Dynamic Scoring in Open Economies

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Abstract

This paper fills a gap in the literature by focusing on the degree of self-financing of tax cuts in a New Keynesian two-country model. We find that the degree of self-financing of income tax cuts is negative on impact but it quickly becomes positive. The open economy dimension does not matter much for the long-run degree of self financing. This is because the main channel through which the open economy dimension affects the results—an expenditure switching effect stemming from exchange rate appreciation—is not active in the new steady state, in which the economy reaches a new flexible-price equilibrium.

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1. Introduction

The debate on whether tax cuts can pay for themselves is often associated with the idea, popularized in the 1980s, of the Laffer curve. The original Laffer argument was that there is, at any given point in time, a hump-shaped relationship between the tax rate and actual revenue collection. Later academic and policy discussions have extended this concept in a dynamic sense. While the precise meaning of a dynamic Laffer curve is open to interpretation and various definitions have been used in the literature, a minimum necessary condition for dynamic Laffer effects to happen is that a tax cut today will increase growth and, at some point in the future, deliver higher tax revenues in the absence of other policy changes.[1] In reality, the idea that this might be possible pre-dates the Laffer debate and goes back at least to Keynes, who stated that: *"Nor should the argument seem strange that taxation may be so high as to defeat its object, and that, given sufficient time to gather the fruits, a reduction of taxation will run a better chance than an increase of balancing the budget."* (Keynes 1933; p.5).

In more recent years, Auerbach (2005) has stressed that the methodology used by the US Joint Committee on Taxation (JCT) to forecast the revenue impact of legislation changes is a partial equilibrium one, in the sense that it takes nominal GDP and other macro aggregates as given. Auerbach (2005) argues that such practice, also referrered to as "static scoring", by ruling out the possibility of a positive response of economic activity to tax reductions, biases the legislative process against tax cuts. To overcome this problem, he suggests that the JCT should adopt a general equilibrium—or "dynamic scoring"—methodology, in which feedback effects from taxes to other macroeconomic variables are taken into account.

Outside the US, as noted by Keen, Kim and Varsano (2008), much of the rhetoric in countries which have implemented so called "flat tax" reforms has been concerned more with the rate reduction aspect of the reform than with flatness itself. From this point of view, a main drive behind the recent wave of flat taxes has been the idea that tax cuts would be largely self-financing.[2]

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[1] If this minimum necessary condition is not satisfied, none of the various definitions of dynamic Laffer effects used in the literature (see, for example, Ireland (1994), p. 563; Novales and Ruiz (2002), p. 188) can be satisfied. Some authors have stressed that Laffer effects can arise because lower tax rates can reduce tax evasion (see for example Papp and Takats 2008). In this paper, however, we assume full compliance of economic agents with their tax obligations and we abstract from tax evasion.

[2] While the term "flat tax" has been used loosely and the various versions which have been adopted (most notably by Russia and by other countries in Central and Eastern Europe) vary widely, common features have often been both a reduction of the number of income tax brackets and a substantial reduction in tax rates. See Keen, Kim and Varsano (2008) for an interesting analysis of recent "flat tax" experiences.

Starting with the contribution of Mankiw and Weinzierl (2006), the focus of academic research has shifted from the question of whether Laffer effects exist to a comparison of the static scoring and the dynamic scoring impact of tax cuts. As we will explain in more detail in Section 4, such comparison allows a calculation of the degree of self-financing of tax cuts. In another words, the key issue is not any longer whether a tax cut can *completely* pay for itself, but the *degree* to which it pays for itself. This implies a shift from a qualitative question (do Laffer curve exist?) to a quantitative one (what is the degree of self-financing of tax cuts?).

In this paper we focus on a quantitative analysis of the degree of self-financing of unilateral income and consumption tax cuts in a New Keynesian two-country model with imperfect competition and nominal rigiditities.[3] The importance of the open economy dimension is underscored in our analysis by the role played by various transmission channels (an expenditure switching effect, a terms of trade effect, and a current account balance effect) in affecting both the domestic and foreign economy after a unilateral domestic tax reform.

In their Harry G. Johnson Lecture, Frenkel and Razin (1989) argued that, due to the increased integration of world economies and its effects on policy interdependence between countries, a proper analysis of the implications of tax reforms should be carried out within a global open-economy framework. This statement, which was without doubt already true when the Lecture was delivered, is all the more valid in relation to today’s highly globalized world economy. However, while recent literature (for example, Mankiw and Weinzierl 2006, Leeper and Yang 2008, Trabandt and Uhlig 2010) has seen a renewed interest in the study of the impact of tax cuts, the open economy aspects of those issues have usually been neglected. In this paper we aim to fill this gap in the literature.

Our results show that in our framework tax cuts cannot be considered a “free lunch”, because the minimum necessary condition for Laffer effects to emerge, that a tax cuts today increases tax collection at some point in the future, is not satisfied. Therefore, both income and consumption tax cuts have negative budgetary consequences for the country which implements them. In this regard, our New Keynesian framework yields results which are closer to those of Mankiw and Weinzierl (2006) and Trabandt and Uhlig (2010) than those of Ireland (1994) and Novales and Ruiz (2002), who find dynamic Laffer effects under certain parameterizations.

[3] Following the seminal paper by Obstfeld and Rogoff (1995, 1996), important contributions to the open economy New Keynesian literature include, but are not limited to, Betts and Devereux (2000), Corsetti and Pesenti (2001), and Obstfeld and Rogoff (2000, 2002). Surveys of this literature are provided by Lane (2001), Sarno (2001), Lane and Ganelli (2003), Coutinho (2005), and Corsetti (2007).

