Tax Cuts in Open Economies[1]

Alejandro Cuñat
University of Vienna
alejandro.cunat@univie.ac.at

Szabolcs Deák
University of Exeter
s.deak@exeter.ac.uk

Marco Maffezzoli
Università Bocconi and IGIER
marco.maffezzoli@unibocconi.it

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Abstract

A reduction in capital tax rates generates substantial dynamic responses within the framework of the standard neoclassical growth model. The short-run revenue loss after a tax cut is partly — or, depending on parameter values, even completely — offset by growth in the long-run, due to the resulting incentives to further accumulate capital. We study how the dynamic response of government revenue to a tax cut changes if we allow a Ramsey economy to engage in international trade: the open economy's ability to reallocate resources between labor-intensive and capital-intensive industries reduces the negative effect of factor accumulation on factor returns, thus encouraging the economy to accumulate more than it would do under autarky. We explore the quantitative implications of this intuition for the US in terms of two issues recently treated in the literature: *dynamic scoring* and the *Laffer curve*. Our results demonstrate that international trade enhances the response of government revenue to tax cuts by a relevant amount. In our benchmark calibration, a reduction in the capital-income tax rate has virtually no effect on government revenues in steady state.

Keywords: International Trade; Heckscher-Ohlin; Dynamic Macroeconomics; Taxation; Revenue Estimation; Laffer Curve.

JEL codes: E13, E60, F11, H20.

1 Introduction

This paper studies the dynamic response of government revenues to income tax cuts in an environment in which countries engage in commodity trade. In particular, we construct a model in which two Ramsey economies specialize according to their factor abundance. We show that the long-run negative effect of a reduction in a country's capital-income tax rate on government revenues is much smaller than in the standard closed-economy Ramsey model.

The different behavior of the closed and open economies can be understood in terms of the different ways their sectorial factor allocation mechanisms work. A reduction in the capital-income tax rate raises the after-tax return to capital, thus creating an incentive to accumulate capital. Under autarky, an increase in the aggregate capital-labor ratio implies higher sectorial capital intensities; the diminishing marginal productivity of capital therefore reduces the return to capital and thereby the incentive to accumulate. In the open economy, instead, capital-labor intensities do not respond to exogenous[1] increases in the aggregate capital-labor ratio that much, as resources are reallocated from labor-intensive to capital-intensive industries. This enables the open economy to accumulate capital without affecting the gross return to capital as much as under autarky. Obviously, this generates a stronger reaction of capital income to the initial tax cut, and therefore reduces the negative impact of the tax cut on government revenues.

The paper's main contribution consists in a quantitative assessment of the relevance of this intuition. For this purpose, we calibrate our dynamic two-country model with the US and the rest of the world in mind, and compute the short-run and long-run responses of government revenue to tax cuts. We relate our results to two issues, dynamic scoring and the Laffer curve, that have been treated recently in the literature.

First, Mankiw and Weinzierl (2006) criticize the way the Congressional Budget Office and the Joint Committee on Taxation score the proposed legislation each time the US Congress considers tax policy changes: the way the revenue impact of tax changes is calculated is usually referred to as *static scoring*, because it ignores the feedback effect from tax changes to any macroeconomic variable.[2] Mankiw and Weinzierl (2006) take a firm stand in favor of *dynamic scoring*: they use a closed-economy Ramsey model to show that the short-run response of government revenues to tax-rate changes is always stronger than the long-run response.[3]

Second, in a more recent reference, Trabandt and Uhlig (2011) use the neoclassical growth model to characterize the shape of the Laffer curve in the US and Europe. They find that both the US and Europe are on the upward sloping side of the Laffer curve; however, they point out that Europe is quite close to the Laffer curve's 'slippery slope,' that is, its downward sloping side.

Regarding dynamic scoring, we find that our dynamic trade model generates a much larger response on the factor accumulation side to a tax cut than in the autarky model, as we discussed above.[4] In our benchmark calibration, for example, a capital tax cut is

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[1] By "exogenous" changes in capital-labor endowments we actually refer to changes in factor endowment ratios that are not a response to technical progress.

[2] It is static from a macroeconomic point of view only, because feedback effects from microdynamic behaviour are incorporated into the forecast. For details, see Auerbach (1996).

[3] Leeper and Yang (2008) point out that the results of Mankiw and Weinzierl (2006) are sensitive to their assumption on how government deficits are financed.

[4] In fairness to Mankiw and Weinzierl (2006), we should point out that they are aware of the open-economy model yielding a stronger dynamic effect. See section 3.6 in their paper.

almost fully able to finance itself in the long run, whereas the dynamic response to the tax cut in the autarky economy only compensates for 61% of the short-run revenue loss. As for the Laffer curve, we find that the US is almost on the Laffer curve's 'slippery slope': the actual average US tax rate on capital income is 27.3%, while the revenue-maximizing tax rate in our model, the peak of the Laffer curve, equals 27.9%. In contrast, under autarky, the peak of the Laffer curve occurs at a tax rate of 46.3%.

The main intuition of our paper is based on Ventura (1997), who shows, in the context of the neoclassical growth model, that the negative effect of capital accumulation on the return to capital is reduced by free trade. Although insightful and elegant, the Ventura model turns out not to be a very useful workhorse for performing a quantitative exercise of the kind we have in mind, since it yields international factor price equalization. First of all, this is obviously not a very realistic feature when contrasted with the data; secondly, the treatment of steady states in the presence of taxation becomes somewhat tricky, as the equalization of before-tax interest rates implies different after-tax interest rates if capital-income taxation differs across countries. Therefore, for our calibration exercise we produce a model based on Cuñat and Maffezzoli (2007), which is a dynamic generalization of Dornbusch et al. (1980). This set-up enables us to model Heckscher-Ohlin trade with trade frictions and therefore no factor price equalization (both important features in reality) in a rather straightforward way. See Davis and Weinstein (2001) and Romalis (2004) for empirical evidence supporting this model's predictions.

The link between taxation and international trade is obviously not new.[5] Whalley (1980) is a good example of a "Computable General Equilibrium" model of taxation and international trade, which compares the welfare implications of tax policies under autarky and trade.[6] Baxter (1992) shows that changes in taxation can affect cross-country specialization patterns within a dynamic model of Ricardian comparative advantage. This is also the case in our model: comparative advantage is influenced by taxation through its effects on factor accumulation. More interestingly, we show that the quantitative effects of taxation depend on an economy's ability to reallocate resources according to the evolution of its comparative advantage. Mendoza and Tesar (1998) studies tax reforms in a one-good, two-country dynamic model calibrated to U.S. and European tax policies, focusing on the role of intertemporal trade in the transmission of fiscal policy shocks across countries. In the same framework, Mendoza and Tesar (2005) discuss the issue of international tax competition, and Mendoza et al. (2014) and Auray et al. (2016) study the effects of fiscal adjustments to restore fiscal solvency in response to debt shocks. Bianconi (1995) studies tax policy in a neoclassical two-country dynamic model with integrated capital markets analytically. Kim and Kose (2014) and Choi and Kim (2016) study the welfare implications of revenue-neutral fiscal reform programs for developing economies in a multi-sector model of a small open economy. In comparison with these

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[5]The closed-economy literature on taxation in a dynamic set-up is clearly vast. An early reference that studies the dynamic incidence of labor taxes in a neoclassical growth model analytically is Bernheim (1981). Other notable examples of works that study the dynamic consequences of tax policies in a neoclassical framework are Cooley and Hansen (1992), Ireland (1994), Pecorino (1995), and Stokey and Rebelo (1995). More recent contributions are Bruce and Turnovsky (1999), who present a dynamic scoring exercise with the main focus on the sustainability of the fiscal balance of the government; and Novales and Ruiz (2002), who use a numerically simulated endogenous growth model to compare the feasible pairs of tax rates on capital and labour from a welfare point of view. It is also worth mentioning Backus et al. (2008), who study the empirical relationship between different measures of effective tax rates on capital and the cross-country dispersion of capital-labor ratios for a group of OECD countries.

[6]See Shoven and Whalley (1984) for a survey of CGE models of taxation and international trade.

references, we ignore capital mobility; but the international dimension we exploit, goods trade and changes in production structures, also yields striking results from a quantitative perspective. More recently, Andersen (2007) studies tax competition in a static Ricardian trade model, and Epifani and Gancia (2009) studies the empirical relationship between international trade and the size of the government. The value added of our work here is the treatment of fiscal policy effects in a dynamic setting.

As far as the empirical evidence is concerned, Johansson and Olaberria (2014) look at the effects of labor taxes on industrial specialisation in 26 sectors of 37 OECD and non-OECD countries. They find a significant relationship between the labor tax wedge and the intensity of labor in production. This suggests that countries with higher labor taxes tend to specialise in industries that are less labor intensive. Our exercise is instead about the effects of capital taxation, but the economics of the long-run effects of factor-income taxation on specialization patterns is likely to be similar across types of production factors.

The rest of the paper is structured as follows: section 2 lays out a rather general dynamic trade model; in section 3 we develop some intuition by working out a very particular case, while in section 4 we simulate a more realistic version of the model; section 5 checks the sensitivity and robustness of our results; finally, section 6 presents our concluding remarks.

2   The Model

This and the next two sections present the dynamic Heckscher-Ohlin model with which we study the dynamic effects of tax cuts. We first sketch out the main ingredients of the model economy; then solve for a particular case analytically; finally, we calibrate a more realistic, albeit less tractable, case.

2.1   The Representative Household's Problem

Countries, indexed by j, are populated each by a *continuum* of identical households that can be aggregated into a single representative household. The representative household owns the capital stock and supplies capital and labor services elastically; and either consumes or invests a final good. Governments collect taxes on factors of production (with possibly different rates applied to capital K and labour L); government revenues are paid back to households via lump-sum transfers. The representative household's preferences over consumption streams can be summarized by the following intertemporal utility function:

$$U_j = \sum_{t=0}^{T} \beta^t \frac{[C_{jt}(N_j - L_{js})^{\gamma}]^{1-\frac{1}{\mu}} - 1}{1 - \frac{1}{\mu}}, \tag{1}$$

where β is the subjective intertemporal discount factor, $\gamma > 0$ is the share of leisure in total utility, and μ the elasticity of intertemporal substitution. T denotes the representative household's time horizon; C denotes consumption of the final good. The representative households maximize equation (1) subject to the following intratemporal budget constraint

$$P_{jt}(C_{jt} + I_{jt} - R_{jt}) = (1 - \tau_j^L) w_{jt} L_{jt} + (1 - \tau_j^K) r_{jt} K_{jt},$$

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where P is the price of the final good; I denotes investment; r and w are factor prices; τ^L and τ^K are the tax rates on labor and capital, respectively; and

$$R_{jt} = \tau_j^L \frac{w_{jt}}{P_{jt}} L_{jt} + \tau_j^K \frac{r_{jt}}{P_{jt}} K_{jt} \tag{2}$$

denotes real government transfers.[7] Factor prices are taken as given by the representative household. The capital stocks evolve according to the following accumulation equation:

$$K_{jt+1} = (1 - \delta) K_{jt} + I_{jt},$$

where $\delta \in [0, 1]$ is the depreciation rate.[8] L_j is assumed constant. The first-order conditions

$$\beta C_{jt+1}^{-\frac{1}{\mu}} (N_j - L_{j,t+1})^{\gamma\left(1-\frac{1}{\mu}\right)} \left[\left(1 - \tau_j^K\right) \frac{r_{jt+1}}{P_{jt+1}} + 1 - \delta \right] = C_{jt}^{-\frac{1}{\mu}} (N_j - L_{j,t})^{\gamma\left(1-\frac{1}{\mu}\right)}, \tag{3}$$

$$\gamma C_{jt} = (N_j - L_{jt}) \left(1 - \tau_j^L\right) \frac{w_{jt}}{P_{jt}}, \tag{4}$$

$$K_{jt+1} = \left(1 - \tau_j^L\right) \frac{w_{jt}}{P_{jt}} L_{jt} + \left[\left(1 - \tau_j^K\right) \frac{r_{jt}}{P_{jt}} + 1 - \delta \right] K_{jt} + R_{jt} - C_{jt}, \tag{5}$$

and the corresponding transversality condition are necessary and sufficient for the representative household's problem. A recursive competitive equilibrium for this economy is characterized by equations (3)-(5) together with the equations that determine prices in the "static" equilibrium, to be discussed below.

2.2 Equilibrium Prices

Capital and labor are assumed to be internationally immobile. In each period, prices are determined in a "static" equilibrium, where we consider both autarky and trade.[9]

2.2.1 The Final Good

The final good, which is assumed to be nontradable, is produced under perfect competition with a *continuum* of intermediate goods. The representative firm operating in the final good sector maximizes profits subject to the following Cobb-Douglas production function, taking all prices as given:

$$Y_j = \exp \left[\int_0^1 \ln x_j(z) dz \right],$$

where $x(z)$ denotes the quantity of intermediate good z used.[10] Hence, the demand for intermediate good z is given by

$$x_j(z) = \frac{P_j Y_j}{p_j(z)},$$

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[7]For the sake of simplicity, we assume a balanced budget, and rule out any productive and/or welfare-enhancing role for public expenditure.

[8]For the sake of notational simplicity, we ignore exogenous technical progress. This does not affect our results significantly.

[9]For convenience, in this section we avoid time subscripts on variables, which might vary over time.

[10]We use z to denote both intermediate inputs and the industries that make them. Industries are assumed to produce each one intermediate input only.

