On the Distributional Effects of International Tariffs

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[PRELIMINARY AND INCOMPLETE]

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 increase bilateral tariffs by 20 percentage points and examine several budget-neutral fiscal policies for redistributing tariff revenue. Without redistribution, tariffs hurt all households, especially the poor and the skilled. With redistribution, lowering the labor income tax leads to lower economic activity but higher average welfare and a lower dispersion of welfare costs relative to lowering the capital income tax; nevertheless, both policies reduce average welfare. Finally, when tariff revenue is rebated to households as lump-sum transfers, tariffs can be welfare improving.

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 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 as well as 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 may be unequally distributed across households. For instance, tariffs raise the prices of tradable goods and services. Carroll and Hur (2019) have documented that the share of household expenditures devoted to tradables decline 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. Reduced costs of capital goods from trade are thought to contribute to the rise in the skill-premium (Parro 2013). Thus, the wage effects from tariffs are likely to affect workers differently based on skill.\(^2\)

In this paper, we focus on understanding the distributional consequences of an escalation of trade distortions through tariffs. Specifically we think about 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, and thus the distributional impacts are not independent of how that revenue is allocated.

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. 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), and non-homothetic preferences so that poor households have a higher tradable expenditure share.

Using the calibrated model, we compute the distribution of welfare changes arising from a bilateral 20 percent increase in import tariffs. In our first case, we assume tariff revenue is not redistributed to households. This isolates the economic costs of the tariff and its affects

\(^2\)Labor skill and income can also change the costs of tariffs through their effect on a household’s mobility across industries, sectors, or geography (Autor et al. 2014).
on the distribution. We find an average welfare loss that is equivalent to a permanent 3.1 percent reduction in consumption. All households lose from imposing tariffs, but two groups suffer disproportionately more: the poor and the skilled. The poor are harmed because of the increase in the price of tradables, while the skilled are harmed because tariffs lead to capital-shallowing which reduces the skilled 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. We find that these three policies have very different implications for both the aggregates in the economy as well as 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 equalizing welfare losses 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 large welfare losses; however, neither reform can generate an average welfare gain. 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 whom the transfer is a valuable source of social insurance against income fluctuations.

The welfare consequences of tariffs can be decomposed into three channels. The first captures the effect of an increase in the tradables price, which tends to hurt poor households disproportionately (the expenditure channel). The second contains effects from the rise in the price of investment (the investment channel). In an environment with incomplete asset markets, this benefits wealthy households because they are typically sellers of capital and hurts high-income low-wealth households, who are buyers of capital. The expenditure and investment channels are constant across the various fiscal policies as we show analytically that the effect on the tradable and investment prices depend only on the total trade distortion.

Finally, there is the factor price channel, which captures the effect of changes to after-tax factor prices and transfers. Unlike the other two channels, how the factor price channel affects a particular household depends on which fiscal policy is implemented. Generally, a household desires a rise in the price of the factor which composes the bulk of their income.
Rich households want an increase in the after-tax return on capital. Poorer households, which have relatively more labor income than capital income, benefit from a rise in their after-tax wage. Furthermore, the direction and magnitude of the wage change depends on the household’s skill type.

Related literature. Our paper draws from several strands of the literature. We build on the Ricardian model of trade as in Dornbusch et al. (1977) by introducing Stone-Geary non-homothetic preferences as in Buera and Kaboski (2009), Herrendorf et al. (2013), Uy et al. (2013), and Kehoe et al. (2018) and by introducing households with uninsurable income risk as in Aiyagari (1994), Bewley (1986), Huggett (1993), and Imrohoroğlu (1989). We also adopt capital-skill complementarities in the spirit of Stokey (1996), Krusell et al. (2000), and Parro (2013).³

Our paper is closely related to recent works that have quantified the heterogeneous welfare gains and losses from trade. Fajgelbaum and Khandelwal (2016) focus on heterogeneity along income, whereas Artuç et al. (2010), Caliendo et al. (2019), Dix-Carneiro (2014), Dix-Carneiro and Kovak (2017), Galle et al. (2017), and Kondo (2018) focus on heterogeneity across labor markets. Until recently, the literature has abstracted from wealth heterogeneity. Lyon and Waugh (2019) also use a Ricardian trade model with uninsurable income risk to study how labor market reallocation frictions affect the gains from trade, and Carroll and Hur (2019) study the heterogeneous impacts of trade along the income and wealth distribution in the absence of labor market frictions. In this paper, we focus on the heterogeneous impact of tariffs along not only in the income and wealth distribution, but also across skill types.

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.⁴ 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) develop Heckscher-Ohlin models in which trade can

³See 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.

⁴See 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).
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.

Finally, our paper is related to studies of the interaction between trade and fiscal policies. While Costinot et al. (2015) and Opp (2010) 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 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.\footnote{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).}

## 2 Model

We consider a two-country model with balanced trade and without labor or capital flows. For convenience we drop time subscripts.

### 2.1 Households

Each country is populated by a mass $\bar{H}_i$ of skilled households and a mass $\bar{L}_i$ of unskilled households who consume a non-tradable good, $c_N$, and a consumption bundle made up of tradable goods, $c_T$. We assume a separable period utility function

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

where $\ell$ is labor supplied by the household. When $\bar{c}_i \neq 0$, the utility function represents Stone-Geary non-homothetic preferences. Labor is perfectly substitutable across sectors, so
there is a single efficiency wage rate, $w_{ij}$, for each skill $j = H, L$.