Given the lack of dynamic Laffer effects in our framework, we mostly focus our analysis on whether tax cuts can be at least largely self-financing, in the sense of Mankiw and Weinzierl (2006). We find that, following a domestic income tax cut, the degree of self financing is negative on impact but it quickly becomes positive. In the new steady state, it is equal to about 22 percent, a value of the same order of magnitude as those calculated in closed economy models such as Mankiw and Weinzierl (2006) and Trabandt and Uhlig (2010). As we discuss in more detail in Section 4, the negative short-term degree of self-financing is explained by the fact that, in an open economy with nominal rigidities, the "general equilibrium" (dynamic scoring) fall in revenue is larger than the "partial equilibrium" (static scoring) one, because the latter does not account for the expenditure switching effect stemming from real exchange rate appreciation, while the former does. In order to be able to evaluate the relative importance of short-run and long-run results we also calculate the present value of the degree of self-financing. We find the negative short-run degree of self-financing has a relatively weak impact on its present value, and the latter is closer to the long-run degree of self-financing.

Overall, one conclusion that we can draw from our analysis is that the open economy dimension does not matter much for the degree of self-financing of labor income tax cuts in the steady state. This is because the main channel through which the open economy dimension affects the results, the expenditure switching effect, is not active in the new steady state, when all firms are free to adjust their prices in response to the initial shock and the economy reaches a new flexible-price equilibrium.

In the case of domestic consumption tax cuts, dynamic Laffer effects also do not emerge. While previous literature has not delved into the analysis of consumption tax cuts, this result is consistent, for example, with Novales and Ruiz (2002). In the case of consumption taxes the degree of self-financing is higher (around 55 percent) in the short run and lower (about 12 percent) in the new steady state. The explanation for this dynamics lays in the fact that, for the reasons discussed in detail in Section 5, a consumption tax cut generates a depreciation of the nominal exchage rate (rather than an appreciation like in the case of income tax cuts). As a consequence, in the case of consumption tax cuts the expenditure switching effect, which is more relevant in the short run due to nominal rigidities, works in favor of the domestic country, shifting demand in the short run towards its goods and therefore increasing the short-run degree of self-financing (compared to the long-run one).

We also carry out a welfare analysis of income and consumption tax cuts, and we find that in both cases utility increases in both countries. This is because, due to imperfect competition, the initial levels of world output and consumption are ineficiently low, and reducing taxes brings them closer to their efficient level. The result that tax cuts increase welfare is also consistent with the findings of closed-economy, endogenous growth models (for example, Van Oudheusden 2010).

As explained in detail in Section 3, we carefully paremeterize our model on the basis of existing empirical evidence on the values of the relevant parameters. Our chosen parameterization implies realistic levels of the initial level of total revenue to output. In addition, as discussed in Section 4, our results match empirical evidence (as provided, for example, by IMF (2010) and Arin and Koray (2009)) on the macroeconomic impact of tax changes.

In Section 6 we also explore the sensitivity of our results to changes in various parameters and assumptions, such as the degree of nominal rigiditiy, the Frisch elasticity of labor supply, the consumption elasticity of money demand, the country size, and the currency of invoicing of exports. The overall conclusion of the sensitivity analysis is that our findings are quite robust. Our results can therefore be interpreted as pertaining to the New Keynesian class of models to which our model belongs, rather than being valid only for our specific benchmark parameterization.

One limitation of our model is the lack of capital accumulation, and thus capital income taxation. In addition, we do not model balanced economic growth, public debt, and public spending. Notwitstanding these limitations, we believe that our current setup strikes a reasonable balance in terms of analysing the issue of self-financing in a New Keynesian framework without unduly complicating the model. Given that we focus on a New Keynesian model with price rigidities, it is not unreasonable to omit capital, since price rigidities are relevant only in the short term, when the capital stock is approximately fixed. Infact, the absence of capital is a feature that our model shares with large part of the New Keynesian open economy literature.[4]

Similarly, the focus on short-run analysis means that New Keynesian models typically do not have balanced growth. Since we assume that tax revenue is distributed back to the households, the way in which the tax cut is financed is irrelevant in our framework. This justifies our choice to focus on balanced-budget tax cuts, ruling out government debt from the model.[5] Introducing public spending in our model would imply that a balanced-budget tax cut would reduce public consumption, rather than reducing transfers to households as in the current setup. In this case, the welfare effects of tax cuts would depend on the choice of what

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[4] Noteworthy exceptions are Ghironi (2000) and Bergin (2006).

[5] Carrying out a similar exercise in a New Keynesian finite-horizon model with public debt (such as Ganelli 2005) is a possible avenue for future research.

kind of public consumpion is cut to finance them. For example, the results would be different depending on whether the public spending which is cut substitutes for or complements private consumption. In this paper we prefer to abstract from the impact of such spending composition issues, and we therefore focus on tax reductions financed by reduced transfers to households.

In summary, we believe that, while the framework that we use has several limitations, it is still appropriate for the issues that mostly interests us in this paper, namely the degree of self-financing in an open economy New Keynesian model. We therefore see the introduction of capital, a balanced growth path, public debt and public as extensions beyond the scope of the current paper, and we leave them for future research.

The paper is organized as follows. Sections 2 and 3 respectively introduce the model and our benchmark parameterization. Section 4 and 5 analyses the degree of selg-financing of income and consumption tax cuts. Section 6 presents the sensitivity analysis. Section 7 concludes.

2. The Model

We use a standard New Keynesian two country model, similar to the one developed by Betts and Devereux (2000). Compared to the latter, there are two main differences. The first is the introduction of income and consumption taxes instead of lump-sum ones. The second is that nominal rigidities take the form of staggered price setting as in Calvo (1983), rather than one-period fixed prices.

The open economy macroeconomics literature (e.g. Betts and Devereux 2000) has shown that the international effects of macroeconomic and policy shocks are different depending on the currency of invoicing of exports, i.e. depending on whether export prices are set in the producer's currency (PCP for producer currency pricing) or in the local currency of the consumer (LCP for local currency pricing). In our model we therefore allow for both PCP and LCP.

The model contains two countries. Firms and households are indexed by $z \in [0,1]$. A fraction n of households and firms are located in the domestic country, while $1-n$ are located in the foreign country. Each firm produces a differentiated good. There are two types of firms. A fraction b of firms in each country can "price-to-market". These firms use LCP and they are referred as LCP firms. The rest of the firms, a fraction $1-b$, set a unified price across the countries. These firms use PCP and they are referred to as PCP firms. These firms let prices abroad move one-to-one with the exchange rate.

