sup>Some households with low wealth may lose from the investment channel if their current productivity level is above average. Because they have low wealth, the capital gain is small, but at the same time, these households have a strong desire to save and so dislike the lower future returns from saving.

Figure 6: Welfare decomposition (lump-sum transfer and full retaliation)

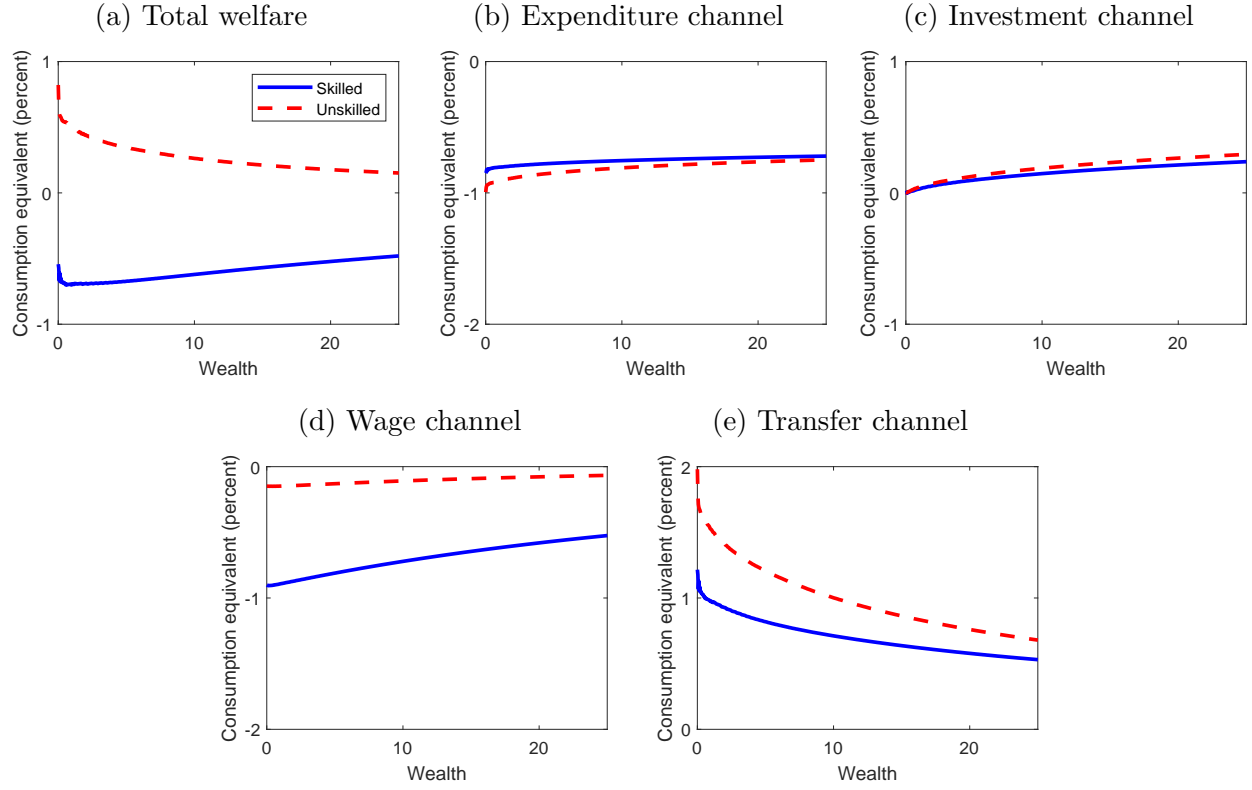


Figure 7: Welfare decomposition (labor income tax and full retaliation)

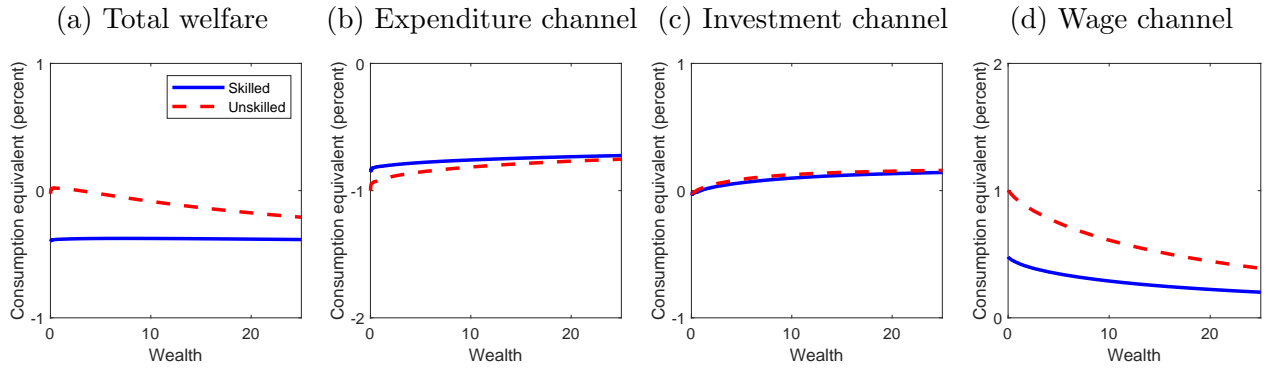
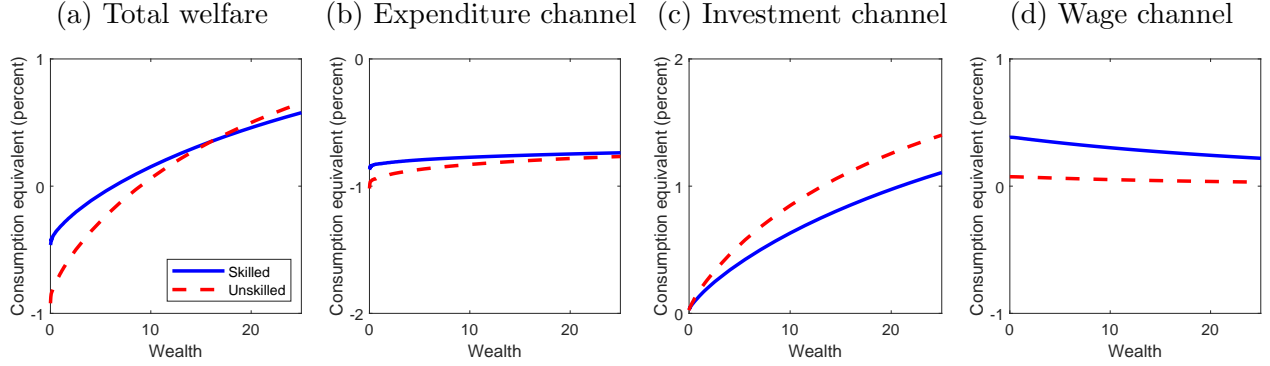