Households face uninsurable idiosyncratic productivity risk. Each period, a household draws a realization of labor productivity $\varepsilon$ from a finite set $\mathcal{E}$. Households earn a wage $w_{ij}\phi_{ij}\varepsilon$ where $\phi_{ij} > 0$ and $w_{iH}\phi_{iH}/(w_{iL}/\phi_{iL}) - 1$ is the skill premium. We assume that $\varepsilon$ follows a Markov process with transition matrix $\Gamma(\varepsilon', \varepsilon)$. 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 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 $\tau_{il}$ 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 $\tilde{r}_i = (1 - \tau_{ik})(r_i - \delta P_{iX})$ and the after-tax wage as $\tilde{w}_{ij} = (1 - \tau_{il})w_{ij}\phi_{ij}$.

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

$$V_{ij}(k, \varepsilon) = \max_{c_T, c_N, \ell, k'} u(c_T, c_N, \ell) + \beta \mathbb{E}_{\varepsilon'}|\varepsilon' V_{i}(k', \varepsilon') \quad (1)$$

s.t. $P_{iT}c_T + P_{iN}c_N + P_{iX}(k' - k) \leq \tilde{w}_{ij}\ell\varepsilon + \tilde{r}_i k$

$k' \geq 0$

Solving this yields decision rules $g_{iJT}(k, \varepsilon)$, $g_{iJN}(k, \varepsilon)$, $g_{ij\ell}(k, \varepsilon)$, and $g_{ijk}(k, \varepsilon)$ for tradable consumption, non-tradable consumption, labor, and capital, respectively.

### 2.2 Nontradables Production

A perfectly competitive representative firm in country $i$ produces non-tradable output $Y_{iN}$ using skilled labor ($H_{iN}$) and unskilled labor ($L_{iN}$) and capital according to

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

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 is similar to ones used in Stokey (1996), Krusell et al. (2000), and Parro (2013), and allow for the elasticities between skill types and capital to be different. In particular, by setting $\chi < \zeta$, we will assume that there is capital-skill complementarity. It solves a static profit maximization problem

$$\max_{H_{iN}, L_{iN}, K_{iN}} P_{iN}Y_{iN} - w_{iH}H_{iN} - w_{iL}L_{iN} - r_iK_{iN}$$

s.t. (2).

The optimality conditions are given by

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

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

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

where

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

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

### 2.3 Final tradables producer

A representative final tradables producer in country $i$ bundles the varieties $\omega \in [0,1]$ of intermediate tradable goods produced in country of origin $o = 1, 2$, $q_{oi} (\omega)$, into a single homogeneous tradable good, $Y_{iT}$, according to

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

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

$$\max_{\{q_{oi}(\omega)\}_{o, \omega}} P_{IT} Y_{iT} - \int_0^1 \left( \sum_{o=1,2} \tau_{oi} p_o(\omega) q_{oi}(\omega) \right) d\omega$$

s.t. (9)

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.\(^6\) Then, the producer’s optimality conditions are given by

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

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

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

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

### 2.4 Intermediate tradables producer

A representative intermediate tradables firm in country $i$ produces a single variety, $\omega$, of tradable good and hires skilled and unskilled labor and capital to produce according to the production function

$$y_i(\omega) = z_i(\omega) \left[ (1 - \mu) h_i(\omega)^{\xi} + \mu [(1 - \alpha) h_i(\omega)^{\chi} + \alpha k_i(\omega)^{\chi}] \right]^{\frac{1}{\xi}}.$$  \(^6\)Without loss of generality, we assume that the producer sources domestically in the case that costs are equal.
Taking prices \( p_i(\omega) \) as given, the producer solves

\[
\max_{h_i(\omega),l_i(\omega),k_i(\omega)} p_i(\omega) y_i(\omega) - w_iH h_i(\omega) - w_iL l_i(\omega) - r_i k_i(\omega)
\]  
(s.t. (13)).

The intermediate firm’s optimality conditions are given by

\[
w_{iL} = (1 - \mu) p_i(\omega) z_i(\omega) G (l_i(\omega), h_i(\omega), k_i(\omega))^{1-\zeta} l_i(\omega)^{\zeta-1},
\]
\[
w_{iH} = \mu (1 - \alpha) p_i(\omega) z_i(\omega) G (l_i(\omega), h_i(\omega), k_i(\omega))^{1-\zeta} M (h_i(\omega), k_i(\omega))^{\zeta-x} h_i(\omega)^{x-1},
\]
\[
r_i = \mu \alpha p_i(\omega) z_i(\omega) G (l_i(\omega), h_i(\omega), k_i(\omega))^{1-\zeta} M (h_i(\omega), k_i(\omega))^{\zeta-x} k_i(\omega)^{x-1}.
\]

We assume the productivities for variety \( \omega \) in each country is given by

\[
z_1(\omega) = e^{\eta\omega},
\]
\[
z_2(\omega) = e^{\eta(1-\omega)}
\]
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 non-tradable goods according to

\[
X_i = z_iX I_t^{i_T} I_N^{1-\kappa}.
\]

Taking prices \( P_{iT}, P_{iN}, \) and \( P_{iX} \) as given, the producer solves

\[
\max_{I_t, I_N} P_{iX} X_i - P_{iT} I_t - P_{iN} I_N
\]  
(s.t. (20)).
The capital producer’s optimality conditions are given by

\begin{align*}
P_{IT} &= \kappa P_{iX} z_{iX} I_{IT}^{\kappa - 1} I_{iN}^{1 - \kappa}, \\
P_{iN} &= (1 - \kappa) P_{iX} z_{iX} I_{iN}^{\kappa} I_{iN}^{-\kappa}.
\end{align*}

(22)

(23)

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

\begin{align*}
I_{iN} &= \frac{X_i}{z_{iX}} \left( \frac{1 - \kappa}{\kappa} \frac{P_{iX}}{P_{iN}} \right)^{\kappa} \\
I_{iT} &= \frac{X_i}{z_{iX}} \left( \frac{1 - \kappa}{\kappa} \frac{P_{iX}}{P_{iN}} \right)^{1 - \kappa}
\end{align*}

(24)

(25)

2.6 Government

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

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, \(B\), on \(S\).

