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The distributional consequences of trade liberalization: Consumption tariff versus investment tariff reduction

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ABSTRACT

This paper uses numerical simulations to highlight the contrasting effects of consumption and investment tariff reductions on the dynamic adjustments of key measures of aggregate activity and inequality. The consumption tariff has only a weak effect on activity. If implemented instantaneously it leads to a negligible reduction in wealth inequality but a substantial increase in income inequality. If gradual, it causes a more significant decline in wealth inequality but a milder increase in income inequality. A comparable reduction in an investment tariff increases activity significantly. It leads to a significant long-run reduction in wealth inequality if implemented instantaneously, which is moderated if introduced gradually. It is associated with a tradeoff between the short-run and long-run effects on income inequality, reducing it in the very short run, while increasing it slightly over time. The simulations are supplemented with extensive sensitivity analysis, suggesting some sensitivity to key structural parameters.

1. Introduction

The last three decades have witnessed dramatic trade liberalization and in particular tariff reductions. Between 1984 and 2010 average tariff rates declined from around 32% for developing economies and 15% for high income economies to around 9%, and 6% respectively.¹ Over a similar period, the comprehensive database developed by Milanovic (2014) indicates that income inequality within countries, as measured by the Gini coefficient, has increased steadily, across the spectrum of development, in some instances quite dramatically. While many factors have clearly contributed to the worldwide increase in inequality, the extent to which trade liberalization, and specifically tariff reduction, may (or may not) have been a significant contributing factor is an issue that has recently been receiving increased attention, both from a theoretical standpoint, as well as empirically.

Two alternative mechanisms immediately come to mind. The first, based on the traditional Heckscher-Ohlin trade model, suggests that given differences in the relative endowments of skilled and unskilled labor between developed and developing economies, a tariff reduction

will likely reduce inequality in a developing economy, but increase it in an advanced economy. Alternatively, a standard one-sector growth model with accumulating physical capital and endogenous labor supply, suggests that the increase in employment following a tariff reduction will tend to increase the return to capital over time, thereby encouraging capital accumulation and increasing income inequality.

Two recent studies use cross-country panel data sets to examine the impact of trade liberalization on income inequality and come to rather different conclusions. Jaumotte et al. (2013) find that trade liberalization is associated with less income inequality, with most of the observed increase being due primarily to the impact of technological change. In contrast, Rojas-Vallejos and Turnovsky (2017) obtain a weak positive relationship between tariff liberalization and income inequality, the differences likely reflecting, at least in part, differences in the data sets used.²

Apart from the alternative channels identified whereby a specific tariff may impact the economy, another explanation for the conflicting empirical results is the diverse nature of the tariffs themselves. In this respect, much of the theoretical literature is restricted to tariffs on

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¹ These estimates are based on the data on Trade and Import Barriers data at the World Bank compiled by Francis K.T. Ng consisting of 170 countries over the period 1981–2010.

² Because of data limitations, Jaumotte et al. (2013) use inequality data based on both income and consumption expenditure surveys. As they note, mixing these two concepts makes a comparison of levels of inequality across countries potentially misleading. The inequality measure employed by Rojas-Vallejos and Turnovsky (2017) uses only income data.

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consumption.³ While this is important, most open economies – particularly developing economies – also impose substantial tariffs on the imports of investment goods. Indeed, several papers compare the effects of consumption versus investment tariffs on the dynamics of the aggregate economy; see Brecher and Findlay (1983), Brock and Turnovsky (1993), Osang and Pereira (1996), Osang and Turnovsky (2000). As these papers demonstrate, these two tariffs impinge on the aggregate dynamics in sharply contrasting ways. In particular, investment tariffs have a more adverse impact on level of activity and growth than do consumption tariffs, an implication that is strongly supported by recent empirical evidence; see Estevadeordal and Taylor (2013).

It is clear that the contrasting aggregate effects of the two tariffs will generate differential factor returns, which in turn will be reflected in differential impacts on income inequality. Indeed this is strongly confirmed by some initial panel regressions, reported in the [online Appendix](#), which suggest that reducing the consumption tariff will increase inequality, while reducing the investment tariff will decrease inequality. With the two tariff rates having offsetting effects, this suggests that the typical empirical practice of calculating tariff rates by dividing total tariff revenues by GDP obscures their sharply differential effects. Indeed, it may well lead to the erroneous conclusion that tariff policy has only weak distributional effects, whereas in fact both tariffs are significant but mutually offsetting.

Since the ongoing trade liberalization has involved a general reduction in tariffs, in this paper we introduce both a consumption tariff and an investment tariff and contrast their respective consequences for wealth and income inequality. As is well known, to derive explicit distributional implications of tariff policy (or any structural change) one must impose some restrictions on the economy, and we do so by adopting the “representative consumer theory of distribution” [Caselli and Ventura, 2000]. Under these conditions, aggregation results pioneered by Gorman (1953) enable the macroeconomic equilibrium and distributional consequences to be determined sequentially.

Much of the literature assessing the effects of tariffs on investment makes the polar assumption that all capital goods are imported; see Osang and Pereira (1996), Brock and Turnovsky (1993), Osang and Turnovsky (2000). This is unrealistic since comprehensive empirical evidence suggests that on average about 60% of total investment expenditures are on nontraded capital goods; see Bems (2008). Accordingly, we distinguish between traded and nontraded capital, thus enabling us to evaluate how their relative significance and substitutability in production influences the growth-inequality tradeoff.

The framework we adopt is the standard two-sector dependent economy model. We first derive a number of theoretical implications linking the effects of tariff reduction on both the aggregate economy and its distributional consequences. The sharply contrasting ways the two tariffs impinge on the economy account for their sharply contrasting effects on both the aggregate and distributional dynamics. They reflect a basic characteristic of the dependent economy model, namely that long-run factor returns, sectoral allocations, and relative prices are determined entirely by production conditions. As a consequence, the investment tariff has a direct impact on the sectoral production structure. In contrast, the consumption tariff by impacting final demand has no long-run effect on these quantities. It determines sectoral outputs solely through its impact on sectoral labor allocation as required to ensure market clearance in the nontraded goods market.

The dynamics of the aggregate economy following a tariff reduction drive the evolution of wealth inequality via the impact on two offsetting factors during the transition. First, to the extent that discounted aggregate consumption increases (decreases), this will tend to increase (decrease) wealth inequality. This is because wealthy people tend to

consume relatively less and save relatively more. Second, to the extent that discounted gross labor income, assumed to be uniform across agents, increases (decreases), this has the opposite effect. The net effect on wealth inequality depends upon which dominates. In the case of both tariff reductions the negative effect tends to prevail and wealth inequality tends to decline. In addition to reflecting this reduction in wealth inequality, the response in income inequality includes an offsetting positive effect due to a reduction in the aggregate consumption expenditure-wealth ratio, and the fact that the rich save relatively more (consume relatively less) than do the poor.

A key factor influencing the impact of a tariff reduction on distribution concerns the speed with which it is implemented. This is important, since in practice there is substantial variation in the rate at which trade liberalizations have proceeded.⁴ We consider two scenarios. In the first, the tariff reduction is completed instantaneously, and we compare this to the alternative where it is implemented gradually over time. While the time path affects only the *transitional* path of the aggregate variables, it has not only *transitional*, but also *permanent*, consequences for both wealth and income inequality.

Because of the complexity of the model, it is necessary to conduct the dynamic analysis using numerical simulations. To calibrate the model, we set parameters so as to approximate a plausible initial equilibrium structure, the objective being to facilitate our understanding of the channels through which tariffs influence the equilibrium, rather than to replicate any specific economy or episode. In particular, we assume initial consumption tariff and investment tariff rates of 22% and 11% respectively, with the differential of the two rates being typical of the relative rates. Starting from that point, we consider a 10 percentage point reduction in each tariff in turn. For the benchmark parameterization we find that in the long run, the reduction in the consumption tariff has weak sectoral and aggregate output effects. A comparable reduction in the investment tariff is much more stimulating, consistent with the empirical study of Estevadeordal and Taylor (2013).

The contrasting aggregate dynamics cause the two tariff rates to have sharply contrasting distributional effects. A reduction in the consumption tariff that is completed immediately has a negligible impact on wealth inequality, but a more significant negative effect, if implemented gradually. The long-run reduction in the consumption-wealth ratio dominates the decline in wealth inequality, so that long-run income inequality is always increased, but less so if it occurs gradually. In contrast, the immediate reduction in the investment tariff always reduces long-run wealth inequality. It also leads to a much smaller increase in long-run income inequality than does the consumption tariff, and if implemented gradually, it actually reduces long-run income inequality.

Overall, the numerical simulations performed for the benchmark economy suggest two important conclusions. First, assuming that the regression estimates reported in the [online Appendix](#) reflect the empirical reality that tariff policy is generally gradual, the numerical simulations are qualitatively consistent with this evidence, in suggesting that reducing the consumption tariff increases income inequality, while a gradual decrease in the investment tariff reduces income inequality. Second, reducing tariffs gradually is better from the standpoint of not exacerbating income inequality.

There is an extensive empirical literature exploring the relationship between various measures of trade liberalization and income inequality employing a range of measures of liberalization. Overall, the empirical evidence is inconclusive. Some studies focus on developed economies, others on developing economies, in some instances comparing the two. Often conflicting results are obtained. The fact that our simulations are

³ See e.g. Eichengreen (1981), Sen and Turnovsky (1989), Engel and Kletzer (1990), Fender and Yip (2000), who focus on the dynamic evolution of the aggregate economy in response to a consumption tariff.

⁴ We have examined the sample of 45 countries developed by Forbes (2000). There we see substantial variation in the speed with which countries reduced their tariffs over the period 1990–2010. Generally we find that advanced economies tended to reduce them at a much slower rate than have developing countries (approximately 6% per annum versus 12%).

based on a generic economy and highlight the channels through which the two tariffs impact income inequality offers the important advantage that the framework is sufficiently flexible to reconcile the diverse empirical estimates and provide plausible explanations for the different findings. Key features facilitating this are: (i) the contrasting distributional consequences of the two tariffs and (ii) that the distributional implications are highly sensitive to the speeds with which the tariff reductions are implemented and the intertemporal tradeoffs that this entails.⁵

The paper is organized as follows. Section 2 sets out the analytical framework, while Section 3 derives and characterizes the macroeconomic equilibrium. Section 4 characterizes the distributions of wealth, and income, and derives the main analytical results. Section 5 describes the calibration, while Sections 6 and 7 illustrate these results with numerical simulations describing the long-run and transitional effects of the alternative modes of tariff reduction. Section 8 compares the impact of the tariff reductions on the dynamics of wealth and income inequality. Section 9 concludes, while insofar as possible technical details are relegated to the Appendix.

2. Macroeconomic model

We consider an economy in which households consume a domestically produced tradable good, a domestic nontradable good, and an imported consumption good, the latter subject to a tariff, τ_c . They also accumulate some of the nontraded good as capital, which for expositional convenience and as a reflection of its nontradable characteristic, we designate as “structures”. In addition, households import a second capital good, denoted as “equipment”, which is subject to a tariff, τ_e . They also have access to an international financial market where they can borrow or lend. We focus on the case of international borrowing, so that the economy is a debtor nation, although the case of a lender is symmetric. Our justification is that the vast majority of economies are debtors, overwhelmingly so with respect to developing and emerging economies.⁶

2.1. Firms

Domestic production takes place in two sectors by a single aggregate representative firm. Output of the tradable good, Y_T , (the numeraire) is produced using structures (S_T), equipment (E_T), and labor (L_T) by means of a linearly homogeneous neoclassical production function:

$$Y_T = F(S_T, E_T, L_T) \equiv f(s_T, e_T)L_T, \quad \text{where } s_T \equiv \frac{S_T}{L_T}, e_T \equiv \frac{E_T}{L_T}. \quad (1a)$$

Analogously, the nontraded good (Y_N) is produced using structures (S_N), equipment (E_N), and labor (L_N) by means of a second linearly homogeneous production function:

⁵ References to and a detailed discussion of the relevant literature and examples of how by varying parameters appropriately this model can provide insight into the diverse results see the working paper version Turnovsky and Rojas-Vallejos (2018) available at https://econ.washington.edu/sites/econ/files/documents/research/turnovsky-rojas-final_version_05-18.pdf. In presenting the formal model, we should note that the evolution of wealth inequality plays a key role in determining the evolution of income inequality. Motivation for this is in part provided by the pioneering research of Piketty (2011). In doing so, we assume that labor is homogeneous and abstract from issues pertaining to the skill premium and its impact on wage inequality, a topic on which there is also an extensive empirical, but inconclusive, literature.

⁶ As supporting evidence we observe that of the 17 industrial economies in Forbes's (2000) dataset of 45 economies, 12 are debtors according to data reported in Lane and Milesi-Ferretti (2007, Fig. 10). Of the remaining 28 developing and emerging economies in Forbes's study, 25 are debtor nations again based on Lane and Milesi-Ferretti.

$$Y_N = H(S_N, E_N, L_N) \equiv h(s_N, e_N)L_N, \quad \text{where } s_N \equiv \frac{S_N}{L_N}, e_N \equiv \frac{E_N}{L_N} \quad (1b)$$

Factors of production can move freely between sectors, subject to their sectoral allocation constraints

$$S_T + S_N = S \quad (2a)$$

$$E_T + E_N = E \quad (2b)$$

$$L_T + L_N = 1 \quad (2c)$$

where S and E denote the aggregate capital stocks accumulated by households and $L = 1$, are the short-run supplies available to firms for allocation across the two sectors. The relative price, p , of nontraded output in terms of traded output serves as a proxy for the real exchange rate so that the total capital stock, K , in the economy measured in terms of the traded good is $K = pS + E$. The representative firm allocates its productive inputs to maximize profits, so that the returns to the two types of capital, r_s, r_e , and the wage rate, w , all expressed in terms of the numeraire satisfy, the conventional static efficiency conditions, expressed in intensive per capita units

$$r_s \equiv f_s(s_T, e_T) = ph_s(s_N, e_N) \quad (3a)$$

$$r_e \equiv f_e(s_T, e_T) = ph_e(s_N, e_N) \quad (3b)$$

$$w \equiv f(s_T, e_T) - s_T f_s(s_T, e_T) - e_T f_e(s_T, e_T) \\ = p[h(s_N, e_N) - s_N h_s(s_N, e_N) - e_N h_e(s_N, e_N)] \quad (3c)$$

In addition, the sectoral allocation equations (2a)–(2c) expressed in terms of intensive units become:

$$S = s_T L_T + s_N (1 - L_T) \quad (4a)$$

$$E = e_T L_T + e_N (1 - L_T) \quad (4b)$$

2.2. Consumers

The economy is populated by a mass 1 of infinitely-lived individuals, indexed by j , who are identical in all respects except for their initial endowments of structures, $S_{j,0}$, equipment, $E_{j,0}$ and their initial debt position, $Z_{j,0}$. While there are many potential sources of heterogeneity, initial endowments are arguably among the most significant.⁷ Since we are interested in distribution and inequality we shall focus on individual j 's relative holdings of capital and bonds, $s_j(t) \equiv S_j(t)/S(t)$, $e_j(t) \equiv E_j(t)/E(t)$, $z_j(t) \equiv Z_j(t)/Z(t)$, where $Z(t)$ denotes the economy-wide average stock of debt. Initial relative endowments, $s_{j,0}, e_{j,0}, z_{j,0}$ have mean 1 and relative standard deviations, $\sigma_{s,0}, \sigma_{e,0}, \sigma_{z,0}$ across agents.⁸ Each agent is also endowed with one unit of time that he can allocate to labor in the traded sector, $L_{j,T}$, or in the nontraded sector, $L_{j,N}$, implying $L_{j,T}(t) + L_{j,N}(t) = 1$. With a continuum of agents, the economy-wide supply of labor in each sector is $L_z = \int_0^1 L_{j,z} dj$ ($z = T, N$) with the economy-wide labor supply fixed inelastically at unity. Other aggregates are defined analogously.

All agents have identical lifetime utility that depends upon an isoe-

⁷ Compelling evidence supporting this view is provided by the well known studies by Piketty (2011) and Stiglitz (2012).

⁸ These initial endowments can be perfectly arbitrary and therefore consistent with any required non-negativity constraints. They may also be correlated across agents. As will become apparent in the course of the analysis, the form of the distribution of the initial endowments will be reflected in the evolving distributions of wealth and income.

lastic function of the domestically produced tradable good, $C_{j,T}$, the domestically produced nontradable good, $C_{j,N}$, and the imported consumption good, $C_{j,F}$, the latter subject to a tariff, τ_c :

$$U_j = \frac{1}{\gamma} \int_0^\infty \left[(C_{j,T})^\theta (C_{j,N})^{1-\theta} (C_{j,F})^\eta \right]^\gamma e^{-\beta t} dt \tag{5}$$

$$0 \leq \theta \leq 1, 0 < \eta, -\infty < \gamma \leq 1, \theta\gamma < 1, \eta\gamma < 1$$

where $1/(1-\gamma)$ is the household's intertemporal elasticity of substitution, θ measures the relative importance of the domestic traded vs. nontraded consumption, η , parameterizes the relative importance of the imported consumption good, and β is the subjective discount rate. The remaining restrictions in (5) ensure concavity of the utility function in the three consumption goods.