The setup of our model allows us to consider both the full PCP and LCP cases by varying the parameter b from 0 to 1. In our analysis, we consider the PCP case (b=0) as the benchmark case, but we also look at the LCP case (b=1) to check the sensitivity of our results to the PCP assumption. We focus on the PCP case for two reasons. First, as originally noted by Grassman (1973, 1976) and more recently discussed in Ligthart and da Silva (2007), goods trade between industrialized countries is predominantly invoiced in the exporter's currency. Second, LCP implies that currency depreciations should be associated with an improvement in a country's terms of trade. This is inconsistent with the empirical evidence provided by of Obstfeld and Rogoff (2000), which shows that depreciations are associated with a worsening of terms-of-trade.

In the presentation of the model below we will introduce domestic equations. Unless equations for the foreign country are explicitly discussed, they can be assumed to be symmetric to the equations for the domestic country.

2.1 Households

Households gain utility from private consumption and real balances, and experience disutility from supplying labor. Their utility function is therefore given by

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t} [\log C_s + \frac{\chi}{1-\varepsilon} (\frac{M_s}{P_s})^{1-\varepsilon} - \frac{l_s(z)^{\nu+1}}{\nu+1}] \tag{1}$$

where $0 < \beta < 1$ is the discount factor, C_s is a composite good representing private consumption and P_s is the price index associated with it. M_s denotes nominal money balances and $l_s(z)$ the household's supply of labor; $\varepsilon > 0$ is the inverse of the consumption elasticity of money demand, ν is the elasticity of the marginal disutility of producing output with respect to output (this implies that the Frisch elasticity of labor supply is $1/\nu$) and χ is a positive parameter.

The composite private consumption good is defined in the following equation as an aggregate across the individual goods produced by firms

$$C_t = [\int_0^1 c_t(z)^{\frac{\theta-1}{\theta}} dz]^{\frac{\theta}{\theta-1}} \tag{2}$$

where $1 < \theta << \infty$ is the elasticity of substitution between any pair of individual goods. The associated price index is

$$P_t = [\int_0^n p_t(z)^{1-\theta} dz + \int_n^{n+(1-n)b} (p_t^*(z))^{1-\theta} dz + \int_{n+(1-n)b}^1 (E_t q_t^*(z))^{1-\theta} dz]^{\frac{1}{1-\theta}}. \quad (3)$$

Where p denotes prices in domestic currency, q denotes prices in foreign currency, E is the nominal exchange rate, defined as the price of the foreign currency in terms of the domestic currency, and asterisks denote foreign variables. Therefore, $p_t(z)$ is the domestic currency price of a domestic good, $p_t^*(z)$ is the domestic currency price of a foreign good and $q_t^*(z)$ is the foreign currency price of a foreign good.

Similarly, the foreign price index is

$$P_t^* = [\int_0^{n(1-b)} (p_t(z)/S_t)^{1-\theta} dz + \int_{n(1-b)}^n (q(z))^{1-\theta} dz + \int_n^1 (q_t^*(z))^{1-\theta} dz]^{\frac{1}{1-\theta}},$$

where $q_t(z)$ is the foreign currency price of a domestic good.

The budget constraint of the domestic representative household is given by

$$M_t + \delta_t D_t = D_{t-1} + M_{t-1} + (1-\tau_t^I) w_t l_t(z) - (1+\tau_t^C) P_t C_t + \pi_t + P_t T_t \quad (4)$$

where D denotes the household's holding of nominal bonds. Bonds are denominated in the currency of the domestic country and account for international shifts in wealth, δ is the price of a bond (the inverse of one plus the nominal interest rate), w_t is the nominal wage paid to the household in a competitive labor market, π is the household's share of profits received from firms, τ_t^I and τ_t^C are the tax rates on household labor income and consumption, and T_t denotes real transfers from the government.[6] Given that bonds are denominated in domestic currency, the budget constraint of the foreign representative household is

$$M_t^* + \delta_t \frac{D_t^*}{E_t} = \frac{D_{t-1}^*}{E_t} + M_{t-1}^* + (1-\tau_t^{I^*}) w_t^* l_t^*(z) - (1+\tau_t^{C^*}) P_t^* C_t^* + \pi_t^* + P_t^* T_t^* \quad (5)$$

where foreign variables are denoted by asterisks. A global asset-market clearing condition $nD_t + (1-n)D_t^* = 0$ also holds.

[6] Since we do not have capital in the model, the tax rate τ^I refers to a labor income tax and not a universal income tax. For simplicity, in what follows we will refer to labor income taxes simply as "income taxes".

Domestic households maximize (1) subject to (4), and an analogous optimization problem holds for foreign households. The resulting first-order conditions are

$$\delta_t(1+\tau_t^C)P_{t+1}C_{t+1} = \beta(1+\tau_{t+1}^C)P_tC_t \tag{6}$$

$$\delta_t(1+\tau_t^{C*})P_{t+1}^*C_{t+1}^*E_{t+1} = \beta(1+\tau_{t+1}^{C*})P_t^*C_t^*E_t \tag{7}$$

$$l_t^\nu = \frac{(1-\tau_t^I)}{(1+\tau_t^C)}\frac{w_t}{C_tP_t} \tag{8}$$

$$l_t^{*\nu} = \frac{(1-\tau_t^{I*})}{(1+\tau_t^{C*})}\frac{w_t^*}{C_t^*P_t^*} \tag{9}$$

$$\frac{M_t}{P_t} = \left(\frac{\chi(1+\tau_t^C)C_t}{1-\delta_t}\right)^{\frac{1}{\varepsilon}} \tag{10}$$

$$\frac{M_t^*}{P_t^*} = \left(\frac{\chi(1+\tau_t^{C*})C_t^*}{1-\frac{\delta_tE_{t+1}}{E_t}}\right)^{\frac{1}{\varepsilon}} \tag{11}$$

Equations (6) and (7) are the Euler equations for optimal domestic and foreign consumption including taxes. They reduce to standard Euler equations if the tax rate on consumption is kept constant. Equations (8) and (9) are the domestic and foreign optimal labor supply equations, which equate the disutility of supplying an extra unit of labor with the marginal utility of the extra private consumption that can be bought due to the marginal increase in labor supply. Equations (8) and (9) show that higher labor or consumption taxes reduce labor supply for given levels of the real wage and consumption. Finally, equations (10) and (11) show that households' optimal money demand is an increasing function of private consumption (including taxes) and a decreasing function of the interest rate.