Definition. A steady state recursive equilibrium given fiscal policies \(\{\tau_{il}, \tau_{ik}, \tau_{oiP}, G_i\}_{i=1,2}\) is, for \(i = 1, 2\), a collection of functions \(\{V_{ij}, g_{ijT}, g_{ijN}, g_{ijT}, g_{ijk}\}_{j \in \{H,L\}}\); prices \(\{r_i, \{w_{ij}\}_{j}\}_{\omega \in [0,1]}\); non-tradable 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 \(\{y_{ij}(\omega), h_i(\omega), l_i(\omega), k_i(\omega)\}_{\omega}\); capital producer plans \(\{X_i, I_{iT}, I_{iN}\}\); and invariant measures \(\{\mu_{ij}\}_{j}\) such that

1. For \(j = H, L\), given \(\{r_i, w_{ij}, P_{iT}, P_{iN}, P_{iX}\}, \{V_{ij}, g_{ijT}, g_{ijN}, g_{ijT}, g_{ijk}\}\) satisfy the household problem in (1).
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).

6. Markets clear:
   
   (a) \( Y_{iN} = \sum_{j=H,L} \int_S g_{ijN}(k, \varepsilon) \, d\mu_{ij}^*(k, \varepsilon) + I_{iN} + G_i \),
   
   (b) \( Y_{iT} = \sum_{j=H,L} \int_S g_{ijT}(k, \varepsilon) \, d\mu_{ij}^*(k, \varepsilon) + I_{iT} \),
   
   (c) \( X_i = \delta \sum_{j=H,L} \int_S g_{ijk}(k, \varepsilon) \, d\mu_{ij}^*(k, \varepsilon) \),
   
   (d) \( y_i(\omega) = \tau_{i1} q_{11}(\omega) + \tau_{i2} q_{12}(\omega) \) for \( \omega \in [0, 1] \),
   
   (e) \( L_{iN} + \int_0^1 l_i(\omega) \, d\omega = \int_S \varepsilon \phi L_{iL}(k, \varepsilon) \, d\mu_{iL}^*(k, \varepsilon) \),
   
   (f) \( H_{iN} + \int_0^1 h_i(\omega) \, d\omega = \int_S \varepsilon \phi H_{iH}(k, \varepsilon) \, d\mu_{iH}^*(k, \varepsilon) \).

7. Trade is balanced: \( \int_0^1 \tau_{12} p_1(\omega) q_{12}(\omega) \, d\omega = \int_0^1 \tau_{21} p_2(\omega) q_{21}(\omega) \, d\omega \).

8. Government budget constraint holds, for \( o \neq i; \)

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

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

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

2.8 Characterization of equilibrium

For simplicity, we assume that the two countries are identical except for the intermediate tradable productivities, which are as specified in equations (18)–(19), so that \( w_H = w_{1H} = \)
w_{2L}, \ w_L = w_{1L} = w_{2H}, \ r = r_1 = r_2, \ \tau = \tau_{12} = \tau_{21}, \ et \ cetera. \ In \ what \ follows, \ we \ will \ omit
the \ country \ notation \ unless \ necessary. \ Furthermore, \ we \ set \ z_N = 1 \ and \ normalize \ the \ price
of \ non-tradables, \ by \ setting \ P_N = 1.

By \ combining \ equations \ (4) \ and \ (5), \ we \ can \ solve \ for \ the \ optimal \ composite \ of \ skilled
labor \ and \ capital \ in \ the \ nontradable \ sector, \ M(H_N, K_N), \ which \ we \ can \ plug \ into \ equation
(6) \ to \ obtain

\[ 1 = \left[ (1 - \mu) \left( \frac{w_L}{(1 - \mu)} \right)^{\frac{\zeta}{\chi}} + \mu \left( (1 - \alpha) \left( \frac{w_H}{\mu (1 - \alpha)} \right)^{\frac{\lambda}{\chi}} + \alpha \left( \frac{r}{\alpha \mu} \right)^{\frac{\lambda}{\chi}} \right) \right]^{\frac{\chi}{\zeta}}. \]  \hfill (26)

Similarly, \ we \ can \ solve \ for \ the \ optimal \ mix \ of \ skilled \ labor \ and \ capital \ for \ each \ interme-
diate \ producer, \ M(h_i(\omega), k_i(\omega)), \ by \ combining \ equations \ (15) \ and \ (16), \ and \ substitute \ in \ to
(17) \ to \ obtain \ the \ price \ of \ variety \ \omega \ produced \ in \ country \ i,

\[ p_i(\omega) = \frac{1}{z_i(\omega)}. \]  \hfill (27)

In \ equilibrium, \ there \ are \ two \ thresholds \ which \ determine \ the \ production \ of \ the \ interme-
diate \ tradable \ goods. \ For \ \omega > \bar{\omega}(\tau), \ production \ takes \ place \ only \ in \ country \ i = 1, \ where

\[ \bar{\omega}(\tau) = \min \left\{ 1, \frac{\eta + \log \tau - 1}{2\eta} \right\}, \]  \hfill (28)

which \ can \ be \ obtained \ from \ the \ condition \ \tau p_2(\bar{\omega}(\tau)) = p_1(\bar{\omega}(\tau)). \ By \ symmetry, \ for \ \omega < 1 - \bar{\omega}(\tau), \ production \ takes \ place \ only \ in \ country \ i = 2. \ Both \ countries \ produce \ the \ varieties
\omega \in [1 - \bar{\omega}(\tau), \bar{\omega}(\tau)]. \ Figure \ 1 \ illustrates \ the \ pattern \ of \ production, \ trade, \ and \ specialization.
Note \ that \ when \ \tau = 1, \ we \ obtain \ \bar{\omega}(\tau) = 1/2, \ which \ corresponds \ to \ free \ trade \ and \ full
specialization, \ and \ when \ \tau \geq e^{\eta}, \ we \ obtain \ \bar{\omega}(\tau) = 1, \ which \ corresponds \ to \ autarky.