Households own both capital stocks, which depreciate at the constant rates, δ_S and δ_E , respectively. Thus, each household's investment expenditures on structures, $I_{j,S}$, and equipment, $I_{j,E}$, are governed by the conventional accumulation equations

$$\dot{S}_j = I_{j,S} - \delta_S S_j \tag{6a}$$

$$\dot{E}_j = I_{j,E} - \delta_E E_j \tag{6b}$$

We assume that the agent chooses his rates of consumption, $C_{j,T}(t)$, $C_{j,N}(t)$, $C_{j,F}(t)$, and rates of accumulation of structures, $S_j(t)$, equipment, $E_j(t)$, and international debt, $Z_j(t)$, so as to maximize intertemporal utility, (5), subject to his capital accumulation equations, (6a) and (6b), and flow budget constraint. Expressed in terms of units of domestic tradable output as numeraire, this is

$$\begin{aligned} \dot{Z}_j(t) = & C_{j,T} + pC_{j,N} + (1 + \tau_c)C_{j,F} + pI_{j,S} + (1 + \tau_c)I_{j,E} - w - r_s S_j - r_e E_j \\ & - T_j + i \left(\frac{Z}{pS} \right) Z_j \end{aligned} \tag{7}$$

where we normalize the (international) price of the imported consumption good and imported investment good to equal the unitary price of the tradable consumption good.

Equation (7) asserts that the agent's expenditures comprise his consumption of the domestic tradable good, his consumption and investment expenditures on the nontradable good, the imported consumption good and equipment, both inclusive of their respective tariffs, together with the interest owing on his holdings of debt. His earnings include wages, income from his holdings of nontraded and traded capital, and lump-sum transfers received from the government. To the extent that expenditures exceed income the agent accumulates debt and vice versa.

The budget constraint is written from the standpoint of a borrower, although $Z_j < 0$ corresponds to a lender. Whether the equilibrium turns out to be one in which the agent is a debtor or creditor depends upon the relative magnitudes of the rate of time preference and the given world rate of interest, i^* . In either case, a key element of the model is that while the economy has access to the international capital market, it faces a friction in the form of increasing borrowing costs expressed by:

$$i \left(\frac{Z}{pS} \right) = i^* + v \left(\frac{Z}{pS} \right). \quad v(0) = 0, v' > 0, v'' > 0 \tag{8}$$

This equation asserts that the financial friction facing the economy is in the form of a borrowing premium $v(\cdot)$ over the fixed world interest rate. The premium is a positive convex function of its debt relative to its level of development as parameterized by its stock of domestically produced (nontraded) capital. There are several alternative ways to formulate this borrowing constraint, but the qualitative implications are essentially identical. The shape of the function reflects the degree of openness of the economy with respect to the international financial market, and the fact

that the debt is normalized by the market value of nontraded capital means that larger, wealthier, economies are less constrained by the financial friction implicit in (8). While the individual household takes the borrowing costs as given, the equilibrium borrowing cost is determined by their collective actions.

Details of the optimization and the agent's resulting consumption expenditures are provided in Appendix A.1. Having identical preferences, each individual consumes the three consumption goods in the same proportion; see equations (A.2a)–(A.2c).

2.3. The government

To isolate the impact of the tariff reduction, the domestic government is assigned a very minor role, simply levying the tariffs on the imported consumption good and equipment and then rebating the revenues to consumers as lump-sum transfers. It issues no debt, nor conducts any other expenditures, maintaining a balanced budget in accordance with

$$T(t) = \tau_c(t)C_F(t) + \tau_e(t)I_E(t) \tag{9}$$

where $C_F(t)$, $I_E(t)$ denote aggregates. To avoid ad hoc distributional effects we assume further that the tariff revenues are rebated uniformly across the agents so that $T_j(t) = T(t)$ for each j .

Programs of trade liberalization, and specifically tariff reductions, typically involve extensive negotiations and therefore are likely to be implemented gradually over an extended period of time. To allow for this we assume that tariffs are adjusted gradually from the initial rates, $\tau_{c,0}$, $\tau_{e,0}$, to their post liberalization rates, $\tilde{\tau}_c, \tilde{\tau}_e$, in accordance with the known path

$$\tau_z(t) = \tilde{\tau}_z + (\tau_{z,0} - \tilde{\tau}_z)e^{-\nu_z t}, \quad z = c, e \tag{10}$$

The parameter, $\nu_z > 0$, thus specifies the speed with which the tariff change occurs, and hence defines the time path it follows. The conventional assumption, where the tariff is fully adjusted instantaneously, is obtained by letting $\nu_z \rightarrow \infty$ in (10). But the more general specification introduced in (10) is important. This is because, as the numerical simulations will demonstrate, there is a sharp contrast between how ν_z affects the adjustment of *aggregate quantities* and their *distributions* across agents. As expected, the time path of tariffs affects the transitional path of the aggregate economy and not the aggregate steady state. But in contrast, it influences both the time paths and the steady-state levels of both wealth and income inequality, thereby having permanent distributional consequences.⁹

3. Macroeconomic equilibrium

In Appendix A.2 we show how the decisions of the agents described in Section 3 lead to the macroeconomic equilibrium summarized by the following dynamic equations:

$$\dot{S} = h(s_N, e_N)(1 - L_T) - \left(\frac{1 - \theta}{1 + \eta} \right) \frac{C}{p} - \delta_S S \tag{11a}$$

$$\begin{aligned} (1 - E_Z)\dot{Z} = & \left(\frac{\theta}{1 + \eta} + \frac{\eta}{(1 + \eta)(1 + \tau_c)} \right) C + \delta_E E - f(s_T, e_T)L_T + i \left(\frac{Z}{pS} \right) Z \\ & + E_p \dot{p} + E_S \dot{S} + E_{\tau_c} \dot{\tau}_c \end{aligned} \tag{11b}$$

⁹ This is because the homogeneity of the utility function (5), which causes individuals to maintain fixed relative consumption over time, introduces a “zero root” into the dynamics of the distributional measures, as a result of which their equilibrium values become path dependent; see Atolia et al. (2012) where this general issue is discussed in more detail.

$$\frac{\dot{p}}{p} = \left[i\left(\frac{Z}{pS}\right) - (h_s(s_N, e_N) - \delta_S) \right] \tag{11c}$$

$$\begin{aligned} \frac{\dot{C}}{C} = & \frac{1}{1 - \gamma(1 + \eta)} \left[(1 - \theta)\gamma(h_s(s_N, e_N) - \delta_S) + [1 - \gamma(1 - \theta)]i\left(\frac{Z}{pS}\right) - \beta \right. \\ & \left. - \eta\gamma\left(\frac{\dot{\tau}_c}{1 + \tau_c}\right) \right] \end{aligned} \tag{11d}$$

$$\dot{\tau}_c = -\nu_c(\tau_c - \tilde{\tau}_c) \tag{11e}$$

$$\dot{\tau}_e = -\nu_e(\tau_e - \tilde{\tau}_e) \tag{11f}$$

where S, Z are aggregates defined above and $C \equiv C_T + pC_N + (1 + \tau_c)C_F$ denotes aggregate consumption expenditure, inclusive of the consumption tariff. The sectoral capital intensities s_T, e_T, s_N, e_N , labor allocation L_T , and equipment, E , are obtained from the short-run efficiency conditions, (3a)–(3c), the sectoral allocation equations (4a) and (4b) combined with the arbitrage conditions (A.1d) and (A.1f). In each case the variable can be expressed in terms of the dynamically evolving variables S, Z, p, τ_e . Equation (11a) describes equilibrium accumulation of structures consistent with maintaining equilibrium in the nontraded goods market; (11b) describes the aggregate accumulation of debt; (11c) describes the equilibrium relationship between the rate of return on structures and debt implied by (A.1d) and (A.1e); (11d) describes the equilibrium dynamics of aggregate consumption; (11e) and (11f) specify the rates of tariff adjustment.

One key observation is that the aggregate equilibrium is independent of any distributional considerations. This is a consequence of the homogeneity assumptions and a reflection of the “representative consumer theory of distribution” that our approach embodies. In Section 7 below we shall analyze the local dynamics following a decrease in the tariff rates, by linearizing the dynamic equations about their steady state. The formal structure of this system is set out in (A.15).

3.1. Steady-state equilibrium

The steady-state equilibrium (denoted by tildes) is attained when $\dot{S} = \dot{Z} = \dot{C} = \dot{p} = \dot{E} = \dot{\tau}_e = \dot{\tau}_c = 0$. As is characteristic of the standard two sector-two good dependent economy model, steady state is determined in two stages. In the first, the sectoral capital labor ratios and relative price are determined. Having derived these, aggregate market clearing conditions determine the equilibrium levels. Thus, combining (3a)–(3d), together with (A.1e) and (A.1f), yields:

$$f_s(\tilde{s}_T, \tilde{e}_T) = \tilde{p}h_s(\tilde{s}_N, \tilde{e}_N) \tag{12a}$$

$$f_e(\tilde{s}_T, \tilde{e}_T) = \tilde{p}h_e(\tilde{s}_N, \tilde{e}_N) \tag{12b}$$

$$\begin{aligned} f(\tilde{s}_T, \tilde{e}_T) - \tilde{s}_T f_s(\tilde{s}_T, \tilde{e}_T) - \tilde{e}_T f_e(\tilde{s}_T, \tilde{e}_T) = & \tilde{p}[h(\tilde{s}_N, \tilde{e}_N) - \tilde{s}_N h_s(\tilde{s}_N, \tilde{e}_N) \\ & - \tilde{e}_N h_e(\tilde{s}_N, \tilde{e}_N)] \end{aligned} \tag{12c}$$

$$f_e(\tilde{s}_T, \tilde{e}_T) = [\beta + \delta_E](1 + \tilde{\tau}_e) \tag{12d}$$

$$h_s(\tilde{s}_N, \tilde{e}_N) = \beta + \delta_S \tag{12e}$$

These five equations determine the long-run equilibrium values of $\tilde{s}_T, \tilde{s}_N, \tilde{e}_T, \tilde{e}_N$, together with \tilde{p} , independently of demand conditions, including the consumption tariff, τ_c . As a further consequence, the long-run wage rate and return to capital are unaffected, while sectoral outputs, \tilde{Y}_T, \tilde{Y}_N move in proportion to sectoral labor movements, \tilde{L}_T, \tilde{L}_N ; see equations (1a) and (1b). In contrast, by directly affecting the rate of return on investment in equipment, (12d), the investment tariff impacts all these quantities. In the case that the sectoral production functions $f(s_T, e_T)$,

$h(s_N, e_N)$ are of the CES form with a common elasticity of substitution less than unity ($\sigma \leq 1$), so that structures and equipment are complements in production, one can show that a decrease in the investment tariff increases all four sectoral capital-labor ratios. The effect on the relative price, however, depends upon the relative sectoral intensities of the two capital goods. These responses are critical causes of the contrasting distributional effects of the two tariffs, which we summarize in the following proposition:

Proposition 1.

- (i) Reducing the consumption tariff has no long-run effect on sectoral capital intensities, $\tilde{s}_T, \tilde{s}_N, \tilde{e}_T, \tilde{e}_N$, the wage, \tilde{w} , or the returns to structures or equipment, \tilde{r}_s, \tilde{r}_e . Sectoral output responses are proportional to sectoral labor reallocation.
- (ii) If $\sigma \leq 1$, reducing the investment tariff increases all sectoral capital intensities, $\tilde{s}_T, \tilde{s}_N, \tilde{e}_T, \tilde{e}_N$, raising \tilde{w} . It reduces the return on equipment, \tilde{r}_e while its effect on structures, \tilde{r}_s reflects that of \tilde{p} .

The remaining steady-state conditions are:

$$\tilde{S} = \tilde{s}_T \tilde{L}_T + \tilde{s}_N (1 - \tilde{L}_T) \tag{13a}$$

$$\tilde{E} = \tilde{e}_T \tilde{L}_T + \tilde{e}_N (1 - \tilde{L}_T) \tag{13b}$$

$$h(\tilde{s}_N, \tilde{e}_N)(1 - \tilde{L}_T) - \left(\frac{1 - \theta}{1 + \eta}\right) \frac{\tilde{C}}{\tilde{p}} - \delta_S \tilde{S} = 0 \tag{13c}$$

$$f(\tilde{s}_T, \tilde{e}_T) \tilde{L}_T - \beta \tilde{Z} = \left(\frac{\theta}{1 + \eta} + \frac{\eta}{(1 + \eta)(1 + \tilde{\tau}_e)}\right) \tilde{C} + \delta_E \tilde{E} \tag{13d}$$

$$i\left(\frac{\tilde{Z}}{\tilde{p}\tilde{S}}\right) = \beta \tag{13e}$$

Having obtained $\tilde{s}_T, \tilde{s}_N, \tilde{e}_T, \tilde{e}_N$, and \tilde{p} , equations (13a)–(13e) determine the equilibrium sectoral labor allocation, \tilde{L}_T , the equilibrium capital stocks, \tilde{S}, \tilde{E} , the stock of debt, \tilde{Z} and aggregate consumption, \tilde{C} . Comparing (12) and (13) highlights the distinct ways the two tariff rates impinge on the economy. The investment tariff, $\tilde{\tau}_e$, exerts its entire impact via the production decisions in (12) [see 12a]. In contrast, the role of the consumption tariff, $\tilde{\tau}_c$ is to ensure that the total demand for imports (consumption plus investment) is consistent with the country's resources generated by its production, adjusted for its debt-serving commitments [see 13d]. Finally, from (12) and (13) we can infer all other equilibrium quantities such as the sectoral outputs and the various components of consumption.

4. Wealth and income inequality

We now analyze the consequences of tariff liberalization for wealth and income inequality.

4.1. Wealth inequality

To abstract from any direct, but arbitrary, discretionary distributional effects arising from lump-sum transfers, we assume that tariff revenues are rebated uniformly across the agents, namely $T_j(t) = T(t)$, for all j . For convenience, we shall price imported equipment inclusive of the tariff, so that the gross wealth of household j , measured in terms of traded output is

$$V_j = pS_j + (1 + \tau_e)E_j - Z_j \tag{14}$$

where we assume that $V_j > 0$ so that the agent has net positive wealth and is therefore solvent. Taking the time derivative of (14), using the individual's budget constraint, (7), the arbitrage condition, (A.1e), and the distributional assumption $T_j(t) = T(t)$, the rate of wealth

accumulation for agent j is

$$\dot{V}_j(t) = i \left(\frac{Z}{\rho S} \right) V_j(t) + w(t) + T - C_j \quad (15)$$

and aggregating over all agents j yields

$$\dot{V}(t) = i \left(\frac{Z}{\rho S} \right) V(t) + w(t) + T - C \quad (15')$$

Next, we define individual j 's share of aggregate wealth to be $v_j \equiv V_j/V$. Taking the time derivative of v_j and combining with (15) and (15'), together with $C_j = \varphi_j C$, we obtain

$$\dot{v}_j = \frac{1}{V} \{ [C(t) - w(t) - T(t)](v_j - 1) + (1 - \varphi_j)C(t) \} \quad (16)$$

Equation (16) indicates how the evolution of an individual agent's relative wealth depends upon the evolution of aggregate gross consumption expenditure, the real wage rate, as well as his own specific endowments as reflected in v_j and φ_j .

Before proceeding it is convenient to consider some of the steady-state relationships between consumption and wealth. First, considering (15') at steady state and using (13e), we see that

$$\tilde{C} = \beta \tilde{V} + \tilde{w} + \tilde{T} \quad (17)$$

so that aggregate steady-state consumption equals the income from wealth, plus wage income and the tariff revenue. Next, considering (15) at steady state and subtracting (17) yields:

$$\tilde{C}_j - \tilde{C} = \beta \tilde{V}(\tilde{v}_j - 1) = \beta(\tilde{V}_j - \tilde{V}) \quad (18)$$

From (18) we see that if agent j has above average wealth, his long-run marginal propensity to consume (inclusive of the tariff) out of the above-average component of his wealth equals β . Also, since (17) implies $\tilde{C} > \beta \tilde{V}$, it follows that the average long-run propensity to consume out of wealth exceeds β , implying that wealthier agents save proportionately more and consume proportionately less.

From (18) we obtain $\varphi_j - 1 = (\beta \tilde{V} / \tilde{C})(\tilde{v}_j - 1)$, enabling us to write (16) as¹⁰:

$$\dot{v}_j = (1/V) \{ [C(t) - w(t) - T(t)](v_j - 1) + (\beta \tilde{V} / \tilde{C})(1 - \tilde{v}_j)C(t) \} \quad (19)$$

To determine the evolution of wealth inequality involves three steps. First, we linearize (19) around the steady state $[\tilde{C}, \tilde{w}, \tilde{V}, \tilde{T}]$. Second, for the long-run distribution of wealth to be non-degenerate, $v_j(t)$ must be bounded and this requires that the forward-looking solution to (19) be chosen.¹¹ Third, wealth inequality measured as a coefficient of variation is conveniently obtained by integrating the relative wealth across agents. Details are provided in Appendix A.3, where the time path of wealth inequality, $\sigma_v(t)$, is summarized by

$$\sigma_v(t) = \chi(t) \tilde{\sigma}_v = \frac{\chi(t)}{\chi(0)} \tilde{\sigma}_{v,0} \quad (20a)$$

and for notational convenience

¹⁰ Since $\beta \tilde{V} / \tilde{C} < 1$ we see that consumption inequality, which remains constant, is less than long-run wealth inequality.