2.2 The Government

We assume that all government spending is for public transfers to households, which can be financed through income and consumption taxes or seignorage. We therefore abstract from government spending for public consumption and investment. In addition, in what follows we will keep money supply constant, therefore abstracting from seignorage. Taking into account symmetry across agents, the consolidated budget constraint of fiscal and monetary authorities in per-capita terms can therefore be written as

$$T_t = \tau_t^I\frac{w_t}{P_t}l_t + \tau_t^CC_t + \frac{M_t - M_{t-1}}{P_t} \tag{12}$$

where T_t denotes real transfers.

Both income and consumption tax rates follow an AR(1) process

$$\hat{\tau}_t^i = \rho_i \hat{\tau}_{t-1}^i + \varphi_{i,t}$$

where i=I,C, $\rho_i \in [0,1]$ and $\varphi_{i,t}$ is a zero mean white-noise process that represents an unexpected change to the rate. Percentage changes from the initial steady state (denoted by the subscript zero) are denoted by hats (for example: $\hat{\tau}_t^I = \frac{d\tau_t^I}{\tau_0^I}$). In practice, tax rates are very stable and can only be changed through policy decisions. In the policy exercises that we carry out in this paper we therefore set the persistency parameter $\rho_i = 1$, while the parameter $\varphi_{i,t}$ is used to model policy shifts. Setting $\rho_i = 1$ is consistent with the Barro's tax-smoothing model of government finance, which predicts that taxes should follow a random walk (Barro 1981). Since we look at unilateral tax cuts implemented domestically, tax policy is unchanged in the foreign country. The relative changes in tax rates in our policy exercises are therefore defined as $\hat{\tau}_t^i - \hat{\tau}_t^{i*} = \hat{\tau}_{t-1}^i - \hat{\tau}_{t-1}^{i*} + \varphi_{i,t}$.

2.3 Monetary Policy

In our framework, monetary policy is characterized by a fixed money supply rule. Since the amount of money is fixed in nominal terms, any discrepancy between real money demand and real money supply needs to be corrected by movements in the price index (3) and in its foreign counterpart. Since prices of differentiated goods are sticky in the currency of production, this implies that the nominal exchange rate needs to jump to equate the demand and the supply of money in each country. Under this monetary framework, our results are sensitive to the consumption elasticity of money demand. In Section 6 we carry out some sensitivity analysis for this parameter.

2.4 Firms

2.4.1 Technology and Profits

Each firm produces a differentiated good according to the simple production function

$$y_t(z) = l_t(z) \tag{13}$$

where $y_t(z)$ is the total output of firm z and $l_t(z)$ the labor input used by firm z. For domestic LCP firms, total output is divided between output sold in the home country, $x_t(z)$, and output sold in the foreign country, $v_t(z)$. In the case of foreign firms, total output is divided between output sold in the home country, $v_t^*(z)$, and output sold in the foreign country, $x_t^*(z)$. Profits are given by

$$\pi_t^{PCP}(z) = p_t(z)y_t(z) - w_t l_t , \quad (14)$$

$$\pi_t^{LCP}(z) = p_t(z)x_t(z) + Eq_t(z)v_t(z) - w_t l_t , \quad (15)$$

$$\pi_t^{*PCP}(z) = q_t^*(z)y_t^*(z) - w_t^* l_t^* , \quad (16)$$

$$\pi_t^{*LCP}(z) = (p_t^*(z)v_t^*(z))/E_t + q_t^*(z)x_t^*(z) - w_t^* l_t^* . \quad (17)$$

Equations (14) and (15) show the profits of a domestic PCP and LCP firm, respectively. Equations (16) and (17) show the profits of the corresponding foreign firms.

We assume that all firms use either PCP $(b=0)$ or LCP $(b=1)$. The demands for the goods can be written as

$$y_t^{PCP}(z) = (\frac{p_t(z)}{P_t})^{-\theta}(nC_t + (1-n)C_t^*) , \quad (18)$$

$$x_t(z) = (\frac{p_t(z)}{P_t})^{-\theta} nC_t , \quad (19)$$

$$v_t(z) = (\frac{q_t(z)}{P_t^*})^{-\theta}(1-n)C_t , \quad (20)$$

$$y_t^{*PCP}(z) = (\frac{q_t(z)}{P_t^*})^{-\theta}(nC_t + (1-n)C_t^*) , \quad (21)$$

$$v_t^*(z) = (\frac{p_t^*(z)}{P_t})^{-\theta} nC_t , \quad (22)$$

$$x_t^*(z) = (\frac{q_t^*(z)}{P_t^*})^{-\theta}(1-n)C_t . \quad (23)$$

Equation (18) shows the demand for a domestic PCP firm. Equation (19) and (20) are the demand for a domestic LCP firm in the home and country, respectively. The corresponding foreign equations are (21)-(23).

2.4.2 Price Setting

In the absence of price rigidities, for instance, a domestic LCP firm would maximize $\pi_t^{LCP}(z)$ with respect to $p_t(z)$ and $q_t(z)$. This would imply

$$p_t(z) = E_t q_t(z) = \frac{\theta}{\theta - 1} w_t . \qquad (24)$$

This implies that the price of the good is given by a simple mark-up over wages (marginal costs). In the absence of price rigidities, the law of one price holds, and the good is sold at the same price, when expressed in the same currency, in the both countries. A domestic PCP firm maximizes $\pi_t^{PCP}(z)$ with respect to $p_t(z)$. The price of the good is a constant markup over marginal costs, as in equation (24).