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where $p_j(z)$ represents the price of intermediate good z and P_j is the price of the final good:

$$P_j = \exp\left[\int_0^1 \ln p_j(z)dz\right].$$

2.2.2 Intermediate Goods

Intermediate goods are produced also under perfect competition. The representative producer in industry z maximizes profits subject to the following Cobb-Douglas production function, taking again all prices as given:

$$y_j(z) = \phi_j k_j(z)^{\alpha(z)} l_j(z)^{1-\alpha(z)},$$

where $\alpha(z) \in [0,1]$ denotes the capital share in industry z, $k(z)$ and $l(z)$ the capital and labor allocated to the production of intermediate good z, respectively, and ϕ_j is a time-invariant country-specific technology parameter. We label intermediate goods so as to have their capital intensities increase in z, *i.e.* $\alpha'(z) \geq 0$. Technologies are identical across countries, but for the exogenous factor-augmenting coefficients ϕ_j.

Intermediate goods can be traded. We model trade frictions as iceberg-type transport costs: $\nu \geq 1$ units of a good must be shipped from the country of origin for one unit to arrive to the country of destination. $\nu = 1$ therefore corresponds to free trade. A high enough ν yields autarky instead.

2.2.3 Autarky Equilibrium Prices

Assume that ν is such that intermediate goods are not traded. Choosing the final good as the numeraire, the autarky static equilibrium conditions (discussed in the appendix) yield the following equilibrium before-tax factor prices:

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\begin{aligned}
r_j &= \phi_j A \left(\frac{1-\tilde{\alpha}}{\tilde{\alpha}}\right)^{\tilde{\alpha}-1} \left(\frac{K_j}{L_j}\right)^{\tilde{\alpha}-1}, \\
w_j &= \phi_j A \left(\frac{1-\tilde{\alpha}}{\tilde{\alpha}}\right)^{\tilde{\alpha}} \left(\frac{K_j}{L_j}\right)^{\tilde{\alpha}},
\end{aligned}
$$

where $A \equiv \exp\left[\int_0^1 \ln a(z)dz\right]$, $a(z) \equiv \alpha(z)^{\alpha(z)}[1-\alpha(z)]^{1-\alpha(z)}$ is an industry-specific constant, and $\tilde{\alpha} = \int_0^1 \alpha(z)dz$ is the autarky economy's aggregate capital share.[11]

It is easy to show that the allocation of labor to each sector is a constant fraction of the economy's total amount of labor:

$$l_j(z) = \frac{1-\alpha(z)}{1-\tilde{\alpha}} L_j.$$

Finally, sectorial capital-labor intensities move one-to-one with the economy's aggregate capital-labor ratio:

$$\frac{k_j(z)}{l_j(z)} = \frac{\alpha(z)}{1-\alpha(z)} \frac{w_j}{r_j} = \frac{\alpha(z)}{1-\alpha(z)} \frac{1-\tilde{\alpha}}{\tilde{\alpha}} \frac{K_j}{L_j}. \tag{6}$$

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[11]The autarky version of the model is equivalent to a one-sector Ramsey model with a Cobb-Douglas production technology of the form $Y_j = \phi_j A K_j^{\tilde{\alpha}} L_j^{1-\tilde{\alpha}}$; our closed-economy framework is thus comparable to similar papers in the literature.

2.2.4 Trade Equilibrium Prices

We consider two cases here: a free-trade scenario, in which factor prices are equalized across countries; and a more realistic scenario, in which trade frictions prevent the law of one price from holding. Below we use the free-trade case to produce an analytically solvable example providing some intuition; the case with trade frictions is used in the quantitative section of the paper.

Free Trade Assume $\nu = 1$. For simplicity, consider a worldwide factor price equalization (FPE) equilibrium, in which the world as a whole behaves as an "integrated equilibrium" in which goods and factors can move freely. That is, the whole world behaves like the autarky economy described above. Provided that countries do not have capital-labor ratios that are "too different" from the world's aggregate capital-labor ratio, then they will not be completely specialized, and will have the integrated equilibrium's factor prices.[12] This implies factor prices are independent of the country's own factor endowments. A direct implication of this is the independence of sectorial capital-labor intensities from the country's own capital-labor ratio. In fact, factor prices are exclusively a function of the world's capital-labor ratio in exactly the same form that the factor prices of the closed economy above are a function of its own capital-labor ratio.

Trade Frictions Assume there are two countries, North and South, indexed by $j = N, S$, respectively. We assume that the North is capital abundant, *i.e.* $K_N/L_N > K_S/L_S$, and therefore has a comparative advantage in the production of capital-intensive goods. Intermediate goods can be traded, but not freely: $\nu > 1$.[13] A trading equilibrium is characterized by two cut-off values $0 \leq z_N < z_S \leq 1$, that divide the range of intermediate goods into three subregions:

1. The intermediate goods $z \in [0, z_N)$ are exclusively produced in the South and shipped to the North.

2. The intermediate goods $z \in [z_N, z_S]$ are produced in both countries and nontraded. These commodities are not worth shipping from one country to another despite comparative advantage. This is due to the price wedge the trade cost introduces between countries.

3. The intermediate goods $z \in (z_S, 1]$ are exclusively produced in the North and shipped to the South.

The corresponding equilibrium conditions are discussed in the appendix. For further details, see Cuñat and Maffezzoli (2007).

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[12]Below we make sure that the small open economy is in the FPE set. For a discussion on factor price equalization and the integrated equilibrium, see Dixit and Norman (1980).

[13]For the autarky equilibrium to be sustainable, *at autarky prices* transport costs must make it pointless to ship goods across countries. In other words, it has to be the case that

$$b(0, \phi_N, r_N, w_N) \leq \nu b(0, \phi_S, r_S, w_S),$$
$$b(1, \phi_S, r_S, w_S) \leq \nu b(1, \phi_N, r_N, w_N),$$

where r_j and w_j are the autarky prices described above and $b(z, \phi_j, r_j, w_j)$ the unit-cost function of industry z evaluated in country j. This implies that, if $(w_N/r_N)/(w_S/r_S) = (K_N/L_N)/(K_S/L_S) \leq \nu^{\frac{2}{\alpha(1)-\alpha(0)}}$, autarky will take place. If, on the other hand, $(K_N/L_N)/(K_S/L_S) > \nu^{\frac{2}{\alpha(1)-\alpha(0)}}$, autarky will not be sustainable and countries will trade.

3 A Simple Free-trade Case

Let us first address a two-period, free-trade case, which we can solve analytically. Assume $K_{j0} > 0$, $L_j = 1$, $T = 1$, $\mu = 1$ (log-utility), $\delta = 0$, $\nu = 1$ (free trade), $\tau_j^L = 0$ and $\phi_j = 1$. We will use the final good as the numeraire: $P = 1$. Furthermore, for the sake of notational simplicity, we will drop time and country indexes, since they turn out to be redundant under the assumptions imposed in this Section. The Euler equation (3) can then be rewritten as:

$$\beta \left(Y_0 - I_0\right) \left[1 + \left(1 - \tau^K\right) r_1\right] = Y_1 + K_1, \tag{7}$$

where $Y_0 = r_0 K_0 + w_0 L$ and $I_0 = K_1 - K_0$. The transversality condition associated to the representative household's maximization problem is simply $K_2 = 0$.

3.1 Autarky Economy

The Euler equation (7) implicitly solves for K_1, where the return to capital is given by the corresponding expression in Section 2.2.3. We can now study the dynamic implications of changes in taxation (around this equilibrium). By the Implicit Function Theorem, we can compute the effect of changes in τ^K on capital accumulation:

$$\left.\frac{dK_1}{d\tau^K}\right|_A = \frac{-\beta r_1 \left(Y_0 - I_0\right)}{1 + r_1 + \beta \left\{1 + \left(1 - \tau^K\right) r_1 \left[\tilde{\alpha} + (1 - \tilde{\alpha}) \frac{Y_0 + K_0}{K_1}\right]\right\}} < 0, \tag{8}$$

as $Y_0 - I_0 > 0$. A fall in τ^K raises the after-tax return to capital, thus encouraging further capital accumulation.

The effect of τ^K on period-1 gross interest rate is also easy to compute:

$$\left.\frac{dr_1}{d\tau^K}\right|_A = \frac{dr_1}{dK_1} \left.\frac{dK_1}{d\tau^K}\right|_A = (\tilde{\alpha} - 1) A \left(\frac{1 - \tilde{\alpha}}{\tilde{\alpha}}\right)^{\tilde{\alpha} - 1} \left(\frac{K_1}{L}\right)^{\tilde{\alpha} - 2} \left.\frac{dK_1}{d\tau^K}\right|_A > 0.$$

For future reference, it will be useful to also compute:

$$\varepsilon_{r_1} = (\tilde{\alpha} - 1) \left.\varepsilon_{K_1}\right|_A > 0,$$

where

$$\varepsilon_x \equiv \frac{dx}{d\tau^K} \frac{\tau^K}{x}$$

represents the elasticity of a generic variable x with respect to changes in τ^K.

The gross return to capital falls with the aggregate capital-labor ratio due to the diminishing marginal productivity of capital: from (6), it is easy to see that sectorial capital intensities rise with the economy's aggregate capital-labor ratio. Thus, the effect of a reduction in τ^K on government revenue has two opposing components: an increase in the capital stock, and a reduction in its gross return.

3.2 Small Open Economy

For simplicity, consider a factor price equalization (FPE) equilibrium, in which the world (the integrated equilibrium) has got a capital-labor ratio with a time path identical to that of the autarky economy above. Consider a small open economy that has got the

same initial condition K_0 and parameter values as in the autarky equilibrium. Since this economy faces the same factor prices of the autarky economy, the Euler equation (7) must yield the same solution for K_1 as under autarky.[14] The return to capital is given by the corresponding expression in Section 2.2.3 as a function of the world's capital-labor ratio. Given our small-open-economy assumption here, the world's capital-labor ratio (and the return to capital) does not respond to changes in the country's own capital-labor ratio.

Once again, by the Implicit Function Theorem, we can compute the effect of changes in τ^K on capital accumulation (around this equilibrium):

$$\left.\frac{dK_1}{d\tau^K}\right|_O = \frac{-\beta r_1 (Y_0 - I_0)}{1 + r_1 + \beta \left[1 + (1 - \tau^K) r_1\right]} < 0. \tag{9}$$

Comparing (8) and (9), it is easy to see that the effect of a tax cut on K_1 is larger under free trade than under autarky, as $Y_0 + K_0 > K_1$:[15]

$$\left|\left.\frac{dK_1}{d\tau^K}\right|_O\right| > \left|\left.\frac{dK_1}{d\tau^K}\right|_A\right|.$$

Since commodity prices are given for the small open economy, $\left.\frac{dr_1}{d\tau^K}\right|_O = 0$.

The different behavior of the closed and open economies can be understood as due to the different ways their factor allocation mechanisms work. A reduction in τ raises the after-tax return to capital in both economies, creating an incentive to raise K_1. Under autarky, an increase in K_1 implies higher sectorial capital-labor intensities; the diminishing marginal productivity of capital thereby reduces the return to capital and, therefore, the incentive to accumulate. In the open economy, instead, capital-labor intensities do not respond to increases in the aggregate capital-labor ratio (as factor-price ratios remain constant), and the marginal productivity of capital therefore does not fall: full employment of resources is achieved by a reallocation of resources from labor-intensive to capital-intensive industries. In other words, factor price insensitivity to an increase in the aggregate capital-labor ratio is possible if and only if it is accompanied by a shift in production structures. Openness to trade allows this reshuffling and enables an economy to accumulate capital without affecting the gross return to capital.[16]

Figures 1 and 2 illustrate this point in the two-good case. The dimensions of the box represent a country's given quantities of the two factors, capital and labor. Factor quantities allocated to sector 1 and 2 are measured, respectively, with respect to O_1 and O_2. Let us start with the FPE case in Figure 1. Consider an initial endowment (K, L), and take point A as the corresponding allocation of resources in a small open economy under factor price equalization. The slopes of vectors $O_1 A$ and $O_2 A$ represent the capital-labor intensities of sectors 1 and 2, respectively. An increase in the capital endowment of the economy implies a vertical enlargement of the box. Given the small-open-economy factor-price-equalization assumption, capital-labor intensities remain constant, and full employment must obtain through the reallocation of factors from the labor-intensive to the capital-intensive sector, i.e., from industry 2 to 1. The new allocation of factors is represented by point A'. Figure 2 illustrates the 2x2 Cobb-Douglas closed-economy case. When the capital endowment increases, the amounts of labor allocated to both sectors do not vary at all. At the same time, the sectoral capital-labor intensities change

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[14]In the FPE jargon, our open economy is on the diagonal of the FPE set in both periods.

[15]The rest of variables and parameters in equations (8) and (9) are identical.
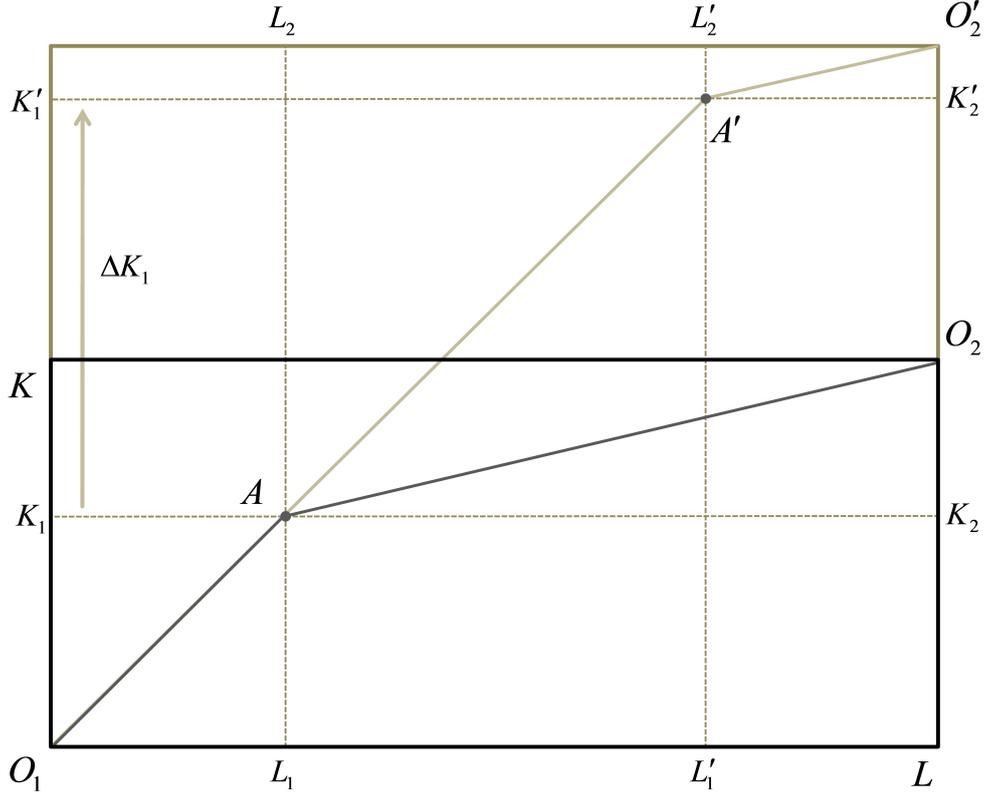
[16]See Ventura (1997).