Substituting \ the \ price \ in \ (27) \ into \ the \ tradable \ price \ aggregator \ in \ (12), \ we \ obtain

\[ P_T = \frac{1}{z(\tau)}. \]  \hfill (29)
Figure 1: Pattern of production, trade, and specialization
where $\bar{z}(\tau)$ is a measure of average productivity:

$$\bar{z}(\tau) = \left[ \tau^{1-\theta} \int_0^{1-\bar{\omega}(\tau)} z_2(\omega)^{\theta-1} d\omega + \int_{1-\bar{\omega}(\tau)}^1 z_1(\omega)^{\theta-1} d\omega \right]^{\frac{1}{\theta-1}}. \quad (30)$$

Note that $d\bar{z}(\tau)/d\tau < 0$, i.e., lower trade costs result in higher average productivity. Combining the capital producer’s optimality conditions in equations (22) and (23), we obtain

$$P_X = \frac{1}{z_X} \left( \frac{P_T}{\kappa} \right)^\kappa \left( \frac{1}{1-\kappa} \right)^{1-\kappa}. \quad (31)$$

It is straightforward to show that

$$\frac{d\log (P_T)}{d\tau} = -\frac{d\log (\bar{z}(\tau))}{d\tau} > 0 \quad (32)$$

and

$$\frac{d\log (P_X)}{d\tau} = -\kappa \frac{d\log (\bar{z}(\tau))}{d\tau} > 0. \quad (33)$$

That is, higher trade costs increase the price of tradables by decreasing average productivity in the tradable sector and, to a lesser extent, increase the price of investment. We will quantitatively analyze the effects of a change in trade costs in the next section.

### 3 Quantitative analysis

#### 3.1 Calibration

We choose parameters so that the model’s steady-state equilibrium matches several features of the U.S. economy. We summarize the parameters in Table 1.

We normalize the aggregate labor endowment, $\bar{H} + \bar{L}$, to one, and set $\bar{H}$ to match the fraction of college graduates in the labor market, 33 percent (2014, SCF). We set the household’s discount factor $\beta$, so that the model matches the net-worth-to-GDP ratio in the U.S., 4.8 (2014, U.S. Financial Accounts). We choose the tradable share parameter, $\gamma$, and the non-homothetic preference parameter, $\bar{c}$, so that the model matches the average tradable
expenditure shares in the U.S. of 36 percent and that of the top 10 percent of the wealth distribution, 30 percent (2004–2014, Carroll and Hur 2019). The household’s disutility from labor, $\psi$, is set so that the model generates a share of disposable time spent working of 0.3. We normalize the unskilled labor efficiency parameter, $\phi_L$, to one, and set $\phi_H$ to match a skill premium of 105 percent (2014, CPS).

We set the weight on capital and unskilled labor in tradables and nontradables production $\alpha$ and $\mu$ to match the aggregate capital and unskilled labor income shares, respectively. 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 U.S. manufacturing establishments (at least 100 employees), which is 32.1 percent (2014, U.S. Census, Business Dynamics Statistics). 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 the literature. We set the tradable share in capital production, $\kappa$, to match the tradable share of capital production inputs calculated from the U.S. input-output table, 59 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 U.S. 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 U.S. government consumption share of GDP, 15 percent (2014, OECD).

There are six parameters that we do not calibrate. 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). The labor productivity shocks $\varepsilon$ are assumed to follow an

---

7 Ideally, we would target the size distribution of exporting establishments. Without access to that data, we are using the set of large manufacturing establishments as a proxy for the set of exporting establishments.

8 For example, see Simonovska and Waugh (2014).

9 Though Krusell et al. (2000) estimate these elasticities under a slightly different productivity function, 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. We plan to provide sensitivity analysis with regards to these parameters in upcoming versions.
Table 1: Calibration