Figure 8: Welfare decomposition (capital income tax and full retaliation)



distribution of welfare gains with gains tilted strongly in favor of high-wealth households,  
as shown in Figure 8. Despite averting the capital-shallowing dynamics and producing  
higher levels of economic activity, this scenario delivers the lowest average welfare among  
the redistributive policies. The primary force for the unequal distribution is the investment  
channel (Panel (c)). Not only do rich households realize a capital gain from  $P_X$  rising, but  
the path of effective future returns (Figure 3 Panel (a)) is also elevated over the transition.  
The capital income tax reform is also the only one of the four policies studied that favors the  
skilled over the unskilled. The welfare decomposition shows that this difference comes from  
the wage channel (Panel (d)). Because capital deepens in this scenario, the skilled wage rises  
by more than the unskilled wage (Figure 3 Panels (b) and (c)).

#### 4.4 Mobility Across Sectors

So far, we have assumed that labor is perfectly mobile between the tradable and nontradable  
sectors. This assumption has strong implications for both the dispersion and composition  
of welfare changes. In particular, a household that initially works in the tradables sector  
can, upon the realization of tariffs, switch to the nontradables sector. Equilibrium forces  
will equate skill-specific wages across sectors so that the distribution of welfare costs is  
independent of a household's initial sector.

We now consider the opposite extreme: a household can never change sectors. While the  
total labor supply of a skill type within a sector may change due to changes in hours worked,  
the number of workers of each skill type is fixed. In the perfect mobility case, factor prices  
were equated immediately as workers flowed between sectors. Now, factor prices will remain  
permanently different after tariffs are imposed.

While most of the equations that characterize the equilibrium remain similar to those in the baseline model, several change in important ways. First, the marginal cost for nontradables producers in each country (shown in equation (27)) is now only a function of the nontradables wages and the interest rate. Similarly, we can express the marginal cost of tradables producers as a function of the tradables wages and interest rate,

$$\phi_i = \left[ (1 - \mu) \left[ \frac{w_{iLT}}{(1 - \mu)} \right]^{\frac{\zeta}{\zeta-1}} + \mu \left( (1 - \alpha) \left[ \frac{w_{iHT}}{\mu(1 - \alpha)} \right]^{\frac{\chi}{\chi-1}} + \alpha \left[ \frac{r_i}{\alpha\mu} \right]^{\frac{\chi}{\chi-1}} \right)^{\frac{\chi-1}{\chi} \frac{\zeta}{\zeta-1}} \right]^{\frac{\zeta-1}{\zeta}} \quad (37)$$

and the tradables price reflects these marginal costs in both countries,

$$P_{iT} = \left[ \int_0^{\bar{\omega}_i} \left( \frac{\tau_{2i}\phi_2}{z_2(\omega)} \right)^{1-\theta} d\omega + \int_{\bar{\omega}_i}^1 \left( \frac{\tau_{1i}\phi_1}{z_1(\omega)} \right)^{1-\theta} d\omega \right]^{\frac{1}{1-\theta}} \quad (38)$$

Finally, the cutoff values for determining the pattern of trade over intermediates must also be updated to take imbalances in marginal costs across countries into account,

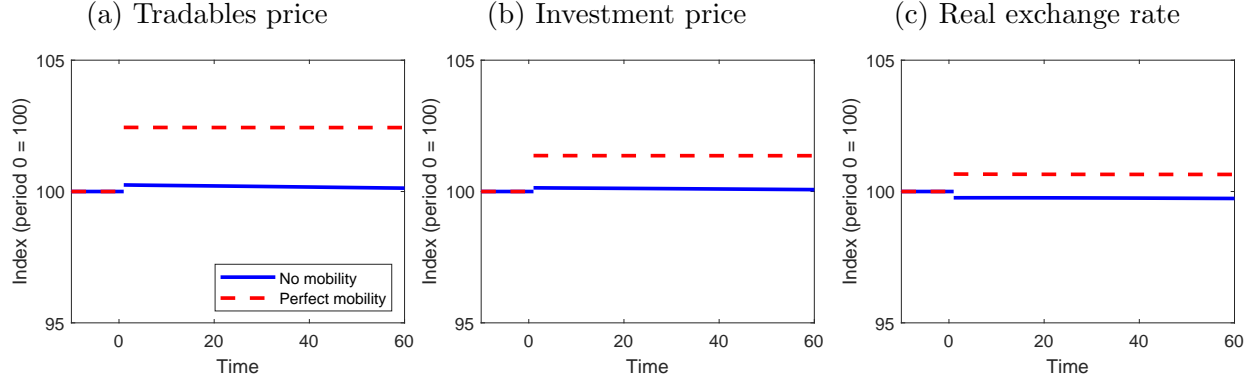
$$\bar{\omega}_1 = \max \left\{ 0, \frac{1}{2\eta} \left( \eta - \log \tau_{21} - \log \frac{\phi_2}{\phi_1} \right) \right\} \quad (39)$$