Figure 1: Capital accumulation and allocation under free trade: two goods.

proportionally as much as the aggregate capital-labor ratio of the economy. Thus, during the growth process the Cobb-Douglas closed economy's allocation shifts vertically from B to B'.[17]

3.3 Tax Revenues

Let us now compare the effect of a tax cut on government revenues, $R = \tau^K r K$, in the closed and open economy. Recall that the autarky and open economies have got the same R before the tax cut. Differentiating R_1 with respect to τ^K:

$$\frac{dR_1}{d\tau^K} = r_1 K_1 \left(1 + \tau^K \frac{dr_1/d\tau^K}{r_1} + \tau^K \frac{dK_1/d\tau^K}{K_1} \right), \tag{10}$$

or, in elasticities with respect to τ^K,

$$\varepsilon_{R_1} = 1 + \varepsilon_{r_1} + \varepsilon_{K_1}. \tag{11}$$

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[17]The Cobb-Douglas functional forms (and the resulting unitary elasticities of substitution) are not completely harmless in this argument: in the closed economy, higher elasticities in the intermediate-good production function, for example, would deliver a lower increase in sectoral capital-labor intensities and some factor price insensitivity. However, estimated elasticities of substitution between capital and labor are not far from one. See, for example, Lucas (1969). In any case, the open economy would always experience a stronger reallocation process and more factor-price insensitivity than the closed economy unless the elasticities tend to infinity.
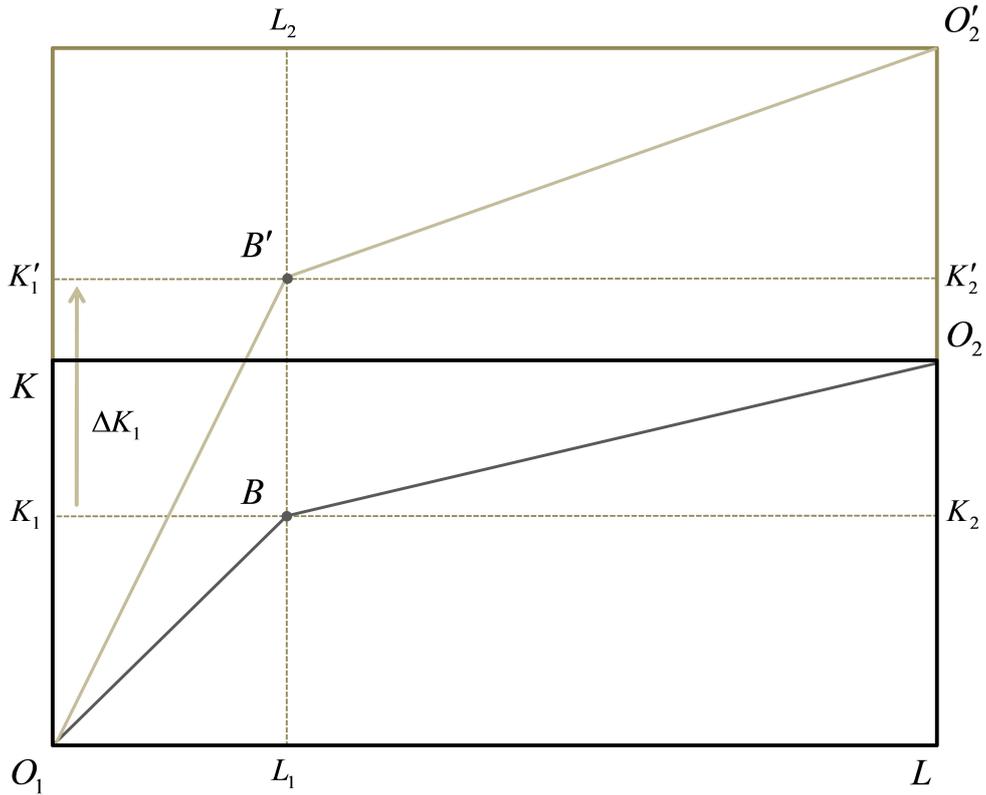
Figure 2: Capital accumulation and allocation in the closed economy: two goods.

Our results above on the responses of K_1 and r_1 to changes in τ^K imply that under free trade the tax cut is less costly for the government in terms of period-1 revenue than under autarky:

$$\varepsilon_{R_1}|_A - \varepsilon_{R_1}|_O = \tilde{\alpha}\, \varepsilon_{K_1}|_A - \varepsilon_{K_1}|_O > (\tilde{\alpha} - 1)\, \varepsilon_{K_1}|_A > 0.$$

This example suggests that openness and autarky display non-trivial quantitative differences in the effects of taxation.

4 Trade with Frictions

Although intuitive, the simple case above is based on a quite unrealistic scenario: free trade, and therefore FPE, are hampered by trade frictions. One other "technical" problem of the dynamic FPE model is that its infinite-horizon case is not that straightforward: the (Ramsey) infinite-horizon version of this model would require, assuming the same rate of time preference across countries, the equalization of after-tax returns to capital across countries in steady state. Under FPE this would only be possible if the capital tax rates were identical across countries, as free trade equalizes before-tax returns to capital. This makes steady-state comparisons of the kind Mankiw and Weinzierl (2006) and Trabandt and Uhlig (2011) perform impossible, unless the rate of time preference is assumed endogenous. To study the quantitative aspects of the issue more in detail, therefore, we turn to the trade-frictions scenario we discussed in Section 2. The intuitions of both models, with and without frictions, turn out to be quite similar: in comparison

with the closed economy, the possibility to reallocate factors across sectors reduces the negative impact of capital accumulation on the return to capital in the trading economy even when factor price equalization does not apply.

Assume $\nu > 1$ and $T = \infty$. It is convenient to choose a different numeraire: $p_S(0) = 1$. In the appendix we show that in order to remain in a steady state with trade in which $K_N/L_N > K_S/L_S$, we need to impose that $\left(1 - \tau_N^K\right)\phi_N > \left(1 - \tau_S^K\right)\phi_S$.[18] This assumption, together with the condition that equalizes the steady-state after-tax real rates of return across countries,

$$\left(1 - \tau_N^K\right)\frac{r_N}{P_N} = \left(1 - \tau_S^K\right)\frac{r_S}{P_S},$$

enables us to solve the equilibrium conditions for the steady state of the model numerically. We characterize both the autarky and trading equilibrium in order to compare the dynamic feedback from tax cuts for the two different regimes.

4.1 Calibration

To perform our quantitative exercise, we calibrate our trade model in terms of the US (the capital-abundant North) *vs.* the Rest of the World (the labor-abundant South). The basic parametrization is taken from Cuñat and Maffezzoli (2007): we set $\mu = 1$, $\beta = 0.96$, and $\delta = 0.048$. We normalize the size of the world labor endowment by setting $L_W \equiv L_N + L_S = 2$; according to data from Heston et al. (2006), roughly 5% of the global labor force is employed in the US economy: we therefore set $L_N = 0.05L_W$.

Anderson and van Wincoop (2004) show that trade costs represent a 170% *ad-valorem-tax-equivalent* trade barrier for a representative rich country. This number breaks down into a 55% of local trade costs and a 74% of international trade costs. Abstracting away from local distribution costs, we assign the value of ν to represent the *ad valorem* equivalent of international trade costs, *i.e.* we set $\nu = 1.74$.

Carey and Rabesona (2002) compute average effective tax rates on factors of production and consumption for 25 OECD countries, extending the Mendoza et al. (1994) methodology: from their Table A2, p. 172, we take the tax rates on capital (based on gross operating surplus) and labor for the 1990-2000 period.[19] We set the tax rates in the North to reproduce the observed US rates, *i.e.* $\tau_N^K = 27.3\%$ and $\tau_N^L = 23.4\%$; to pin down the tax rates in the South, instead, we compute weighted averages of the tax rates on capital and labor for the remaining countries, using the real GDP-PPP levels reported by Heston et al. (2006) for the 1990-2000 period as weights: the resulting values

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[18]We are simply imposing the condition that, for identical capital-labor ratios in both countries, the after-tax marginal productivity of capital be larger in country N. If, for example, $\beta_N = \beta_S$, $\phi_N = \phi_S$, and $\tau_N^K = \tau_S^K$, both countries would have the same capital-labor ratio in steady state, and there would be no trade. Note that we introduce cross-country differences in TFP levels only to guarantee the existence of international trade in steady state: the actual trade flows are generated by the induced differences in relative factor endowments. Hence, if TFP levels were equal across countries, trade could nonetheless emerge during converge towards the steady state (assuming countries with different initial conditions). A large literature on cross-country comparisons of TFP levels, summarized in Caselli (2005), provides empirical evidence supporting the existence of international differences in TFP levels.

[19]As Carey and Rabesona (2002) point out, the fiscal treatment of depreciation allowances is different across countries, making tax rates based on net operating surplus difficult to compare across countries. Furthermore, our model does not incorporate depreciation allowances explicitly, for the sake of simplicity. Hence, we focus on tax rates based on gross operating surplus.

are $\tau_S^K = 28.0\%$ and $\tau_S^L = 30.5\%$.[20]

The function $\alpha(z)$ is a key ingredient in our model. Given the Cobb-Douglas production functions for intermediate goods, $\alpha(z)$ should be directly related to the capital shares in value added at the sectorial level. Taking advantage of the *Gross Domestic Product by Industry* published by the US Bureau of Economic Analysis, we collect data on Value Added (VA), Compensation of Employees (COMP), Proprietors' Income (PROINC), Proprietors' Income Inventory Valuation Adjustment (PROIVA), Full-time Equivalent Employees (FTE), and Persons Engaged in Production (PEP), for 57 US sectors, defined according to the SIC87 classification, over the 1987-97 period.[21]

These data allow us to compute the labor share in value added at the sectorial level. We follow the two most common approaches in the literature to account for the labor income of self employed workers.[22] The first approach assigns the average wage received by employees to self-employed workers, and therefore our first estimate of the labor share is computed as

$$s_N = \frac{\frac{COMP}{FTE}PEP}{VA}.$$

The second approach recognizes that the main problem is the apportionment of proprietors' income, which has components of both labor and capital income, since it mainly represents income of self-employed individuals. We assume that proprietors income, net of inventory valuation adjustment, should be allocated to labor and capital in the same proportions as they represented in the remainder of the economy; hence,

$$s_N VA = COMP + s_N(PROINC + PROIVA).$$

In other words, our second estimate of the labor share is computed as

$$s_N = \frac{COMP}{VA - PROINC - PROIVA}.$$

These two estimates turn out to be highly positively correlated (with a coefficient around 0.96); however, some relevant differences, in particular for labor-intensive sectors, remain. Since both are rough approximations of the true labor share, and both probably capture some distinct aspects of reality, we take the average of these two alternative estimates as our benchmark distribution. The capital share in value added is simply computed as one minus the labor share.

When mapping the capital shares computed above to the function $\alpha(z)$ in our model, we face two difficulties. First, we need to map data from 57 industries to a continuum of sectors indexed by $z \in [0, 1]$. Let α_i, $i = 1, \ldots, 57$, denote the sectorial capital shares observed in the data ordered from lowest to highest. Moreover, let g_i and $G_i = \sum_{j=1}^{i} g_j / \sum_{j=1}^{57} g_j$ denote the value added of these sectors and the cdf associated with their share from value added, respectively. We fit an algebraic polynomial of order 6 using ordinary least squares to the points (G_i, α_i) to get the desired monotonically

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[20]We found no reliable data source for tax rates outside the OECD. Note that our results do not stem from differences in fiscal policy across countries: they do not change qualitatively - and even quantitatively only slightly - if we use the same tax structure in both countries for our model.

[21]We drop the government sector and the housing sector, because by construction they include respectively only labor and capital income. See Gomme and Rupert (2004) for a discussion. Furthermore, and for similar reasons, we drop Educational services, Social services, Private households, and Membership organizations. See the appendix for a full list of the sectors included.

