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# On the Distributional Effects of International Tariffs[1]

Daniel Carroll

Federal Reserve Bank of Cleveland
daniel.carroll@clev.frb.org

Sewon Hur

Federal Reserve Bank of Cleveland
sewon.hur@clev.frb.org

[PRELIMINARY AND INCOMPLETE]

**Abstract**

What are the distributional consequences of tariffs? We build a heterogeneous-agent, incomplete-markets trade model with capital-skill complementarity and distortionary taxation. Using the calibrated model, we increase bilateral tariffs by 20 percentage points and examine several budget-neutral fiscal policies for redistributing tariff revenue. We find that the distributional impacts of tariffs significantly vary across policies. In particular, using tariff revenue to lower labor income taxes reduces average welfare costs, relative to reducing capital income taxes. Finally, when tariff revenue is rebated to households as lump-sum transfers, tariffs can be welfare improving.

KEYWORDS: tariffs, inequality, consumption, welfare, taxation
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# 1 Introduction

What are the distributional consequences of tariffs? To answer this question, we build a heterogeneous-agent Ricardian trade model with distortionary taxation in which households with permanent labor skill types face uninsurable income risk and borrowing constraints in each country. 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, as documented in Carroll and Hur (2019).

Using the calibrated model, we compute the distribution of welfare changes arising from a bilateral 20 percent increase in import tariffs under several budget-neutral fiscal policies for redistributing tariff revenue: reducing labor income taxes, reducing capital income taxes, implementing lump-sum transfers, and increasing wasteful government expenditure. We find that the distributional impacts of trade significantly vary across tax policies: using tariff revenue to reduce labor income taxes reduces welfare costs both on average and for the poor, relative to reducing capital income taxes, despite the fact that lowering capital income taxes generates the smallest reductions in aggregate consumption and output. Additionally, when we rebate the tariff revenue to all households as lump-sum transfers, average welfare increases.

We decompose the welfare changes from tariffs into four channels. The first is the *expenditure* channel. Tariffs lead to a rise in the price of tradable goods as the increase in the cost of foreign inputs induces a reallocation of production within tradable varieties from more efficient foreign firms to less efficient domestic counterparts.[2] As a result, poor households, who spend a larger share of expenditures on tradable goods, suffer larger welfare losses.

The second channel is the *investment* channel. Tradable goods are also an input into capital production so a higher tradable price increases the cost of investment. In an environment with incomplete asset markets, this benefits wealthy households because they are typically sellers of capital and hurts high-wage, low-wealth households, who are buyers of

[2]This is consistent with Broda and Romalis (2008), Amiti et al. (2018), Bai and Stumpner (2019), and Jaravel and Sager (2018) who document that increased import competition from China has resulted in lower prices of tradable goods.

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. We now discuss the channels that depend on how the tariffs are redistributed.

The third channel is the *factor price* channel. With the exception of lower capital income taxes, a higher investment price leads to capital shallowing, which eventually increases the return on capital. When capital is more substitutable with unskilled labor than with skilled labor, capital shallowing also reduces the skill premium, leading to a decline in the after-tax skilled wage. It also reduces the after-tax unskilled wage, except when tariff revenue is used to reduce labor income taxes. In the case of lower capital income taxes, the higher after-tax return on capital offsets the higher investment price and does not lead to significant changes in aggregate capital or wages. With the exception of the capital income tax reduction, the third channel favors unskilled workers relative to skilled workers, and with the exception of the labor income tax reduction, this channel favors the wealthy relative to the poor.

In the case where the government lump-sum rebates the tariff revenue, there is additionally the *transfer* channel. While the transfer is small in absolute value—a little over 1 percent of output per worker—poor households have high marginal utilities and benefit greatly from the transfer.

The decomposition helps us understand the distributional consequences as well as the tradeoffs associated with tariffs. Tariffs hurt poor households by making tradable goods and services more expensive (expenditure channel) and benefit wealthy households by making investment goods more expensive (investment channel). Reducing capital income taxes is associated with the smallest reduction in output, but still leads to an average welfare loss of 1.52 percent (in terms of consumption equivalents). It especially favors wealthy households for whom the benefit of increased after-tax capital returns is largest. We find that using tariff revenue to reduce labor income taxes is less efficient, leading to larger reductions in consumption and output, but increases the after-tax unskilled wage sufficiently to significantly reduce the welfare cost for unskilled households and produce an average welfare loss of 0.98 percent across all households. Finally, redistributing the additional tariff revenue as a lump-sum transfer leads to an average welfare gain, with the gains being largest for unskilled households with low income and low wealth.

Our paper is related to several strands of the literature. On the theoretical side, 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) and Krusell et al. (2000).[3]

Our paper is also related to recent works that have quantified the heterogeneous welfare gains and losses from trade.[4] Fajgelbaum and Khandelwal (2016) develop an Armington model with nonhomothetic preferences and exogenous differences in income to compute the heterogeneous welfare effects of trade along the income distribution. Artuç et al. (2010), Caliendo et al. (2019), Dix-Carneiro (2014), Dix-Carneiro and Kovak (2017), Galle et al. (2017), and Kondo (2018) develop trade models with labor market frictions to quantify the heterogeneous effects of trade without savings. Our work is closely related to Lyon and Waugh (2019), who 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) who 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 trade (disruptions) along not only in the income and wealth distribution, but also across skill types in an environment with capital-skill complementarity.

Finally, our paper is related to studies of optimal trade and fiscal policies. While Costinot et al. (2015) and Opp (2010) study optimal trade policy in a strategic context, Hosseini and Shourideh (2018) focus on optimal trade and fiscal policy under cooperation. Dixit and Norman (1986) study how gains from trade can be redistributed through taxation. Our work is closely related to Lyon and Waugh (2018) who study how progressive labor income taxation can be used to redistribute the gains from trade. We depart from these papers by

[3]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.