However, following Calvo (1983), we introduce nominal rigidities by assuming that each firm resets its price with a probability $1-\gamma$ in each period, independently of other firms and independently of the time elapsed since the last adjustment. Under Calvo pricing, the representative domestic LCP firm seeks to maximize

$$\max_{p_t(z), q_t(z)} V_t^{LCP}(z) = \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} \pi_t^{LCP}(z),$$

where $\zeta_{t,s}$ is the domestic discount factor between period t and period s, defined as $\zeta_{t,s} = \Pi_{j=s}^{t}(1+i_j)^{-1}$, where i the domestic nominal interest rate. The result is that the pricing rules are given by

$$p_t(z) = \left(\frac{\theta}{\theta-1}\right) \frac{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} (C_s) \left(\frac{1}{P_s}\right)^{-\theta} w_s}{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} (C_s) \left(\frac{1}{P_s}\right)^{-\theta}}, \qquad (25)$$

$$q_t(z) = \left(\frac{\theta}{\theta-1}\right) \frac{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} (C_s^*) \left(\frac{1}{P_s^*}\right)^{-\theta} w_s}{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} (C_s^*) \left(\frac{1}{P_s^*}\right)^{-\theta} E_s}. \qquad (26)$$

Equation (26) shows that domestic export prices, expressed in foreign currency, do not change when the nominal exchange rate changes. Consequently, the exchange rate pass-through to export prices is zero for those goods LCP goods whose prices cannot be adjusted.

The representative domestic PCP firm, seeks to maximize

$$\max_{p_t(z)} V_t(z) = \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} \pi_t^{PCP}(z).$$

The result is that the log-linear pricing rule for a domestic PCP good is the same as equation (25). Therefore, domestic PCP firms, who are not able to reset their prices, let foreign currency prices money one-to-one with the exchange rate. Consequently, there is complete exchange rate pass-through to export prices.

The representative foreign LCP firm seeks to maximize

$$\max_{p_t^*(z), q_t^*(z)} V_t^{*LCP}(z) = \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* \pi_t^{*LCP}(z).$$

The pricing rules can be written as

$$p_t^*(z) = (\frac{\theta}{\theta - 1}) \frac{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* (C_s)(\frac{1}{P_s})^{-\theta} w_s^*}{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* (C_s)(\frac{1}{P_s})^{-\theta} \frac{1}{E_s}}, \quad (27)$$

$$q_t^*(z) = (\frac{\theta}{\theta - 1}) \frac{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* (C_s^*)(\frac{1}{P_s^*})^{-\theta} w_s^*}{\sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s}^* (C_s^*)(\frac{1}{P_s^*})^{-\theta}}. \quad (28)$$

Equation (27) shows that the domestic currency price of a foreign good domestic does not change when the nominal exchange rate changes.

The representative foreign PCP seeks to maximize

$$\max_{q_t^*(z)} V_t(z) = \sum_{s=t}^{\infty} \gamma^{s-t} \zeta_{t,s} \pi_t^{*PCP}(z).$$

The log-linear version of the pricing rule is the same as equation (28).

2.5 Symmetric Equilibrium

All firms in a country are symmetric and every firm that changes its price in any given period chooses the same price and output. The structure of price setting implies that each period a fraction of $1-\gamma$ of firms sets a new price and the remaining fraction keeps their price unchanged.

The consolidated budget constraint of the home country can be derived by substituting equations (12), (14) and (14) into equation (4)

$$\delta_t D_t = D_{t-1} - P_t C_t + (1-b) p_t(z) y_t(z) + b\left[p_t(z) x_t(z) + E_t q_t(z) v_t(z)\right]. \qquad (29)$$

In the policy exercises which we carry out below, we log-linearize the model around a symmetric steady state. We consider the special case in which initial net foreign assets are zero ($D_0 = 0$, using the zero subscript to denote the initial steady state). Therefore the following relationship holds $C_0 = y_0$. Equations (8), (13) and (24) can then used to solve the initial equilibrium

$$y_0 = C_0 = l_0 = [(\frac{1-\tau_0^I}{1+\tau_0^C})(\frac{\theta-1}{\theta})]^{\frac{1}{\nu+1}}. \qquad (30)$$

Equilibrium is sequences of variables that clear the labor, goods and money markets in each country in each period, satisfy the conditions for the optimal intertemporal allocation of consumption, satisfy the optimal pricing rules and satisfy the intertemporal budget constraints.

3. Parameterization

As mentioned in Section 2, our baseline parameterization is based on full PCP *(b = 0).* Periods are interpreted as quarters and the discount factor β is set to 0.99. The parameter θ governs the elasticity of substitution between two goods produced in the same country and the elasticity of substitution between domestic and foreign goods. Rotemberg and Woodford (1992) estimate that the elasticity of substitution between differentiated goods is 6. The empirical literature shows a wide range of estimates for the elasticity of substitution between domestic and foreign goods. Sutherland (2006), however, argues that typical estimates are in the range of 5 to 6. We set the elasticity of substitution between differentiated goods θ to 6. This value is widely used in the business cycle literature.

The parameter ε governs the consumption elasticity of money demand, which is 1/ε. It is a key parameter in determining the nominal exchange rate response to tax shocks. The empirical estimates of Mankiw and Summers (1986) show that the consumption elasticity of money demand is close to one in the US. Therefore our baseline choice is ε = 1.

The Frisch elasticity of labour supply is given by $1/\nu$ in our model. Following Trabandt and Uhlig (2010), we set this parameter to one (ν = 1) in our benchmark parameterization. This value is consistent with the empirical estimates of by Kimball and Shapiro (2008). In addition, it is widely used in the New Keynesian literature.

The price rigidity parameter γ is the one which mostly affects the strength and duration of the expenditure switching effect. Therefore, it is important to set its value to match the empirical evidence on price rigidities of internationally traded goods. Gopinath and Rigobon (2008) find that the trade-weighted median time between price changes is 10.6 months for US imports and 12.8 months for US exports. Based on these estimates, γ is set to 0.75, which implies that the average time until a new price is set is one year.

Trabandt and Uhlig (2010) use the methodology of Mendoza et al. (1994) to calculate average effective tax rates from 1995 to 2007 for the US. In setting initial income and consumption tax rates we follow Trabandt and Uhlig's (2010) parameterization for the US. Our initial income and consumption tax rates are respectively 28 and 5 percent $(\tau_0^I = 0.28; \tau_0^C = 0.05)$. In comparison, Mankiw and Weinzierl (2006) and Leeper and Yang (2008) use $\tau_0^I = 0.25$ and there are no consumption taxes in their models.