[22]See Gomme and Rupert (2004) for a recent discussion of the issues at stake, and Cooley and Prescott (1995) for a classical reference.
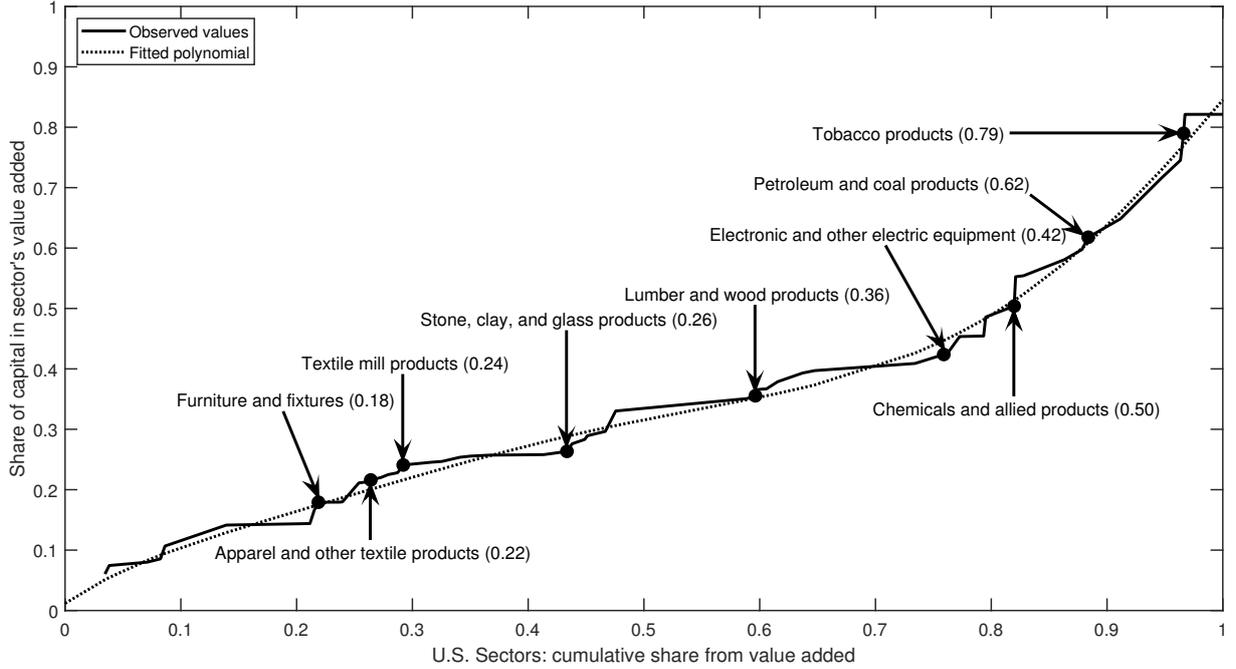
Figure 3: The sectorial distribution of capital shares in VA in the US (1987-1997).

increasing cross-sector distribution of capital intensity $\alpha(z)$. Hence, we map the sectors into the interval $[0,1]$ such that the model is consistent with the cdf associated with their share from value added, $G(\alpha(z))$.[23]

In a closed-economy environment, this would be the end of the story; however, under trade, there is still a second difficulty. In our numerical experiment, the North, *i.e.* the US economy, is assumed to be the capital-abundant country. Hence, the distribution of capital shares actually observed in the US should correspond to the right-hand tail of the true distribution in our model. In other words, only the subset $[z_N, 1]$ of the sectors are operating in the North with $z_N > 0$. To bypass this problem, we fit our polynomial of order 6 to the points $(\tilde{G}_i, \alpha_i)$ using the simple linear transformation $\tilde{G}_i = z_N + (1 - z_N)G_i$ that maps the interval $[0,1]$ into the desired domain $[z_N, 1]$. Figure 3 plots the actual US distribution and the fitted polynomial.[24] The fitted polynomial is then used in our simulations.

We are left with the country-specific productivity parameters, ϕ_j, and the share of leisure from total utility, γ. To pin their values down, we (*i*) make the North reproduce the US value for the time share devoted to labor (0.33), (*ii*) normalize the world capital stock setting $K_W \equiv K_N + K_S = 2$, and (*iii*) calibrate the model to reproduce the observed ratio between the capital-labor ratio in the US and the capital-labor ratio in a Rest-of-the-World aggregate, averaged over the 1990-2000 period, equal to 4.9.[25] The implied values

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[23]We thank an anonymous referee for suggesting this procedure.

[24]In autarky, these values imply an aggregate capital share equal to 0.34, which is close to the 0.33 used in Mankiw and Weinzierl (2006) and the 0.36 used in Trabandt and Uhlig (2011). In the trading equilibrium, these values—together with the calibrated values of the productivity parameters— imply a capital share of 0.37 in the North and 0.33 in the South.

[25]We collect data from Heston et al. (2006) for 140 countries over the 1950-2003 period on population (pop), real GDP per capita (rgdpl and rgdpch-9, real GDP per worker (rgdpwok), and real investment as a share of GDP (ki). Strictly following Caselli (2005) for consistency with the existing literature, we construct estimates for the net physical capital stock using the Perpetual Inventory Method; we assume infinite service lives and a constant geometric depreciation rate equal to 6% for all countries (please note

are $\phi_N = 1.668$, $\phi_S = 0.653$, and $\gamma = 1.150$. As already noted before, $\left(1 - \tau_N^K\right) \phi_N >$ $\left(1 - \tau_N^K\right) \phi_S$ implies $K_N/L_N > K_S/L_S$, so that trade may arise in steady state.

The trade share in income (imports plus exports over GDP) generated by our benchmark calibration reaches 6.9%, which is far below the actual overall trade share of the US (21% on average over the 1990-2000 period), but near the US share in income of trade with developing countries (8.7%),[26] a group of countries for which US trade is likely to be explained to a great extent by differences in relative factor endowments. The fact that our model generates less trade than the observed is not so surprising, as we ignore Ricardian comparative advantage, trade in intermediate inputs and "New-Trade Theory" features such as product differentiation and scale economies. This would be a problem of first-order importance if our exercise focused on understanding how specialization patterns change after a trade liberalization (that is, a fall in trade barriers). Note, however, that the changes in specialization in our exercise are the result of the endogenous response of factor accumulation to changes in after-tax factor returns. (We keep trade barriers constant all along our exercise.) This mechanism is driven entirely by the economics of the Heckscher-Ohlin model we have assumed. The other sources of specialization we ignore do not feature this mechanism and are therefore unlikely to be of quantitative importance for our exercise's object of study.

The recursive structure of our problem guarantees that the solution can be represented as a pair of time-invariant policy functions expressing the optimal level of consumption in each country as a function of the two state variables, K_N and K_S. These policy functions have to satisfy the following functional equations:

$$\beta C_j \left(K_N', K_S'\right)^{-\frac{1}{\mu}} \left(N_j - L_j'\right)^{\gamma\left(1 - \frac{1}{\mu}\right)} \left[\left(1 - \tau_j^K\right) \frac{r_j'}{P_j'} + 1 - \delta\right] =$$
$$C_j \left(K_N, K_S\right)^{-\frac{1}{\mu}} \left(N_j - L_j\right)^{\gamma\left(1 - \frac{1}{\mu}\right)}, \quad (12)$$

where:

$$K_j' = \left(1 - \tau_j^L\right) \frac{w_j}{P_j} L_j + \left[\left(1 - \tau_j^K\right) \frac{r_j}{P_j} + 1 - \delta\right] K_j + R_j - C_j \left(K_N, K_S\right).$$

Factor prices w_j/P_j and r_j/P_j and labor L_j and L_j' are obtained by numerically solving the appropriate equilibrium conditions. To solve equation (12) numerically, we apply the Orthogonal Collocation projection method described in Judd (1992).

4.2 Results

4.2.1 Dynamic Scoring

This section studies the dynamic effects of an unexpected and permanent one-percentage-point reduction in the tax rate on capital income in the North, which in our experiment

that this common depreciation rate differs from the one used in our calibration, 4.8%, which is specific to the US and is originally taken from Cooley and Prescott (1995)). The capital-labor ratio is computed as the ratio between our estimate of the capital stock and the labor force. Finally, the RoW aggregate is just computed as the total capital stock in the world, but for the US, over the total labor force, again excluding the US. To check the robustness of these results, we produced alternative estimates assuming fixed expected service lives (20 years), simultaneous exit mortality patterns, and linear depreciation, as in Maffezzoli (2006): the outcomes are almost identical.

[26]We collect data from the UNCTAD Handbook of Statistics - *International merchandise trade by region* on US trade with developing countries over the 1990-2000 time period. A detailed list of the countries involved can be found on www.unctad.org.
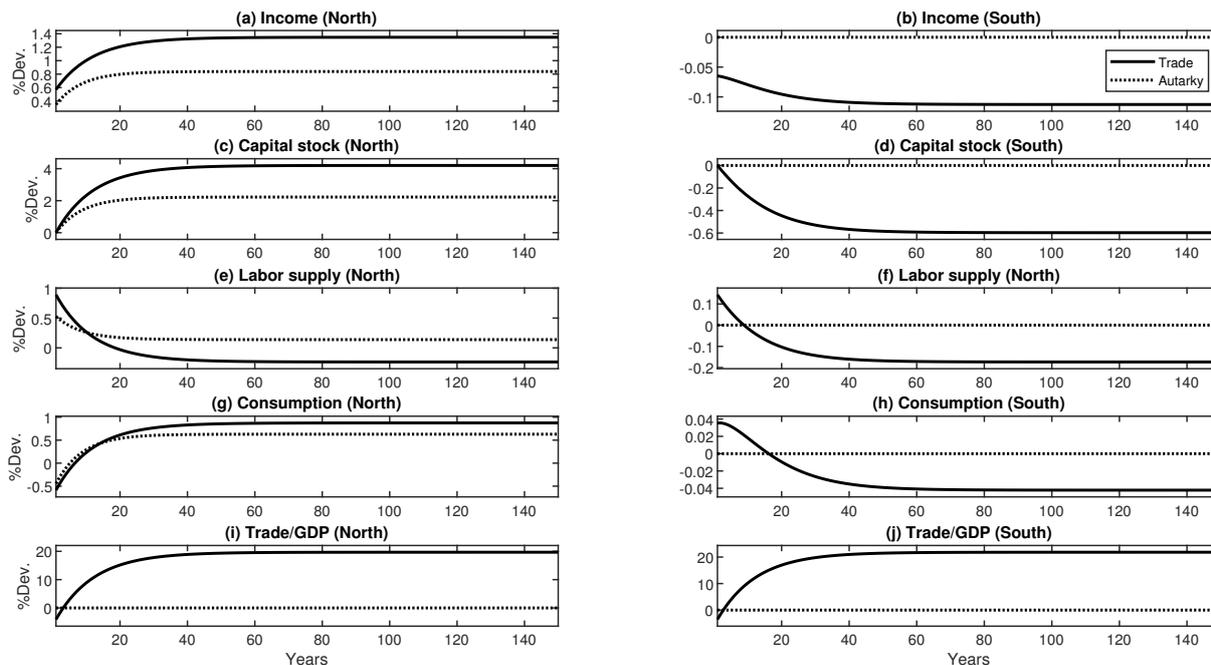
Figure 4: The effects of a capital tax cut in the North: main aggregate variables.

has been calibrated to reproduce the US economy. Figure 4 summarizes the impulse response of the main macroeconomic variables to such a tax cut. We plot income, capital, labor supply, consumption, together with the trade share in income, under both trade and autarky for comparison purposes. All variables are expressed in terms of the final good and as percent deviations from their initial steady-state values. The left-hand side panels report results for the North, while the right-hand side panels report the corresponding results for the South.

A capital-income tax cut in the North is beneficial in terms of higher income and consumption in steady state, under both autarky and trade. Notice, however, that from a quantitative point of view the long-run effect under trade is more than twice larger than under autarky. As already noted, this is due to the different ways the factor allocation mechanisms work under the two regimes. A reduction in τ_N^K raises the after-tax return to capital in the North, creating an incentive to accumulate capital. Under autarky, capital accumulation implies higher sectorial capital-labor intensities: given diminishing marginal returns, this reduces the return to capital and the incentive to accumulate. In the trade model with transport costs, instead, an increase in K_N/L_N leads to an increase in z_N.[27] This enables the North to accommodate part of the increase in its aggregate capital-labor ratio not through a rise in sectorial capital-labor intensities, $k(z)/l(z)$, but by reshuffling resources from industries with low relative demand for capital (over labor) towards industries with high relative demand for capital. This enables the open economy to accumulate more capital, since the negative effect of capital accumulation on the gross return to capital is much smaller than under autarky.[28]

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[27]The change in z_N is proportional to the change in the North's trade share: the value of North's imports is

$$\int_0^{z_N} p_N(z) x_N(z) \, dz = z_N P_N Y_N.$$

Thus, the North's trade share is $2z_N$.

[28]Note that it is not trade *per se* that amplifies the dynamic effects of the tax cut, but the sectorial
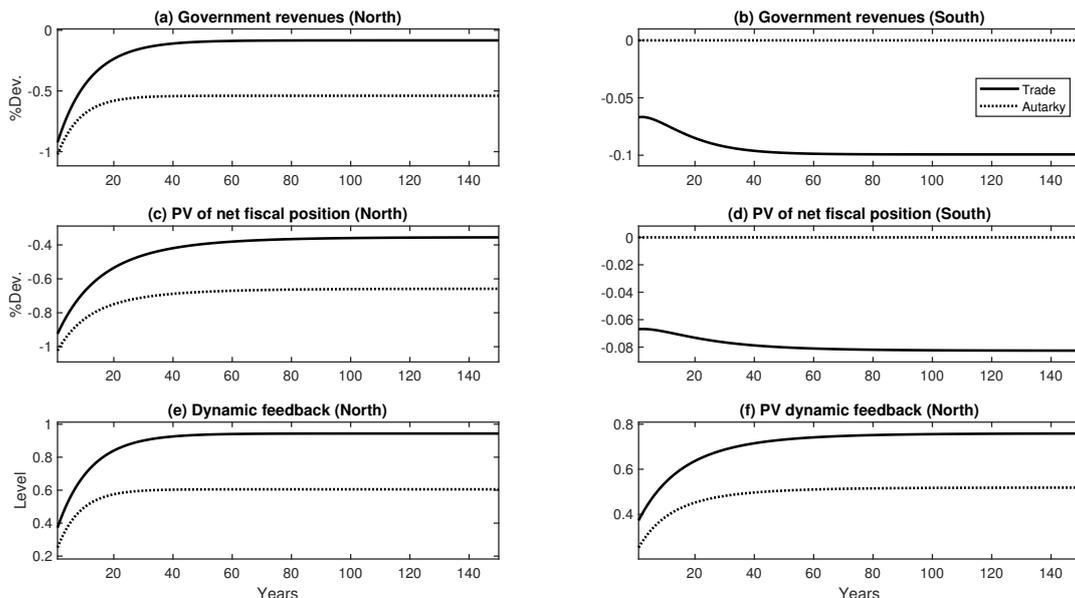
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Figure 5: The effects of a capital tax cut in the North: government balances.