¹¹ In general, the initial jumps in $p(0)$, and $C(0)$, following any structural change, will cause an initial jump in $v_j(0)$ from its previous stationary level. For the simulations we perform this turns out to be extremely small, and it will be exactly zero if initially all agents hold the same portfolio shares, as we shall henceforth assume, in which case $v_j(0) = v_{j,0}$.

$$\chi(t) \equiv \left\{ 1 + \frac{(\tilde{w} + \tilde{T})}{\tilde{V}} \int_t^\infty \left[\frac{w(u) + T(u)}{(\tilde{w} + \tilde{T})} - \frac{C(u)}{\tilde{C}} \right] e^{-\beta(u-t)} du \right\} \quad (20b)$$

Written in this way we can identify the elements driving the dynamics of relative wealth, and therefore its distribution across agents, which occur as the economy traverses its transitional path. The first is the time path of the discounted present value of labor income plus tariff revenues, which we refer to as "gross labor income". With wage income and tariff revenues being uniformly distributed across agents, the more rapidly these approach their new steady-state values following a tariff change, the less the accumulated wealth differences along the transitional path and the smaller the effect on wealth inequality. This is compared to the discounted present value of consumption along the transitional path. Since wealthier people consume relative less and save relatively more, thereby accumulating wealth at a faster rate, more rapid growth in aggregate consumption is associated with increasing wealth inequality. We may summarize this in:

Proposition 2. To the extent that gross labor income is increasing (decreasing) during the transition it will lead to a permanent decrease (increase) in wealth inequality. To the extent that aggregate consumption is increasing (decreasing) it will lead to a permanent increase (decrease) in wealth inequality. Both responses depend upon the speed with which they are occurring.

4.2. Income inequality

There are several natural measures of income inequality that one can consider. We focus on disposable income, taken to include net return on wealth, labor income, plus the transfers received from the tariff revenues. Using the arbitrage conditions (A.1d)–(A.1f), agent j 's income is

$$Q_j(t) = i(t)V_j(t) + w(t) + T(t) \quad (21)$$

with aggregate income being:

$$Q(t) = i(t)V(t) + w(t) + T(t) \quad (21')$$

so that the agent's relative income, $q_j(t) = Q_j(t)/Q(t)$, is

$$q_j(t) - 1 = \frac{i(t)V(t)}{i(t)V(t) + w(t) + T(t)} (v_j(t) - 1) \quad (22)$$

Again, the linearity of (22) enables one to express the relationship between relative income and relative wealth in terms of the coefficients of variation of their respective distributions, σ_q and σ_v , namely

$$\sigma_q(t) = \frac{i(t)V(t)}{i(t)V(t) + w(t) + T(t)} \sigma_v(t) \equiv \zeta(t) \sigma_v(t) \quad (23)$$

where $\zeta(t) \equiv i(t)V(t)/[i(t)V(t) + w(t) + T(t)]$ denotes the share of income from wealth in total disposable income. Hence, at any instant of time inequality can be decomposed into two elements. The first is the dynamics of wealth inequality, $\sigma_v(t)$; the second is the dynamics of factor returns as they impact the share of income from net wealth, $\zeta(t)$.

Assuming that the economy starts out in an initial steady state, (23) reduces to

$$\tilde{\sigma}_{q,0} = \left(\frac{\beta \tilde{V}_0}{\beta \tilde{V}_0 + \tilde{w}_0 + \tilde{T}_0} \right) \tilde{\sigma}_{v,0} \quad (24)$$

and dividing (23) by (24) we derive the following expression for income inequality relative to the initial long-run inequality

$$\frac{\sigma_q(t)}{\tilde{\sigma}_{q,0}} = \zeta(t) \left[\frac{\beta \tilde{V}_0 + \tilde{w}_0 + \tilde{T}_0}{\beta \tilde{V}_0} \right] \frac{\sigma_v(t)}{\tilde{\sigma}_{v,0}} \quad (25)$$

In steady state (25) reduces to:

$$\frac{\bar{\sigma}_q}{\bar{\sigma}_{q,0}} = \left(\frac{\bar{C}_0/\bar{V}_0}{\bar{C}/\bar{V}} \right) \frac{\bar{\sigma}_v}{\bar{\sigma}_{v,0}} \tag{25}$$

so that long-run income inequality varies positively with long-run changes in wealth inequality and inversely with changes in the gross consumption-wealth ratio. The latter response reflects the fact wealthier people consume relatively less and save relatively more, enabling us to state:

Proposition 3. To the extent that a tariff reduction reduces the gross consumption-wealth ratio it will increase long-run income inequality. To the extent that it decreases (increases) wealth inequality it will decrease (further increase) income inequality.

Thus, the overall effect of a tariff change on income inequality will incorporate both these effects. As our numerical simulations suggest, for plausible calibrations a reduction in either tariff will likely reduce wealth inequality. In addition both tariffs tend to reduce the C/V ratio. In general, the decline in response to a reduction in τ_c is sufficiently large to dominate the wealth inequality effect causing long-run income inequality to rise. However, the decline following the reduction in τ_e is somewhat smaller, reducing the increase in income inequality; indeed in some cases it is actually dominated by the wealth inequality effect so that income inequality actually declines.

5. Numerical analysis

To study the local dynamics of the economy following a reduction in tariffs, we employ the linearized system (A.15). The simulations are based on the constant elasticity utility function, (5), while the sectoral production functions are specified as follows:

$$Y_T = A_T [\alpha_T (S_T)^{-\rho} + (1 - \alpha_T)(E_T)^{-\rho}]^{-\frac{\omega_T}{\rho}} (L_T)^{1-\omega_T} \equiv A_T [\alpha_T (s_T)^{-\rho} + (1 - \alpha_T)(e_T)^{-\rho}]^{-\frac{\omega_T}{\rho}} L_T$$

$$Y_N = A_N [\alpha_N (S_N)^{-\rho} + (1 - \alpha_N)(E_N)^{-\rho}]^{-\frac{\omega_N}{\rho}} (L_N)^{1-\omega_N} \equiv A_N [\alpha_N (s_N)^{-\rho} + (1 - \alpha_N)(e_N)^{-\rho}]^{-\frac{\omega_N}{\rho}} L_N$$

The production functions for both sectors are of CES form between the two capital goods, which then combine with labor in Cobb-Douglas form. The elasticity of substitution between the two capital goods is assumed to be the same in the two sectors. The coefficients α_T, α_N characterize the relative intensity of nontraded to traded capital in the two production functions, while $1 - \omega_T, 1 - \omega_N$ parameterize the degree of labor intensity. In addition, the convex increasing borrowing constraint is:

$$i = i^* + \zeta [e^{a(Z/pS)} - 1]$$

5.1. Calibration

Because our basic model is generic and applies to countries at varying stages of development, with a correspondingly wide range of relevant parameters, we adopt the following strategy for its calibration. We first choose a set of benchmark parameters obtained from empirical estimates and other various available sources, generally representing consensus estimates. These are summarized in Table 1.A, with the equilibrium values of key macro quantities reported in Table 1.B. These are taken to be typical of an emerging trade-dependent open economy. Then in Table A.1, briefly summarized in Section 8.4 below, we subject key parameters to extensive sensitivity analysis, with the objective of characterizing the differential impacts on more or less developed economies.

Turning first to preferences, $\gamma = -1.5$ implies an intertemporal elasticity of substitution equal to 0.4, well within the range of empirical estimates; see Guvenen (2006). The exponents on preferences,

Table 1
Benchmark calibration and equilibrium.

A. The Benchmark Economy	
Preference parameters:	$\gamma = -1.5; \theta = 0.40; \eta = 0.20, (0.40); \beta = 0.05$
Production parameters:	$\alpha_T = 0.60, (0.40); \alpha_N = 0.60, (0.40); \omega_T = 0.44, (0.50); \omega_N = 0.28, (0.34); \sigma = 1.0, (0.2, 0.5, 1.5)$
Productivity parameters:	$A_T = 1.0, A_N = 1.0$
Depreciation rate:	$\delta_S = 0.075, \delta_E = 0.10$
World interest rate:	$i^* = 0.035$
Premium on borrowing:	$a = 0.06, (0.03, 0.10)$
Weight on the premium:	$\xi = 1$
Tariffs:	$\tau_c = 0.22, \tau_e = 0.11$
B. Key Equilibrium Quantities	
Capital-Output ratio:	2.57
Consumption to Wealth:	0.35
Debt-GDP:	0.42
Tariff revenues/GDP	3.5%
$\bar{p}\bar{S}/\bar{E}$:	2.00
Labor productivity traded/ nontraded	1.29
Labor share of income:	0.64
Traded share of GDP	0.48
Labor employed in traded sector, L_T	0.42
Wealth inequality	1
Income inequality	0.14

$\theta = 0.4, \eta = 0.2$ imply that 50% of total consumption expenditures are on tradables, consistent with evidence of Lombardo and Ravenna (2012).¹² The rate of time preference of 5% together with the world (real) interest rate of 3.5%, and the parameterization of the borrowing premium ($a = 0.06, \xi = 1$) implies that the economy is a debtor with an equilib-

rium debt-GDP ratio of 0.42.

It is apparent from the evidence provided by Lane and Milesi-Ferretti (2007) that the net position of countries – developed and less developed – in the international financial market varies dramatically both over countries and over time. Our benchmark equilibrium ratio is close to the average of major emerging economies like Brazil (2004), Indonesia (1996, 2004), Turkey (1996, 2004) and Mexico (1996, 2004).¹³ Industrial economies such as Netherlands, Sweden, Canada, as well as many Latin American Countries (Colombia, Uruguay, Argentina) have debt-GDP ratios of around 0.2. At the other extreme, several economies, including both developed countries (New Zealand, Australia), as well as less developed economies (particularly African economies and ex Soviet states) have ratios approaching unity. Since it turns out that the distributional implications of reductions in the investment tariff are highly sensitive to the country's debt position, which in turn is driven by the borrowing premium, in Table A.1 below we subject this parameter to a degree of sensitivity analysis which effectively spans this range of debt-GDP ratios.

Information on the production structure of two sector models is sparse, although detailed information is provided by Bems (2008). Using

¹² Using the definition of tradable consumption based on the share in CPI expenditure, Lombardo and Ravenna (2012) find the mean tradable consumption share in a sample of 25 industrial and emerging economies to be around 55% or 49%, depending upon the threshold used to define tradable.

¹³ World Bank Development Indicators.

a UN sample exceeding 110 countries over the period 1960–2004, he finds that an average of around 60% of aggregate investment expenditures are devoted to nontradables, an allocation that he finds is extremely stable over time. Assuming depreciation rates of structures and equipment $\delta_S = 0.075$ and $\delta_E = 0.10$, respectively, in steady state the constraint $\tilde{p}\tilde{I}_S = 0.6(\tilde{p}\tilde{I}_S + \tilde{I}_E)$ translates to $\tilde{p}\tilde{S}/\tilde{E} = 2.0$, a ratio that our steady state exactly matches (2.00).

Since the nontraded sector includes services that are generally more labor intensive, we set $\omega_T = 0.44$, $\omega_N = 0.28$, implying corresponding sectoral elasticities of labor productivity of 0.56 and 0.72, respectively. Given the rest of the calibration this yields an equilibrium labor share of output of around 0.64. While this is typical of developed economies, [Guerrero \(2012\)](#) suggests that it is somewhat lower for developing countries, an issue we address as part of our sensitivity analysis.

Further constraints are obtained by applying the equilibrium sectoral allocation conditions (12). As a benchmark we assume that the two sectors are equally intensive in the two capital goods, setting $\alpha_T = \alpha_N = \alpha$. In this case (12a)–(12c) imply

$$\frac{\tilde{s}_T}{\tilde{s}_N} = \frac{\tilde{e}_T}{\tilde{e}_N} = \left(\frac{1 - \omega_N}{1 - \omega_T} \right) \frac{\omega_T}{\omega_N} = 2.02 \quad (26a)$$

which, together with the capital market clearing conditions (13a), (13b), implies

$$\frac{\tilde{p}\tilde{s}_T}{\tilde{e}_T} = \frac{\tilde{p}\tilde{s}_N}{\tilde{e}_N} = \frac{\tilde{p}\tilde{S}}{\tilde{E}} = 2.00 \quad (26b)$$

Another crucial parameter is the elasticity of substitution, σ , between the two capital goods, structures and equipment. Early empirical studies by [Sato \(1967\)](#) and [Boddy and Gort \(1971\)](#) employ data on US manufacturing and obtain estimates of 1.63 and 1.72, respectively. Using data for 43 countries, [Temple \(1998\)](#) estimates $\sigma = 0.97$, insignificantly different from 1, while [Krusell et al. \(2000\)](#) set $\sigma = 1$. However, we should bear in mind that in our analysis “structures” and “equipment” pertain to domestic and imported capital, for which estimates of σ are much sparser. [Hentschel \(1992, Table 5.7\)](#) estimates σ between domestic and imported capital goods for 12 emerging, economies. Estimates range from 0.15 to 1.37, most being below 1 and none being significantly greater than 1.¹⁴ On the basis of this evidence, we choose $\sigma = 1$ as the benchmark and vary σ between 0.2, and 1.5, thereby capturing most of the variation in the empirical estimates.

The final key productive parameter is α . In general the productive elasticity of structures in the composite “capital index” $K \equiv [\alpha S^{-\rho} + (1 - \alpha)E^{-\rho}]^{-1/\rho}$ is $\alpha(S/K)^{-\rho}$ which reduces to α in the benchmark case of the Cobb-Douglas function. If we assume that this reflects the relative expenditure devoted to nontraded capital, this suggests setting $\alpha = 0.6$ as the appropriate benchmark, although some variation is allowed in our sensitivity analysis.

The implied aggregate capital-output ratio is 2.57. The share of GDP produced in the traded sector 0.48 is close to the average of the set of economies reported by [Morshed and Turnovsky \(2004\)](#). With around 42% of labor employed in that sector this implies the ratio of labor productivity in the traded sector to that in the nontraded sector to be about 1.29. A recent study employing a panel of 56 countries by [Mano](#)

¹⁴ The 12 economies comprise 9 Latin American countries, plus Indonesia, Malaysia, and the Philippines.

¹⁵ The equilibrium consumption-wealth ratio implies that the ratio of income inequality to that of wealth inequality, as measured by the relative coefficient of variation is around 0.14. While the Gini coefficient on wealth is uniformly significantly larger than that of income, this ratio overstates the difference. The main reason for this is because much of income inequality is due to wage inequality, which we abstract from here. Despite this caveat, we feel that the measure provides reasonable guidance to the relative impacts of the changes in tariff policy on both wealth and income inequality.

and [Castillo \(2015\)](#) shows how this productivity ratio varies across regions and industries. Our estimate of 1.29 is remarkably close to their all sample benchmark ratio of 1.26.¹⁵

The base tariff on consumption is set at 22%, while the investment tariff is set at 11%, which is close to the average of low and middle income countries for around 1990; see [World Bank \(2015\)](#). Together they generate a tariff revenue of around 3.5% of GDP, which is very close to the average of emerging economies for the period 1995–2000.¹⁶

While we do not attempt to calibrate to a specific economy or episode, we view this calibrated equilibrium as providing a plausible benchmark designed to facilitate our understanding of the mechanisms in play as the economy evolves over time in response to tariff reductions, the specification of which is as follows. Starting from the initial benchmark, $\tau_c = 0.22$, $\tau_e = 0.11$, in each case we specify a 10 percentage point reduction in two alternative ways.¹⁷ The first assumes the reduction is completed instantaneously. The second specifies the reduction to occur gradually, at the constant rate of 10% per year (cf. footnote 4). The key point is that the moment the tariff policy is announced, its *future* levels along the transitional path become fully anticipated and begin to influence behavior.

6. Tariff reductions: long-run aggregate effects

We begin by comparing the long-run effects of a 10 percentage point reduction in the two tariff rates for the benchmark parameterization presented in [Table 2](#).

6.1. Reduction in consumption tariff

The reduction in τ_c leaves the long-run relative price, \tilde{p} , sectoral capital intensities $(\tilde{s}_T, \tilde{s}_N, \tilde{e}_T, \tilde{e}_N)$, and factor returns unchanged, consistent with (12). The reduced consumption tariff lowers the domestic price of the imported consumption good, encouraging more trade, shifting resources from the nontraded to the traded sector. Thus L_T increases by around 0.5 percentage points (1.20%) with a corresponding reduction in L_N . The constancy of the sectoral capital intensities implies that the two capital goods both move in the same proportions. With $s_T > s_N, e_T > e_N$, (13a) and (13b) imply that in long-run equilibrium the total stocks of both capital goods increase slightly, with the increase in \tilde{E} slightly exceeding that of \tilde{S} . This results in an overall increase in the total capital stock, \tilde{K} , of around 0.35%. In addition, with the sectoral capital-labor ratios, s_T etc., remaining unchanged, the reallocation of resources to the traded sector means that \tilde{Y}_T increases while \tilde{Y}_N declines and since $s_T/s_N = e_T/e_N > 1$ the increase in \tilde{Y}_T exceeds the decline in \tilde{Y}_N . The resulting marginal increase in GDP is less than that of \tilde{K} , and the overall capital-output ratio rises. The reduction in nontraded output, coupled with the resources necessary to replace the depreciated nontraded capital, leaves less nontraded output available for consumption. The proportionality of the three consumption components [see (A.4a)–(A.4c)] thus requires overall consumption, \tilde{C} , to decline. With the long-run borrowing cost tied to β , the long-run increase in \tilde{S} is matched by a proportional long-run increase in foreign debt, \tilde{Z} . This offsets the increase in capital and overall gross wealth, \tilde{V} , increases by 0.33%. Finally, the decline in \tilde{C} , coupled with the increase in \tilde{V} implies a reduction in the equilibrium \tilde{C}/\tilde{V} of 1.52%.