One relevant question is how well our model fits actual data under our parameterization. Our benchmark parameterization implies that total tax revenue as percentage of initial output is 25 percent. OECD (2011) finds that total tax revenues as a percentage of GDP in the US in 2005 was 27%. The model therefore generates a realistic total tax revenue to output ratio under our benchmark parameterization.[7]

4. The Domestic and International Effects of a Cut in the Income Tax Rate

In this section we analyze the implications of an unexpected reduction in the income tax rate τ_t^I from 0.28 (a 28 percent income tax rate) to 0.27 (a 27 percent income tax rate), which corresponds to a roughly 3.6 percent cut in the rate. Since we want to initially focus on the macroeconomic and budgetary implications of income tax reform abstracting from changes

[7] We simulate the model using the algorithm developed by Klein (2000) and McCallum (2001).

in other taxes, we leave the consumption tax rate τ_t^C unchanged at its initial steady state level of 0.05 (an 5 percent consumption tax rate) in this section.

The results of this policy exercise are presented in Figure 1. Typically, the vertical axes show percentage deviations from the initial steady state.[8] The degree of self-financing is expressed in percentages. Figure 1 shows the response of domestic and foreign macroeconomic variables (including total revenue collection). Figure 1(h) shows the response of the domestic terms of trade, defined as the Calvo-weighted relative price of domestic exports in terms of domestic imports. Therefore, the increase in Figure 1(h) implies an improvement of the domestic terms of trade in the short run. The change in the terms of trade, in the case of PCP, is given by

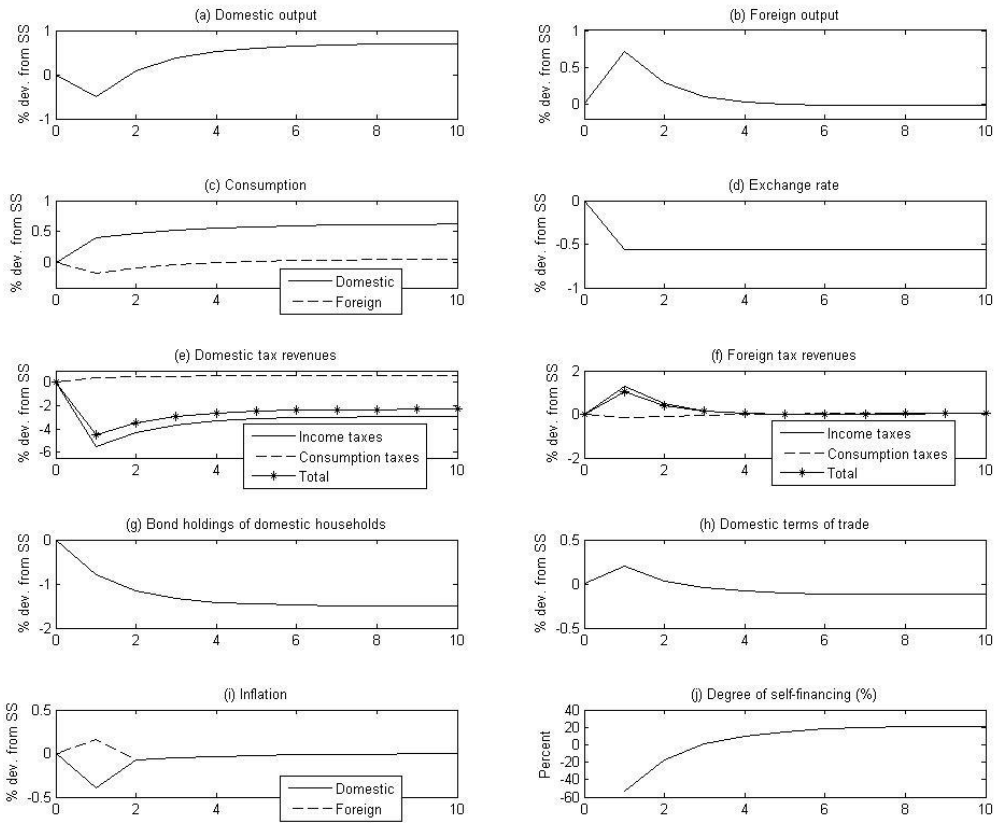
$$\hat{ToT} = \hat{b}_t(z) - \hat{E}_t - \hat{b}_t^*(z),$$

where $\hat{b}_t(z)$ and $\hat{b}_t^*(z)$ are, respectively, the Calvo-weighted prices of domestic and foreign goods

$$\hat{b}_t(z) = \gamma b_{t-1}(z) + (1-\gamma)\hat{p}_t(z),$$
$$\hat{b}_t^*(z) = \gamma b_{t-1}^*(z) + (1-\gamma)\hat{q}_t^*(z).$$

[8] In the change in bond holding, of which initial value is zero, is expressed as a deviation from initial consumption.

Figure 1
The Effects of a Domestic Income Tax Reduction



The log-linearized version of the government's budget constraint implies that the change in tax revenue collection is

$$\hat{T} = u(\hat{\tau}_t^I + \hat{w}_t + \hat{l}_t - \hat{P}_t) + (1-u)(\hat{\tau}^C + \hat{C}_t) \tag{31}$$

where u denotes the share of income tax on total taxes in the initial steady state (in our benchmark parameterization this share is equal to 0.82, see Appendix for the derivation). Equations (31) refers to *total* revenue collection. In equation (31), $u(\hat{\tau}_t^I + \hat{w}_t + \hat{l}_t - P_t)$ denotes the change in income tax collection, while $u(\hat{\tau}^C + \hat{C}_t)$ denotes the change in consumption tax collection.