$$\bar{\omega}_2 = \min \left\{ 1, \frac{1}{2\eta} \left( \eta + \log \tau_{12} - \log \frac{\phi_2}{\phi_1} \right) \right\}. \quad (40)$$

Notice that in the perfect mobility baseline, wages are equated across sectors, leading to  $P_{iN} = \phi_i$ . The effect of tariffs on the tradables prices can be separated into four channels. First, tariffs directly distort the quantity of imported varieties used in production, i.e.,  $\partial P_{1T}/\partial \tau_{21} > 0$ . Second, tariffs increase the tradables price by distorting the set of goods traded, i.e.,  $\partial \bar{\omega}_1/\partial \tau_{21} < 0$ . Third, tariffs also affect the real exchange rate, which may rise or fall, depending on whether there is retaliation from the trading partner, and if so, the relative size of the two countries. Finally, by reducing the demand for tradable goods, tariffs may reduce the wages in the tradable sectors, which leads to lower tradables prices. The last channel is specific to the immobility case.

We repeat the 5 percent tariff exercise under full retaliation and no redistribution. Figure 9 plots the resulting transition path of  $P_T$ ,  $P_X$ , and the real exchange rate, along with their counterparts from the perfect mobility case. Notice that when workers are immobile, these

Figure 9: Prices (no redistribution and full retaliation)



prices are far less responsive to tariffs. This is a result of a decline in the marginal cost of production in the tradables sector that offsets most of the upward pressure on  $P_T$  from tariffs.

The paths of net return to capital, aggregate consumption, GDP, and capital are very similar across the two cases as well (Figure 10). In fact, all the action is in the behavior of wages across sectors. Figure 10 panels (b) and (c) plot the skilled wages and unskilled wages, respectively, in each sector. Workers in the nontradables sector experience a small wage increase with the skilled wage rising relatively more as capital flows from the tradables sector into the nontradables sector. For workers in the tradables sector, the results are reversed. Both skill types face large decreases in their wages, but it is especially severe for skilled workers.

Perhaps surprisingly, assuming perfect immobility instead of perfect mobility has almost no effect on average welfare. When workers cannot switch sectors, the average welfare loss is -0.99 percent as opposed to -1.01 percent in the baseline. Instead, sectoral immobility has a big effect on the distribution of welfare changes because of the starkly different wage dynamics across sectors. First, unlike in the baseline, there are winners from tariffs even without redistribution: 8.35 percent of households gain. These gains are very small and go to the relatively poor households in the nontradables sector. In contrast, households in the tradables sector experience very large welfare losses (shown in Figure 11 panel (a)). A decomposition of the welfare changes (shown in panels (b)-(d)) makes clear that with immobility across sectors, the welfare costs of tariffs manifest almost entirely through the wage channel. Because of the muted effect of tradables and investment prices, the expenditure and investment channels play almost no role in the allocation of welfare across the distribution in this case.

Figure 10: Factor prices and aggregates (no redistribution and full retaliation)