[4]Costinot and Rodríguez-Clare (2014) provide an excellent review of this literature.

focusing on how tariffs interact with labor and capital income taxes. Additionally, there is a large literature examining Ramsey optimal taxation in closed economies with incomplete markets.[5]

# 2 Model

We consider a two-country model with balanced trade and without labor or capital flows. There are a continuum of tradable goods indexed by $\omega$ and a single non-tradable numeraire. 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

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

where $\ell$ is labor supplied by the household. When $\bar{c}_i \neq 0$, the utility function represents Stone-Geary 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 $w_{iH}\phi_{iH}/\left(w_{iL}/\phi_{iL}\right) - 1$ is the skill premium. We assume that $\varepsilon$ follows a Markov process with transition matrix $\Gamma\left(\varepsilon', \varepsilon\right)$. 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

[5] See, for example, Aiyagari (1995), Imrohoroğlu (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).

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 $\tilde{r}_i = (1 - \tau_{ik})(r_i - \delta P_{iX})$ and the *after-tax wage* as $\tilde{w}_{ij} = (1 - \tau_{i\ell}) w_{ij}\phi_{ij}$.

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

$$V_{ij}(k,\varepsilon) = \max_{c_T, c_N, \ell, k'} u(c_T, c_N, \ell) + \beta E_{\varepsilon'|\varepsilon} V_i(k', \varepsilon') \tag{1}$$
$$\text{s.t. } P_{iT}c_T + P_{iN}c_N + P_{iX}(k' - k) \le \tilde{w}_{ij}\ell\varepsilon + \tilde{r}_i k$$
$$k' \ge 0$$

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. 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 $S$.

## 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

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

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. Notice that if $\chi < \zeta$, there is capital-skill complementarity. It solves a static profit maximization problem

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

The optimality conditions are given by

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

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

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

where

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

$$M(H_{iN}, K_{iN}) = \left((1-\alpha) H_{iN}{}^{\chi} + \alpha K_{iN}{}^{\chi}\right)^{\frac{1}{\chi}}. \tag{8}$$

## 2.3 Final tradables producer

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

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

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

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

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,

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

the producer's optimality conditions are given by

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

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

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

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

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

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

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

The intermediate firm's optimality conditions are given by

$$w_{iL} = (1-\mu) p_i(\omega) z_i(\omega) G(l_i(\omega), h_i(\omega), k_i(\omega))^{1-\zeta} l_i(\omega)^{\zeta-1}, \tag{15}$$
$$w_{iH} = \mu(1-\alpha) p_i(\omega) z_i(\omega) G(l_i(\omega), h_i(\omega), k_i(\omega))^{1-\zeta} M(h_i(\omega), k_i(\omega))^{\zeta-\chi} h_i(\omega)^{\chi-1}, \tag{16}$$
$$r_i = \mu\alpha p_i(\omega) z_i(\omega) G(l_i(\omega), h_i(\omega), k_i(\omega))^{1-\zeta} M(h_i(\omega), k_i(\omega))^{\zeta-\chi} k_i(\omega)^{\chi-1}. \tag{17}$$

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

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

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

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 non-tradable goods according to

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

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

$$\max_{I_T, I_N} P_{iX} X_i - P_{iT} I_{iT} - P_{iN} I_{iN} \tag{21}$$

$$\text{s.t. } (20).$$

The capital producer's optimality conditions are given by

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

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

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

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

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

## 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

**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 $\{V_{ij}, g_{ijT}, g_{ijN}, g_{ij\ell}, g_{ijk}\}_{j\in\{H,L\}}$, prices $\Big\{r_i, \{w_{ij}\}_j$ $P_{iT}, P_{iN}, P_{iX}, \{p_i(\omega)\}_{\omega\in[0,1]}\Big\}$, non-tradable producer plans $\{Y_{iN}, H_{iN}, L_{iN}, K_{iN}\}$, final tradable producer plans $\Big\{Y_{iT}, \{q_{oi}(\omega)\}_{\omega,o\in\{1,2\}}\Big\}$, 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 $\{r_i, w_{ij}, P_{iT}, P_{iN}, P_{iX}\}$, $\{V_{ij}, g_{ijT}, g_{ijN}, g_{ij\ell}, g_{ijk}\}$ 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 $\Big\{P_{iT}, \{p_o(\omega)\}_{\omega,o}\Big\}$, $\Big\{Y_{iT}, \{q_{oi}(\omega)\}_{\omega,o}\Big\}$ 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) $y_i(\omega) = \tau_{i1} q_{i1}(\omega) + \tau_{i2} q_{i2}(\omega)$ for $\omega \in [0, 1]$,

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

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

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 $o \neq i$,:

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

9. For any subset $(\mathcal{K}, \mathcal{E}) \in \mathcal{B}$, $\mu_{ij}^*$ satisfies

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

## 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

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

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 in to

(17) to obtain the price of variety $\omega$ produced in country $i$,

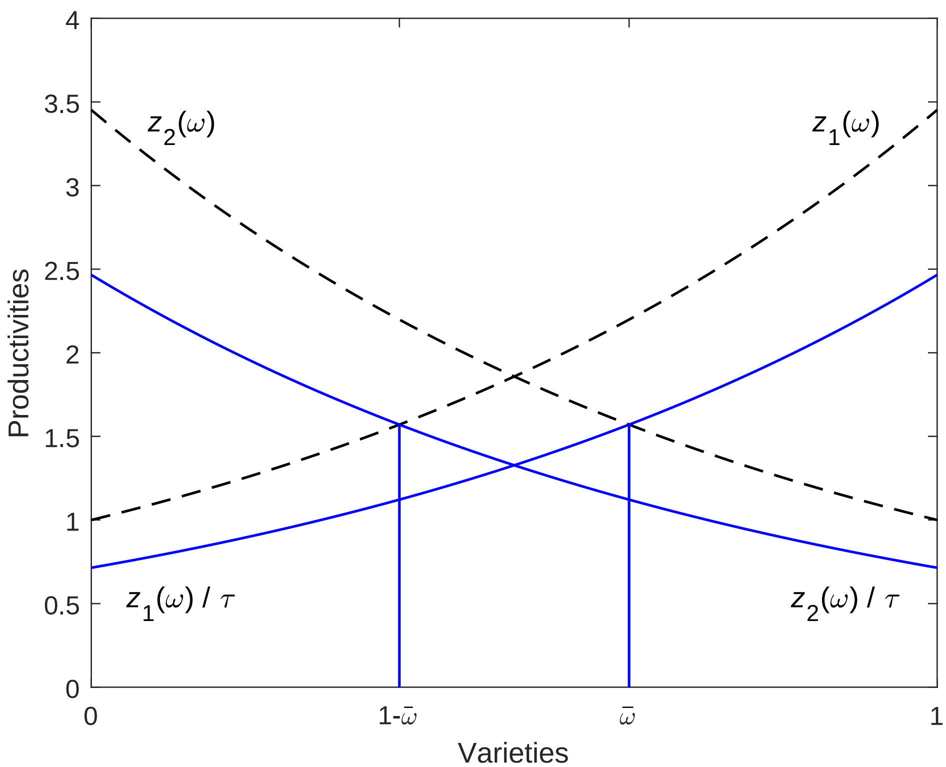
$$p_i(\omega) = \frac{1}{z_i(\omega)}. \tag{27}$$