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Targets / Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount factor, $\beta$</td>
<td>0.96</td>
<td>Wealth-to-GDP: 4.8</td>
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<tr>
<td>Risk aversion, $\sigma$</td>
<td>2</td>
<td>Standard value</td>
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<tr>
<td>Tradable share, $\gamma$</td>
<td>0.27</td>
<td>Tradable expenditure share: 36 percent</td>
</tr>
<tr>
<td>Non-homotheticity, $\bar{c}$</td>
<td>0.09</td>
<td>Tradable expenditure share of wealthiest decile: 30 percent</td>
</tr>
<tr>
<td>Disutility from labor, $\psi$</td>
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<td>Average hours: 33 percent</td>
</tr>
<tr>
<td>Frisch elasticity, $1/\nu$</td>
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<td>Standard value</td>
</tr>
<tr>
<td>Skilled fraction, $\bar{H}$</td>
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<td>Skilled labor force: 33 percent</td>
</tr>
<tr>
<td>Capital weight, $\alpha$</td>
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<td>Capital income share: 36 percent</td>
</tr>
<tr>
<td>Skilled weight, $\mu$</td>
<td>0.61</td>
<td>Skilled labor income share: 36 percent</td>
</tr>
<tr>
<td>Elasticity of substitutions,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>unskilled–capital, $1/(1 - \zeta)$</td>
<td>1.67</td>
<td>Krusell et al. (2000)</td>
</tr>
<tr>
<td>skilled–capital, $1/(1 - \chi)$</td>
<td>0.67</td>
<td>Krusell et al. (2000)</td>
</tr>
<tr>
<td>tradable intermediates, $\theta$</td>
<td>5.7</td>
<td>Trade elasticity: 4</td>
</tr>
<tr>
<td>Factor elasticity, $\kappa$</td>
<td>0.59</td>
<td>Tradable input shares in capital production</td>
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<tr>
<td>Productivity distribution, $\eta$</td>
<td>1.29</td>
<td>Employment share of top 17 percent of large manufacturing establishments: 32 percent</td>
</tr>
<tr>
<td>Iceberg cost, $(\tau - 1) \times 100$</td>
<td>0.27</td>
<td>Import share: 17 percent</td>
</tr>
<tr>
<td>Income tax, $\tau_\ell = \tau_k$</td>
<td>0.19</td>
<td>Government consumption: 15 percent of GDP</td>
</tr>
<tr>
<td>Persistence, $\rho_\varepsilon$</td>
<td>0.92</td>
<td>Floden and Lindé (2001)</td>
</tr>
<tr>
<td>Standard deviation, $\sigma_\nu$</td>
<td>0.21</td>
<td>Floden and Lindé (2001)</td>
</tr>
</tbody>
</table>

An order-one auto-regressive process as follows:

$$
\log \varepsilon_t = \rho_\varepsilon \log \varepsilon_{t-1} + \nu_t, \nu_t \sim N(0, \sigma^2_\varepsilon) ;
$$  \hspace{1cm} (34)

with persistence $\rho_\varepsilon = 0.92$ and standard deviation $\sigma_\nu = 0.21$, following Floden and Lindé (2001). This process is approximated with a five-state Markov process using the Rouwenhurst procedure described in Kopecky and Suen (2010). Finally, we normalize the productivities in the nontradable and capital sectors, $z_N = z_X = 1$. 

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3.2 Quantitative exercise: Increase in tariffs

Next, we use our calibrated model to analyze the impacts of trade disruptions caused by symmetric increases in tariffs. At the beginning of period one, before any agent’s decisions are made, there is an unanticipated increase in $\tau_P$ from 0.0 to 0.2. This can be thought of a global economy-wide application of the new tariffs imposed by the U.S. in 2018, which ranged from 10 to 30 percent, on 12 percent of US imports (Congressional Budget Office 2019).

Over time, the two countries transit to the higher trade cost steady state. Because the wealth distribution evolves over time, prices and household decisions are time-dependent. For clarity, we introduce time subscripts to make explicit that the value function and decision rules depend upon $\mu_t$.

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

$$V_{jt}(k, \varepsilon) = \max_{c_T, c_N, h, k'} u(c_T, c_N, h) + \beta E_{\varepsilon'|\varepsilon} V_{j,t+1}(k', \varepsilon_{t+1})$$

s.t. $P_T c_T + c_N + P_{Xt}(k' - k) \leq \bar{w}_jt h \varepsilon + \bar{r}_tk + T_t,\quad k' \geq 0$  \hspace{1cm} (35)

Solving this yields time-dependent decision rules $g_{jTt}(k, \varepsilon), g_{jNt}(k, \varepsilon), g_{jh}(k, \varepsilon), \text{ and } g_{jk}(k, \varepsilon)$ for tradables consumption, non-tradables consumption, labor, and saving, respectively.

To solve the transition, we begin with the stationary wealth distribution in the initial steady state, $\mu^*_j$, at $t = 0$. We then introduce a permanent increase in trade costs in $t = 1$, and solve for a sequence of value functions $\{V_{jt}\}^{\infty}_{t=1}$, decision rules $\{g_{jTt}, g_{jNt}, g_{jh}, g_{jk}\}^{\infty}_{t=1}$, wealth distributions $\{\mu_{jt}\}^{\infty}_{t=1}$, and prices $\{r_t, w_{jt}, P_{Tt}, P_{Xt}, T_t \{p(\omega)\}_{\omega}\}^{\infty}_{t=1}$, for $j \in \{H, L\}$, such that given prices, households and firms make optimal decisions, markets clear, and distributions are consistent with household savings decisions.

Many of our quantitative results will depend critically upon whether or not tariff revenues are redistributed, and if they are redistributed, how. We start by examining a case where tariff revenues are used to increase wasteful government spending. Specifically, the government purchases nontradable goods and then throws these goods into the ocean. This policy most closely correlates with a common thought experiment from the trade literature where
iceberg trade costs change.\textsuperscript{10} It also provides a lower bound for average welfare by removing any compensation from redistribution and isolates the costs of tariffs.

### 3.2.1 Outcome without redistribution

In the long run, the increase in total trade costs, $\tau$, from 1.003 to 1.203, reduces economic activity. The final tradables producer responds to the increase in the cost of foreign varieties by shifting the composition of its inputs toward home produced intermediates ($\bar{\omega}$ increases). As a result, the import share of output falls from 17 percent to 8 percent. As shown in Figure 2(a), the substitution of tradable intermediates from foreign firms to less efficient domestic firms produces an immediate and permanent 7.3 percent increase in the price of tradable goods.

Since capital production uses tradables as an input, some of the rise in the price of tradables passes through to investment prices, as shown in equation (31). $P_X$ jumps by 4.2 percent which induces capital-shallowing in the economy. (Figure 2(b)). This causes wages of both the skilled and the unskilled to fall over time (Figure 2(c)), but the former falls by a greater percentage due to skilled labor’s strong complementarity with capital in production (3.7 percent vs. 1.0 percent).