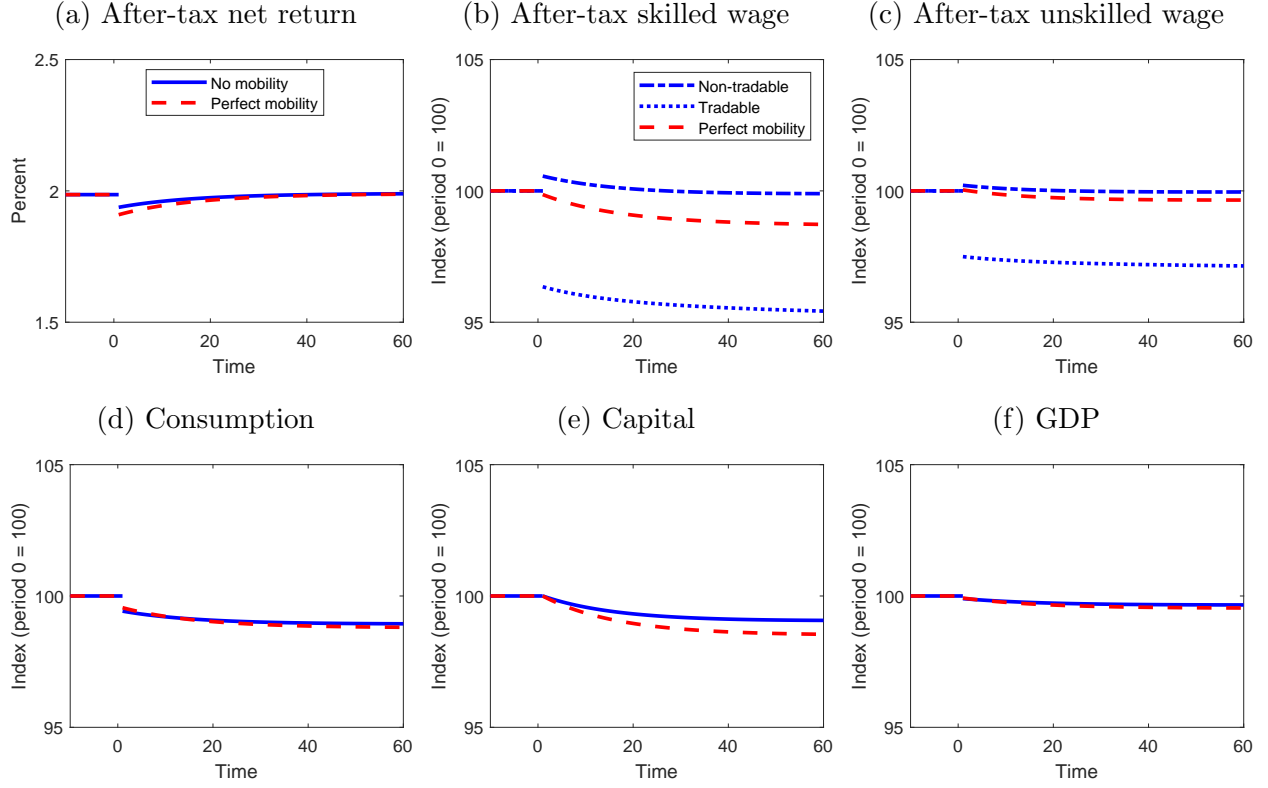
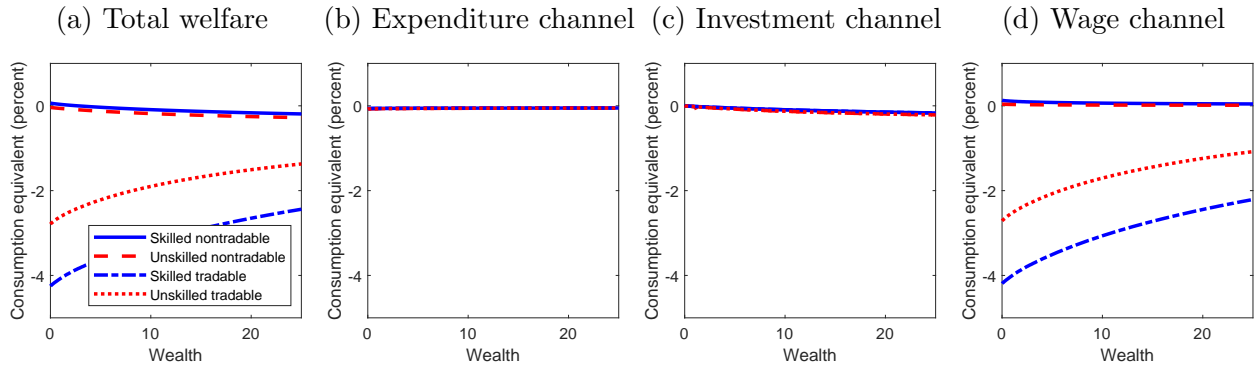


Figure 11: Welfare decomposition (no mobility)



## 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 unilateral and bilateral tariff increases in a 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. Without redistributing tariff revenue, tariffs hurt everyone, especially the poor and skilled. With redistribution, the gains and losses from tariffs depend on the way in which the government uses the new tariff revenue and whether there are retaliatory tariffs. In particular, using tariff revenue to reduce capital income taxes leads to higher levels of economic activity, but also to larger and more unequally distributed welfare costs than does reducing labor income taxes. Lump-sum transfers can produce an average welfare gain, even with retaliatory tariffs, with unskilled households winning at the expense of skilled households.

We have built a two-country model with rich layers of heterogeneity and studied the aggregate and distributional effects of tariffs. The model, however, could be readily applied to study other policies such as capital account liberalization and immigration policies. While our baseline model abstracts from labor market frictions, we also showed that the main result—that tariffs harm poor and skilled workers—is robust to a version of the model with sectoral immobility. The model could also be extended to allow for partial mobility across sectors. 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 aged between 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. Next, we construct wages by dividing labor income by hours, where hours is the sum of hours worked, hours unemployed, and sick hours. We then deflate wages using the CPI. We drop observations with missing education, with wages that are less than half of the minimum wage, with topcoded income, and with hours less than 1000 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 5 years, leaving final samples of 1,659 skilled households (college graduates) and 3,065 unskilled households, with an average length of 17 years. On these separate samples, we compute the autocovariance matrix of the residuals. The stochastic process in equation (35) is estimated using GMM, targeting the covariance matrix, where the weighting matrix is the identity matrix. We thank Chris Tonetti for providing the Matlab routines that perform the estimation.