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

$$\bar{\omega}(\tau) = \min\left\{1, \frac{\eta + \log\tau}{2\eta}\right\}, \tag{28}$$

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.

Figure 1: Pattern of production, trade, and specialization



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

$$P_T = \frac{1}{\tilde{z}(\tau)} \tag{29}$$

where $\tilde{z}(\tau)$ is a measure of average productivity:

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

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

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

It is straightforward to show that

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

and

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

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, PSID and CEX). 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 to $\alpha$ 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*).[7] 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.[8]. 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,

[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).

following Krusell et al. (2000).[9] The labor productivity shocks $\varepsilon$ are assumed to follow an order-one auto-regressive process as follows:

$$\log \varepsilon_t = \rho_\varepsilon \log \varepsilon_{t-1} + \nu_t, \nu_t \sim N\left(0, \sigma_\varepsilon^2\right); \tag{34}$$

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, $z_N = z_X = 1$.

## 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 an economy-wide application of the new tariffs imposed 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 household with skill type $j \in \{L, H\}$ can be stated recursively as

$$\begin{aligned} V_t\left(k, \varepsilon, j\right) = & \max_{c_T, c_N, h, k'} u\left(c_T, c_N, h\right) + \beta E_{\varepsilon'|\varepsilon} V_{t+1}\left(k', \varepsilon_{t+1}, j\right) \\ & \text{s.t.} \quad P_{Tt} c_T + c_N + P_{Xt}\left(k' - k\right) \leq \tilde{w}_{jt} h \varepsilon + \tilde{r}_t k + T_t, \\ & \qquad k' \geq 0 \end{aligned} \tag{35}$$

Solving this yields time-dependent decision rules $g_{Tt}\left(k, \varepsilon, j\right)$, $g_{Nt}\left(k, \varepsilon, j\right)$, $g_{ht}\left(k, \varepsilon, j\right)$, and

[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

| Parameters | Values | Targets / Source |
|---|---|---|
| Discount factor, $\beta$ | 0.96 | Wealth-to-GDP: 4.5 |
| Risk aversion, $\sigma$ | 2 | Standard value |
| Tradable share, $\gamma$ | 0.27 | Tradable expenditure share: 36 percent |
| Non-homotheticity, $\bar{c}$ | 0.09 | Tradable expenditure share of wealthiest decile: 30 percent |
| Disutility from labor, $\psi$ | 440 | Average hours: 33 percent |
| Frisch elasticity, $1/\nu$ | 0.5 | Standard value |
| Skilled fraction, $\bar{H}$ | 0.33 | Skilled labor force: 33 percent |
| Capital weight, $\alpha$ | 0.83 | Capital income share: 36 percent |
| Skilled weight, $\mu$ | 0.61 | Skilled labor income share: 36 percent |
| Elasticity of substitutions, | | |
| unskilled–capital, $1/(1-\zeta)$ | 1.67 | Krusell et al. (2000) |
| skilled–capital, $1/(1-\chi)$ | 0.67 | Krusell et al. (2000) |
| tradable intermediates, $\theta$ | 5.7 | Trade elasticity: 4 |
| Factor elasticity, $\kappa$ | 0.59 | 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, $(\tau - 1) \times 100$ | 0.27 | Import share: 17 percent |
| Income tax, $\tau_\ell = \tau_k$ | 0.19 | Government consumption: 15 percent of GDP |
| Persistence, $\rho_\varepsilon$ | 0.92 | Floden and Lindé (2001) |
| Standard deviation, $\sigma_\nu$ | 0.21 | Floden and Lindé (2001) |

$g_{kt}(k, \varepsilon, j)$ 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, $\mu_0^*$, at $t = 0$. We then introduce a permanent increase in trade costs in $t = 1$, and solve for a sequence of value functions $\{V_t\}_{t=1}^{\infty}$, decision rules $\{g_{Tt}, g_{Nt}, g_{ht}, g_{kt}\}_{t=1}^{\infty}$, wealth distributions $\{\mu_t\}_{t=1}^{\infty}$, and prices $\{r_t, w_t, P_{Tt}, P_{Xt}, Tr_t \{p(\omega)\}_{\omega}\}_{t=1}^{\infty}$, 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 how the government uses the tariff revenue raised. We consider four cases. In the first case, the government uses the new revenue to purchase nontradable goods and then throws these goods into the ocean. This policy most closely correlates with a common thought experiment considered in the trade literature where iceberg trade costs change.[10]. It also provides a lower bound for average welfare by removing any offset from redistribution and isolates the costs of tariffs by ignoring potential offsetting gains through redistribution.

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.

Finally, we examine a case where the government redistributes 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.

[10]See, for example, Arkolakis et al. (2012).

### 3.2.1 Aggregate effects

Regardless of which fiscal policy is enacted, the equilibrium paths of $P_X$ or $P_T$ are identical since these prices are functions only of total trade costs, as demonstrated in equations (29) and (31).

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, 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 unless the capital tax rate is reduced (Figure 2a).