The after-tax return to capital, $\tilde{r}$, decreases sharply in the first period of transition which may seem contradictory since the capital income tax rate is the same and capital is shallowing (Figure 2(d)). The cause of the decline is the permanent rise in $P_X$ which increases the depreciation costs and shift $\tilde{r}$ down. From the first period onward, the behavior $\tilde{r}$ is consistent with capital shallowing, and in the long run, $\tilde{r}$ is one-tenth of a percentage point above its pre-tariff value.

The adoption of tariffs leads to a substantial reduction in long-run real economic activity. Figure 3 plots the transition path of the main aggregate variables. Real GDP falls by 1.7 percent, and aggregate real household consumption is 3.5 percent lower. Investment plummets 5.8 percent initially and in the long run remains 4.3 percent below its initial level as it responds to the rise in $P_X$. Low investment causes capital to severely contract, declining by 4.3 percent.

\textsuperscript{10}See, for example, Arkolakis et al. (2012).
Figure 2: Prices

(a) Tradables price

(b) Investment price

(c) After-tax wage

(d) After-tax net return
Figure 3: Quantities

(a) Consumption

(b) Investment

(c) GDP

(d) Capital
Welfare costs. 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, Δ, would initial steady state tradables and nontradables consumption have to be permanently increased in order to make a household indifferent to the policy change. 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 trade cost environment. Formally, given the household value functions at the beginning of the transition, \( V_{j,t=1}(k,\varepsilon) \), and the initial steady state decision rules, \( g_{jT}^{ss}, g_{jN}^{ss}, g_{jh}^{ss}, \) and \( g_{jk}^{ss} \), we solve for \( \Delta_j(k,\varepsilon) \), such that

\[
V_{j,k,\varepsilon}^{\Delta}(k,\varepsilon) = V_{j,t=1}(k,\varepsilon)
\]

where

\[
V_{j,k,\varepsilon}^{\Delta}(k,\varepsilon) = u \left( (1 + \Delta) \times g_{jT}^{ss}, (1 + \Delta) \times g_{jN}^{ss}, g_{jh}^{ss} \right) + \beta E_{\varepsilon'} V_{j,k,\varepsilon'} \left( g_{jk}^{ss}, \varepsilon' \right).
\]

Figure 4(a) plots average welfare by wealth across the initial steady state wealth distribution, normalized by per capita output. Notice that in the absence of redistribution, all households suffer a welfare loss from imposing tariffs. The average welfare loss across all households is 3.13 percent. Moreover, the welfare losses are not equally distributed, but rather decrease with wealth. For a given level of wealth, skilled households suffer more than unskilled, and except near the borrowing constraint, high productivity households lose more than low productivity households.

Welfare decomposition. Individual welfare varies considerably, not only along the wealth dimension, but also along the skill and productivity dimensions. Here, we decompose the welfare gains and losses for each households type.

Total welfare losses can be attributed to changes in three channels: the expenditure channel, the investment channel, and the factor price channel. Increased trade costs distort the production of tradables goods, leading to an increase in the tradable price. As a result, poor

\[\text{For reference, median wealth is 2.2, and the top 10 percent richest households have more than 11.9.}\]
Figure 4: Welfare change: without redistribution

(a) All channels

(b) Expenditure channel

(c) Investment channel

(d) Factor price channel
households, who spend a larger share of expenditures on tradable goods, suffer larger welfare losses—we call this the expenditure channel. Since tradable goods are also an input of capital production, the higher tradable price leads to an increase in the price of investment. This raises the cost of saving, and so it has opposite welfare effects for buyers and sellers of assets. Low-productivity, high-wealth households benefit as they are the ones selling assets in order to smooth consumption, while high-productivity, low-wealth households are worse off as they want to buy assets for precautionary savings—this is the investment channel. Finally, tariffs alters the after-tax returns to labor and to capital. Any change in after-tax returns affects households differently based upon the composition of their income. Because a low-wealth household’s total income is derived mostly from labor, it suffers more than a wealthy household does when wages fall, and it benefits less when interest rates rise—this is the factor price channel.

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 is active (the investment channel), and for the third ghost type, only the after-tax wages and return on capital follow their equilibrium paths (the factor price channel).

Panels (b)–(d) of figure 9 plot the welfare contributions from each channel. The expenditure channel accounts for the largest share of welfare losses, particularly for low productivity, low skill households. The factor price channel shows the strongest differential effect across skill type. Because skilled labor is a complement with capital, the capital shallowing that results from the tariff increase causes a much deeper decline in the skilled wage than the unskilled wage, leading to the dispersion in welfare across skill types.

The investment channel may ameliorate or exacerbate the total welfare loss depending upon a household’s state at the time of the policy change. For low-productivity, wealthy households, the rise in the investment price provides additional consumption at just the right
time for low productivity households with some capital to sell. Meanwhile, for low wealth households with high productivity, it increases the harm as these are the households for whom the precautionary saving motive is strongest.

### 3.2.2 Redistribution through fiscal policy

Our environment features a number of distortions arising from incomplete asset markets and binding borrowing limits as well as proportional taxes on labor and on capital income. Given that the agents in our model do not live in a first best world, it is reasonable to ask how the government, using limited fiscal instruments, could mitigate the costs of these distortions. In the next two cases, the government uses the proceeds from tariffs to reduce distortionary taxes, either on labor income or on capital income. Both polices redistribute income unequally across households, depending upon the relative composition of their income between capital and labor. They also affect factor prices more subtly in general equilibrium by encouraging households to either work or save more.