In autarky, the South remains completely unaffected by tax cuts in the North. Under trade, however, factor prices in the South are influenced by the North's tax cut: the resulting increase in K_N/L_N not only raises z_N, but also reduces z_S. The South therefore reallocates factors from its most capital intensive industries to more labor intensive industries. This brings about a reduction in the South's return to capital: while the North accumulates capital, the opposite takes place in the South. The latter starts to eat its capital stock, and ends up in a steady state with lower capital, output, and consumption. This process further enhances its comparative advantage in labor intensive goods, and spurs an increase in international trade. These results suggest that fiscal policy decisions may have some spillover effects via international trade.

We measure the welfare effect of the tax cut in terms of consumption equivalent welfare changes (Lucas, 1990). That is, we compute the proportional change in the household's consumption stream required for the household to be as well off in the equilibrium after the tax cut as in the equilibrium before the tax cut. The net gain is decomposed into a long-run gain that compares the steady states before and after the tax cut, and the short-run costs of the transitional dynamics. Under trade, steady-state welfare is 1.01% higher in the North after the tax cut. However, the initial negative responses of consumption and leisure imply a transitional cost of 0.67%. The overall net welfare gain is 0.34%. In the South, the tax cut reduces steady-state welfare by 0.10%: leisure increases as a result of the tax cut, but this effect is dominated by a reduction in consumption. Taking into account the transitional dynamics, the net welfare cost of the tax cut is equivalent to 0.02% of the household's consumption stream. Under autarky, steady-state welfare in the North is only 0.55% higher after the tax cut, but the considerably lower transitional costs imply a net welfare gain of 0.23%.

Figure 5 summarizes the dynamic response of government balances along the transitional path.[29] Panels (a) and (b) (as before, North on the left-hand side and South on the

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reallocation of capital induced by international trade. In a numerical experiment not reported in the paper (available upon request), we show that if we keep the specialization patterns constant at the initial steady state, the dynamic effects under trade and autarky are very similar.

[29]Recall that for the sake of simplicity we assume a balanced budget and that government revenues are

right-hand side) plot the adjustment path for government revenues. On impact, the tax cut affects the North's government revenues negatively under both autarky and trade. In the South, the tax cut that took place in the other country has a significantly negative and permanent effect on government revenues in the long run under trade. In both countries, these effects stem from the different adjustment paths for capital: enhanced capital accumulation in the North, the reverse process in the South. Note that this mechanism explains why in the North the actual decrease in government revenues in the long run is definitely smaller under trade than under autarky: in the former case, government revenues almost converge back to the initial steady-state value.

Panels (c) and (d) show the present-value *net fiscal position* of the government at different time horizons, defined as

$$\frac{\sum_{s=0}^{t} \rho_{js}\hat{\Delta}R_{js}}{\sum_{s=0}^{t} \rho_{j,-1}^{s}R_{j,-1}}$$

where

$$\rho_{jt} = \prod_{s=0}^{t} \left[\left(1 - \tau_j^K\right) \frac{r_{js}}{P_{js}} + 1 - \delta \right]$$

is the discount factor along the transitional path and $\hat{\Delta}R_{js} \equiv R_{js} - R_{j,-1}$, where $R_{j,-1}$ represents the total tax revenues prevailing before the tax cut. This variable represents the amount of resources the government should borrow or lend, in terms of the present discounted value of its initial revenue plan $R_{j,-1}$, to keep the level of its revenues at the same level as before the tax-cut. If its value is positive, then the tax cut pays for itself as the government could lend some of its revenues and still keep its 'expenditure' at their original level. Panels (c) and (d) show that, if we focus on the net financial position, the cost of the tax cut in terms of revenue to the North's government is much smaller under trade, while exactly the opposite happens in the South.

Panel (e) plots the *dynamic feedback*, which measures the extent to which a tax cut is self-financing in levels over time. Let us define the *static effect* of a tax cut as the revenue loss induced by the tax cut under the assumption that none of the variables adjusts: hence, the static loss always equals the change in the tax rate times the initial tax base. The share of the static effect which is dynamically offset by factor accumulation can be calculated as $\left(\hat{\Delta}R_{jt} - \Delta\bar{R}_j\right) / \left|\Delta\bar{R}_j\right|$, where $\Delta\bar{R}_j$ denotes the static effect. If the tax cut is more than self-financing, then the change in government revenues is positive and the dynamic feedback is larger than one; if the tax cut is only partially self-financing, then the change in government revenues is negative but larger (smaller in absolute value) than the static effect and the dynamic feedback lies between zero and one. Panel (f) plots the *present-value dynamic feedback*, which represents the extent to which a tax cut is self financing in present discounted values and is computed as

$$\frac{\sum_{s=0}^{t} \rho_{js}\hat{\Delta}R_{js} - \sum_{s=0}^{t} \rho_{j,-1}^{s}\Delta\bar{R}_j}{\sum_{s=0}^{t} \rho_{j,-1}^{s}\left|\Delta\bar{R}_j\right|},$$

The value of the present value feedback has the same interpretation as the dynamic feedback: if the tax cut is self-financing, then it is larger than one; if the tax cut is partially self-financing, then it is between zero and one.

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paid back to households via lump-sum transfers.

Panels (e) and (f) summarize our main results in terms of dynamic feedbacks: under autarky, the dynamic feedback in the North converges in the long run to 61%, a value in line with the findings of Mankiw and Weinzierl (2006); under trade, the long-run value of the corresponding dynamic feedback converges to 94%. This implies that in the long run a capital tax cut decrease government revenues only slightly. Of course, given that this effect relies on capital accumulation and therefore needs time to build up, the results are less dramatic, but still relevant, if we turn our attention to the present-value dynamic feedback.

4.2.2 Dynamic Feedbacks in the Long Run

The results above imply that the long-run dynamic feedback under trade is larger than its counterpart under autarky. This seems in line with the analytical predictions outlined in Section 3. However, our analytical example was based on two simplifying assumptions: we ignored labor taxation, setting $\tau^L = 0$, and we assumed the same initial capital stock in both the closed and open economies. These two assumptions are blatantly violated in the simulation exercise presented above: labor taxes are set to a positive value and, in general, steady-state capital stocks are different across trade regimes (even under the same parameterization). In order to evaluate the generality of our conclusions, let us focus on the steady state and consider a generalized version of equation (10) to discuss how long-run tax revenues react to changes in capital taxation in detail:[30]

$$\frac{dR}{d\tau^K} = \underbrace{\left(\tilde{r} + \tau^K \frac{d\tilde{r}}{d\tau^K}\right) K}_{>0} + \underbrace{\tau^K \tilde{r} \frac{dK}{d\tau^K}}_{<0} + \underbrace{\tau^L \left(\frac{d\tilde{w}}{d\tau^K} L + \frac{dL}{d\tau^K} \tilde{w}\right)}_{<0}, \qquad (13)$$

where $\tilde{r} \equiv r/P$ and $\tilde{w} \equiv w/P$ represent real factor prices. In steady state, the real rates of return are pinned down by the Euler equations (see also equation 4):

$$\tilde{r} = \frac{1 - \beta(1 - \delta)}{\beta(1 - \tau^K)}.$$

Therefore, in steady state both the real rate of return $\tilde{r}$ and its derivative $d\tilde{r}/d\tau^K$ are positive, and remain invariant across trade regimes. The signs of the three terms on the right-hand side of equation (13) are unambiguous. The real rate of return, the tax rate on capital, the derivative of the rate of return, and the capital stock are all strictly positive. Therefore the first term is positive. The second term is negative because the capital stock reacts inversely to changes in the capital tax rate. Finally, the third term is negative too, since the decrease in the capital stock caused by an increase in the tax rate on capital will depress real labor income.[31]

The dynamic feedback (denoted DF hereafter), if computed for *marginal* decreases in τ^K, can then be written as

$$DF \equiv 1 - \frac{\frac{dR}{d\tau^K}}{\tilde{r}K} = -\left(\varepsilon_{\tilde{r}} + \varepsilon_K + (\varepsilon_{\tilde{w}} + \varepsilon_L)\frac{\tau^L \tilde{w} L}{\tau^K \tilde{r} K}\right). \qquad (14)$$

Since $\varepsilon_{\tilde{r}}$ is invariant across trade regimes, the difference between the dynamic feedbacks (again, for marginal changes in τ^K) under autarky and trade can therefore be expressed

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[30]Country-specific indexes have been omitted for simplicity.

[31]Note that if $\tau^L = 0$, and therefore $R = \tau^K \tilde{r} K$, then equation (13) can be easily rewritten in elasticity terms as $\varepsilon_R = 1 + \varepsilon_{\tilde{r}} + \varepsilon_K$, which reminds us of equation (11).
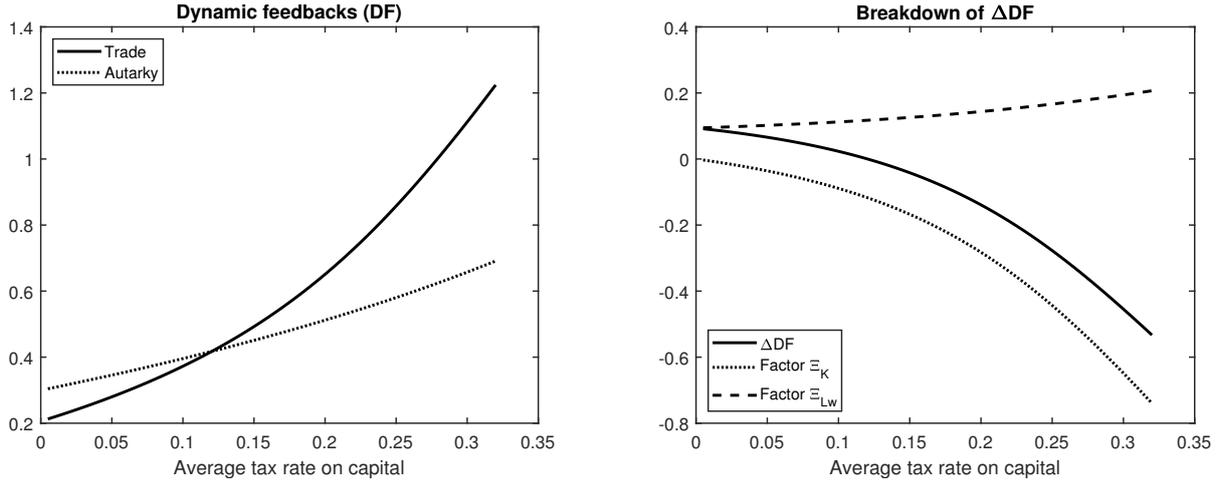
Figure 6: Comparison of long-run dynamic feedbacks across trade regimes.

as the sum of two factors, denoted Ξ_K and Ξ_{Lw}:

$$\Delta DF \equiv DF|_A - DF|_O = \underbrace{(\varepsilon_K|_O - \varepsilon_K|_A)}_{\Xi_K < 0} + + \underbrace{\frac{\tau^L}{\tau^K \tilde{r}} \left[\left((\varepsilon_{\tilde{w}} + \varepsilon_L) \frac{\tilde{w}L}{K} \right) \Big|_O - \left((\varepsilon_{\tilde{w}} + \varepsilon_L) \frac{\tilde{w}L}{K} \right) \Big|_A \right]}_{\Xi_{Lw} > 0}$$

(15)

The left-hand side panel of Figure 6 compares the North's dynamic feedback for marginal changes in τ_N^K under autarky and trade, as expressed in equation (14) and computed for different initial values of τ_N^K.[32] The right-hand side panel reports the breakdown of the difference between dynamics feedbacks into the components described in equation (15). Note that the dynamic feedback under trade is larger than its counterpart under autarky for tax rates on capital above 12.0%, and becomes larger than one for tax rates above 27.5%. However, the dynamic feedback under autarky dominates for tax rates below 12.0%. The breakdown report in the right-hand-side panel shows that the two factors described in equation (15), Ξ_K and Ξ_{Lw}, have different signs. The first factor, Ξ_K, is always negative, increases with τ_N^K, and converges to zero when the tax rate does so: this implies that the elasticity of steady-state capital with respect to changes in τ_N^K is always greater under trade than under autarky. The second factor, Ξ_{Lw}, is always strictly positive, and decreases with τ_N^K. For sufficiently low values of τ_N^K the second factor dominates, and the dynamic feedback under autarky exceeds its counterpart under trade.[33]

The fact that the dynamic feedback under autarky is larger than under trade for some values of τ_N^K does not contradict the intuitions we discussed above. Recall that in our discussion of the free-trade example we fixed parameter values so that the economy had the same steady-state outcomes (capital stocks, factor prices, etc.) under both autarky and trade, and no taxes on labor. This is not the case here, as the autarky and trade regimes yield different steady-state outcomes for the same value of τ_N^K. In this sense, the

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[32]We allow for changes in τ_N^K, leaving the rest of parameters unchanged. Notice that different values of τ_N^K lead to different steady-state outcomes within and across trade regimes.