6.2. Reduction in investment tariff

With $\alpha_T = \alpha_N$, reducing the tariff on investment, τ_e , by 10 percentage

¹⁶ See [OECD \(2015, Graph 9.3\)](#).

¹⁷ The combination of these tariff cuts reduces the share of tariff revenues to GDP from 3.5% to around 1.5%, which is the average of the developing countries over the period 2008–2012; see [OECD \(2015, Graph 9.3\)](#).

Table 2

Key steady-state equilibrium ratios and steady-state responses to tariff reduction. Benchmark case; $\alpha_T = \alpha_N = 0.60$; $\sigma = 1$.

A. Aggregate quantities													
	YN	YT	Y	S	E	p	K	K/Y	LT	Z/Y	C	V	C/V
Initial Eq $\tau_c = 0.22, \tau_e = 0.11$	0.595	0.582	1.220	1.948	1.044	1.071	3.130	2.566	0.415	0.424	0.962	2.728	0.352
Reduce τ_c by 0.10	0.590	0.589	1.221	1.955	1.048	1.071	3.141	2.572	0.420	0.425	0.950	2.737	0.347
% Change	(-0.84)	(1.20)	(0.08)	(0.36)	(0.38)	0	(0.35)	(0.23)	(1.20)	(0.24)	(-1.25)	(0.33)	(-1.52)
Reduce τ_e by 0.10	0.600	0.603	1.252	1.986	1.181	1.081	3.327	2.657	0.420	0.425	0.976	2.806	0.348
% Change	(0.84)	(3.61)	(2.62)	(1.95)	(13.1)	(0.93)	(6.29)	(3.51)	(1.20)	(0.24)	(1.46)	(2.86)	(-1.36)
B. Distributional measures													
	$\bar{\sigma}_v$				$\sigma_q(0)$		$\bar{\sigma}_q$		$\sigma_q(0)$		$\bar{\sigma}_q$		
	Discrete change		Gradual change		Discrete change		Gradual change		Discrete change		Gradual change		
Initial Eq	1.000		1.000		0.1418		0.1418		0.1418		0.1418		
$\tau_c = 0.22, \tau_e = 0.11$	0.9988		0.9911		0.1436		0.1438		0.1418		0.1427		
Reduce τ_c by 0.10	0.9988		0.9911		0.1436		0.1438		0.1418		0.1427		
% Change	(-0.12)		(-0.89)		(1.28)		(1.42)		(0.00)		(0.64)		
Reduce τ_e by 0.10	0.9934		0.9758		0.1416		0.1428		0.1356		0.1402		
% Change	(-0.66)		(-2.42)		(-0.15)		(0.70)		(-4.41)		(-1.11)		

points raises both sectoral traded capital intensities (e_T, e_N) by around 12.7% while the nontraded capital intensities (s_T, s_N) also rises proportionately, but by a lesser amount of around 1.6%. With labor supply fixed the reduction in τ_e raises the relative abundance of capital, and with $\omega_T > \omega_N$ raises the relative productivity of labor in the traded sector. Thus in order for the return to labor to be equalized across sectors, the relative price of nontraded output increases by around 0.93%. In addition, the increased trade shifts resources to the traded sector, and while this is met primarily by an increase in capital, it also involves a modest reallocation of labor. As a result of this, with sectoral capital intensities in the traded sector exceeding those in the nontraded sector [see (26a)], the overall increases in the two capital goods exceed the sectoral increases ($d\hat{S} = 1.95\%, d\hat{E} = 13.1\%$), respectively. A further consequence of the increase in capital is that despite the reallocation of labor, both traded and nontraded output increase, although the overall increase is less than that of capital, so that K/Y increases. In contrast to the reduction in τ_c , the increase in nontraded output, is sufficient, given the need to replace the depreciated nontraded capital for consumption to increase. With the long-run borrowing cost tied to β , the long-run increase in the value of nontraded capital $\bar{p}\hat{S}$ is matched by a proportional long-run increase in foreign debt, \bar{Z} . This partially offsets the increase in capital and overall gross wealth, \bar{V} , increases by 2.86%. This increase in \bar{V} exceeds the increase in \bar{C} , yielding a modest reduction in the equilibrium \bar{C}/\bar{V} of 1.36%.

A comparison of the responses in rows 2 and 3 illustrates the contrasting impacts of the two alternative forms of tariff reduction. In particular, a 10 percentage point reduction in τ_c increases the total capital stock, K , by 0.35% and resulting in an increase in GDP of 0.08%. In contrast, a 10 percentage point reduction in τ_e increases the capital stock by 6.29% and increases GDP by around 2.62%. The strong growth and output effects of an investment tariff reduction is in general agreement with the simulations and empirical evidence provided by [Esteve-Deordal and Taylor \(2013\)](#).

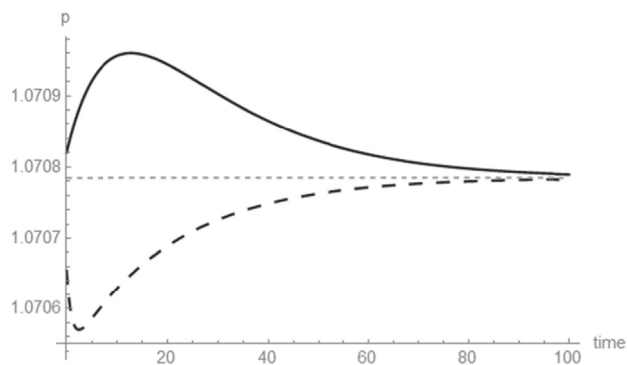
7. Tariff reductions: transitional paths

We now compare the transitional dynamics associated with the two forms of tariff reduction. These are illustrated in [Figs. 1 and 2](#), where the contrasting dynamic responses are clearly evident. These differences reflect the fact that τ_c , by influencing the relative price of the imported consumption good, impacts the economy via final demand, while τ_e , by raising the cost of imported capital, influences production. In both cases we compare the time paths where the tariff reduction is completed instantaneously, with the alternative scenario where it occurs gradually at the rate of 10% per period.

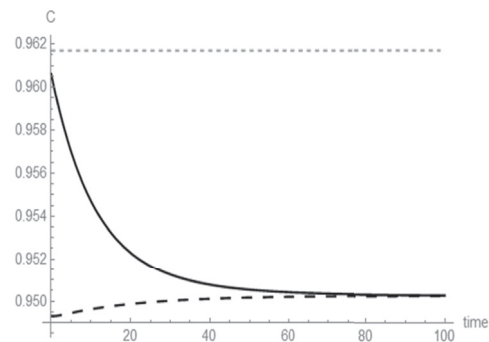
7.1. Reduction in consumption tariff

The dynamics of the aggregate quantities where the 10 percentage point reduction in the consumption tariff is completed instantaneously are illustrated by the dashed lines in the panels of [Fig. 1](#). On impact, the reduction of τ_c decreases total consumption expenditure, $C(0)$, from 0.962 to 0.949; [[Fig. 1\(1b\)](#)]. With imports cheaper, the demand for nontraded consumption declines, causing the relative price, $p(0)$, to drop albeit very slightly by around 0.01% [[Fig. 1\(1a\)](#)]. The decline in tariffs stimulates trade, moving resources from the nontraded to the traded sector. To maintain equilibrium in the factor markets, the sectoral capital-labor ratios must satisfy the constraints, dictated by (26a), so that $d\hat{S}_T = d\hat{S}_N, d\hat{e}_T = d\hat{e}_N$. This constraint, together with (i) the fact that S is fixed in the short run, (ii) total labor supply is inelastic, and (iii) the traded sector is more intensive in both capital goods ($s_T > s_N, e_T > e_N$) implies that the reallocation of resources to the traded sector is accomplished primarily by a reallocation of labor from the nontraded to the traded sector ($dL_T > 0, dL_N < 0$); see [Fig. 1\(2a\)](#) where $L_T(0)$ increases from 0.415 to 0.417. With labor moving to the traded sector, where it is relatively less productive ($\omega_T > \omega_N$) wages immediately decline slightly; see [Fig. 1\(2b\)](#). This movement of labor is accompanied by a reallocation of nontraded capital such that its ratio to labor in both sector declines. In addition, with equipment and structures being cooperative productive factors, e_T, e_N both decline as well [[Fig. 1\(3a\)-\(4b\)](#)]. As a result of this factor reallocation initial traded output increases by around 0.34%, while nontraded output declines by around 0.27% [[Fig. 1\(5a, 5b\)](#)].

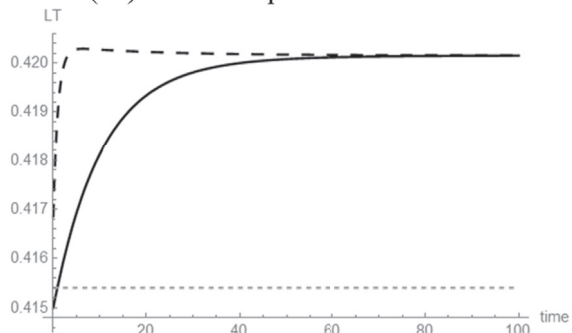
These initial responses generate subsequent dynamics. Thus the reduction in C/p exceeds the decrease in Y_N requiring that S starts to accumulate in order for the nontraded goods market to clear. Likewise, the net effect of the increase in imported consumption stemming from the decline in τ_c and the increase in imported capital dominates the increase in Y_T so that debt starts to accumulate. Third, the initial increase in borrowing costs and the return to nontraded capital causes the growth rate of consumption to rise, while with the increase in the former exceeding that of the latter p starts to rise. As Z and S start to increase these generate more dynamics propelling the economy to its new steady state. In some cases, such as C and p the adjustments are very minor. In other cases, they are more significant and involve subsequent reversals. For example, after approximately 5 periods of increase, debt will begin to decline. This reflects the fact that in the short run with S sluggish, the increase in traded output is met primarily by increasing imported capital together with the migration of labor. As S is accumulated albeit slightly, producers substitute away from machinery, the imports of which decline, reducing the level of debt. Clearance in the structural capital market along the transition implies $\hat{S} = \hat{S}_T + (s_T - s_N)(\hat{L}_T/S)$. With the sectoral capital-labor ratios adjusting in proportion at a rate faster than that of



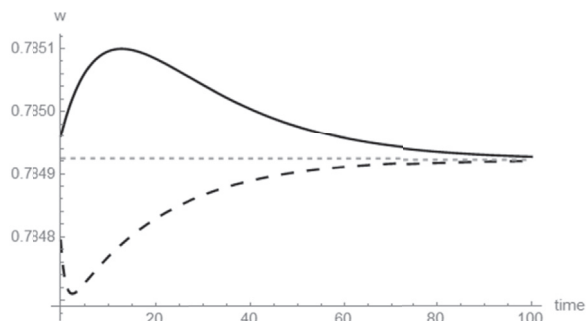
(1a) Relative price



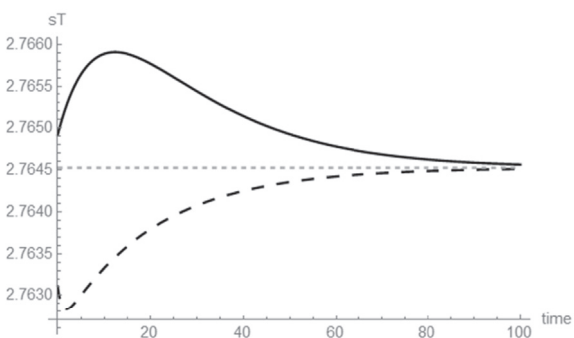
(1b) Consumption



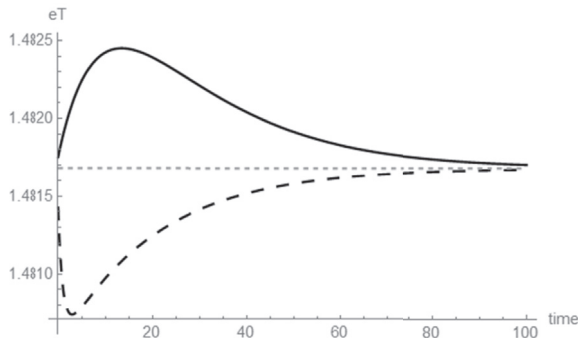
(2a) Sectoral labor allocation



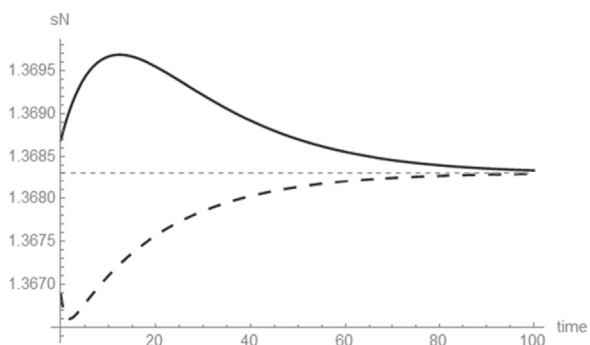
(2b) Wage rate



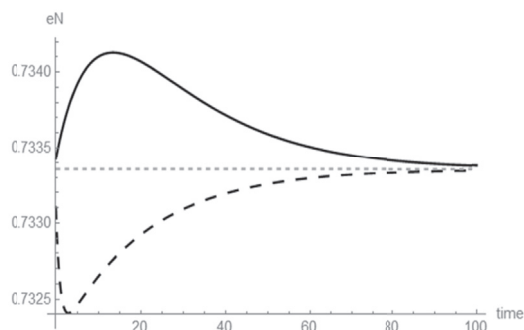
(3a) Structures in tradable Sector



(3b) Equipment in tradable sector



(4a) Structures in nontradable sector

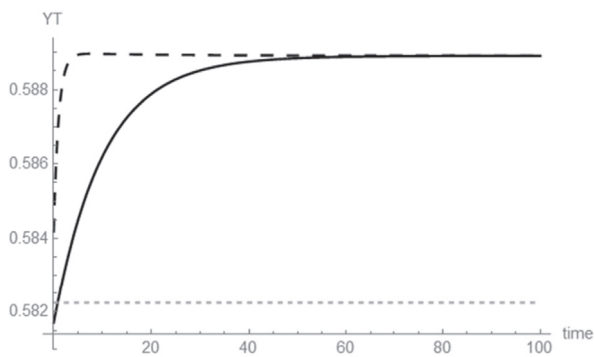


(4b) Equipment in nontradable sector

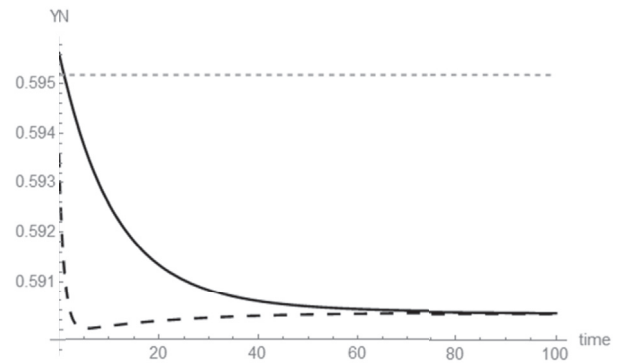
--- : Initial equilibrium — : Gradual Reduction - - - : Instantaneous Reduction

Fig. 1. Dynamics of consumption tariff reduction.