For our third case, we allow the government to redistribute all tariff revenue to households through a lump-sum transfer. 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.

Regardless of which fiscal policy is enacted, the equilibrium paths of \(P_X\) or \(P_T\) are identical to those from the no redistribution case, since these prices are functions only of total trade costs, as demonstrated in equations (29) and (31). As a result, the expenditure and investment channels will likewise be identical to those from the previous case. Thus, any remaining aggregate and distributional effects must come from the change in after-tax factor prices and transfers.

Figure 5 (a)–(c) plot the paths of the three factor prices under each redistributionary policy and the case without redistribution. Under lump-sum redistribution, the paths for wages and net return to saving are broadly similar to those from the no redistribution case. Over time, capital shallowing induced by tariffs causes wages to fall (the skilled wage by more) and the net return to rise. A labor income tax reduction produces a similar trajectory
over time but differs in level since both $\tilde{w}_H$ and $\tilde{w}_L$ jump up mechanically in the first period. In this case, the unskilled wage remains higher than the pre-tariff level throughout the transition.

Figure 5: Prices

(a) After-tax skilled wage

(b) After-tax unskilled wage

(c) After-tax net return

If the government uses the tariff revenue to reduce capital income taxes, the results are strikingly different. This is because the policy action incentivizes saving which completely counteracts the disincentives from the decline in $P_X$. Capital shallowing does not occur; rather there is a slight capital deepening. After-tax wages for both skill groups are roughly unchanged while the after-tax net return to saving jumps in the first period (a direct consequence of the lower tax rate) and then remains steady at its new higher level.
Figure 6 plots the transition path of the main aggregate variables. A deep contraction in the capital stock generates lower output when tariff revenue is used to lower labor income taxes or is redistributed through lump-sum transfers. Even when the government reduces capital income taxes, supporting aggregate investment and avoiding a depletion of capital, both real GDP and aggregate consumption fall after tariffs are enacted. Redistribution through either a lump-sum transfer or a lower labor income tax props aggregate consumption up for a brief portion of the transition, but both policies eventually lead to even lower values in the long-run.

Figure 6: Quantities

(a) Consumption

(b) Investment

(c) GDP

(d) Capital

Table 2 reports the average welfare from each of the fiscal policies. Reducing capital
income taxes produces a larger average welfare loss than does a labor income tax reduction, despite generating the smallest declines in long run aggregate variables. If tariff revenues are rebated lump-sum, average welfare can be increased.

Table 2: Average Welfare with Redistribution

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital inc. tax</td>
<td>−1.52</td>
</tr>
<tr>
<td>Labor inc. tax</td>
<td>−0.98</td>
</tr>
<tr>
<td>Lump-sum tax</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Units: percent.

Figure 7 plots the average welfare of households across the initial steady state wealth distribution. On average, the welfare losses from the labor tax reform are evenly spread across the wealth distribution. In contrast, the capital income tax reform is favored by only the very wealthy, and poor households suffer large welfare losses from it. 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.

Figure 7: Welfare change

Again, we decompose the welfare effects into three channels. In the case of the lump-sum transfer, there is additionally the lump-sum transfer channel, which increase the welfare of all households, but particularly for poor and low-income households.
Capital income tax reform. Imposing tariffs and reducing capital income taxes lead to an average welfare loss of $-1.52$ percent. It is evident from figure 8 that this is due to large welfare losses among the poor. Because after-tax wages are roughly unchanged, the factor price channel in this case captures the rise in the after-tax return on capital. Poor households benefit very little from this rise (Figure 8b) because they do not have much wealth, so these small gains are dominated by the large welfare losses from the expenditure channel (Figure 4b).

In contrast, the wealthy receive big welfare gains from this policy, particularly those with low wages because they sell capital at a higher $P_X$ than before (investment channel in Figure 4c). On net, average welfare is lower because the wealth distribution has relatively few rich households.

Figure 8: Welfare change: reduction in capital income taxes

(a) All channels

(b) Factor price channel

Labor income tax reform. Reducing the labor income tax rate produces a smaller average welfare loss than reducing the capital income tax. As shown in Figure 9 this is because a higher after-tax wage favors the poor relative to the rich. This policy also more evenly spreads the welfare losses across types. The factor price channel works against the expenditure channel, compensating poor households for a higher tradables price. This channel slightly favors poor, high productivity households so it also partially offsets the negative impact to them from the investment channel.
Lump-sum transfer. If the government uses tariff revenue to finance a lump-sum transfer to all households, the welfare gains and loss are most unevenly distributed (Figure 10a). Nearly all unskilled households benefit, while all skilled households lose. Figure 10(b) shows that the difference is not due to the factor price channel, which looks almost exactly as it did under increased government expenditures (Figure 4d). Declines in wages and returns in the early part of the transition are costly for all households, but they are especially costly for the skilled whose wage falls even more. The offsetting factor is the direct benefit of the transfer (Figure 10c) which is positive for all households, but especially large for the low-wealth, low-skill, low-productivity households.

Tables 3 and 4 summarize our findings for welfare across the four fiscal policy experiments for unskilled households and skilled households, respectively.