## B Computational Appendix

1. Let  $\lambda_{ij}^{init}(k, \varepsilon, )$  be an initialization of the distribution over  $k_{fine}$  and  $\mathcal{E}$  for households in country  $i$  with skill type  $j$ .
2. Given tariff policy  $\mathcal{T} = \{\tau_{US}, \tau_{ROW}\}$ , solve for the equilibrium rental rate,  $r_i^*$ , in each country.
  - (a) Guess  $v^n = \{r_i^n, w_{H,i}^n, e^n, B_{US}^n\}$  where  $B_{US}$  is the value of the fiscal policy instrument which clears the government budget constraint in the US (e.g.,  $\tau_{k,US}$ )
  - (b) From  $e^n$  and  $\mathcal{T}$  calculate  $\{P_T^n, P_X^n\}_i$  using equations (31) and (32).
  - (c) The market clearing interest rate can now be solved for each country separately, so we suppress the the subscript  $i$ . Given  $r^n$  and  $w_H^n$ , compute  $w_L^n$  using equation (27).

- (d) Solve the household problem in (1) to obtain the decision rules for each skill type,  
 $g^n = \{g_{jT}, g_{jN}, g_{j\ell}, g_{jk}\}_{j=L,H}$ .
- (e) Begin with  $\lambda_j^0(k, \varepsilon)$ , iterate forward using  $g^n$  to find the invariant distribution,  
 $\lambda_j^{*,n}(k, \varepsilon)$ .
- (f) Aggregating by combining  $g^n$  with  $\lambda_j^{*,n}(k, \varepsilon)$ , we can get  $\{C_T^n, C_N^n, X^n, H^n, L^n, K^n\}$ .
- (g) Use equations (22) and (23) to obtain  $\{I_T^n, I_N^n\}$ .
- (h) Use market clearing conditions for tradable and nontradable final goods to obtain  
 $\{Y_T^n, Y_N^n\}$ .
- (i) Substitute  $G_N^n = Y_N^n$  into equation (4) to obtain  $L_N^n$ .
- (j) Use the market clearing condition for unskilled labor to obtain  $L_T^n = L^n - L_N^n$ .
- (k) Use the first order conditions of the intermediate tradable producers, equations  
(15)–(17), to obtain

$$H_T^n = \left( \frac{1-\mu}{\mu} \frac{1}{(1-\alpha)\Omega} \frac{w_H^n}{w_L^n} \right)^{\frac{1}{\zeta-1}} L_T^n, \quad (41)$$

$$K_T^n = \left( \frac{\alpha}{1-\alpha} \frac{w_H^n}{r^n} \right)^{\frac{1}{\chi-1}} H_T^n, \quad (42)$$

where

$$\Omega = \left[ \alpha \left( \frac{\alpha}{1-\alpha} \frac{w_H^n}{r^n} \right)^{\frac{\chi}{1-\chi}} + 1 - \alpha \right]^{\frac{\zeta-\chi}{\chi}}. \quad (43)$$

- (l) Use the market clearing conditions for skilled labor and capital to obtain  $\{H_N^n, K_N^n\}$ .
- (m) From the first order conditions of the nontradable producer,

$$r^{new} = \alpha \mu (G_N^n)^{1-\zeta} M (H_N^n, K_N^n)^{\zeta-\chi} (K_N^n)^{\chi-1}$$

- (n) We use Brent's Method to solve for  $r^*$  over a fixed interval.
- (o) With  $r^*$  computed for each country, update the remaining elements of  $v$
- (p) The implied skilled wage in each country is

$$w_H^{new} = (1-\alpha) \mu (G_N^n)^{1-\zeta} M (H_N^n, K_N^n)^{\zeta-\chi} (H_N^n)^{\chi-1}.$$



The implied exchange rate,  $e^{new}$  can be computed from the trade balance equation (see equation (26) 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.

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

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

and iterate until convergence.

## C Welfare Decomposition

In order to quantify the importance of each of these channels, we conduct a sequence of partial equilibrium exercises. We introduce a measure-zero collection of “ghost” households, who face prices that are different from the equilibrium prices faced by regular households. Ghosts still optimize in response to the prices they face, but because they are zero measure, their decisions have no effect on the equilibrium.