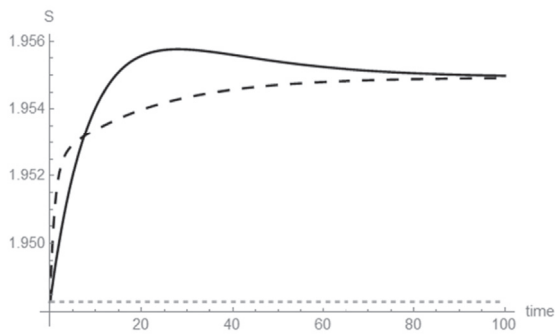
overall structures, and with $s_T > s_N$ it follows that following its initial jump to the traded sector, labor must be gradually reallocated back



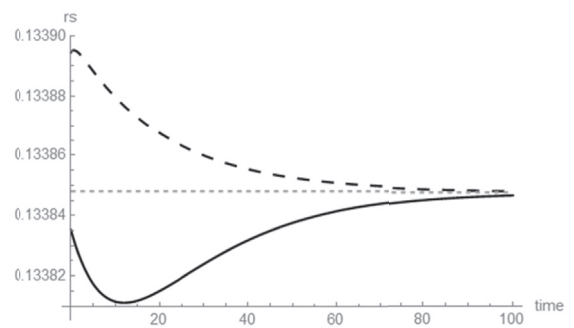
(5a) Traded Output



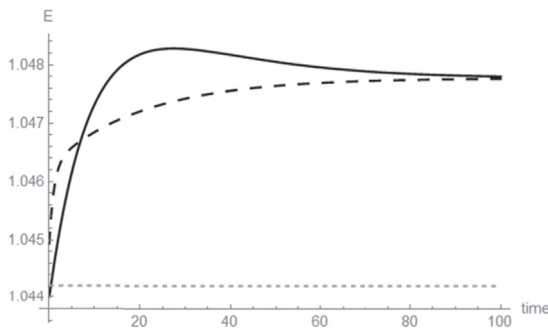
(5b) Non-traded Output



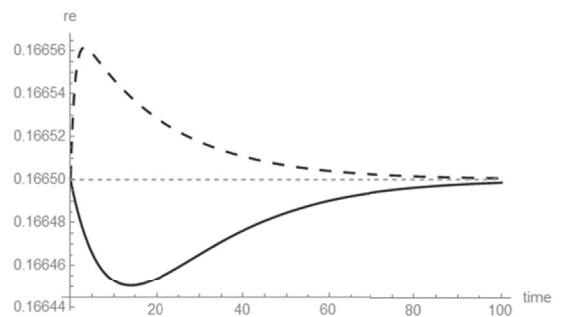
(6a) Structures



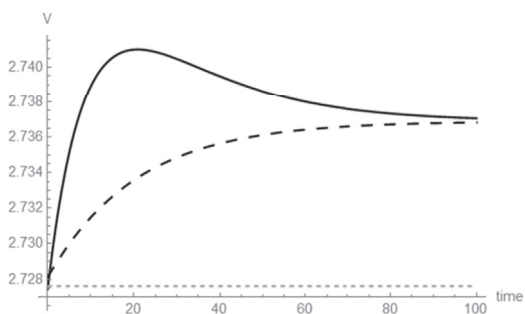
(6b) Returns to structures



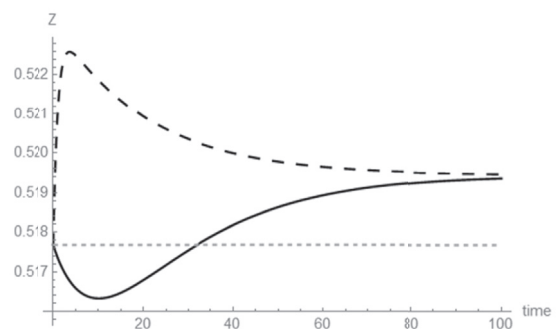
(7a) Equipment



(7b) Returns to Equipment

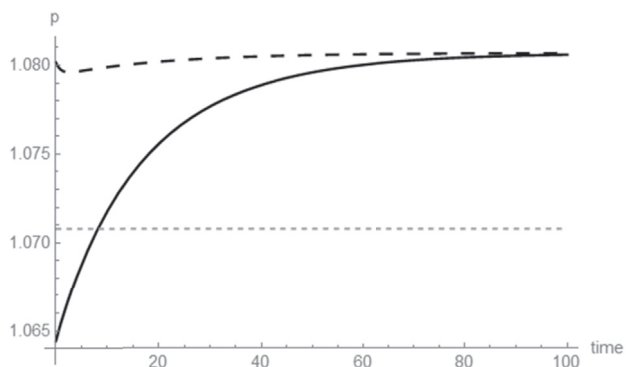


(8a) Tariff adjusted wealth

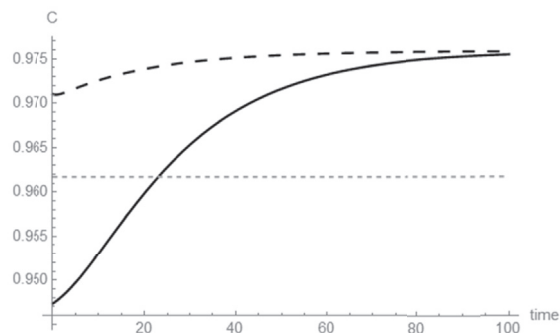


(8b) Debt

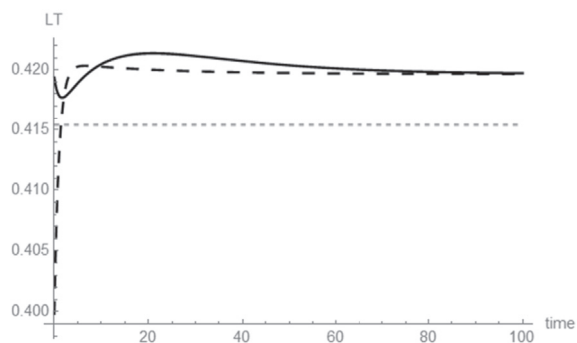
Fig. 1. (continued).



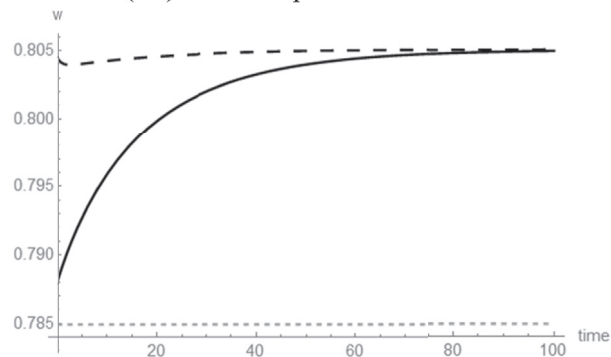
(1a) Relative price



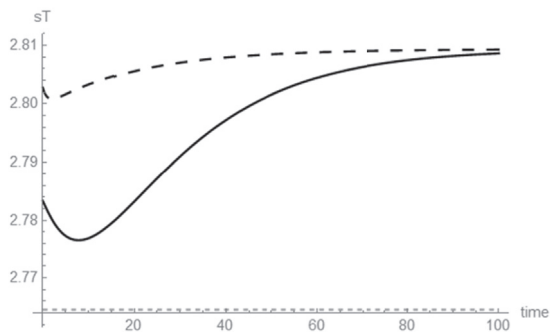
(1b) Consumption



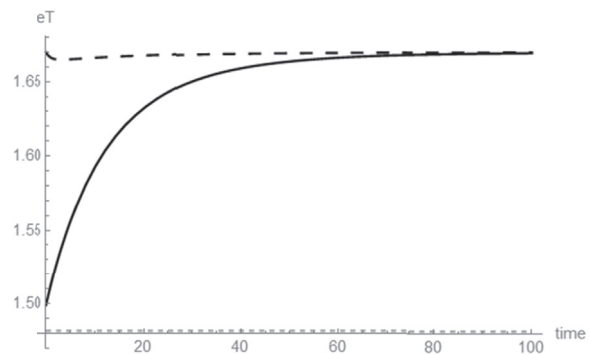
(2a) Sectoral labor allocation



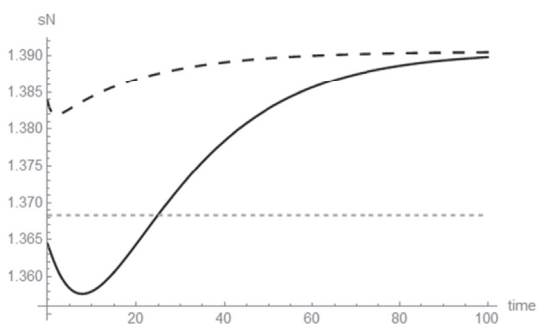
(2b) Wage rate



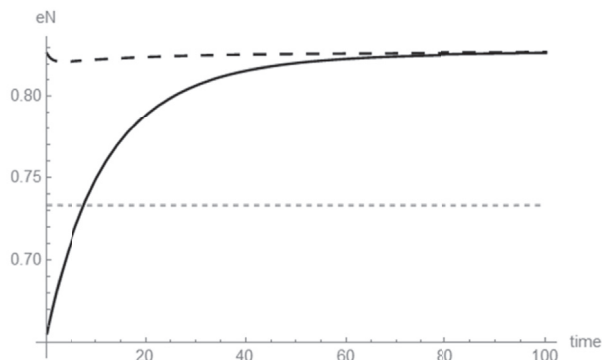
(3a) Structures in tradable Sector



(3b) Equipment in tradable sector



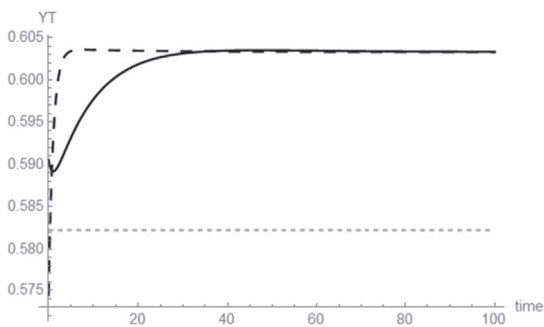
(4a) Structures in nontradable sector



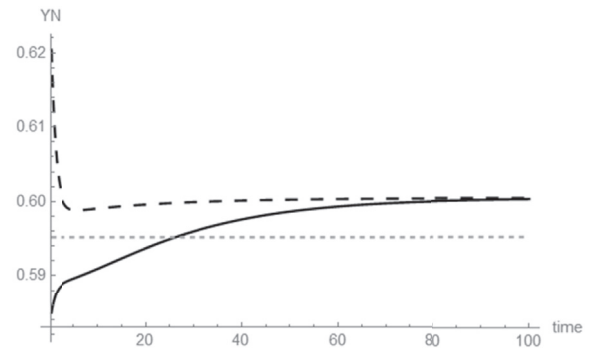
(4b) Equipment in nontradable sector

--- : Initial equilibrium — : Gradual Reduction - - - : Instantaneous Reduction

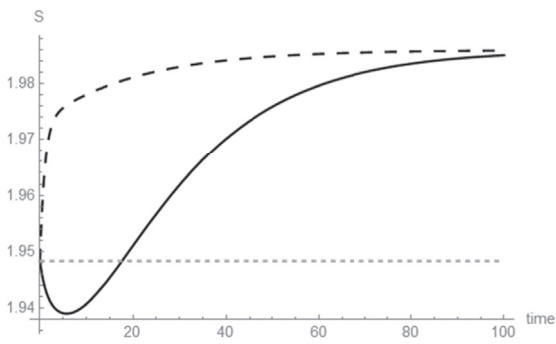
Fig. 2. Dynamics of investment tariff reduction.



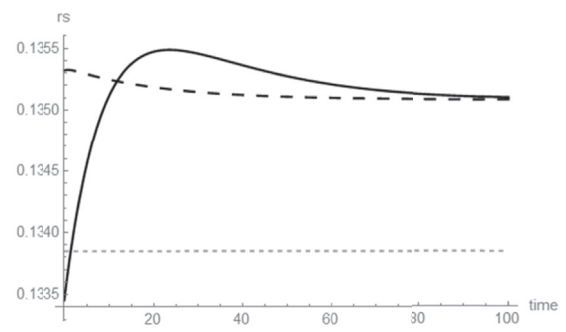
(5a) Traded Output



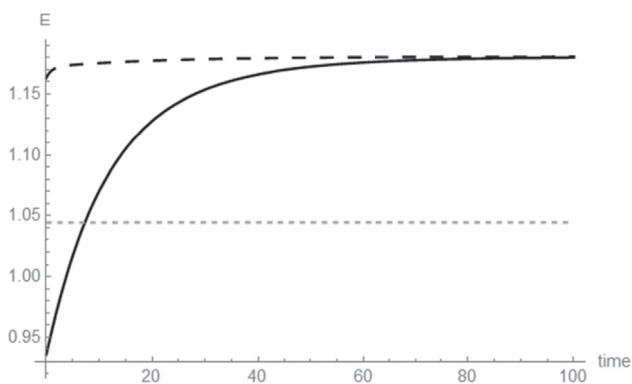
(5b) Non-traded Output



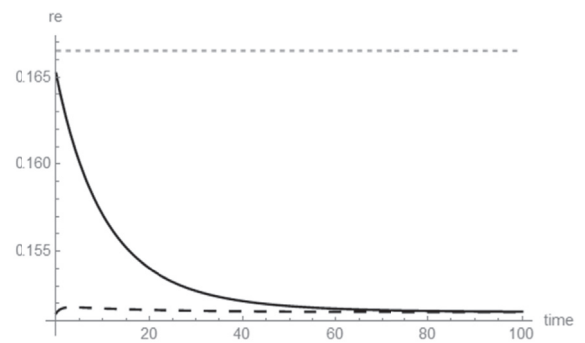
(6a) Structures



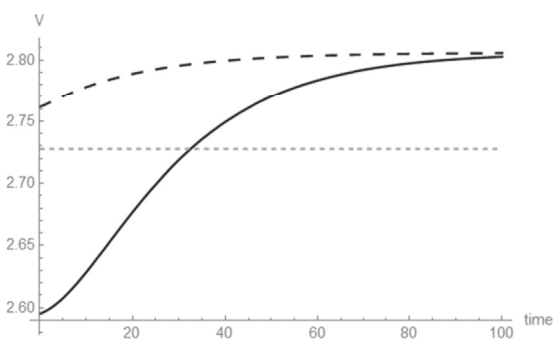
(6b) Returns to Structures



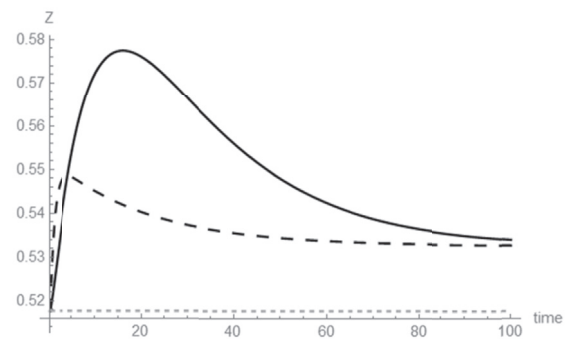
(7a) Equipment



(7b) Returns to Equipment



(8a) Tariff adjusted wealth



(8b) Debt

Fig. 2. (continued).

toward the nontraded sector.

The dynamics in the case where tariffs are reduced gradually at the rate of 10% per period are illustrated by the solid lines. In all cases, the aggregates converge to the same steady state, although the transitional paths diverge dramatically. This reflects the fact that the tariff reduction embodies two factors: (i) an *implementation* effect, which operates when the tariff reduction is actually introduced, and (ii) a *wealth* effect, which comes into effect the instant the policy is announced. In the case of immediate complete tariff reduction both effects come into effect simultaneously, while with a gradual adjustment, the implementation effect only builds up gradually over time.

Thus, the knowledge that in the long run the consumption tariff will be reduced raises agents' wealth. However, since in the short run tariffs remain unchanged, they channel their initial additional purchasing power toward the nontraded good. This raises the price of the nontraded good, causing resources to be reallocated to the nontraded sector, the output of which rises leading to an initial accumulation of nontraded capital. Over time, as the tariffs are gradually reduced, resources are gradually reallocated back to the traded sector, as the implementation effect gains strength.

Whether the reduction in the consumption tariff is completed instantaneously, or implemented gradually, the magnitudes of the dynamic adjustments are small. This reflects the fact that τ_c has no long-run impact on the economy's production structure, as described by sectoral capital intensities and relative price. The bulk of the adjustment occurs through the reallocation of labor across the sectors and the reduction in aggregate consumption (inclusive of the tariff).

7.2. Reduction in investment tariff

The dynamic adjustments following a 10 percentage point reduction in the investment tariff from 11% to 1% are illustrated in Fig. 2, with the instantaneous and gradual tariff adjustments again being denoted by the dashed and solid lines respectively. A striking contrast with the consumption tariff is that, because τ_e directly impacts the production structure, it causes more substantial quantitative adjustments, both in the short run and over time.

On impact, the 10 point reduction in τ_e will reduce the price of equipment, causing an immediate increase in imported capital of around 11.4% [Fig. 2.(7a)]. With structures and equipment being complementary in production, this immediately raises the demand for structures, which are produced in the nontraded sector and therefore take time to acquire. To produce the necessary nontraded output, labor is immediately deployed to the nontraded sector, causing an immediate reduction in L_T from 0.415 to 0.400 (increase in L_N from 0.585 to 0.600) [Fig. 2.(2a)]. The increase in imported capital coupled with a reallocation of the existing structures across the two sectors causes e_T, e_N to both increase by 12.7%, while s_T, s_N both rise by around 1.4% [Fig. 2.(3a-4b)]. Thus, the net immediate effect of the tariff reduction is a paradoxical one: output of the nontraded sector increases by 4.2%, while that of the traded sector declines by 1.4% [see Fig. 2.(5a, 5b)].

The reduction in the tariff on investment requires the economy to balance two conflicting objectives. First, must produce the structures necessary to maintain productive efficiency, given the complementarity of the two investment goods in production. Second, it needs to take advantage of the trade liberalization resulting from the reduced tariff. To achieve this, the economy immediately deploys 1.5% of the total labor force to the nontraded sector, thus accumulating the nontraded output as capital at a rapid rate. It then immediately begins to reallocate the labor back to the traded sector [see Fig. 2.(2a, 6a)], in effect making the deployment of labor very temporary. Following this strategy, after just one period, Y_T has been restored to its initial equilibrium level and it continues to increase beyond that, while Y_N declines correspondingly [Fig. 2.(5b)]. This rapid initial reduction in traded output is reflected in a corresponding rapid initial accumulation of foreign debt, which is also reversed after a couple of periods, when the productive resources have

been moved to the traded sector and exports have been increased [Fig. 2.(8b)].