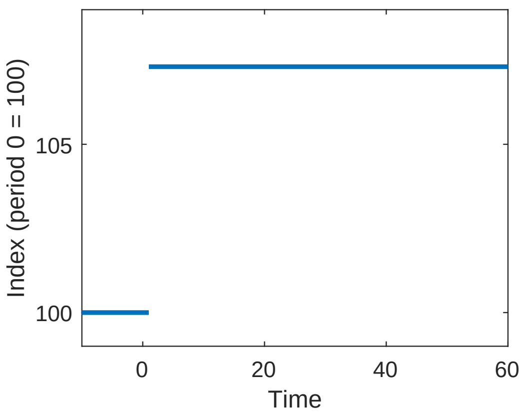
**Factor prices.** Figure 2 (c)–(e) plot the paths of the three factor prices for each fiscal policy. The paths for wages are very similar in the cases where the government leaves tax rates unchanged. Due to skilled labor's strong complementarity with capital in production, the skilled wage declines as capital shallows. The skilled wage declines in the long run by 3.7–4.0 percent. The unskilled wage rises slightly at the beginning of the transition, but declines over time until it is about 1.0 percent lower under either policy.

When the government reduces one of the tax rates, the dynamics for after-tax wages change considerably. If the labor income tax is reduced, there is an initial 2.7 percent increase in the skilled wage that gradually diminishes into a 0.6 percent decrease in the long run. For unskilled labor the wage change is entirely positive: the wage jumps by 2.9 percent and remains 1.9 percent above its initial level in the long run. If instead, the government lowers the tax rate on capital income, preventing capital-shallowing, the after-tax wages for either skilled or unskilled are barely changed from their initial steady state values.

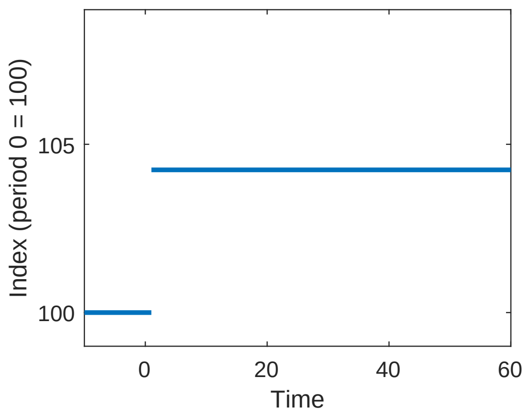
Unless capital income taxes are reduced, the net return to capital falls between 17 and

Figure 2: Prices

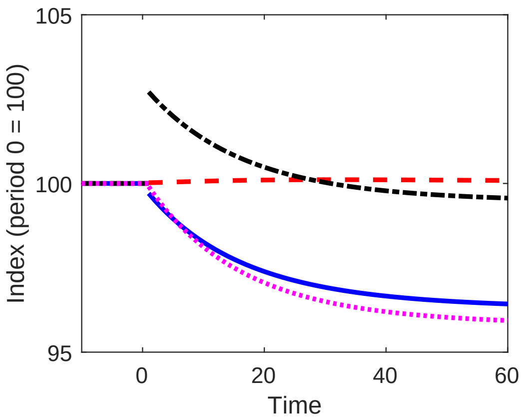
(a) Tradables price



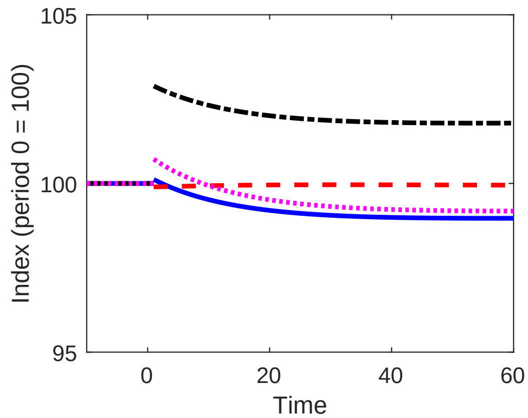

(b) Investment price



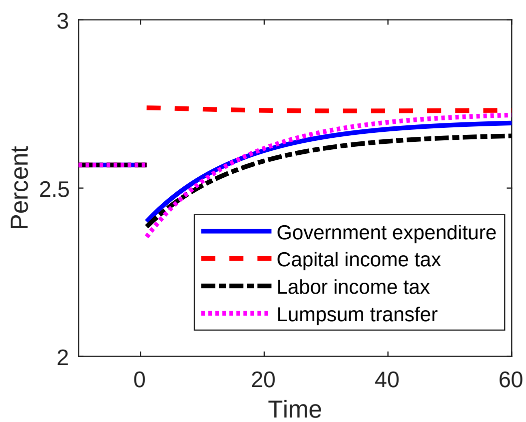

(c) After-tax skilled wage




(d) After-tax unskilled wage




(e) After-tax net return



21 basis points when tariffs are raised and remains below its initial steady state value for a considerable number of periods. The initial drop is caused by the increase in the investment price which makes capital more expensive to maintain. Over time, capital becomes scarce relative to effective labor input, and the return on capital rises until it is 13–16 basis points higher in the long run. If the government lowers $\tau_k$ instead, then the return to capital jumps up 17 basis points and remains at that new level throughout the transition.

**Real variables.** Tariffs generally reduce real economic activity substantially in the long-run. Figure 3 plots the transition path of the main aggregate variables. Real GDP falls by between 0.6 and 2.7 percent with the smallest change occurring when capital taxes are lowered and the greatest under lump-sum transfers. Capital follows a similar but more severe contraction, declining between 4.0 and 5.4 percent, except when the capital income tax is lowered, in which case the capital stock is roughly unchanged.