Figure 1(e) shows that the minimum necessary condition for dynamic Laffer effects to happen (i.e. that a tax cut today will, at some point in the future, deliver higher tax revenues) is not satisfied in our model, since tax collection is reduced at every time horizon. In this sense, there is no “free lunch” in our model. As we have already discussed in the introduction, however, recent research (Mankiw and Weinzierl 2006; Trabandt and Uhlig 2010) has shifted the focus in the literature from “free lunches” to “cheap lunches”, in the sense of investigating whether tax cuts which do not generate dynamic Laffer effects can at least be largely self-financing. The latter is the question which mostly interests us in this paper and on which we focus in what follows.

The degree of self financing has been defined as[9]

$$100*(1-x) \tag{32}$$

where

$$x = \frac{dR/d\tau(gen)}{dR/d\tau(par)} \tag{33}$$

where the numerator of (33) is the response of total revenue collection to tax rate changes in a general equilibrium sense (in which all endogenous variables react to the rate change) while the denominator is the response of total revenue collection to tax rate changes in a partial equilibrium sense (in which the response of endogenous variables is shut off). The intuition behind this definition is that if x=1 then the general equilibrium effect of tax changes on revenue collection is equal to the partial equilibrium effect (i.e. dynamic scoring is equal to static scoring). In this case there is no self-financing (the degree of self-financing is zero) and the partial equilibrium methodology (static scoring) used by the JCT to evaluate the impact of proposed tax legislation is appropriate. In most cases, however, the degree of self-financing is likely to be positive but less than 100 percent.

Using (31), we can easily calculate the ratio x, as defined in (33), for our model. This ratio is in time horizon t:

$$x_t = \frac{u\left(\hat{\tau}_t^I + \hat{w}_t + \hat{l}_t - \hat{P}_t\right) + (1-u)\left(\hat{\tau}_t^C + \hat{C}_t\right)}{u\hat{\tau}_t^I + (1-u)\hat{\tau}_t^C} \tag{34}$$

The numerator of equation (34) is the general equilibrium responses of tax collection to tax rates changes, while the denominator is the partial equilibrium responses in which

[9] See Mankiw and Weinzierl (2006) and Trabandt and Uhlig (2010).

endogenous variables do not react to tax changes ($\hat{w}_t = \hat{l}_t = \hat{C}_t = \hat{P}_t = 0$). Figure 1(j) shows the degree of self-financing, given by 100*(1-x), at various time horizons.

We also calculate the present value of the degree of self-financing. The calculation is done as follows: we sum up total revenue collection to tax rate changes in a general equilibrium sense, discounted by the discount factor, and divide it by the response of total revenue collection to tax rate changes in a partial equilibrium sense calculated in the same way. The present value of the degree of self-financing is therefore given by

$$100*(1-\frac{\sum_{s=t}^{\infty}\beta^{s-t}\left[u\left(\hat{\tau}_t^I+\hat{w}_t+\hat{l}_t-\hat{P}_t\right)+\left(1-u\right)\left(\hat{\tau}_t^C+\hat{C}_t\right)\right]}{\sum_{s=t}^{\infty}\beta^{s-t}\left[u\hat{\tau}_t^I+\left(1-u\right)\hat{\tau}_t^C\right]})$$

Table 2 shows the present value of the degree of self-financing.

4.1 The Impact on the Domestic Economy

Reducing the income tax rate increases the opportunity cost of leisure. Domestic households therefore substitute out of leisure and into consumption. The impact of this substitution effect is shown in Figure 1(a) and 1(c): both domestic output and consumption increase in the long run. These results are consistent with the earlier literature. Baxter and King (1993), for example, look at the impact of an exercise symmetric to ours, finding symmetric results: a balanced-budget increase in public spending financed by income taxes reduces both output and consumption in their model.

As Figure 1(e) shows, domestic real revenue collection permanently falls by about 2.4 percent compared to its initial steady-state level as a consequence of the policy that we are analyzing. Although a lower income tax rate increases labor supply, the impact of this on income and total revenue collection is not big enough to compensate for the rate reduction. For the reasons discussed above, real consumption increases following the income tax reduction. This implies that consumption tax revenue collection increases even at an unchanged consumption tax rate. However, the quantitative impact of the increase in consumption tax collection is small (Figure 1(e)). The change in total tax collection can be explained with reference to equation (31). Since the consumption tax rate does not change in this policy exercise $(\hat{\tau}^C = 0)$, the change in real consumption tax collection is given by $(1-u)\hat{C}_t$. The low initial share of consumption taxes in our benchmark parameterization $((1-u)=0.18)$ explains why the impact of an increase in consumption tax collection is not big enough to prevent a strong decrease in overall tax collection.

Table 1

Income Tax Rate Cut: Tax Revenues Collection Changes 1/

t = 1	t = 3	t = 5	steady state
-4.5	-2.9	-2.4	-2.3

1/ See equation (31) for the definition.

Table 1 summarizes the impact on tax collection of a change in the income tax rate at various time horizons: since dynamic Laffer effects do not arise, there is no "free lunch" in our model.

4.1.1 The Degree of Self Financing: Does the Open Economy Dimension Matter?

As mentioned, Mankiw and Weinzierl (2006) and Trabandt and Uhlig (2010) have shifted the focus of research from the question of whether Laffer effects exist to the analysis of the degree of self-financing of tax cuts. Mankiw and Weinzierl (2006) calculate the degree of self-financing to be 17 percent for labor income taxes for the US. Leeper and Yang (2008) find that when income tax cuts are financed by lower transfers the degree of self-financing is 47 percent. Trabandt and Uhlig (2010) find that the degree of self-financing depends on the Frisch elasticity of labor supply, the intertemporal elasticity of substitution and on whether the model is parameterized to EU-15 or US tax rates. They find that the degree of self-financing for income tax cuts is in the range of 21-49 percent and is constant along the balanced growth path.

Table 2

Income Tax Rate Cut: The Degree of Self-Financing

t = 1	t =3	t = 5	steady state	present value
-52.8	0.665	15.1	21.8	20.2

Table 2 reports the degree of self-financing in our model, calculated at various horizons and in present value terms. In the first period, the degree of self-financing is negative. This result is quickly reversed (the degree of self-financing is positive from period 3 onwards), but it is useful to trace the source of the initial negative value. The intuition is related to the fact that we use an open economy model with nominal rigidities. This implies that, when the domestic country cuts income taxes, part of the gains accrue to the foreign country through an expenditure switching effect—discussed in detail in the next sub-section—which worsens the domestic country's competitiveness by making its goods more expensive.