4 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 symmetric tariff increases in a Ricardian trade model with uninsurable income risk, incomplete asset markets, capital-skill complementarity, and non-homothetic preferences. Tariffs reduce allocative efficiency, increase the prices of
Figure 10: Welfare change: lump-sum redistribution

(a) All channels

(b) Factor price channel

(c) Direct welfare from transfer
Table 3: Decomposition of welfare changes for unskilled

<table>
<thead>
<tr>
<th>Channels</th>
<th>Low wealth</th>
<th>High wealth</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low prod.</td>
<td>High prod.</td>
<td></td>
</tr>
<tr>
<td>Expenditure</td>
<td>−3.49</td>
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<td>−2.40</td>
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<tr>
<td></td>
<td>−2.77</td>
<td>−2.20</td>
<td>−2.75</td>
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<td>Investment</td>
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<td></td>
<td>−0.67</td>
<td>0.32</td>
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<tr>
<td>Factor price</td>
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<tr>
<td>Govt Expend</td>
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<td>−0.35</td>
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<td>−0.47</td>
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<td>All</td>
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<td>Govt Expend.</td>
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<td></td>
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Units: percent.

Table 4: Decomposition of welfare changes for skilled

<table>
<thead>
<tr>
<th>Channels</th>
<th>Low wealth</th>
<th>High wealth</th>
<th>Average</th>
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<tbody>
<tr>
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<td>High prod.</td>
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<td>Expenditure</td>
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<td>−2.06</td>
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<td></td>
<td>0.34</td>
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<tr>
<td>Factor price</td>
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<td>Govt Expend</td>
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<td>Labor inc. tax</td>
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<td>1.19</td>
<td>−0.26</td>
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<td></td>
<td>0.47</td>
<td>0.52</td>
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<tr>
<td>Lump-sum redist.</td>
<td>−2.20</td>
<td>−1.82</td>
<td>−1.76</td>
</tr>
<tr>
<td></td>
<td>−1.15</td>
<td>−1.95</td>
<td></td>
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<tr>
<td>All</td>
<td>−4.52</td>
<td>−4.41</td>
<td>−2.35</td>
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<tr>
<td>Govt Expend.</td>
<td>−3.57</td>
<td></td>
<td>−2.78</td>
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<tr>
<td>Capital inc. tax</td>
<td>−2.36</td>
<td>−1.74</td>
<td>0.52</td>
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<td>−0.96</td>
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<tr>
<td>Labor inc. tax</td>
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<td>−1.09</td>
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<td>−1.35</td>
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<tr>
<td>Lump-sum redist.</td>
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<td>−3.45</td>
<td>−1.28</td>
</tr>
<tr>
<td></td>
<td>−2.08</td>
<td>−2.30</td>
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</table>

Units: percent.
tradable goods and investment. Without redistributing tariff revenue, tariffs hurt everyone, especially the poor and skilled. The gains and losses from tariffs depend on the way in which the government uses the new tariff revenue. In particular, using tariff revenue to reduce capital income taxes leads to the smallest reduction in output and consumption, but also to larger and more unequally distributed welfare costs than does reducing labor income taxes. Lump-sum transfers can lead to an average welfare gain, with unskilled, low-income, low wealth households gaining at the expense of skilled households.
References


A Computational appendix

1. Let $\mu_{\text{init}}(k, \varepsilon, j)$ be an initialization of the distribution over $k_{\text{fine}}$ and $\mathcal{E}$.

2. Solve for the equilibrium rental rate, $r^*$:

(a) Guess $\{r^n, w^n_H\}$.

(b) Given $\{r^n, w^n_H\}$, calculate $\{P^n_T, P^n_X, w^n_L\}$ using equations (26), (29), and (31).

(c) Given $\{r^n, w^n_H, w^n_L, P^n_T, P^n_X\}$, solve the household problem in (1) to obtain $g_{jT}$, $g_{jN}$, $g_{j\ell}$, and $g_{jk}$.

(d) Begin with $\mu^n_0(k, \varepsilon)$, use $g_{jT}$, $g_{jN}$, $g_{j\ell}$, and $g_{jk}$ to find the invariant distribution, $\mu^n_j(k, \varepsilon)$.

(e) Aggregating $\mu^n_j(k, \varepsilon)$, we get $\{C^n_T, C^n_N, X^n, S^n, U^n, K^n\}$.

(f) Use equations (22) and (23) to obtain $\{I^n_T, I^n_N\}$.

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

(h) Substitute $G^n_N = Y^n_N$ into equation (4) to obtain $U^n_N$.

(i) Use the market clearing condition for unskilled labor to obtain $U^n_T = U^n - U^n_N$.

(j) Use the first order conditions of the intermediate tradable producers, equations (15)–(17), to obtain

$$S^n_T = \left(\frac{1 - \mu}{\mu} \frac{1}{(1 - \alpha) \Omega w^n_H} \frac{1}{w^n_L} \right)^{\frac{1}{\xi - 1}} U^n_T,$$

(36)

$$K^n_T = \left(\frac{\alpha}{1 - \alpha} \frac{w^n_H}{r^n} \right)^{\frac{1}{\xi - 1}} S^n_T,$$

(37)

where

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

(38)

(k) Use the market clearing conditions for skilled labor and capital to obtain $\{S^n_N, K^n_N\}$. 38
From the first order conditions of the nontradable producer,

\[ w_H^{\text{new}} = (1 - \alpha) \mu (G_N^n)^{1-\zeta} M \left( S_N^n, K_N^n \right)^{\zeta - \chi} (S_N^n)^{\chi - 1} \]
\[ r^{\text{new}} = \alpha \mu (G_N^n)^{1-\zeta} M \left( S_N^n, K_N^n \right)^{\zeta - \chi} (K_N^n)^{\chi - 1} \]

Finally, for \( \nu \in (0, 1) \), update

\[ r^{n+1} = \nu r^{\text{new}} + (1 - \nu) r^n \]
\[ w_H^{n+1} = \nu w_S^{\text{new}} + (1 - \nu) w_S^n \]

3. Check the market clearing condition for aggregate capital

4. We use Brent’s Method to solve for \( r^* \) over a fixed interval.