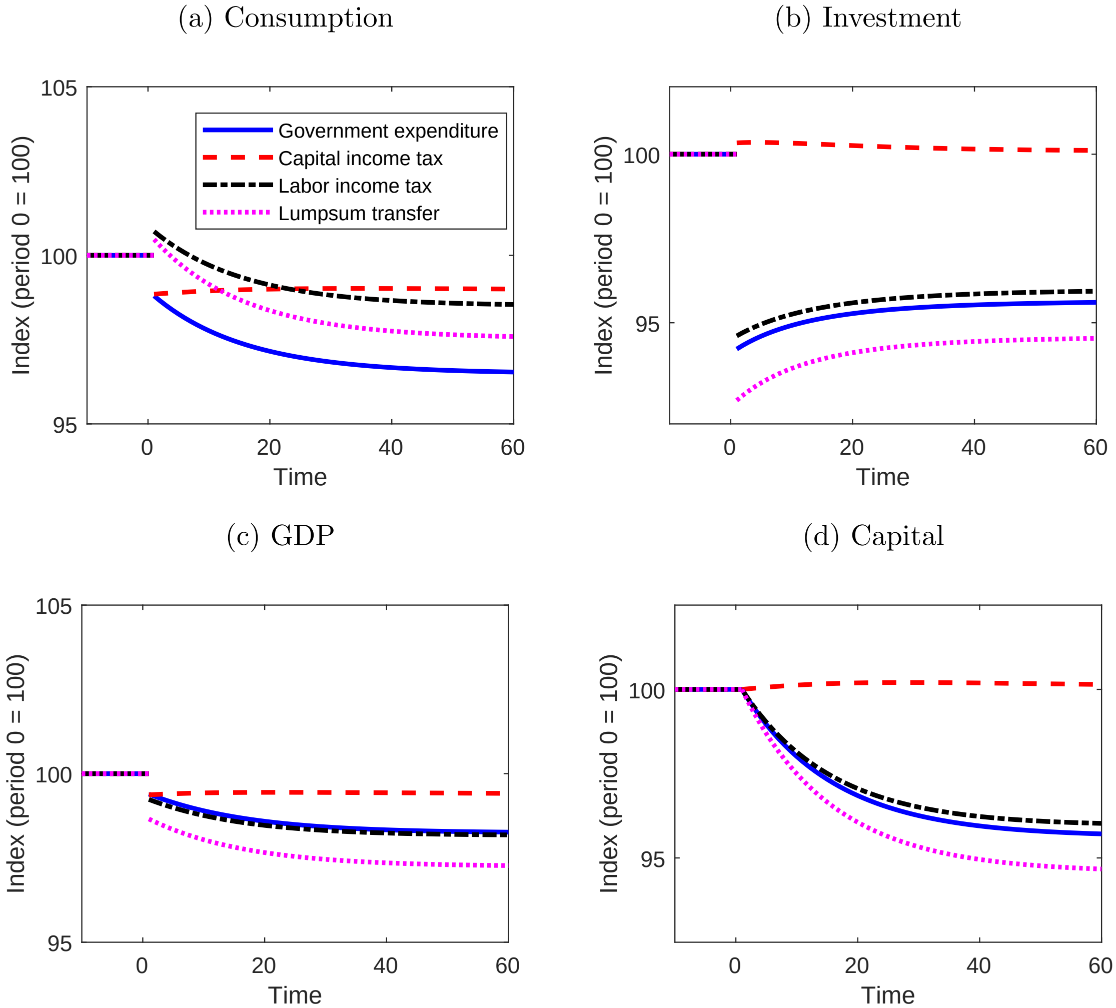
Investment plummets between 5.4 and 7.3 percent initially and 4.0 to 5.4 percent in the long run in response to the rise in $P_X$. Again, this can be avoided with a pro-capital fiscal policy. Total real household consumption may rise or fall initially depending upon fiscal policy, but ends up between 1.0 and 3.5 percent lower in the long run. The long run decrease is smallest under the capital income tax reform; however, labor income tax reform or lump-sum transfers produce a short-term increase in aggregate consumption.

The allocation of factors of production shift across sectors, from tradable to nontradable, across all fiscal policies. Capital and both types of labor immediately exit the tradable sector for the nontradable sector.

### 3.2.2 Welfare costs

The dynamics of prices resulting from tariffs lead to differential effects on household welfare across wealth and income. 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 tradables and nontradables consumption have to be permanently increased in order to make a household indifferent to the policy change. Negative values of $\Delta$ indicate that a household is harmed by raising tariffs since it would be willing to permanently sacri-

Figure 3: Quantities



fice consumption to avoid the transition to a higher trade cost environment. Formally, given the household value functions at the beginning of the transition, $V_1(k, \varepsilon, j)$, and the initial steady state decision rules, $g_T^{ss}$, $g_N^{ss}$, $g_h^{ss}$, and $g_k^{ss}$, we solve for $\Delta(k, \varepsilon, j)$, such that

$$V_\Delta(k, \varepsilon, j) = V_1(k, \varepsilon)$$

where

$$V_\Delta(k, \varepsilon, j) = u\left((1+\Delta) \times g_T^{ss}, (1+\Delta) \times g_N^{ss}, g_h^{ss}\right) + \beta E_{\varepsilon'|\varepsilon} V_\Delta\left(g_k^{ss}, \varepsilon'\right).$$

Table 2 reports the average welfare from each of the fiscal policies. Not surprisingly, average welfare is the lowest when the government wastes tariff revenue. Even though lowering the capital income tax leads to smallest declines in long run aggregate variables, it has the lowest average welfare among the redistributionary policies. Reducing labor income taxes instead is better on average but still leads to an average welfare loss. Interestingly, average welfare can be increased if tariff revenue is rebated lump-sum to all households.

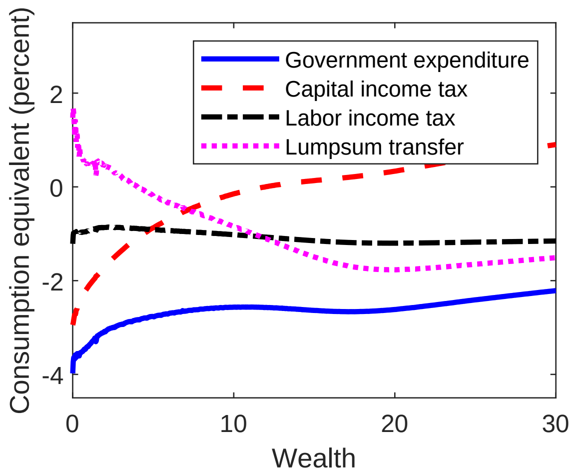
Table 2: Average Welfare

| | |
|---|---|
| Govt expenditure | $-3.13$ |
| Capital inc. tax | $-1.52$ |
| Labor inc. tax | $-0.98$ |
| Lump-sum tax | 0.23 |

Units: percent.