[33]The second factor, Ξ_{Lw}, turns out to be strictly positive because the tax rate on labor τ^L is strictly positive in our benchmark calibration, and because the steady-state capital stocks differ across trade regimes as long as countries trade in equilibrium. Note that it is possible to break the second factor down further, $\Xi_{Lw} = \Xi_L + \Xi_w$, to separate the effects from changes in labor supply and in the real wage. However, both effects are positive and behave similarly and we show their combined effect to simplify the exposition.
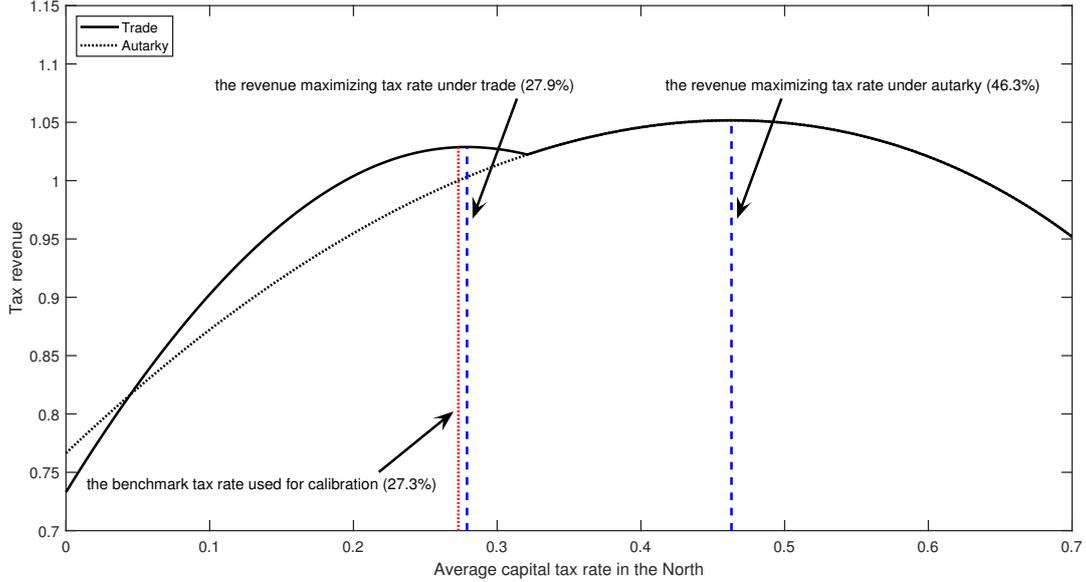
Figure 7: The Laffer curve in the North.

comparison here is not "perfect:" we are not comparing the effects of a tax cut in two economies that are identical but for the trade regimes they are subject to.[34]

4.2.3 The Laffer Curve

Dynamic scoring studies how tax cuts affect government revenues in the long run and along the transitional path to the new steady state. A closely related approach, typically represented by the Laffer curve, studies the relationship between steady-state total tax revenues and different tax rates on capital and labor. Figure 7 plots the Laffer curve in the North resulting from our model: it plots steady-state total tax revenues as a function of the average tax rate on capital, *ceteris paribus*.[35]

The Laffer curve under trade lies above the autarky Laffer curve for capital tax rates above 4.5%. The North will specialize in the production of capital-intensive goods, and this will induce further capital accumulation and therefore generate a higher capital stock in steady state. The steady-state return to capital has to be the same under both trade and autarky, and therefore the overall revenues from capital taxes will be higher with trade. The real wage rate will be higher while labor supply lower with trade due to the higher capital stock and openness, and the overall revenues from labor taxes will be higher under autarky. For capital tax rates below 4.5% the lower labor tax revenues dominate and the Laffer curve under trade lies below the autarky Laffer curve.[36]

If the tax rate on capital is higher than 32.1%, then - *ceteris paribus* - the trade

---

[34]Actually, a counterfactual experiment in which countries *are* identical but for the trade regime can be devised. The experiment (results are available from the authors upon request) runs as follows: for each value of τ_N^K, compute the minimum value of the trade cost v that makes the open economy converge to the autarky one, *i.e.* the trade cost that makes international trade not feasible. This forces the two economies to be identical, in terms of allocations, at the initial steady state, and consequently yields $\varepsilon_{\tilde{w}}$ practically equal under both trade regimes. Then perform the simulations described in the text: the results confirm that $\Delta DF = \varepsilon_K|_O - \varepsilon_K|_A < 0$ for all values of τ_N^K.

[35]As in the previous Section, we allow for changes in τ^K, leaving the rest of parameters unchanged.

[36]With exogenous labor supply even tax returns from labor taxes will be higher under the trade regime and the Laffer curve under trade lies always above the autarky Laffer curve.

equilibrium "collapses" into autarky. As the North's tax rate on capital income rises, the North's steady-state capital-labor ratio decreases relative to the that of the South. Thus, for a high enough τ_N^K transport costs make trade not profitable. Hence, for higher tax rates the Laffer curves under autarky and trade coincide. As a result, the Laffer curve becomes twin-peaked: the slope is positive initially, becomes negative, turns suddenly positive again and then finally turns negative.

The three vertical lines denote - from left to right - the benchmark tax rate used for calibration (27.3%), the revenue maximizing tax rate under trade (27.9%), and the revenue maximizing tax rate under autarky (46.3%). Note that taking the consequences of trade into account has strong implications as far as fiscal policy is concerned: under trade, the actual marginal tax rate in the US, as measured by Carey and Rabesona (2002), turns out to be only slightly below the revenue-maximizing rate, and therefore the US is close to the "slippery slope" of the curve. Under autarky, instead, the actual tax rate remains quite far from the peak.

4.2.4   The Slope of the Laffer Curve

A close look at Figure 7 reveals that the Laffer curve under trade is steeper than its counterpart under autarky for sufficiently low levels of capital taxation. This may appear to contradict our theoretical argument. Once again, this is due to the fact that we are not comparing the effects of a tax cut in two economies that are identical but for the trade regimes they are subject to.

The difference between the slope of the Laffer curve under autarky and its slope under trade can be decomposed in the following way:

$$
\Delta \frac{dR_N}{d\tau_N^K} \equiv \left.\frac{dR_N}{d\tau_N^K}\right|_A - \left.\frac{dR_N}{d\tau_N^K}\right|_O =
$$
$$
\underbrace{\left(\tilde{r} + \tau_N^K \frac{d\tilde{r}}{d\tau_N^K}\right)\left(K_N|_A - K_N|_O\right)}_{\Pi_K < 0} + \underbrace{\tau_N^K \tilde{r}\left(\left.\frac{dK_N}{d\tau_N^K}\right|_A - \left.\frac{dK_N}{d\tau_N^K}\right|_O\right)}_{\Pi_{dK} > 0} +
$$
$$
+ \underbrace{\tau_N^L\left(\left.\frac{d\tilde{w}_N}{d\tau_N^K}L_N\right|_A - \left.\frac{d\tilde{w}_N}{d\tau_N^K}L_N\right|_O\right)}_{\Pi_{dw} > 0} + \underbrace{\tau_N^L\left(\left.\frac{dL_N}{d\tau_N^K}\tilde{w}\right|_A - \left.\frac{dL_N}{d\tau_N^K}\tilde{w}\right|_O\right)}_{\Pi_{dL} < 0}. \quad (16)
$$

The first term on the right-hand side of equation (16), denoted Π_K, takes the role of the initial capital stocks into account, and has a negative sign, since in steady state $K_N|_A < K_N|_O$ for any tax rate on capital (the North will always have an incentive to accumulate more capital under the trade regime than under autarky). The second term, Π_{dK}, focuses instead on the role of the adjustment dynamics: the theoretical argument described in the previous Sections suggests that the derivative of the capital stock with respect to the tax rate on capital should always be greater (in absolute value) under trade than under autarky, since capital will be reallocated from labor-intensive to capital-intensive sectors; this implies that the second term should have a positive sign. The same argument also explains the sign of the last two terms. The derivative of the real wage rate (labor) should always be larger (smaller) under trade (again, in absolute value), and therefore the term Π_{dw} (Π_{dL}) should have a positive (negative) sign. The difference in the slope of the Laffer curve across trade regimes will depend on the relative sizes of these four components.
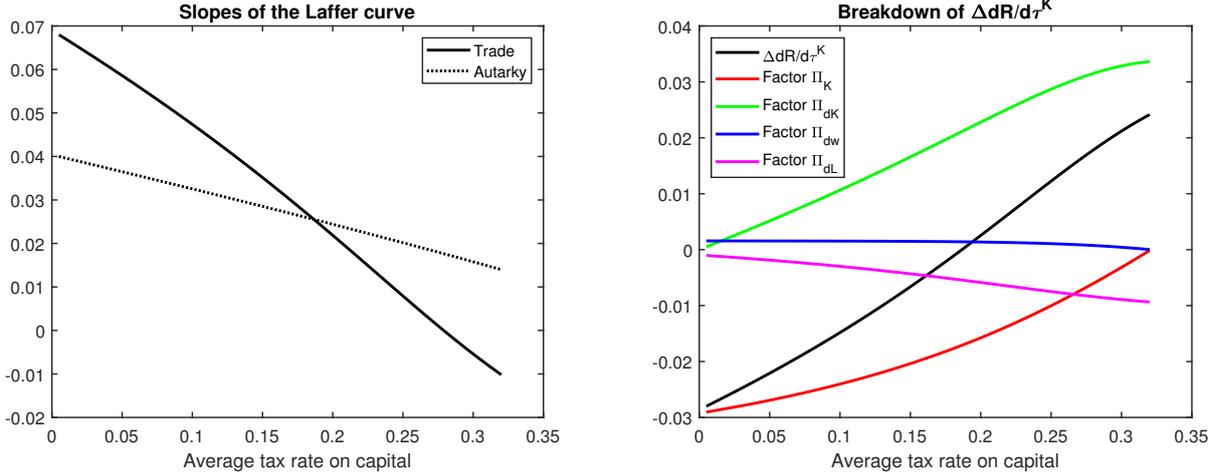
21

Figure 8: Comparison of the slope of the Laffer curve across trade regimes.

The left panel of Figure 8 plots the slopes of the North's Laffer curves under trade and autarky for different levels of τ_N^K. The right panel plots the difference between the slopes of the North's Laffer curve under autarky and trade, *i.e.* the left hand side of equation (16), and each of the four terms in the right hand side of the same equation. These results confirm that for sufficiently low capital tax rates (approximately below 18.5%) the Laffer curve under trade is steeper than its autarky counterpart: this is because for this range of values the Π_K component, linked to the difference between the initial capital stocks, dominates. At low levels of capital taxation, the North's steady-state capital stock is much larger under trade than under autarky. Thus, for low τ_N^K, reductions in τ_N^K yield larger reductions in government revenue under trade than autarky because the subsequent increases in revenue through increases in the tax base do not compensate for the revenue losses arising from taxing the original tax base at a lower rate.

Note that Π_K increases monotonically with τ_N^K and converges to zero (from below) as soon as the capital tax rate is high enough to make the open economy collapse into autarky. Π_{dK} is monotonically increasing in τ_N^K, too, but remains always positive. Finally, both Π_{dw} and Π_{dL} decrease monotonically with τ_N^K and Π_{dw} converges to zero. For values of τ_N^K above the 18.5% threshold, the positive components start to dominate, and the Laffer curve under autarky becomes steeper than its counterpart under trade.

4.2.5 Nonlinearities in the Magnitude of the Dynamic Feedback

In our numerical experiments we study the effects of a one percent tax cut. The main reason is computational convenience; the change is small enough that the economy stays close to the steady state along the transitional path, while the dynamic effects can be reported directly without any normalization. Since our numerical solution method is fully nonlinear, in this section we explore how the magnitude of the dynamic feedback changes with the size of the tax cut.

Table 1 reports the dynamic feedback and the present-value dynamic feedback to an unexpected and permanent reduction in the capital tax rate in the North. We consider both smaller and larger tax cuts than in our benchmark experiment, ranging from 0.1 to 10 percentage point in size. The extent to which a tax cut is self financing decreases with the size of the tax cut in both closed- and open-economy environments, but decreases more so in open economies.

| Size of the | Autarky | | Trade | |
| tax cut | Dynamic | PV dyn. | Dynamic | PV dyn. |
(%)	feedback	feedback	feedback	feedback
0.1	0.6136	0.5220	0.9668	0.7738
0.5	0.6099	0.5205	0.9564	0.7672
1.0	0.6053	0.5185	0.9434	0.7590
5.0	0.5687	0.5036	0.8374	0.6959
10.0	0.5238	0.4869	0.7044	0.6247

Table 1: Dynamic feedbacks after a capital tax cut in the North for different tax cuts.

The first result is a direct consequence of the Laffer curve's concavity. Recall that the static effect is defined as the revenue loss induced by the tax cut under the assumption that none of the variables adjusts. Hence, the static loss always equals the change in the tax rate times the initial tax base and thus it increases proportionally with the size of the tax cut. The decrease in tax revenues, on the other hand, is accelerated with the size of the tax cut as indicated by the concavity of the Laffer curve. Hence, the extent to which the tax cut is self-financing is decreasing with the size of the tax cut.[37] The second result follows from the fact that the open economy's Laffer curve is steeper to the right of the tax rate in the initial steady state. However, our main result that the trade model generates a much larger response to a tax cut than the autarky model remains unaltered by the size of the tax cut.

5   Sensitivity Analysis

We consider alternative calibrations and model versions to assess whether our results are due to the particular calibration strategy chosen or assumptions made. To conserve space, we only summarize the sensitivity analysis here and report its details in Appendix D.

Our calibration procedure parameterizes the $\alpha(z)$ distribution using empirical evidence on the US sectorial structure and taking the implications of our theoretical trade model literally. Two alternative procedures, based on the same data, may seem natural. The first one consists in fitting our polynomial on the actual US distribution of capital intensities without extrapolating the left-hand tail. Our second alternative takes our argument to the extreme, and extrapolates the capital intensity distribution not only on the left-hand side, but also on the right-hand one, in order to span the full range of possible capital intensities $[0, 1]$. Both alternative procedures generate results that are in line with the outcome of our benchmark parametrization.