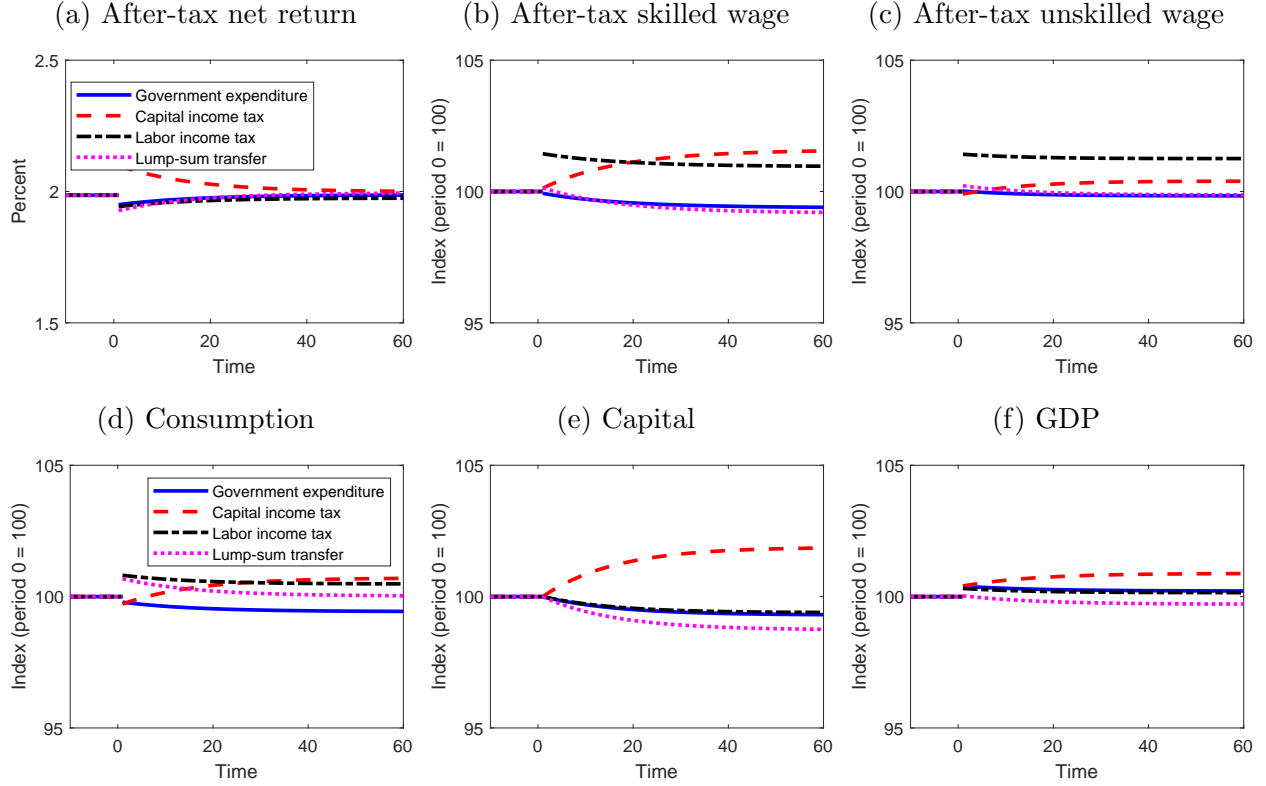
We compare three ghost types. The first ghost only experiences the change in the equilibrium price of tradables (the expenditure channel). For the second type, only the price of investment and the return on capital are active (the investment channel), and for the third ghost type, only the after-tax wages follow their equilibrium paths (the wage channel). In the case in which the government redistributes tariff revenue through lump-sum transfers, there is additionally a ghost that experiences only the equilibrium path of transfers (the transfer channel).

## D Additional Figures

### D.1 Results with No Retaliation

In section 4.2, we discussed how, in the absence of retaliation, the prices of tradable and investment goods rise less, due to an improvement in the terms of trade. For each method of spending the tariff revenue, the smaller increase in the investment price leads to less capital shallowing (or more capital deepening), and therefore smaller declines (or larger increases)

Figure 12: Factor prices and aggregates (no retaliation)



in wages, consumption, and output, which can be seen by comparing Figure 12 to Figure 3. Furthermore, inspecting Figure 13 and 4 reveals that the welfare consequences across the wealth distribution are also similar, except that the levels are higher without retaliation. Figures 14–17, which show the welfare decompositions for each method of spending tariff revenue, reveal that, compared to the decompositions with retaliation, the expenditure channel has a smaller effect and the wage channel is less negative (or more positive).

Figure 13: Welfare change (no retaliation)

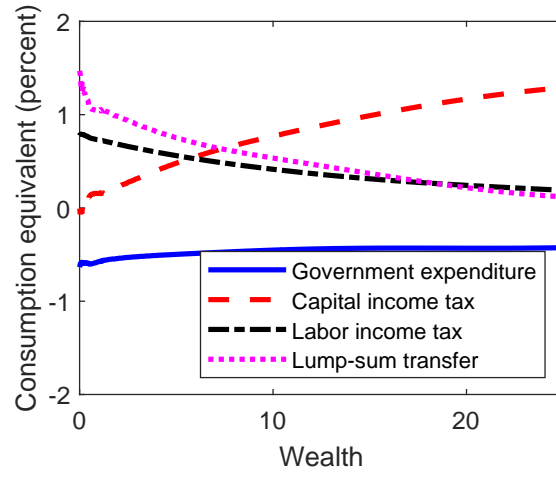


Figure 14: Welfare decomposition (no redistribution and no retaliation)

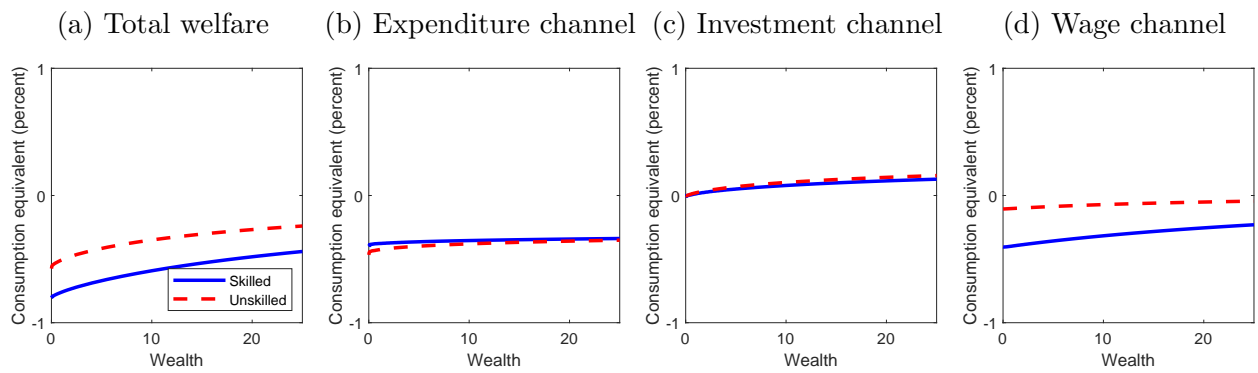


Figure 15: Welfare decomposition (lump-sum transfer and no retaliation)