Figure 4 plots average welfare households across the initial steady state wealth distribution, normalized by per capita output. For reference, median wealth is 2.2, and the top 10 percent richest households have more than 11.9. 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 4: Welfare change




### 3.2.3 Decomposing welfare changes

Individual welfare varies considerably across the four fiscal policies, not only along the wealth dimension, but also along the skill and productivity dimensions. Here, we examine each case separately and 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 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 and the corresponding fiscal policies can have various effects on after-tax returns to labor and to capital. A 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 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.

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). It is important to note that the expenditure and investment channels are constant across the various fiscal policies as we demonstrated that the equilibrium paths of $P_X$ or $P_T$ are functions only of total trade costs, as demonstrated in equations (29) and (31).

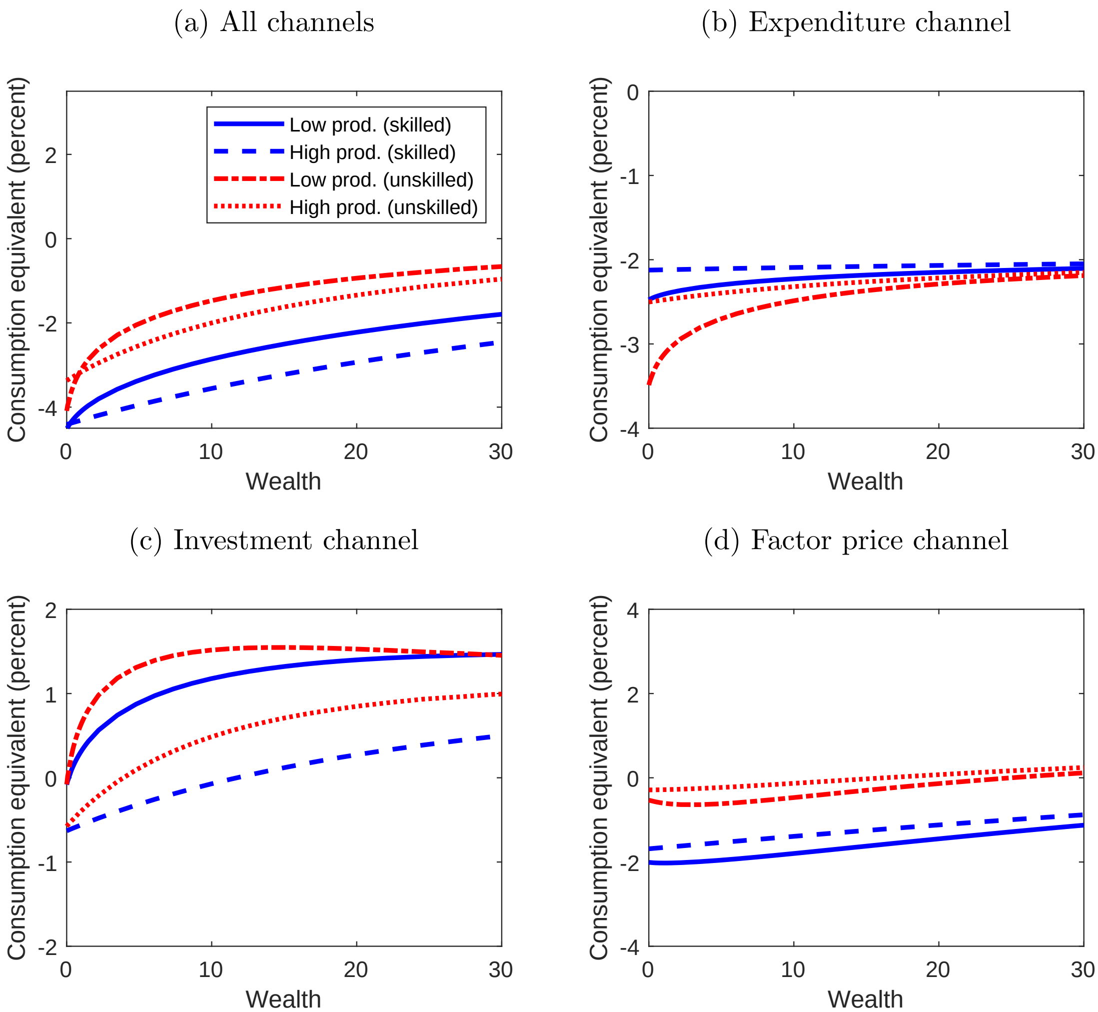
**Increased government expenditure.** Figure 5(a) plots $\Delta$ across the wealth distribution at the moment the tariff policy is announced for low-productivity and high-productivity households by skill type.

Panel (a) shows the total welfare change by household type. Notice that in the absence of redistribution, all households suffer a welfare loss from imposing tariffs, especially the poor. 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.

Panels (b)-(d) 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.

The investment channel may ameliorate or exacerbate the total welfare loss depending

Figure 5: Welfare change: wasteful government spending



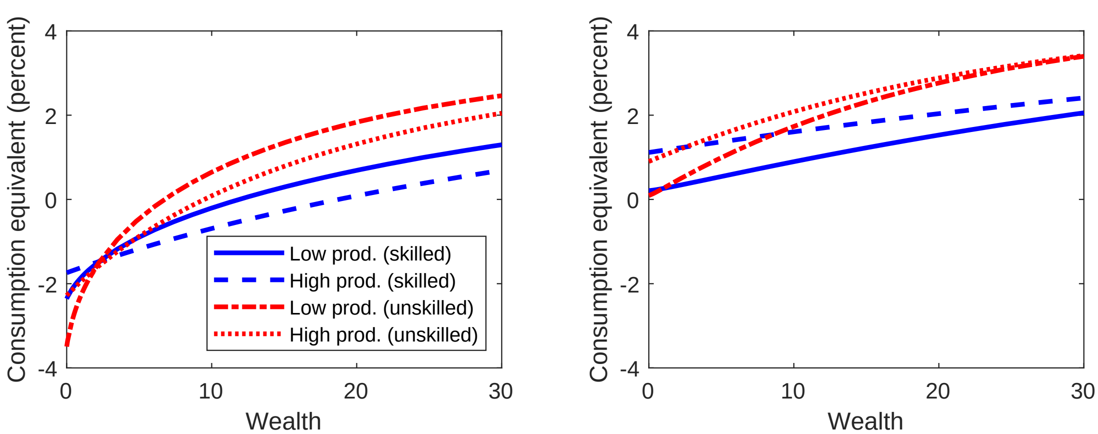
upon a household's state at the time of the policy change. For low-productivity, wealthy households, the rise in the investment price provides additional consumption at just the right time for low productivity households with some capital to sell. Meanwhile, for low wealth households with high productivity,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

**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 6 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 6b) because they do not have much wealth, so these small gains are dominated by the large welfare losses from the expenditure channel (Figure 5b).