The degree of openness, summarized by the trade cost ν, and the elasticity of intertemporal substitution ν are also key features in our framework. The higher trade costs are, the closer the economy is to autarky and the weaker dynamic feedback is expected to be. We consider four different values of the trade cost (ceteris paribus). The elasticity of intertemporal substitution is an important determinant of the speed of capital accumulation, and therefore the speed of convergence towards the steady state. We are considering alternative values of μ that lie symmetrically around our benchmark value

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[37]The dynamic feedback is one minus the slope of the tangent line connecting the initial and the final points on the Laffer curve. Since the Laffer curve is concave (and both points are to the left of the revenues maximizing tax rate), the slope of the tangent line is decreasing in the size of the tax cut.

of 1. All variables of interest remain robust for all these alternative parameter values considered.

Throughout our paper we assume that production factors are internationally immobile and we rely on international trade to generate the changes in production structures that drive our results. To assess to what extent our results depend on this assumption, we also consider an alternative economic environment where households can invest in either country. In such an environment capital mobility eliminates any arbitrage between the investment opportunities in the two countries and implies that the after-tax real return on capital is equalized not only in steady state, but also in every period along the transitional path. Following the tax cut North experiences a sudden inflow of capital from South that equalizes the after-tax real returns on capital. This raises the real wage and, via the corresponding substitution effect, reduces the supply of hours. Overall, labor income increases. The tax cut is already self-financing on impact since the increased tax revenues from labor income compensate for the static loss of the tax cut. Capital accumulation reinforces this effect further; however, the contribution of capital accumulation is small when capital is internationally mobile and our results are mainly driven by the reallocation of capital across countries.

6   Concluding Remarks

Opening the neoclassical growth model to trade changes its quantitative implications regarding the effects of taxation in a rather stark way. Given the shrinking size of the US economy relative to the world, and its relatively high degree of openness, our set-up seems to be a better workhorse for understanding the effects of tax policies than the standard closed-economy Ramsey model. At the same time, ours is still an incomplete model, as we ignore sources of comparative advantage other than capital abundance and, perhaps more importantly, "new-trade" theory features explaining intraindustry trade.[38] This is left for future work.

For simplicity, we have assumed away international capital mobility. Notice, however, that allowing for capital mobility and assuming source-based taxation would, if anything, make the model's results stronger over the transition to the steady state. The country reducing the capital-income tax rate would attract capital inflows from the rest of the world; this would yield even stronger dynamic feedback effects.[39] Conversely, the effects of capital taxation usually discussed in neoclassical models with capital mobility would become much stronger if they were considered within our framework (as opposed to the usual setup with two countries with identical invariant aggregate production functions).

An issue that usually arises in connection with international capital mobility is that of international tax competition. The effects on the South of a tax cut in the North are not dramatic in our benchmark calibration, but suggest that the South might have an incentive to "retaliate." We also leave this topic for future work, as our model is not well equipped to address the behavior of welfare-optimizing governments: one would need a less simplistic government side, in which government expenditure raises the representative

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[38]See Burstein and Vogel (2017) for a recent paper that extends the Heckscher-Ohlin framework by incorporating productivity differences across producers within a sector.

[39]The distinction between source-based and residence-based taxation matters here. Our argument assumes implicitly that a tax cut on capital income in the US would mainly affect capital accumulation in the US. The empirical evidence that highlights a "home bias" in portfolio choices, see Obstfeld and Rogoff (2000), may partially support our assumption.

consumer's utility (or enhances productivity in the production function) and there is thus a trade-off to an income tax cut between the utility loss from lower government expenditure and the efficiency gain from lower taxation.[40]

Another issue regarding government behavior that we have ignored is the treatment of government deficits. Since we were mainly interested in a comparison between autarky and trade, we do not think our balanced budget assumption is that misleading, and leave this issue as well as part of our research agenda.

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[40]See, for example, Barro (1990).

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A Appendix: Equilibrium Conditions

A.1 Autarky

The equilibrium conditions of the "static" autarky model (that is, the equilibrium prices of the model for given production factors) are rather straightforward. Since all markets are perfectly competitive, we just need price equal to marginal cost for every good (final and intermediate) and market clearing for every good and production factor. Aggregate factor demands are obtained as the aggregation of sectorial factor demands, taking into account that all sectors produce positive amounts: this follows from the fact that the marginal productivity of any intermediate good is infinite if a zero amount of it is used in the production of the final good.

1. Unit-cost function:
$$b(z, \phi_j, r_j, w_j) = \frac{r_j^{\alpha(z)} w_j^{1-\alpha(z)}}{\phi_j a(z)}.$$

2. Commodity prices:

$$
\begin{aligned}
P_j &= \exp\left[\int_0^1 \ln p_j(z) dz\right] = 1, \\
p_j(z) &= b\left(z, \phi_j, r_j, w_j\right).
\end{aligned}
$$

3. Goods market clearing:
$$y_j(z) = x_j(z) = \frac{P_j Y_j}{p_j(z)},$$

where $P_j Y_j = r_j K_j + w_j L_j$.

4. Factor market clearing:

$$
\begin{aligned}
\int_0^1 \frac{\partial b\left(z, \phi_j, r_j, w_j\right)}{\partial r} y_j(z)\, dz &= K_j, \\
\int_0^1 \frac{\partial b\left(z, \phi_j, r_j, w_j\right)}{\partial w} y_j(z)\, dz &= L_j.
\end{aligned}
$$

A.2 Trade with Frictions

The equilibrium conditions here are a bit more nuanced than under trade, as we need to keep track of specialization patterns and the fact that the law of one price does not hold because of transport costs. When specifying the equilibrium pricing conditions, we need to take into account that for an intermediate good produced in a given country, the local price is simply the marginal cost. If a country instead imports an intermediate good, it has to pay the other country's marginal cost compounded by transport cost ν.

The goods market clearing condition also need to take into account whether a country is the only producer of a good (in which case, its production must meet world demand) or whether the good is non-traded (in which case the goods market clears at the country level).

Aggregate factor demands are obtained again as the aggregation of sectorial factor demands. Unlike under autarky, however, complete specialization implies that a country

does not necessarily produce all intermediate goods. That is, we allow for zero production of the intermediate goods imported by a country.

Finally, we need to specify the condition of the "marginal" goods that determine the specialization ranges of countries: a country is indifferent between producing a good or importing it when its own corresponding marginal cost of production equals the marginal cost of importing it, that is the exporting country's marginal cost of production compounded by transport cost ν.

1. Commodity prices: For $z \in [0, z_N)$,

$$p_N(z) = \nu p_S(z) = \nu b(z, \phi_S, r_S, w_S).$$

For $z \in [z_N, z_S]$,
$$p_j(z) = b(z, \phi_j, r_j, w_j).$$

For $z \in (z_S, 1]$,
$$p_S(z) = \nu p_N(z) = \nu b(z, \phi_N, r_N, w_N).$$

2. Goods market clearing: For $z \in [0, z_N)$,

$$y_N(z) = 0 \quad y_S(z) = x_S(z) + \nu x_N(z).$$

For $z \in [z_N, z_S]$,
$$y_j(z) = x_j(z).$$

For $z \in (z_S, 1]$,
$$y_S(z) = 0 \quad y_N(z) = \nu x_S(z) + x_N(z).$$

3. Factor market clearing:

$$\int_{z_N}^{1} \frac{\partial b(z, \phi_N, r_N, w_N)}{\partial r} y_N(z) dz = K_N,$$

$$\int_{z_N}^{1} \frac{\partial b(z, \phi_N, r_N, w_N)}{\partial w} y_N(z) dz = L_N,$$

$$\int_{0}^{z_S} \frac{\partial b(z, \phi_S, r_S, w_S)}{\partial r} y_S(z) dz = K_S,$$

$$\int_{0}^{z_S} \frac{\partial b(z, \phi_S, r_S, w_S)}{\partial w} y_S(z) dz = L_S.$$

4. Marginal commodity conditions:

$$b(z_j, \phi_j, r_j, w_j) = \nu b(z_j, \phi_{-j}, r_{-j}, w_{-j}). \tag{17}$$

5. The numeraire:
$$p_S(0) = 1.$$

B   Appendix: Steady State with Trade

This appendix establishes the condition under which we can have a steady state with trade in which countries N and S produce ranges $[z_N, 1]$ and $[0, z_S]$, respectively. Given that the two countries have got the same discount factor and depreciation rate, in steady state,

$$\left(1 - \tau_N^K\right) \frac{r_N}{P_N} = \left(1 - \tau_N^K\right) \frac{r_S}{P_S}. \tag{18}$$

We need to make this equation compatible with the equilibrium conditions discussed above.

The price indices P_N and P_S can be expressed as

$$P_N = \exp \left[\int_0^{z_N} \ln \left[\nu b_S(z) \right] dz + \int_{z_N}^1 \ln \left[b_N(z) \right] dz \right] = \tag{19}$$

$$= \nu^{z_N} \exp \left[- \int_0^1 \ln \left[a(z) \right] dz - z_N \ln \phi_S - (1 - z_N) \ln \phi_N + \right.$$

$$+ \int_0^{z_N} \alpha(z) dz \ln r_S + \int_0^{z_N} \left[1 - \alpha(z) \right] dz \ln w_S +$$

$$\left. + \int_{z_N}^1 \alpha(z) dz \ln r_N + \int_{z_N}^1 \left[1 - \alpha(z) \right] dz \ln w_N \right],$$

$$P_S = \exp \left[\int_0^{z_S} \ln \left[b_S(z) \right] dz + \int_{z_S}^1 \ln \left[\nu b_N(z) \right] dz \right] = \tag{20}$$

$$= \nu^{1 - z_S} \exp \left[- \int_0^1 \ln \left[a(z) \right] dz - z_S \ln \phi_S - (1 - z_S) \ln \phi_N + \right.$$

$$+ \int_0^{z_S} \alpha(z) dz \ln r_S + \int_0^{z_S} \left[1 - \alpha(z) \right] dz \ln w_S +$$

$$\left. + \int_{z_S}^1 \alpha(z) dz \ln r_N + \int_{z_S}^1 \left[1 - \alpha(z) \right] dz \ln w_N \right],$$

where $b_j(z)$ is short hand for $b\left(z, \phi_j, r_j, w_j\right)$. From (17), the marginal commodities z_S and z_N must satisfy

$$b_S(z_S) = \nu b_N(z_S), \tag{21}$$
$$\nu b_S(z_N) = b_N(z_N), \tag{22}$$

respectively. From (21) and (22),

$$\frac{w_N}{w_S} = \nu^{\frac{2}{\alpha(z_S) - \alpha(z_N)}} \left(\frac{r_N}{r_S} \right). \tag{23}$$

From (21),

$$\frac{r_N}{r_S} = \left[\nu^{-1} \frac{\phi_N}{\phi_S} \left(\frac{w_N}{w_S} \right)^{\alpha(z_S) - 1} \right]^{\frac{1}{\alpha(z_S)}}. \tag{24}$$

From (23) and (24),

$$\frac{r_N}{r_S} = \nu^{\frac{2[\alpha(z_S) - 1]}{\alpha(z_S) - \alpha(z_N)} - 1} \frac{\phi_N}{\phi_S}. \tag{25}$$

From (18), (19), (20), (23), and (25),

$$\frac{\phi_N\left(1 - \tau_N^K\right)}{\phi_S\left(1 - \tau_S^K\right)} = \nu^\chi > 1,$$

where

$$\chi = 2\left[z_N + \frac{(z_S - z_N)\,\alpha\,(z_S) - \int_{z_N}^{z_S} \alpha\,(z)\,dz + 1 - \alpha\,(z_S)}{\alpha\,(z_S) - \alpha\,(z_N)}\right] > 0.$$

Thus, we need $\phi_N\left(1 - \tau_N^K\right) > \phi_S\left(1 - \tau_S^K\right)$.