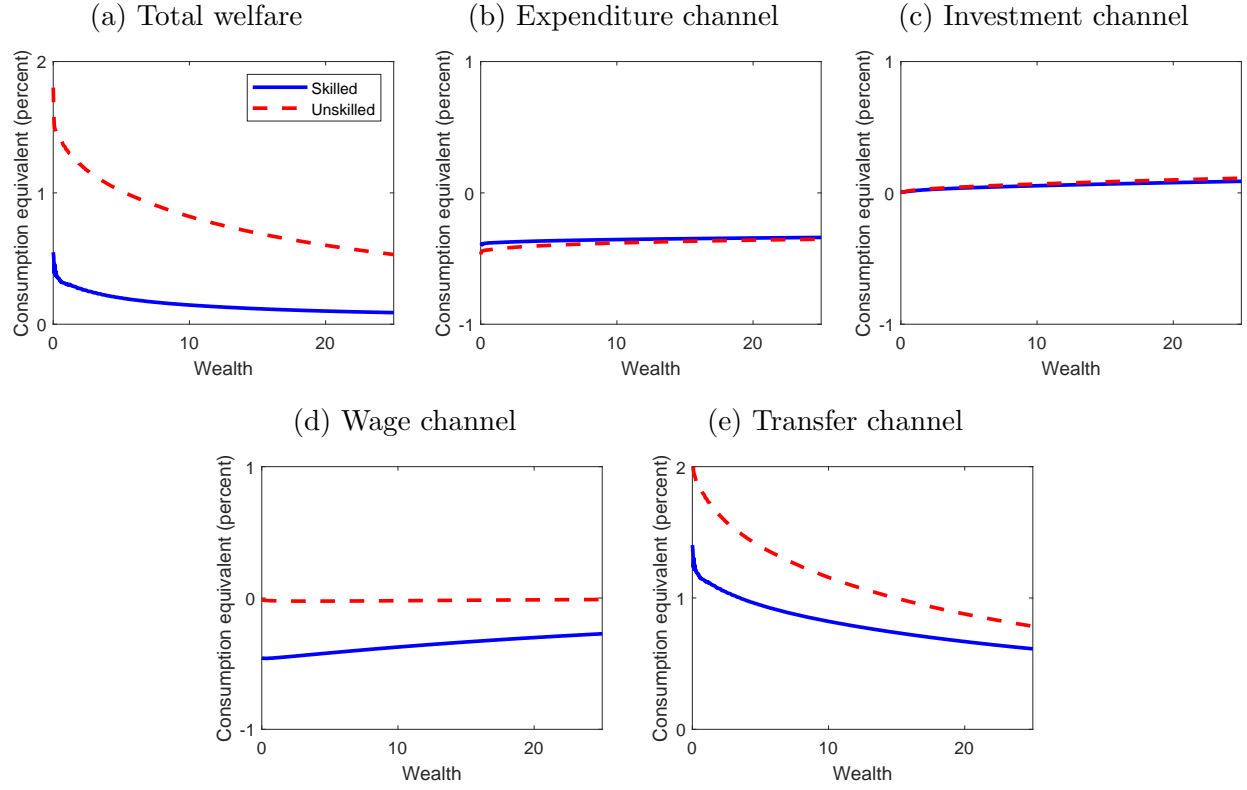


Figure 16: Welfare decomposition (labor income tax and no retaliation)

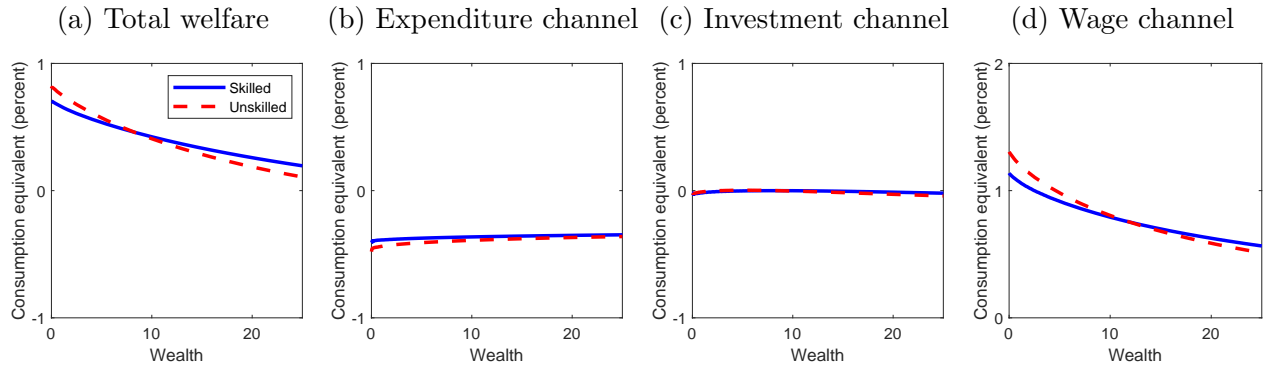
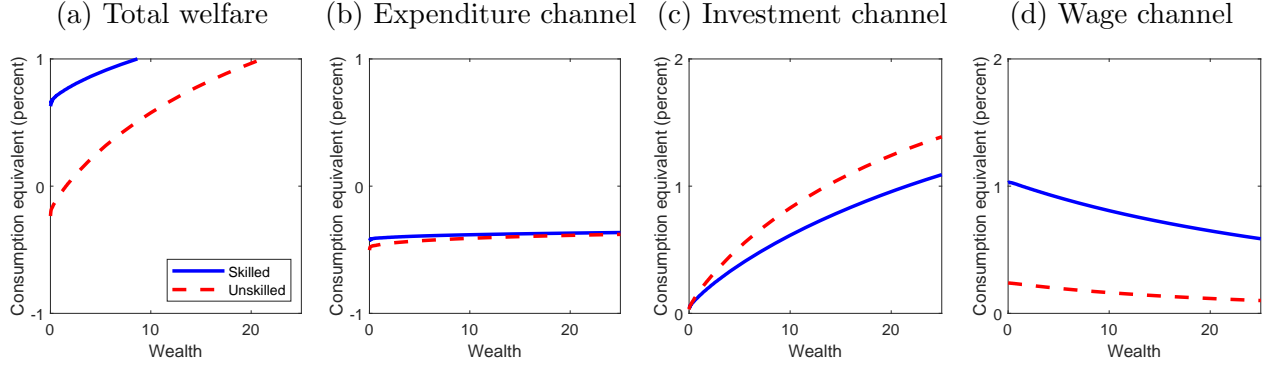