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 5c). On net, average welfare is lower because the wealth distribution has relatively few rich households.

Figure 6: Welfare change: reduction in capital income taxes

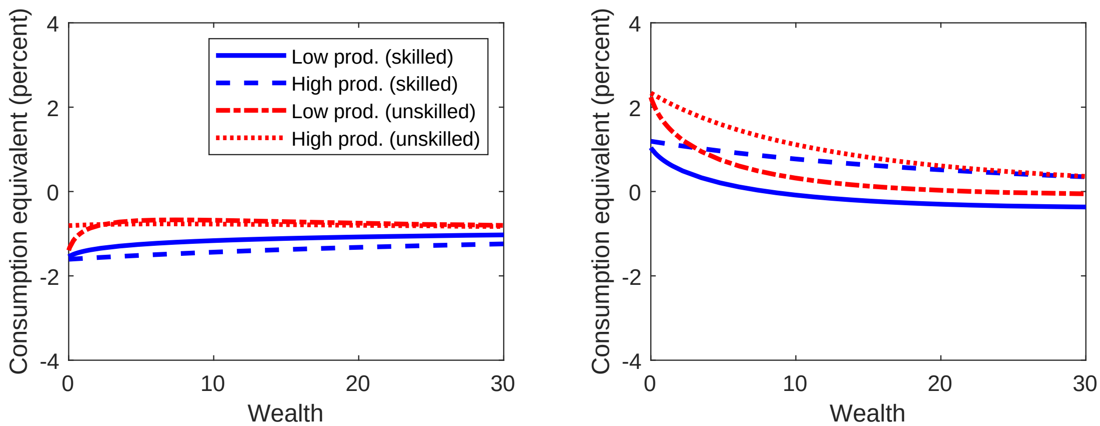
(a) All channels　　　(b) Factor price channel



**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 7 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.

Figure 7: Welfare change: reduction in labor income taxes

(a) All channels (b) Factor price channel

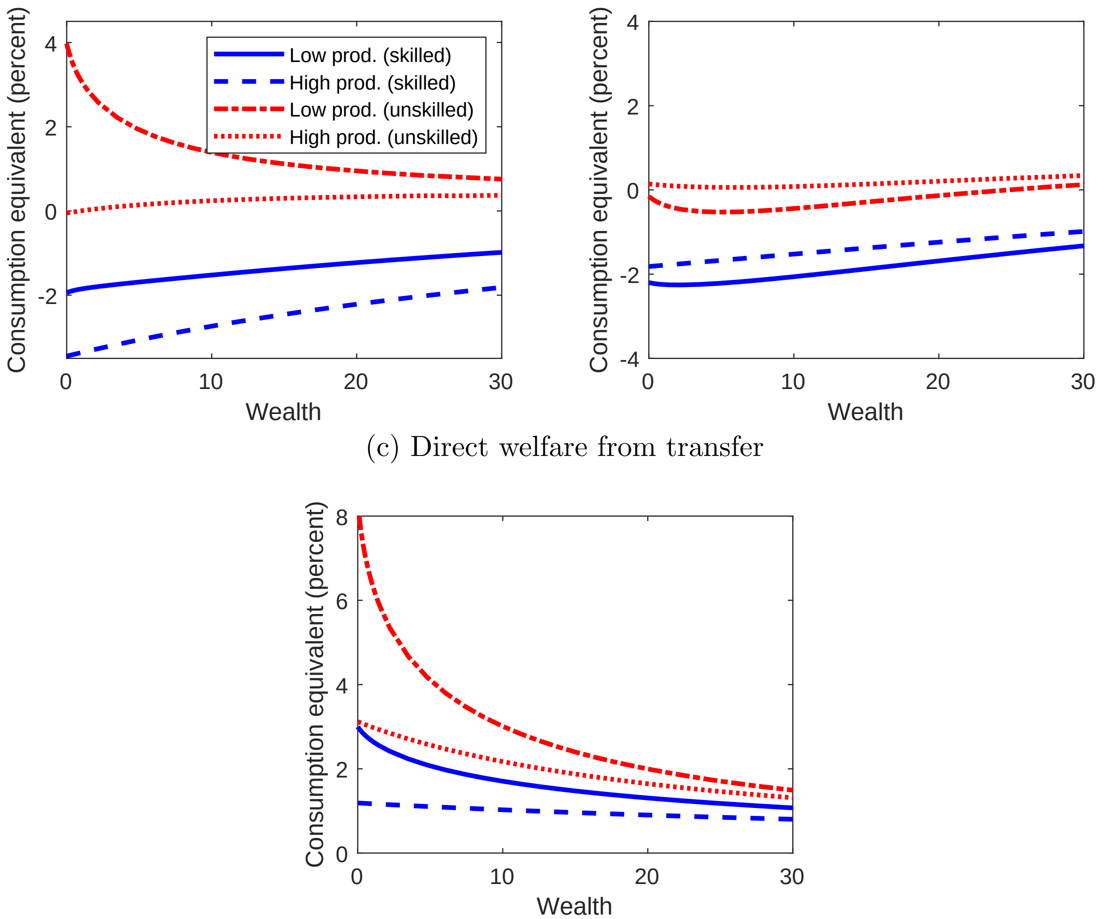



**Lump-sum transfer.** If the government uses tariff revenue to finance a lump-sum transfer to all households, the welfare gains and loss are most unevenly distributed (Figure 8a). Nearly all unskilled households benefit, while all skilled households lose. Figure 8(b) shows that the difference is not due to the factor price channel, which looks almost exactly as it did under increased government expenditures (Figure 5d). 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 8c) 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.