At the same time, the reallocation of capital across sectors causes an initial rise in the gross return to structures, r_s from its initial equilibrium of 13.38% to around 13.53% [Fig. 2.(6b)], which in turn leads to an initial increase in the relative price, $p(0)$ of approximately 0.9%, and illustrated in Fig. 2.(1a)]. The higher price of nontraded goods leads to a reduction in their consumption, so that the net effect is to increase net total consumption $C(0)$ by approximately 1%, from 0.962 to 0.971, as illustrated in Fig. 2.(1b).

From Fig. 2 it is evident that the rapid adjustment characteristic of the initial stages is driven by the need to increase the stock of structures (which takes time) in response to the increase in equipment (available instantaneously through trade). Much of the adjustment is therefore completed during the first 2–3 periods immediately following the reduction in tariffs, after which the evolution proceeds at a much more leisurely pace.

The dynamic adjustments following a gradual reduction in τ_e contrast sharply with those we have just been discussing. Again the contrast arises due to the distinction between the “implementation effect”, which arises when the tariff reduction begins to take effect, and the “wealth effect”, which occurs when information about the impending tariff reduction is revealed. In this case, since the tariff reduction proceeds gradually it impacts the economy by slightly reducing the required rate of return on investment in equipment, f_e , from around 0.167 to 0.165. This induces firms to reallocate equipment from the nontraded to the traded sector, and given their complementarity, likewise for structures. The net effect is a slight reduction in f_s , leading to a reduction in the relative price of nontraded goods, p , which in turn leads to an immediate decline in V . Given the initial stock of structures, S , and the relative sectoral intensities, $s_T > s_N$, the mild increase in s_T , dominates the mild drop in s_N leading to a slight initial reallocation of labor to the nontraded sector. This in turn together with the corresponding reallocation of equipment to the traded sector necessitates an immediate reduction in E . With E actually declining on impact, there is no need to immediately raise S , (as when τ_e declines instantaneously). As a result, the allocation of capital toward the traded sector suffices to immediately raise traded output. Over time, as τ_e gradually declines the forces associated with the implementation effect gradually increase and the aggregate economy evolves to the new equilibrium.

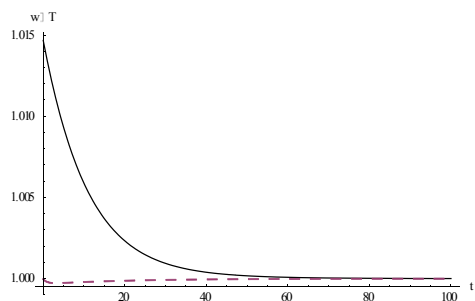
Comparing Figs. 1 and 2 highlights two sharply contrasting aspects of the transitional dynamics. The first is that between the immediate versus the gradual tariff reduction. But in addition, in either of these cases the dynamic adjustments generated by the two tariffs are also in sharp contrast, this being a reflection of their differential impact the economy.

8. Dynamics of wealth and income inequality

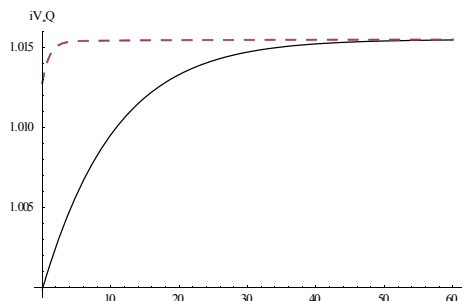
As discussed in Section 4, the dynamics of wealth inequality are driven by the discounted sum of expected future consumption relative to that of labor income inclusive of tariff rebates, (gross labor income); see (20b). Knowing the time path for wealth inequality, the dynamics of income inequality then depends upon the evolution of the share of income from wealth relative to that of personal income; see (23). To facilitate understanding of the link between the aggregate dynamics and the distributional implications, it is helpful to consider Fig. 1.(1b), 2.(1b) (aggregate consumption), Fig. 3.(1a, 3a), (gross labor income), and Fig. 3.(1b, 3b) (share of income due to wealth).

8.1. Reduction in consumption tariff

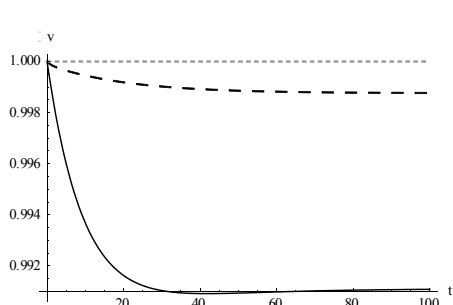
Comparing Fig. 1.(1b) with Fig. 3.(1a) with we see that when the reduction in the consumption tariff, τ_c , is completed instantaneously, the initial declines in C and $w + T$ are such that aggregate consumption approaches its steady state at a slightly slower rate than does gross labor income. Since this is so uniformly along the transitional path, and since



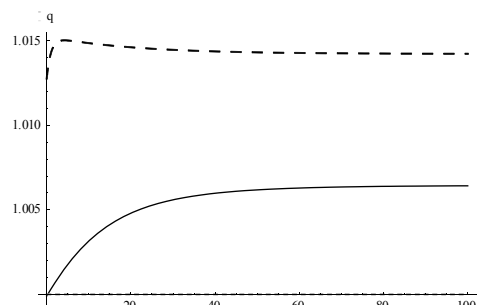
(1a) Gross labor income



(1b) Share of income due to wealth

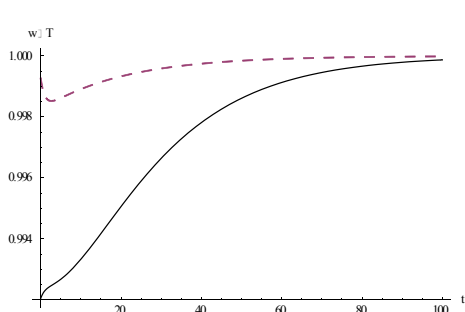


(2a) Wealth inequality

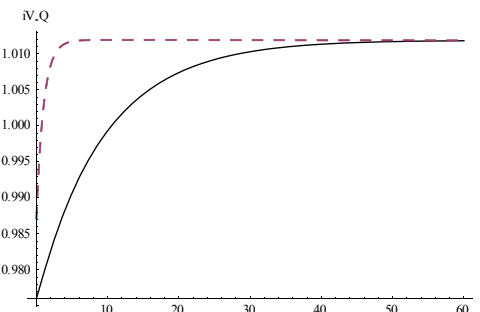


(2b) Income inequality

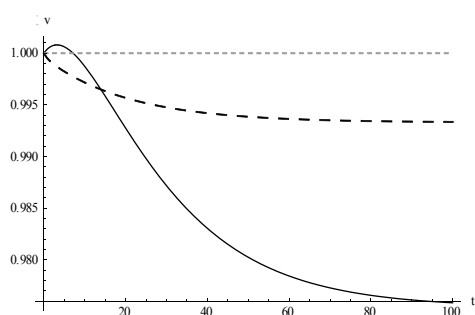
A. Reduction in Consumption Tariff



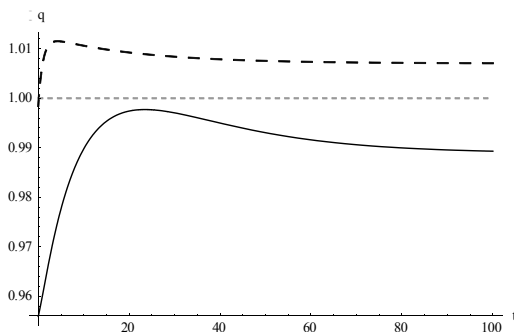
(3a) Gross labor income



(3b) Share of Income due to wealth



(4a) Wealth inequality



(4b) Income inequality

B. Reduction in Investment tariff

--- : Initial equilibrium — : Gradual Reduction - - - : Instantaneous Reduction

Fig. 3. Effects of tariff reduction on inequality.

gross labor income is equally distributed across agents, wealth inequality falls, albeit very slightly. As illustrated in Fig 3.(2a) long-run wealth inequality is reduced by 0.12%. In addition, the discrete 10 percentage point reduction in τ_c by causing an immediate decline in Q causes iV/Q to increase by around 1.28%, which over time increases further to around 1.55%. Adjusting for the slight decline in wealth inequality, this translates to a long-run increase in income inequality of around 1.42%; see Fig. 3.(2b).

In contrast, if τ_c is reduced only gradually, C adjusts at a slower rate relative to $(w + T)$ and there is more transitional time for relative income to adjust and wealth inequality declines by 0.9%. The increase in iV/Q also proceeds gradually and coupled with the larger long-run decline in wealth inequality nets out to a smaller increase in income inequality of around 0.64%.

8.2. Reduction in investment tariff

Reducing the investment tariff instantaneously, causes both C and $(w + T)$ to immediately increase on impact. Again, the initial response moves gross labor income closer to its new steady state than it does consumption, so that for similar reasons to those above, wealth inequality declines steadily, eventually falling by 0.66%; see Fig. 3. (4a). On impact, iV/Q declines sharply, due almost entirely to the immediate rise in the wage rate and therefore labor income and causing a very temporary decrease in income inequality of 0.15%. Thereafter, iV/Q rises rapidly as structures are accumulated to match the additional equipment, with iV/Q essentially reaching its long run increase of around 1.38% after a couple of periods, with inequality increasing by about 1.15%. Thereafter, the gradual decline in income inequality reflects the decline in wealth inequality and in the long run income inequality declines by just 0.70%.

If τ_e is reduced only gradually, wealth inequality rises initially before gradually declining. This reflects the fact that the smaller increase in w [see Fig. 2.(2b)], coupled with the sluggishness of the tariff revenues means that the initial increase in $w + T$ is much smaller so that it actually declines relative to its long-run responses during the early stages of the transition. With this adverse short-run response of labor income, this leads to an initial increase in wealth inequality, which eventually is reversed over time. The relative share of income from wealth, iV/Q adjusts more gradually and when considered in conjunction with the non-monotonic adjustment of wealth inequality, leads to a non-monotonic adjustment in income inequality.

8.3. Tariffs and tradeoffs

The responses in the benchmark economy highlight the sharp contrasts between the two tariffs, and particularly the tradeoffs they involve between capital accumulation (growth) and inequality.

Reducing the consumption tariff, τ_c by 10 percentage points is characterized by the following:

- (i) A weak impact on economic growth as reflected by a small increase in the capital stock.
- (ii) A slight reduction in wealth inequality if implemented instantaneously, a larger reduction if introduced gradually.
- (iii) A substantial and rapid increase in income inequality if implemented instantaneously, a more gradual and milder increase if introduced gradually.

Reducing the tariff on investment, τ_e by 10 percentage points has the following effects:

- (i) A powerful effect on capital accumulation
- (ii) A significant gradual reduction in wealth inequality if implemented instantaneously. A more substantial long-run reduction if

introduced gradually and even associated with an increase in wealth inequality in the short run.

- (iii) A modest steady increase in income inequality if implemented instantaneously. A substantial initial decline in income inequality followed by a fairly rapid increase, though remaining below its initial level if introduced gradually.

In both cases gradual reduction of the tariffs is preferable from the standpoint of any adverse impact on income inequality.

8.4. Sensitivity analysis

Because of the fact that economies at varying stages of development have diverse economic structures, we have undertaken extensive sensitivity analysis, reported in Table A.1. We focus on five critical parameters, reflecting in part the range of empirical evidence taken into account in the process of calibrating the model. These include: (i) an increase in the relative importance of the imported consumption good, η ; (ii) a decrease in the relative importance of nontraded capital in production, α ; (iii) varying the elasticity of substitution of the two capital goods in production; (iv) decreasing the relative income share of labor, ω_T, ω_N , characteristic of many developing economies; (v) varying the cost of foreign borrowing, ρ . The sensitivity of the long-run responses of capital and the inequality measures to the reductions in the two tariff rates are clearly apparent from the table and are discussed in more detail in Turnovsky and Rojas-Vallejos (2018). Of particular interest is the sensitivity of the impact of the investment tariff to the relevant production characteristics, which impact both the transitional dynamics (Fig. A.1) and the long-run (Table A.1).

9. Conclusions

In this paper we have investigated the relationship between trade liberalization, in the form of tariff reduction, and the increase in inequality that has characterized most countries in recent years. Most of the literature examining this issue has been at the aggregate level, but the fact that consumption tariffs and investment tariffs operate in dramatically different ways and that the larger share of capital is nontraded requires that the issue be addressed in a disaggregated model, such as employed here. Our main conclusions, based on the benchmark calibration, suggest important tradeoffs between the two tariffs and their respective impacts on activity and distribution. These tradeoffs pertain to the contrasting effects of the tariffs themselves, and particularly the speed with which the tariff reduction proceeds. Moreover, the qualitative nature of the responses to the two tariffs and the tradeoffs they involve are fairly robust with respect to variations in key structural parameters, with the exception of the elasticity of substitution between the two capital goods, and its consequences for the impact of the tariff on investment.

In concluding, it is important to place our numerical results in perspective. Trade liberalization is just one factor among many potentially contributing to wealth and income inequality. The growth of human capital, skill-biased technological developments, and fiscal policy are other obvious factors that are important and likely dominate. Nevertheless, the role of trade liberalization cannot be dismissed as minor, and it is therefore important to understand the channels through which it impinges on the economy. Indeed, the fact that the benchmark calibration suggests that the gradual reduction in the tariff on investment may actually ameliorate growing income inequality is important in implementing a coherent tariff policy.

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in part by the Van Voorhis Endowment at the University of Washington. Rojas’s research was supported in part by the BecasChile Scholarship Program of the Chilean Government and the Grover and Creta Ensley Fellowship of the University of Washington.

Appendix A

A.1. Derivation of individual’s optimality conditions

Maximizing the individual’s utility (5), subject to the accumulation equations (6a) and (6b) and budget constraint, (7), yields the following standard first order optimality conditions:

$$\theta(C_{j,T})^{\theta-1}(C_{j,N})^{\gamma(1-\theta)}(C_{j,F})^{\eta} = \lambda_j \quad (\text{A.1a})$$

$$(1-\theta)(C_{j,T})^{\theta}(C_{j,N})^{\gamma(1-\theta)-1}(C_{j,F})^{\eta} = p\lambda_j \quad (\text{A.1b})$$

$$\eta(C_{j,T})^{\theta}(C_{j,N})^{\gamma(1-\theta)}(C_{j,F})^{\eta-1} = (1+\tau_c)\lambda_j \quad (\text{A.1c})$$

$$i\left(\frac{Z}{pS}\right) = \beta - \frac{\dot{\lambda}_j}{\lambda_j} \quad (\text{A.1d})$$

$$\frac{r_s}{p} - \delta_s + \frac{\dot{p}}{p} = \beta - \frac{\dot{\lambda}_j}{\lambda_j} \quad (\text{A.1e})$$

$$\frac{r_e}{(1+\tau_c)} - \delta_e + \frac{\dot{\tau}_c}{(1+\tau_c)} = \beta - \frac{\dot{\lambda}_j}{\lambda_j} \quad (\text{A.1f})$$

where λ_j is agent j ’s marginal utility of wealth, which for a debtor is the marginal utility of reducing debt. The following transversality conditions also hold

$$\lim_{t \rightarrow \infty} \lambda_j p S_j e^{-\beta t} = 0; \quad \lim_{t \rightarrow \infty} \lambda_j E_j e^{-\beta t} = 0; \quad \lim_{t \rightarrow \infty} \lambda_j Z_j e^{-\beta t} = 0; \quad (\text{A.1g})$$

Defining agent j ’s total consumption expenditure, in terms of the traded good, inclusive of the consumption tariff, τ_c , by $C_j \equiv C_{j,T} + pC_{j,N} + (1+\tau_c)C_{j,F}$, using equations (A.1a)–(A.1c) we may express the agent’s consumption expenditures as

$$C_{j,T}(t) = \left(\frac{\theta}{1+\eta}\right)C_j(t) \quad (\text{A.2a})$$

$$pC_{j,N}(t) = \left(\frac{1-\theta}{1+\eta}\right)C_j(t) \quad (\text{A.2b})$$

$$(1+\tau_c)C_{j,F}(t) = \left(\frac{\eta}{1+\eta}\right)C_j(t) \quad (\text{A.2c})$$