Figure 17: Welfare decomposition (capital income tax and no retaliation)



## D.2 Sensitivity to Elasticity Parameters

We investigate the sensitivity of our baseline quantitative results to alternative values for the elasticities of substitution. Keeping all other parameters constant, we change the values of  $\zeta$  and  $\chi$  so that the elasticities of substitution between capital and unskilled and skilled labor are 1.5 and 0.75, respectively. With these alternative parameter values, we repeat the exercise in Section 4 for the case with no redistribution and full retaliation. Figure 18 demonstrates that, besides level differences, the transition dynamics are nearly identical to that of the baseline. Moreover, comparing Figure 19 to Figure 5 reveals that the welfare changes along the distribution of wealth and skill are also very similar. We conclude that our main findings are robust to changes in the elasticity of substitution values.

Figure 18: Factor prices and aggregates (no redistribution and full retaliation)

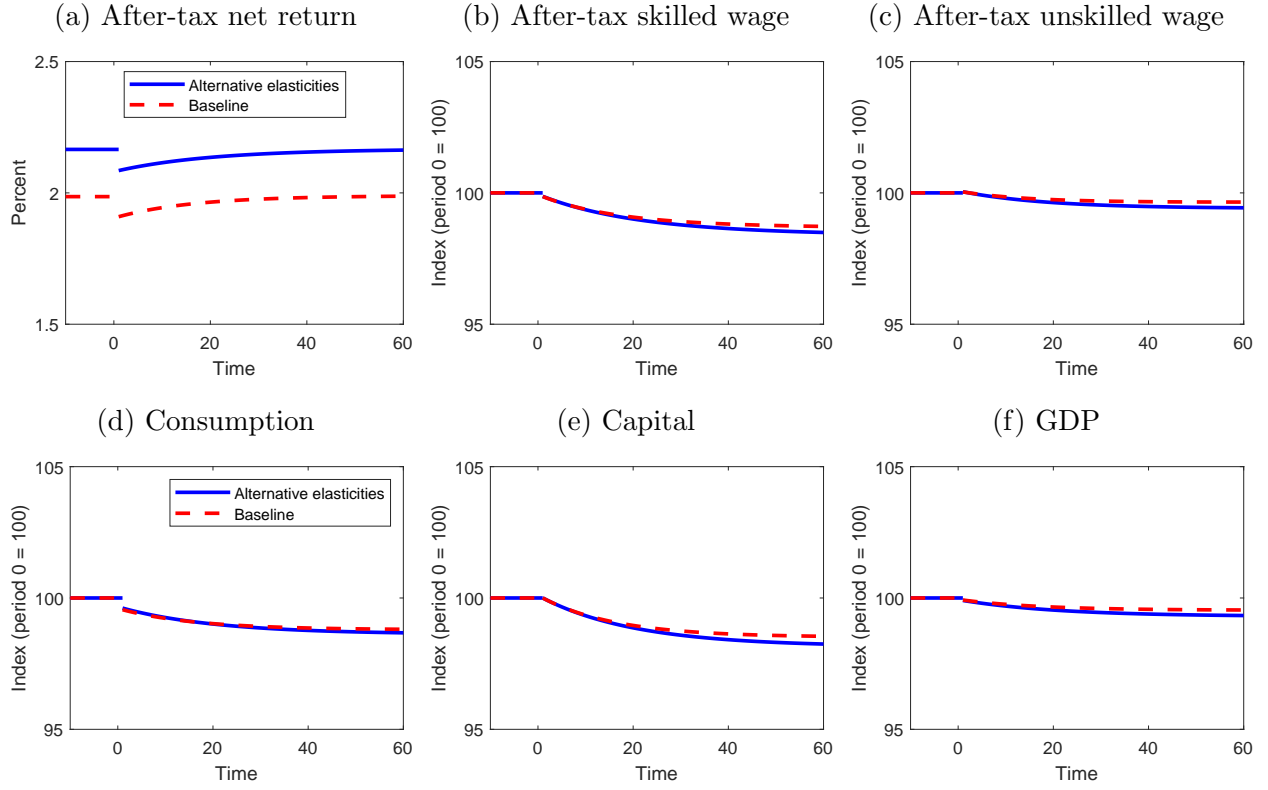


Figure 19: Welfare decomposition (no redistribution and full retaliation)