C   Appendix: List of Sectors

Sector	Data			Model
	s_K^1	s_K^2	s_K	$\alpha(z)$
Farms	0.64	0.56	0.60	0.60
Agricultural services, forestry, and fishing	0.26	0.19	0.23	0.21
Metal mining	0.56	0.55	0.55	0.51
Coal mining	0.39	0.46	0.42	0.45
Oil and gas extraction	0.75	0.74	0.75	0.76
Nonmetallic minerals, except fuels	0.48	0.49	0.49	0.48
Construction	0.16	0.12	0.14	0.13
Lumber and wood products	0.36	0.35	0.36	0.35
Furniture and fixtures	0.19	0.17	0.18	0.17
Stone, clay, and glass products	0.27	0.26	0.26	0.29
Primary metal industries	0.25	0.26	0.26	0.25
Fabricated metal products	0.29	0.30	0.30	0.30
Industrial machinery and equipment	0.25	0.24	0.25	0.23
Electronic and other electric equipment	0.42	0.42	0.42	0.45
Motor vehicles and equipment	0.26	0.26	0.26	0.29
Other transportation equipment	0.08	0.09	0.09	0.09
Instruments and related products	0.06	0.06	0.06	0.05
Miscellaneous manufacturing industries	0.39	0.34	0.37	0.36
Food and kindred products	0.46	0.45	0.45	0.48
Tobacco products	0.79	0.79	0.79	0.77
Textile mill products	0.24	0.24	0.24	0.22
Apparel and other textile products	0.22	0.21	0.22	0.20
Paper and allied products	0.38	0.38	0.38	0.36
Printing and publishing	0.26	0.25	0.25	0.24
Chemicals and allied products	0.49	0.52	0.50	0.51
Petroleum and coal products	0.62	0.62	0.62	0.61
Rubber and miscellaneous plastics products	0.23	0.23	0.23	0.21
Leather and leather products	0.37	0.36	0.37	0.35
Railroad transportation	0.28	0.28	0.28	0.29
Local and interurban passenger transit	0.18	0.18	0.18	0.19
Trucking and warehousing	0.27	0.24	0.26	0.26
Water transportation	0.30	0.28	0.29	0.30
Transportation by air	0.28	0.28	0.28	0.30

| | **Data** | | | **Model** |
Sector	s_K^1	s_K^2	s_K	$\alpha(z)$
Pipelines, except natural gas	0.82	0.82	0.82	0.77
Transportation services	0.33	0.40	0.37	0.35
Telephone and telegraph	0.65	0.65	0.65	0.66
Radio and television	0.54	0.57	0.55	0.52
Electric, gas, and sanitary services	0.71	0.72	0.72	0.73
Wholesale trade	0.42	0.40	0.41	0.43
Retail trade	0.36	0.34	0.35	0.35
Depository institutions	0.58	0.58	0.58	0.57
Nondepository institutions	0.21	0.21	0.21	0.20
Security and commodity brokers	0.21	0.21	0.21	0.19
Insurance carriers	0.39	0.39	0.39	0.37
Insurance agents, brokers, and service	0.23	0.21	0.22	0.21
Other real estate	0.82	–	0.82	0.85
Holding and other investment offices	–	0.07	0.07	0.05
Hotels and other lodging places	0.42	0.37	0.40	0.37
Personal services	0.27	0.23	0.25	0.23
Business services	0.23	0.28	0.26	0.28
Auto repair, services, and parking	0.48	0.42	0.45	0.46
Miscellaneous repair services	0.27	0.06	0.17	0.17
Motion pictures	0.15	0.06	0.11	0.09
Amusement and recreation services	0.31	0.35	0.33	0.31
Health services	0.11	0.18	0.14	0.17
Legal services	0.08	0.28	0.18	0.19
Other services	0.09	0.07	0.08	0.08

Table 2: Observed and calibrated capital shares in US sectors.

Table 2 reports the capital shares in value added in the data and in our model for the sectors we use to calibrate the function $\alpha(z)$ in our model. The data is collected for 57 US sectors, defined according to the SIC87 classification, over the 1987-97 period. We use this data to compute the labor share in value added. The capital share in value added is simply computed as one minus the labor share. Columns s_K^1 and s_K^2 differ how we account for the labor income of self employed workers:

1. We compute s_K^1 by assigning the average wage received by employees to self-employed workers.

2. We compute s_K^2 by assuming that proprietors income, net of inventory valuation adjustment, should be allocated to labor and capital in the same proportions as they represented in the remainder of the economy.

These two estimates are highly positively correlated (with a coefficient around 0.96); however, some relevant differences, in particular for labor-intensive sectors, remain. Since both are rough approximations of the true labor share, and both probably capture some distinct aspects of reality, we take the average of these two alternative estimates as our benchmark distribution reported in column s_K.

Parameter value	Trade share	Dynamic feedbacks in steady state		Revenue max. tax rate
		Gov. rev.	Net. fiscal pos. (PV)	
Distribution of capital shares, $\alpha(z)$				
Benchmark	**6.9%**	**0.94**	**0.76**	**27.9%**
No extrapolation	5.5%	0.97	0.77	27.3%
Trade cost, ν				
1.70	11.11%	0.92	0.74	28.3%
1.74	**6.89%**	**0.94**	**0.76**	**27.9%**
1.79	2.21%	0.96	0.78	27.6%

Table 3: Sensitivity analysis: capital intensities and trade costs.

The column $\alpha(z)$ reports the capital share in each sector implied by the calibrated capital share function $\alpha(z)$ in our model. The correlation between the data implied capital share s_K and our calibrated capital share $\alpha(z)$ is 0.996.

D   Sensitivity Analysis

D.1   The Distribution of Capital Shares

Our calibration procedure parameterizes the $\alpha(z)$ distribution using empirical evidence on the US sectorial structure and taking the implications of our theoretical trade model literally. Two alternative procedures, based on the same data, may seem natural. The first one consists in fitting our polynomial on the actual US distribution of capital intensities without extrapolating the left-hand tail. This is more conservative from an empirical perspective, but not so faithful to our theory, as we attribute the sectorial shares of the interval $(z_N, 1]$ to the whole interval $[0, 1]$ Our second alternative takes our argument to the extreme, and extrapolates the capital intensity distribution not only on the left-hand side, but also on the right-hand one, in order to span the full range of possible capital intensities $[0, 1]$. This second approach could be justified by noting that the level of disaggregation of the available sectorial data is quite coarse, and some of the highest (and lowest) capital shares could have simply been hidden by the aggregation process.

The first panel of Table 3 summarizes the main results for the three parameterizations discussed above. Notice that the cross-sector dispersion of capital intensities has an obvious effect on trade: the more disperse the distribution, the more room for taking advantage of comparative advantage and therefore more trade. More importantly, both alternative procedures generate results that are in line with the outcome of the benchmark parametrization. We do not graph the corresponding Laffer curves, as they are all very similar.

D.2   Trade Costs

The degree of openness, summarized by the trade cost ν, is another key feature in our framework. Figure 9 plots the Laffer curve in the North for four different values of the trade cost (*ceteris paribus*). These generate trade shares in GDP ranging from 32% to 161% of our benchmark's trade share. A lower trade cost boosts trade and specialization
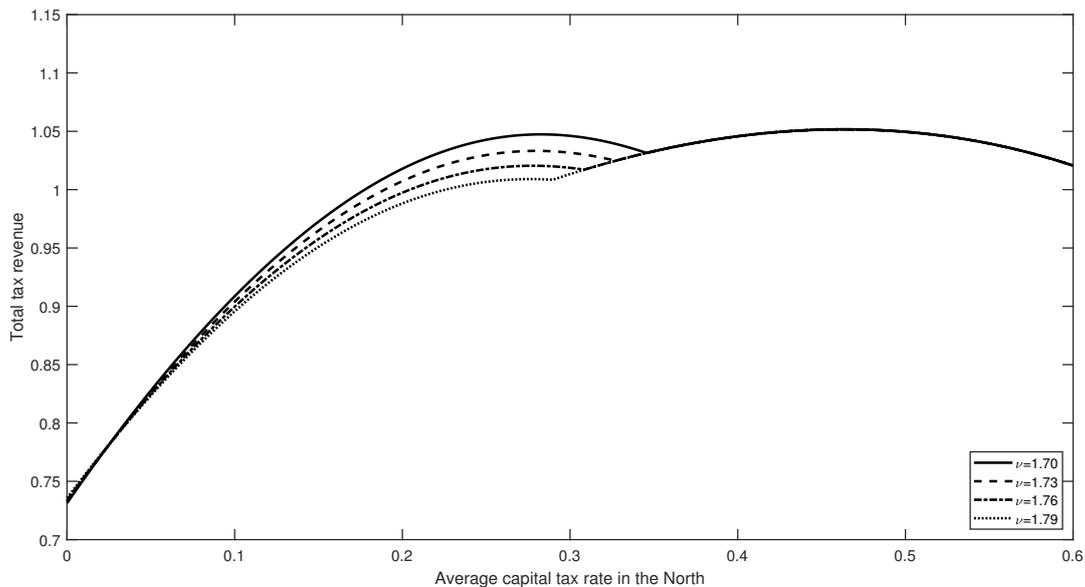
Figure 9: The Northern Laffer curve for different degrees of trade integration.

and therefore capital accumulation in the North. This makes the Laffer curve expand upwards and to the right, shifting the revenue-maximizing tax rate to the right.

The implications for our results, as summarized in the second panel of Table 3, are straightforward: for the given actual US tax rate, equal to 27.3%, an increase in the degree of openness will reduce the steady-state feedback effect under trade, for both government revenues and the net fiscal position. Furthermore, it will reduce the distance between the actual tax rate and the revenue maximizing tax rate, bringing the North possibly back to the upward sloping side of the Laffer curve.[41]

D.3   The Elasticity of Intertemporal Substitution

The elasticity of intertemporal substitution is key in determining the speed of capital accumulation, and therefore the speed of convergence towards the steady state. Table 4 summarizes our main results for some alternative values of μ that lie symmetrically around our benchmark value. Almost all variables of interest remain unaltered, except for the present-value dynamic feedback for the net fiscal position. The speed of convergence as measured by the half life - the number of periods needed to cover half their way to the new steady state - increases slightly with μ, as expected.

D.4   Capital Mobility

Throughout our paper we assume that production factors are internationally immobile and we rely on international trade to generate the changes in production structures that drive our results. Following a capital tax cut, the lack of capital mobility implies large and persistence differences in the after-tax real return to capital between the two countries.

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[41]Note that, for $\nu = 1.7$, the actual and the revenue-maximizing tax rates reported in Table 3 almost coincide, and therefore the one-percentage-point tax cut we are examining takes the economy to the upward sloping side of the Laffer curve, since the dynamic feedback is less than unity. If the tax rate is reduced by a marginal amount, and therefore the economy remains on the "slippery" side, the dynamic feedback would remain (marginally) larger than one.

Elast. inter. substitution	PV dyn. feedback in steady state	Dynamic feedback Half life	
μ	*PV net fiscal pos.*	*Gov. rev.*	*PV net fiscal pos.*
0.50	0.58	16	17
0.75	0.68	11	14
1.00	**0.76**	**9**	**12**
1.50	0.87	5	9
2.00	0.98	3	5

Table 4: Alternative elasticities of intertemporal substitution.

Allowing for this arbitrage opportunity to persist is key in determining the speed of convergence towards the steady state and may have strong quantitative implications for our results.

In this section we are relaxing the assumption of capital immobility and we are considering an alternative economic environment where the representative household in country j can invest its wealth D_{jt} in either country. Market clearing requires

$$D_{Nt} + D_{St} = K_{Nt} + K_{St} \tag{26}$$

where K_{jt} denotes the capital stock rent to intermediate producers in country j. Capital mobility eliminates any arbitrage between the investment opportunities in the two countries and implies that the after-tax real return on capital is equalized not only in steady state, but also in every period along the transitional path:

$$\left(1 - \tau_N^K\right) \frac{r_{Nt}}{P_{Nt}} = \left(1 - \tau_S^K\right) \frac{r_{St}}{P_{St}}. \tag{27}$$

Equations (26) and (27) determine uniquely the distribution of capital across countries, given wealth D_{Nt} and D_{St}.

The representative household maximizes equation (1) subject to the intratemporal budget constraint

$$P_{jt}\left(C_{jt} + D_{jt+1} - R_{jt}\right) = \left(1 - \tau_j^L\right) w_{jt} L_{jt} + \left[\left(1 - \tau_j^K\right) r_{jt} + (1 - \delta)P_{jt}\right] D_{jt}, \tag{28}$$

where government transfers are given by (2). The first-order conditions of the household's problem are again (3) and (4), while (5) is replaced with (28) above. The rest of the equilibrium conditions are the same as in our benchmark trade model.

Figure 10 summarizes the implications of capital mobility for the economy's dynamic response to an unexpected and permanent one-percentage-point reduction in the tax rate on capital income in the North. Following the tax cut North experiences a sudden inflow of capital from South to equalize the after-tax real return on capital. This increases the real wage in the North and the substitution effect implies a lower supply of hours, increasing labor income overall. As a result, the tax cut is already self-financing on impact since the increased tax revenues from labor income compensate for the static loss of the tax cut. Capital accumulation reinforces this effect further as the capital stock, labor income and consequently government revenues are increasing further in the North along the transitional path. However, the contribution of capital accumulation is small when capital is internationally mobile and our results are driven by the reallocation of capital across countries that mostly takes place on impact.
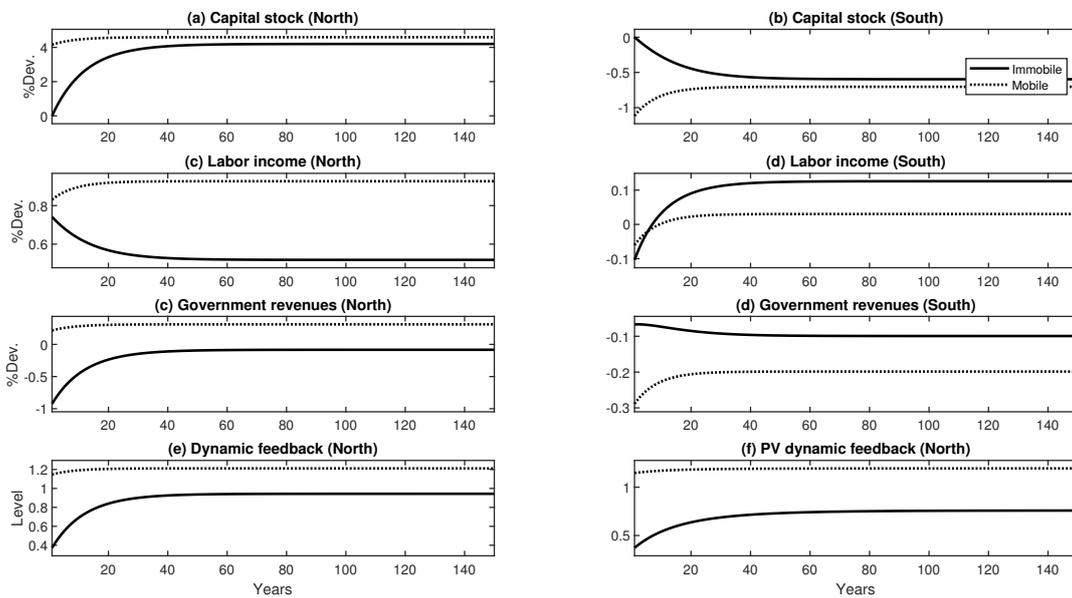
Figure 10: The effects of a capital tax cut with and without international capital mobility.