A.2. Derivation of aggregate dynamics

To begin we take the time derivatives of (A.2a)–(A.2c), and combine with (A.1d)–(A.1f):

$$\frac{\dot{C}_{j,T}}{C_{j,T}} = \frac{\dot{C}_j}{C_j} = \frac{1}{1-\gamma(1+\eta)} \left[(1-\theta)\gamma \left(\frac{r_s}{p} - \delta_s\right) + [1-\gamma(1-\theta)]i\left(\frac{Z}{pS}\right) - \beta - \eta\gamma \left(\frac{\dot{\tau}_c}{1+\tau_c}\right) \right] \quad (\text{A.3a})$$

$$\frac{\dot{C}_{j,N}}{C_{j,N}} = \frac{1}{1-\gamma(1+\eta)} \left[[1-\gamma(\theta+\eta)] \left(\frac{r_s}{p} - \delta_s\right) + \gamma(\theta+\eta)i\left(\frac{Z}{pS}\right) - \beta - \eta\gamma \left(\frac{\dot{\tau}_c}{1+\tau_c}\right) \right] \quad (\text{A.3b})$$

$$\frac{\dot{C}_{j,F}}{C_{j,F}} = \frac{1}{1-\gamma(1+\eta)} \left[(1-\theta)\gamma \left(\frac{r_s}{p} - \delta_s\right) + [1-\gamma(1-\theta)]i\left(\frac{Z}{pS}\right) - \beta - (1-\gamma) \left(\frac{\dot{\tau}_c}{1+\tau_c}\right) \right] \quad (\text{A.3c})$$

Since the right hand sides of equation (A.3) are common to all agents, each individual, j , will choose the same growth rate for the three consumption goods as well as for their respective total consumption, C_j . Because of the linearity of the individual optimality conditions, (A.2), we can immediately sum these equations over all agents and express the equilibrium aggregate economy-wide consumption levels, $C_T(t), C_N(t), C_F(t)$, respectively in terms of

the total consumption expenditure, $C \equiv C_T + pC_N + (1 + \tau_c)C_F$, namely

$$C_T(t) = \left(\frac{\theta}{1 + \eta}\right)C(t) \tag{A.4a}$$

$$pC_N(t) = \left(\frac{1 - \theta}{1 + \eta}\right)C(t) \tag{A.4b}$$

$$(1 + \tau_c)C_F(t) = \left(\frac{\eta}{1 + \eta}\right)C(t) \tag{A.4c}$$

which together with (A.2) imply

$$\frac{\dot{C}_{jT}}{C_{jT}} = \frac{\dot{C}_T}{C_T} = \frac{\dot{C}_j}{C_j} = \frac{\dot{C}}{C}, \quad \frac{\dot{C}_{jN}}{C_{jN}} = \frac{\dot{C}_N}{C_N}, \quad \frac{\dot{C}_{jF}}{C_{jF}} = \frac{\dot{C}_F}{C_F} \quad \text{for all } j \tag{A.5}$$

Thus, $C_j = \varphi_j C$, where $\int_0^1 \varphi_j dj = 1$, and φ_j , which defines agent j 's relative consumption, is constant over time for each j , and is determined by eq. (18). Combining equations (A.3a), (A.4a) with (A.5) we may express the equilibrium dynamics of aggregate consumption in the form

$$\frac{\dot{C}}{C} = \frac{1}{1 - \gamma(1 + \eta)} \left[(1 - \theta)\gamma \left(\frac{r_s}{p} - \delta_S\right) + [1 - \gamma(1 - \theta)]i \left(\frac{Z}{pS}\right) - \beta - \eta\gamma \left(\frac{\tilde{\tau}_c}{1 + \tau_c}\right) \right] \tag{A.6}$$

Next, domestic nontraded goods market clearance implies

$$Y_N = h(s_N, e_N)(1 - L_T) = C_N + I_S \tag{A.7}$$

where $I_S = \dot{S} + \delta_S S$ is the gross rate of investment in structures and is obtained by aggregating (6a). Substituting for (A.4b), this can be written in the form of the nontraded capital accumulation equation

$$\dot{S} = h(s_N, e_N)(1 - L_T) - \left(\frac{1 - \theta}{1 + \eta}\right) \frac{C}{p} - \delta_S S \tag{A.7'}$$

Aggregating over the individual budget constraints, (7), noting the linear homogeneity of the production functions, using the sectoral allocation conditions, (2), the optimality conditions, (3), and the government budget constraint, (9), yields the current account relationship

$$\dot{Z}(t) = C_T + C_F + I_E - f(s_T, e_T)L_T + i \left(\frac{Z}{pS}\right)Z \tag{A.8}$$

where $I_E = \dot{E} + \delta_E E$ is the gross rate of investment in equipment. Thus, (A.8) asserts that the aggregate rate of accumulation of debt equals the trade deficit plus the interest owing on the country's net holdings of foreign debt. Substituting for C_T, C_F , and I_E this can be expressed as

$$\dot{Z}(t) = \left(\frac{\theta}{1 + \eta} + \frac{\eta}{(1 + \eta)(1 + \tau_c)}\right)C + \dot{E} + \delta_E E - f(s_T, e_T)L_T + i \left(\frac{Z}{pS}\right)Z \tag{A.8'}$$

Finally, the dynamics of the relative price is obtained by combining the optimality conditions pertaining to debt and structures, given by (A.1d) and (A.1e), respectively, namely

$$\frac{\dot{p}(t)}{p(t)} = i \left(\frac{Z}{pS}\right) - \left(\frac{r_s}{p} - \delta_S\right) \tag{A.9}$$

Equations (A.6), (A.7'), (A.8') and (A.9) describe the basic aggregate dynamics. However, the accumulation of debt, (A.8'), also increases with \dot{E} , which is dependent upon that of $Z(t), S(t), p(t)$. To incorporate this dependence into the equilibrium dynamics, we must take account of the short-run equilibrium.

To do this we first combine (A.1d), (A.1f), together with the time derivative of (10) to obtain

$$f_e(s_T, e_T) = \left[i \left(\frac{Z}{pS}\right) + \delta_E \right] (1 + \tau_e) + \nu_e (\tau_e - \tilde{\tau}_e) \tag{A.10}$$

Next, (A.10) and (3a)–(3c), yield four equations that determine the short-run sectoral allocation ratios

$$s_T = s_T(p, Z/S, \tau_e, \tilde{\tau}_e); e_T = e_T(p, Z/S, \tau_e, \tilde{\tau}_e) \tag{A.11a}$$

$$s_N = s_N(p, Z/S, \tau_e, \tilde{\tau}_e); e_N = e_N(p, Z/S, \tau_e, \tilde{\tau}_e) \tag{A.11b}$$

From these equations we see that the short-run effect of the consumption tariff on the sectoral factor allocation occurs solely through its impact on the relative price. The nature of this response depends upon whether the tariff change is completed instantaneously, or occurs gradually. In addition to an analogous price effect, the tariff on investment, by raising the price of equipment directly, impacts the profit maximizing sectoral allocation of productive inputs.

Substituting (A.11) into (4a) we may solve for L_T

$$L_T = \frac{S - s_N(p, Z/S, \tau_e, \tilde{\tau}_e)}{s_T(p, Z/S, \tau_e, \tilde{\tau}_e) - s_N(p, Z/S, \tau_e, \tilde{\tau}_e)} \equiv L_T(p, Z, S, \tau_e, \tilde{\tau}_e) \tag{A.12a}$$

thus yielding the short-run sectoral labor allocation in terms of the dynamically evolving variables, p, Z, S . Combining the terms in (A.11a), (A.11b), and (A.12a) with (4b) we see that the market clearing condition for equipment can be expressed as

$$E = e_T(p, Z/S, \tau_e, \tilde{\tau}_e)L_T(p, Z, S, \tau_e, \tilde{\tau}_e) + e_N(p, Z/S, \tau_e, \tilde{\tau}_e)(1 - L_T(p, Z, S, \tau_e, \tilde{\tau}_e)) \equiv E(p, Z, S, \tau_e, \tilde{\tau}_e) \tag{A.12b}$$

Equation (A.12b) merits two observations. First, the short-run responses in the sectoral factor allocations arising from discrete changes in the relative price and possibly the investment tariff itself, generate instantaneous adjustments in total equipment. With no trade impediments these can be imported instantaneously. Second, taking the time derivative of (A.12b) yields

$$\dot{E}(t) = E_p \dot{p}(t) + E_Z \dot{Z}(t) + E_S \dot{S}(t) + E_{\tau_e} \dot{\tau}_e(t)$$

which highlights the dependence of \dot{E} in (A.8'). Substituting this expression into (A.8') yields

$$(1 - E_Z)\dot{Z}(t) = \left(\frac{\theta}{1 + \eta} + \frac{\eta}{(1 + \eta)(1 + \tau_c)}\right)C + \delta_E E - f(s_T, e_T)L_T + i\left(\frac{Z}{pS}\right)Z + E_p \dot{p}(t) + E_S \dot{S}(t) + E_{\tau_e} \dot{\tau}_e(t) \tag{A.13}$$

where $\dot{p}, \dot{S}, \dot{\tau}_e$ are obtained from (A.9), (A.7') and (10), respectively. Thus equation (A.7'), (A.13), (A.9), and (A.6) correspond to (11a)–(11d) of the macroeconomic equilibrium reported in the text.

To solve (11a)–(11f), we write it in matrix form

$$\begin{pmatrix} \dot{S} \\ \dot{Z} \\ \dot{p} \\ \dot{C} \\ \dot{\tau}_c \\ \dot{\tau}_e \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ \frac{E_S}{1 - E_Z} & \frac{1}{1 - E_Z} & \frac{E_p}{1 - E_Z} & 0 & 0 & \frac{E_{\tau_e}}{1 - E_Z} \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{C}{1 - \gamma(1 + \eta)} & -\frac{C}{1 - \gamma(1 + \eta)} & \frac{\eta\gamma}{1 + \tau_c} \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} h(s_N, e_N)(1 - L_T) - \left(\frac{1 - \theta}{1 + \eta}\right)\frac{C}{p} - \delta_S S \\ \left(\frac{\theta}{1 + \eta} + \frac{\eta}{(1 + \eta)(1 + \tau_c)}\right)C + \delta_E E - f(s_T, e_T)L_T + i\left(\frac{Z}{pS}\right)Z \\ p\left[i\left(\frac{Z}{pS}\right) - (h_s(s_N, e_N) - \delta_S)\right] \\ \left[\left(1 - \theta\right)\gamma(h_s(s_N, e_N) - \delta_S) + [1 - \gamma(1 - \theta)]i\left(\frac{Z}{pS}\right) - \beta\right] \\ -\nu_c(\tau_c - \tilde{\tau}_c) \\ -\nu_e(\tau_e - \tilde{\tau}_e) \end{pmatrix}$$

Letting $x \equiv (S, Z, p, C, \tau_c, \tau_e)$ and denoting the coefficient matrix by $B(x)$, the macrodynamic system can be written more compactly in the form $\dot{x} = B(x)M(x)$. To analyze the local dynamics we linearize around steady state, which occurs at $M(\bar{x}) = 0$ and reduces to (12). Thus, the local dynamics are

$$\dot{x} = B(\bar{x})\left.\frac{\partial M(x)}{\partial x}\right|_{x=\bar{x}}(x - \bar{x}) \tag{A.14}$$

This yields a system of the form

$$\begin{pmatrix} \dot{S} \\ \dot{Z} \\ \dot{p} \\ \dot{C} \\ \dot{\tau}_c \\ \dot{\tau}_e \end{pmatrix} = B(\bar{x}) \begin{pmatrix} m_{11} & m_{12} & m_{13} & m_{14} & 0 & m_{16} \\ m_{21} & m_{22} & m_{23} & m_{24} & m_{25} & m_{26} \\ m_{31} & m_{32} & m_{33} & 0 & 0 & m_{36} \\ m_{41} & m_{42} & m_{43} & 0 & 0 & m_{46} \\ 0 & 0 & 0 & 0 & -\nu_c & 0 \\ 0 & 0 & 0 & 0 & 0 & -\nu_e \end{pmatrix}_{x=\bar{x}} \begin{pmatrix} S - \bar{S} \\ Z - \bar{Z} \\ p - \bar{p} \\ C - \bar{C} \\ \tau_c - \bar{\tau}_c \\ \tau_e - \bar{\tau}_e \end{pmatrix} \tag{A.15}$$

where the elements m_{ij} denote the appropriate partial derivatives, evaluated at steady state and incorporate the short-run responses. Thus, for example,

$$m_{16} \equiv \frac{\partial \dot{S}}{\partial \tau_e} = -h(\tilde{s}_N, \tilde{e}_N) \frac{\partial L_T}{\partial \tau_e} \Big|_{x=\tilde{x}} + (1 - \tilde{L}_T) \frac{\partial h(\tilde{s}_N, \tilde{e}_N)}{\partial \tau_e} \Big|_{x=\tilde{x}}$$

where the partial derivatives are obtained from (3a)–(3c), (A.10) and (A.12a), (A.12b). For further convenience, we may write the linearized system (A.15) as $\dot{x}(t) = D(x(t) - \tilde{x})$.

The linearized dynamic system decomposes into two subsystems. The first consists of the endogenous dynamics of S, Z, p, C and includes two sluggish variables, S, Z , together with two jump variables p, C . Assuming that this is characterized by two stable eigenvalues ($\mu_1, \mu_2 < 0$) this will yield a unique stable transitional path for given tariff rates. In practice, to determine the root structure of this system is impractical, however, extensive numerical simulations confirm this to be the case over virtually all plausible parameter sets.

To the extent that this is augmented by gradual adjustments in tariffs, specified by (10), further sluggishness is imposed on the system. Thus, the general solution to the linearized system (A.15) is:

$$x(t) - \tilde{x} = A_1 v_1 e^{\mu_1 t} + A_2 v_2 e^{\mu_2 t} + A_3 v_3 e^{-\nu_c t} + A_4 v_4 e^{-\nu_e t} \tag{A.16}$$

The vectors v_1, v_2, v_3, v_4 correspond to the eigenvectors associated with the eigenvalues $\mu_1, \mu_2, -\nu_c, -\nu_e$, respectively. The arbitrary constants $A_i, i = 1 \dots 4$ are obtained from initial conditions on the sluggish variables S, Z, τ_c , and τ_e . We normalize the eigenvectors, so that their first component is 1. Thus, they can be written as $v_j = (1, \kappa_{2j}, \kappa_{3j}, \kappa_{4j}, \kappa_{5j}, \kappa_{6j})$, for $j = 1, 2$. Note that because of the exogeneity of $\tau_c, \tau_e, \kappa_{5j} = \kappa_{6j} = 0$. Similarly, we normalize v_3, v_4 such that their component associated with the respective tariff is set equal to one, so that $v_3 = (\pi_{11}, \pi_{21}, \pi_{31}, \pi_{41}, 1, 0)$ and $v_4 = (\pi_{12}, \pi_{22}, \pi_{32}, \pi_{42}, 0, 1)$.

We determine the arbitrary constants by evaluating (A.15) at time zero, yielding:

$$\begin{aligned} A_1 + A_2 + A_3 \pi_{11} + A_4 \pi_{12} &= (S_0 - \tilde{S}) \\ A_1 \kappa_{21} + A_2 \kappa_{22} + A_3 \pi_{21} + A_4 \pi_{22} &= (Z_0 - \tilde{Z}) \\ A_3 &= (\tau_{c,0} - \tilde{\tau}_c), A_4 = (\tau_{e,0} - \tilde{\tau}_e) \end{aligned}$$

The solutions for the dynamics of $S(t), Z(t), p(t), C(t)$ are then obtained by substituting for the constants and eigenvectors into (A.15).