Figure 8: 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

| | Low wealth | | High wealth | | |
|---|---|---|---|---|---|
| Channels | Low prod. | High prod. | Low prod. | High prod. | Average |
| Expenditure | −3.49 | −2.50 | −2.40 | −2.27 | −2.75 |
| Investment | −0.08 | −0.58 | 1.54 | 0.67 | 0.32 |
| Factor price | | | | | |
| *Govt Expend* | −0.53 | −0.29 | −0.35 | −0.04 | −0.47 |
| *Capital inc. tax* | 0.09 | 0.90 | 2.13 | 2.45 | 0.71 |
| *Labor inc. tax* | 2.24 | 2.34 | 0.18 | 0.86 | 1.69 |
| *Lump-sum redist.* | −0.15 | 0.14 | −0.34 | 0.13 | −0.18 |
| All | | | | | |
| *Govt Expend.* | −4.09 | −3.37 | −1.25 | −1.69 | **−2.91** |
| *Capital inc. tax* | −3.49 | −2.28 | 1.14 | 0.67 | **−1.80** |
| *Labor inc. tax* | −1.40 | −0.81 | −0.70 | −0.78 | **−0.80** |
| *Lump-sum redist.* | 3.98 | −0.05 | 1.20 | 0.29 | **1.47** |

Units: percent.

Table 4: Decomposition of welfare changes for skilled

| | Low wealth | | High wealth | | |
|---|---|---|---|---|---|
| Channels | Low prod. | High prod. | Low prod. | High prod. | Average |
| Expenditure | −2.48 | −2.12 | −2.16 | −2.06 | −2.20 |
| Investment | −0.08 | −0.63 | 1.35 | 0.34 | 0.37 |
| Factor price | | | | | |
| *Govt Expend* | −2.01 | −1.69 | −1.51 | −1.03 | −1.74 |
| *Capital inc. tax* | 0.21 | 1.12 | 1.41 | 2.17 | 0.95 |
| *Labor inc. tax* | 1.04 | 1.19 | −0.26 | 0.47 | 0.52 |
| *Lump-sum redist.* | −2.20 | −1.82 | −1.76 | −1.15 | −1.95 |
| All | | | | | |
| *Govt Expend.* | −4.52 | −4.41 | −2.35 | −2.78 | **−3.57** |
| *Capital inc. tax* | −2.36 | −1.74 | 0.52 | 0.28 | **−0.96** |
| *Labor inc. tax* | −1.55 | −1.61 | −1.09 | −1.30 | **−1.35** |
| *Lump-sum redist.* | −1.94 | −3.45 | −1.28 | −2.08 | **−2.30** |

Units: percent.

# 4 Conclusion

We have studied the distributional effects of bilateral 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 tradable goods and investment, and in the absence of a corresponding reduction in capital income taxes, lead to capital shallowing. The gains and losses from tariffs depend on the various ways in which the government uses the new tariff revenue. In particular, using tariff revenue to reduce capital income taxes lead to the smallest reduction in output and consumption, but lead to larger welfare costs than when using tariff revenue to reduce labor income taxes. Using tariff revenue via lump-sum transfers can lead to an average welfare gain, with unskilled, low-income, low wealth households gaining the most.

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# A Computational appendix

1. Guess $\{r^n, w_H^n\}$.
2. Given $\{r^n, w_H^n\}$, calculate $\{P_T^n, P_X^n, w_L^n\}$ using equations (26), (29), and (31).
3. Given $\{r^n, w_H^n, w_L^n, P_T^n, P_X^n\}$, solve the household problem in (1) to obtain $g_{jT}$, $g_{jN}$, $g_{j\ell}$, and $g_{jk}$.
4. Begin with $\mu_j^0(k, \varepsilon)$, use $g_{jT}$, $g_{jN}$, $g_{j\ell}$, and $g_{jk}$ to find the invariant distribution, $\mu_j^n(k, \varepsilon)$.
5. Aggregating $\mu_j^n(k, \varepsilon)$, we get $\{C_T^n, C_N^n, X^n, S^n, U^n, K^n\}$.
6. Use equations (22) and (23) to obtain $\{I_T^n, I_N^n\}$.
7. Use market clearing conditions for tradable and nontradable final goods to obtain $\{Y_T^n, Y_N^n\}$.
8. Substitute $G_N^n = Y_N^n$ into equation (4) to obtain $U_N^n$.
9. Use the market clearing condition for unskilled labor to obtain $U_T^n = U^n - U_N^n$.
10. Use the first order conditions of the intermediate tradable producers, equations (15)–(17), to obtain

$$S_T^n = \left( \frac{1-\mu}{\mu} \frac{1}{(1-\alpha)\,\Omega} \frac{w_H^n}{w_L^n} \right)^{\frac{1}{\zeta - 1}} U_T^n, \tag{36}$$

$$K_T^n = \left( \frac{\alpha}{1-\alpha} \frac{w_H^n}{r^n} \right)^{\frac{1}{\chi - 1}} S_T^n, \tag{37}$$

where

$$\Omega = \left[ \alpha \left( \frac{\alpha}{1-\alpha} \frac{w_H^n}{r^n} \right)^{\frac{\chi}{1-\chi}} + 1 - \alpha \right]^{\frac{\zeta - \chi}{\chi}}. \tag{38}$$

11. Use the market clearing conditions for skilled labor and capital to obtain $\{S_N^n, K_N^n\}$.

12. From the first order conditions of the nontradable producer,

$$
\begin{aligned}
w_H^{new} &= (1-\alpha)\,\mu(G_N^n)^{1-\zeta} M\left(S_N^n, K_N^n\right)^{\zeta-\chi}\left(S_N^n\right)^{\chi-1} \\
r^{new} &= \alpha\mu(G_N^n)^{1-\zeta} M\left(S_N^n, K_N^n\right)^{\zeta-\chi}\left(K_N^n\right)^{\chi-1}
\end{aligned}
$$

13. Finally, for $\nu \in (0,1)$, update

$$
\begin{aligned}
r^{n+1} &= \nu r^{new} + (1-\nu)\, r^n \\
w_H^{n+1} &= \nu w_S^{new} + (1-\nu)\, w_S^n
\end{aligned}
$$