These solutions constitute the core aggregate dynamics. Knowing these, the time paths for the remaining aggregate follow. Specifically, the dynamic adjustments of sectoral intensities can be computed from (A.11a), (A.11b), and the labor allocation and accumulation of equipment from (A.12a), (A.12b). The dynamics of sectoral outputs are obtained from (1a), (1b), and $r_s(t), r_e(t), w(t)$ from (4a)–(4c). The consumption components follow from (A.4), while equilibrium tariff revenues, necessary to compute equilibrium wealth inequality, then follow from (9) and are given by

$$T(t) = \tau_c(t)(1 + \tau_c)^{-1} \eta(1 + \eta)^{-1} C(t) + \tau_e(t) [\dot{E}(t) + \delta_E E(t)]$$

A.3. Solution for wealth inequality

We begin by linearizing equation (16) around steady state, and combine with (17) to yield

$$\dot{v}_j = \beta(v_j - \tilde{v}_j) + \frac{(\tilde{v}_j - 1)}{\tilde{V}} \left\{ \frac{C}{\tilde{C}} (\tilde{w} + \tilde{T}) - (w + T) \right\}$$

To ensure a solution in which each individual's relative wealth is bounded we seek the forward-looking solution to this equation and impose the transversality condition to obtain

$$v_j(t) - 1 = (\tilde{v}_j - 1) \left\{ 1 - \frac{(\tilde{w} + \tilde{T})}{\tilde{V}} \int_t^\infty \left[\frac{C(u)}{\tilde{C}} - \frac{w(u) + T(u)}{(\tilde{w} + \tilde{T})} \right] e^{-\beta(u-t)} du \right\} \tag{A.18}$$

Setting $t = 0$ in (A.18), determines steady-state relative wealth, \tilde{v}_j in terms of initial relative wealth,

$$(\tilde{v}_j - 1) = (v_j(0) - 1) \left\{ 1 + \frac{(\tilde{w} + \tilde{T})}{\tilde{V}} \int_0^\infty \left[\frac{w(u) + T(u)}{(\tilde{w} + \tilde{T})} - \frac{C(u)}{\tilde{C}} \right] e^{-\beta u} du \right\}^{-1} \tag{A.18'}$$

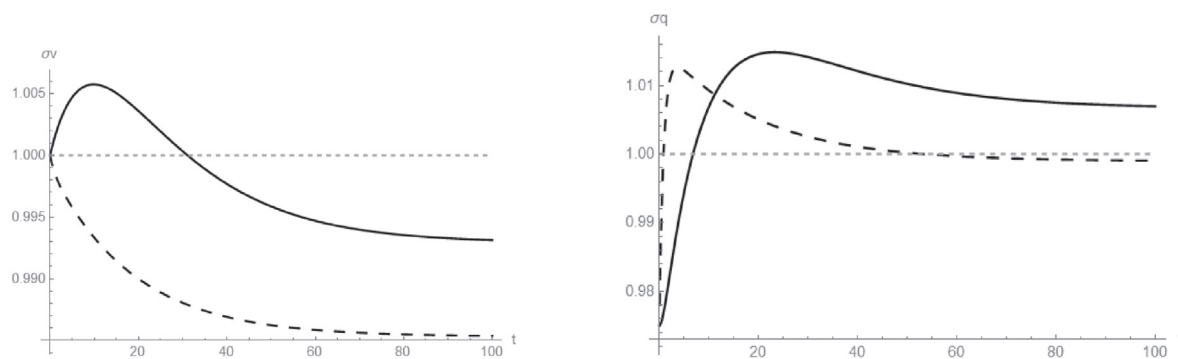
Because of their linearity across agents, equations (A.18) and (A.18'), which pertain to a specific individual's relative asset position, can be directly transformed into a corresponding relationship describing the relative distribution of wealth across agents, as measured by its coefficient of variation, which therefore serves as a convenient measure of wealth inequality. For notational convenience let

$$\chi(t) \equiv \left\{ 1 + \frac{(\tilde{w} + \tilde{T})}{\tilde{V}} \int_t^\infty \left[\frac{w(u) + T(u)}{(\tilde{w} + \tilde{T})} - \frac{C(u)}{\tilde{C}} \right] e^{-\beta(u-t)} du \right\} \tag{A.18''}$$

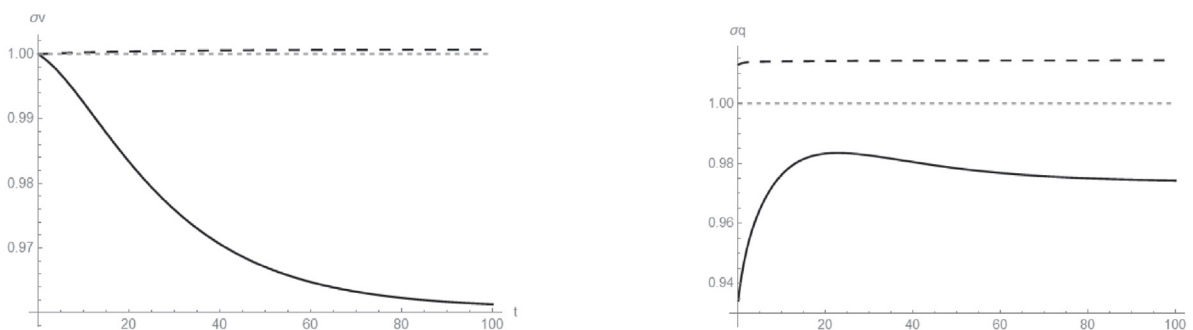
in which case (A.18) and (A.18'') imply (20a) of the text. Thus given $\sigma_{v,0}$, (20a) and (20b) determine the entire time path of wealth inequality, $\sigma_v(t)$.

Table A.1
Sensitivity analysis.

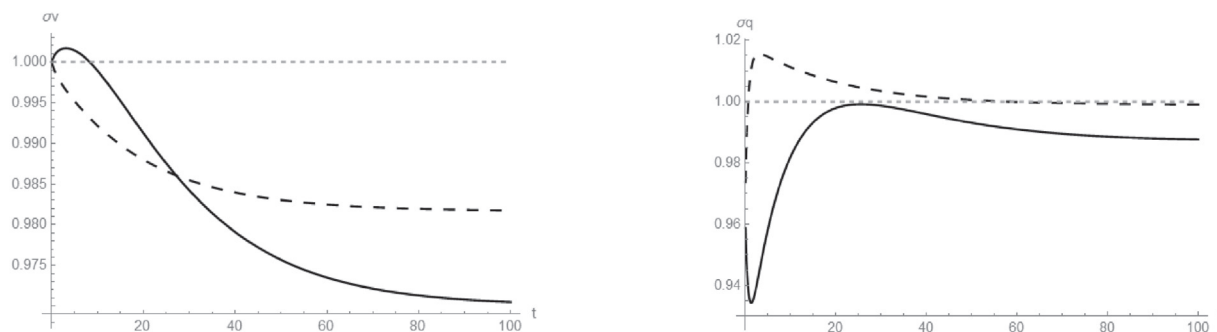
	<u>K</u>	<u>C/V</u>	<u>$\bar{\sigma}_v$</u>		<u>$\sigma_q(0)$</u>	<u>$\bar{\sigma}_q$</u>	<u>$\sigma_q(0)$</u>	<u>$\bar{\sigma}_q$</u>
	% change	% change	Discrete change	Gradual change	Discrete change		Discrete change	Gradual change
A. Variations in consumption openness: η								
Reduce τ_c by 0.10								
$\eta = 0.2$	0.35	-1.52	-0.12	-0.89	1.28	1.42	0	0.64
$\eta = 0.4$	0.49	-2.57	-0.17	-1.45	2.23	2.46	-0.01	1.16
Reduce τ_e by 0.10								
$\eta = 0.2$	6.29	-1.36	-0.66	-2.42	-0.15	0.70	-4.41	-1.11
$\eta = 0.4$	6.24	-1.36	-0.62	-2.27	-0.12	0.75	-4.37	-0.98
B. Variations in productivity of capital: α, σ								
Reduce τ_c by 0.10								
$\alpha = 0.60, \sigma = 0.2$	0.34	-1.52	-0.08	-0.99	1.24	1.47	-0.01	0.55
$\alpha = 0.60, \sigma = 0.5$	0.34	-1.52	-0.10	-0.93	1.27	1.44	-0.01	0.60
$\alpha = 0.60, \sigma = 1.0$	0.34	-1.52	-0.12	-0.89	1.28	1.42	-0.01	0.64
$\alpha = 0.60, \sigma = 1.5$	0.34	-1.52	-0.14	-0.87	1.28	1.41	-0.01	0.67
$\alpha = 0.40, \sigma = 0.2$	0.34	-1.52	-0.12	-0.96	1.25	1.42	-0.01	0.57
$\alpha = 0.40, \sigma = 0.5$	0.34	-1.52	-0.10	-0.93	1.27	1.45	-0.01	0.61
$\alpha = 0.40, \sigma = 1.0$	0.34	-1.52	-0.08	-0.88	1.31	1.47	-0.01	0.66
$\alpha = 0.40, \sigma = 1.5$	0.34	-1.52	-0.07	-0.85	1.34	1.48	-0.02	0.69
Reduce τ_e by 0.10								
$\alpha = 0.60, \sigma = 0.2$	8.60	-1.37	-1.73	1.00	-4.88	-0.32	-2.21	2.40
$\alpha = 0.60, \sigma = 0.5$	7.68	-1.37	-1.50	-0.71	-2.20	-0.10	-2.75	0.67
$\alpha = 0.60, \sigma = 1.0$	6.29	-1.36	-0.67	-2.46	-0.15	0.70	-4.41	-1.11
$\alpha = 0.60, \sigma = 1.5$	5.05	-1.35	0.07	-3.39	1.29	1.43	-6.57	-2.62
$\alpha = 0.40, \sigma = 0.2$	9.39	-1.52	-3.03	-4.09	-4.43	-1.54	-1.28	-2.62
$\alpha = 0.40, \sigma = 0.5$	9.70	-1.73	-1.83	-3.00	-2.63	-0.11	-4.13	-1.30
$\alpha = 0.40, \sigma = 1.0$	10.00	-2.07	-0.75	-3.24	-0.03	1.35	-6.98	-1.19
$\alpha = 0.40, \sigma = 1.5$	10.46	-2.41	0.09	-3.54	2.31	2.57	-9.10	-1.15
C. Variations in labor productivity: ω_T, ω_N								
Reduce τ_c by 0.10								
$\omega_T = 0.44, \omega_N = 0.28$	0.35	-1.52	-0.12	-0.89	1.28	1.42	0	0.64
$\omega_T = 0.50, \omega_N = 0.34$	0.30	-1.48	-0.10	-0.82	1.27	1.41	-0.01	0.67
Reduce τ_e by 0.10								
$\omega_T = 0.44, \omega_N = 0.28$	6.29	-1.36	-0.67	-2.46	-0.15	0.70	-4.41	-1.11
$\omega_T = 0.50, \omega_N = 0.34$	6.99	-1.63	-0.78	-2.42	-0.23	0.87	-4.39	-0.81
	<u>Z/Y</u>	<u>C/V</u>	<u>$\bar{\sigma}_v$</u>		<u>$\sigma_q(0)$</u>	<u>$\bar{\sigma}_q$</u>	<u>$\sigma_q(0)$</u>	<u>$\bar{\sigma}_q$</u>
	initial	% change	Discrete change	Gradual change	Discrete change		Discrete change	Gradual change
D. Variations in international capital mobility: ρ								
Reduce τ_c by 0.10								
$\rho = 0.03$	0.85	-1.52	-0.18	-0.93	1.25	1.37	-0.01	0.61
$\rho = 0.06$	0.42	-1.52	-0.12	-0.89	1.28	1.42	0	0.64
$\rho = 0.10$	0.25	-1.52	-0.09	-0.87	1.29	1.45	-0.01	0.67
Reduce τ_e by 0.10								
$\rho = 0.03$	0.85	-1.41	-0.81	-3.75	-0.01	0.61	-5.58	-2.24
$\rho = 0.06$	0.42	-1.36	-0.66	-2.42	-0.15	0.70	-4.41	-0.98
$\rho = 0.10$	0.25	-1.35	-0.54	-1.96	-0.17	0.81	-4.06	-0.62



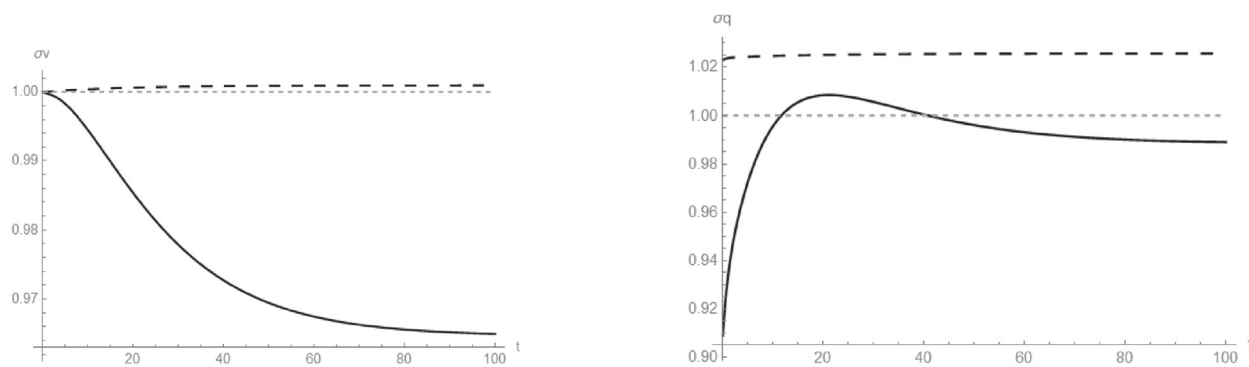
A. Technology structures intensive; very low substitution ($\alpha = 0.6, \sigma = 0.5$)



B. Technology structures intensive; very high substitution ($\alpha = 0.6, \sigma = 1.5$)



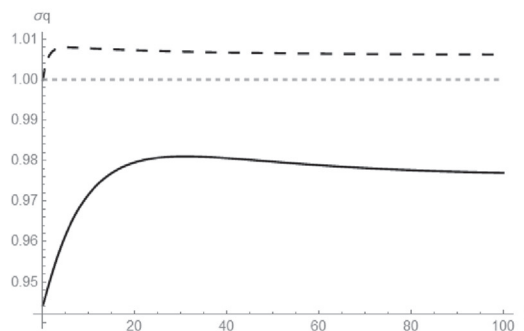
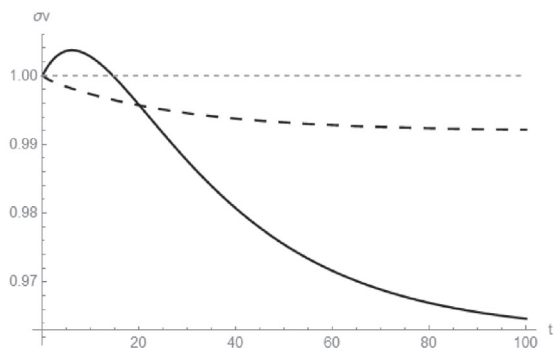
C. Technology machine intensive; very low substitution ($\alpha = 0.4, \sigma = 0.5$)



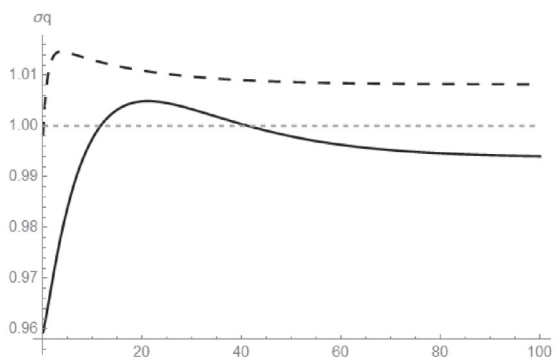
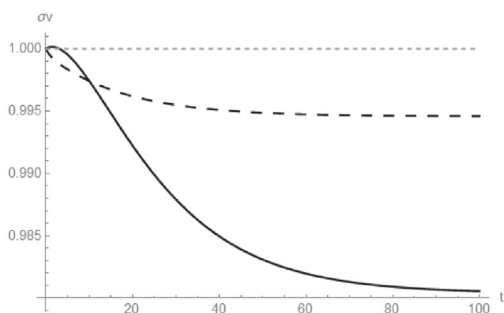
D. Technology machine intensive; very high substitution ($\alpha = 0.6, \sigma = 1.5$)

--- : Initial equilibrium — : Gradual Reduction - - - : Instantaneous Reduction

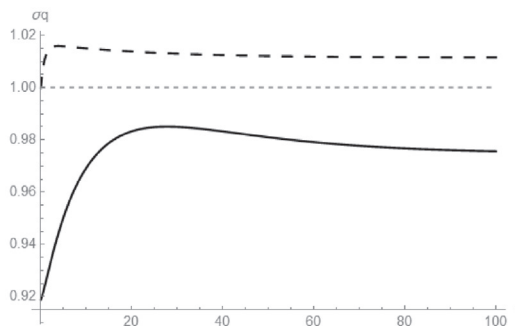
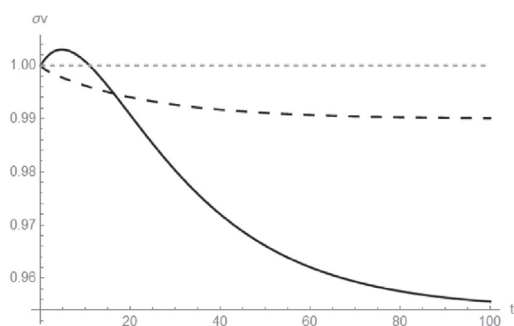
Fig. A.1a. Reduction in tariff on investment: alternative scenarios.



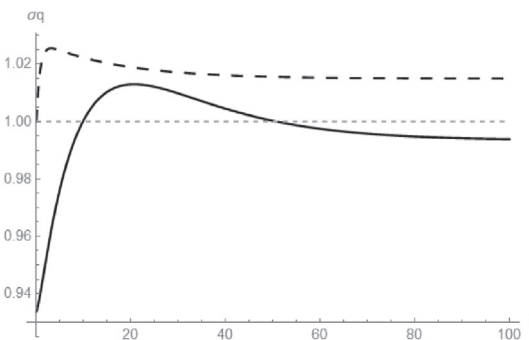
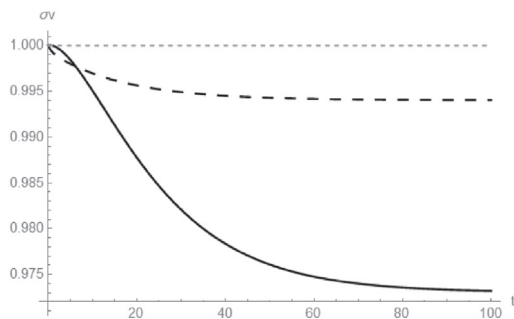
A. Technology structures intensive; high capital mobility ($\alpha = 0.6, a = 0.03$)



B. Technology structures intensive; low capital mobility ($\alpha = 0.6, a = 0.1$)



C. Technology machine intensive; high capital mobility ($\alpha = 0.4, a = 0.03$)



D. Technology machine intensive; low capital mobility ($\alpha = 0.4, a = 0.1$)

--- : Initial equilibrium — : Gradual Reduction - - - : Instantaneous Reduction

Fig. A.1b. Reduction in tariff on investment: alternative scenarios.

Appendix B. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jdeveco.2018.06.001>.

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