In terms of equation (34), a negative self-financing means that the "general equilibrium" fall in revenue collection is larger than the "partial equilibrium" fall ($x>1$), because the latter does not account for the expenditure switching effect (which reduces income tax collection following the appreciation, due to lower domestic output), while the former does. The expenditure switching effect is quantitavely relevant only in presence of nominal price rigidities. This effects becomes therefore weaker in time periods which are more removed from the initial shock, because as time goes by more firms are able to change their prices, and the economy moves towards a long-run flexible price equilibrium in which nominal exchange rate changes have no impact on competitiveness.

The above discussion is also useful to understand why our model generates a long-run degree of self-financing broadly consistent with that of closed economy models. In the new steady state, the degree of self-financing is about 22 percent. This value is of the same order of magnitude of those calculated in closed economy models by Mankiw and Weinzierl (2006) and Trabandt and Uhlig (2010)—17 and 27 percent respectively—for labor income tax cuts in the US using parameterizations similar to ours. Given this similarity in results, one conclusion that we can draw is that the open economy dimension does not matter much for the degree of self-financing of income tax cuts in the steady state. This is because the main channel through which the open economy dimension affects the results, namely the expenditure switching effect, is not active in the new steady state, at which all firms have been able to adjust their prices in response to the initial shock. In addition, the consequence of the wealth effect due to non-zero bond holdings in the new steady state on the degree of self-financing is also negligible. In the next subsection, we move to investigate the international implications of domestic tax cuts in more detail.

4.2 The International Effects

As we have already stressed above, one advantage of our New Keynesian framework is the possibility to analyze how market imperfections interact with the open economy dimension in determining the results. One important open-economy channel obviously works through exchange rate movements. Figure 1(d) shows that the reduction in domestic income taxes implies an appreciation of the domestic nominal exchange rate (a fall in the price of foreign currency in terms of domestic currency). This appreciation is due to a “money demand” effect stemming from the increase in domestic consumption caused by the domestic tax cut. Since money demand is a positive function of consumption including taxes (see equations (10) and (11)), the increase in domestic consumption (both in absolute terms and relative to foreign consumption) increases domestic money demand compared to foreign. This implies that the domestic currency appreciation displayed in Figure 1(d) is required to reestablish equilibrium in the money market.

Figure 1(b) also shows a temporary increase of foreign output following the domestic tax cut. The tax shock appreciates the nominal exchange rate, which lowers the relative price of foreign goods. This shifts global demand towards foreign goods away from domestic goods.

The nominal exchange rate change alters the relative price of goods only as long as prices are sticky. This explains why the increase in foreign output is temporary.

As we discuss above, the expenditure switching effect explains why the degree of self-financing is negative in the short run. As shown in Figure 1(a), domestic output falls in the short run due to the increase in the relative price of the domestic goods. The expenditure switching effect is strong enough to make the degree of self-financing negative (Table 2 and Figure 1(j)), but it peters out quite fast, and therefore the degree of self-financing stays negative only for two periods. Figure 1(j) shows that as prices become flexible the degree of self-financing increases. Table 2 shows that the present value of the degree of self-financing (20.2%) is very close to its steady-state one (21.8%). This implies that the initial negative degree of self-financing does not play a significant role in the present value calculation. However, given the initial strong expenditure switching effect and the gradual adjustment of the economy towards a flexible-price equilibrium, the degree of self-financing greatly changes over time. This is a novel result compared to closed-economy, flexible-price models (such as Mankiw and Weinzierl (2006) and Trabandt and Uhlig (2010)).

The short-run increase in foreign output is matched by a short-run reduction in foreign consumption. In the long run, foreign consumption slightly increases compared to its initial steady-state level. This dynamics of foreign consumption is driven by changes in the terms of trade and by the foreign households' desire to use their temporary income gains to smooth consumption over time. Since in the short run, due to the appreciation of the domestic currency, the foreign terms of trade worsen (an increase in Figure 1(h)), foreign households reduce their short-run consumption. In this way they save part of their extra short-run income (Figure 1(b)), thus running a current account surplus (Figure 1(g)). In the long run, however, the foreign terms of trade improve (a fall in Figure 1(h)) due to a relative increase in the supply of domestic goods which implies a fall in the relative price of domestic goods. This terms of trade effect, together with external wealth accumulation due to the current account surplus, allow foreign households to increase their long-run consumption even though their long-run income returns to almost initial steady-state levels. Figure 1(f) also shows that the domestic tax reform has a temporary positive impact on foreign tax collection, due to the fact that foreign households increase their labor supply at an unchanged income tax rate level.

How do the various channels described above combine to affect the welfare of the representative agent? In what follows, we calculate the welfare effect of a tax cut following the method proposed by Schmitt-Grohe and Uribe (2007). We measure the welfare effect of a tax cut as a percentage of consumption that the household would be willing to pay for a tax cut, to be as well off in the tax rate cut case as in the case where tax rates are kept constant.

Let U_t^{CT} be the discounted present value (DPV) of welfare in the constant tax rate (CT) case in period t and let $\{C_s^{CT}, l_s^{CT}(z)\}_{s=t}^{\infty}$ be the associated consumption and labor supply paths:[10]

$$U_t^{CT} = \sum_{s=t}^{\infty} \beta^{s-t} [\log C_s^{CT} - \frac{(l_s^{CT}(z))^2}{2}].$$

Let U_t^{TC} be welfare in the tax cut (TC) case and let us define λ_{DPV} as the DPV welfare benefit of a tax cut relative to the constant tax rate case, assuming that labor supply is held constant. Making use of λ_{DPV}, U_{DPV}^{TC} can be written as

$$U_t^{TC} = \sum_{s=t}^{\infty} \beta^{s-t} [\log(1+\lambda_{DPV}) C_s^{CT} - \frac{(l_s^{CT}(z))^2}{2}] = \frac{1}{1-\beta} \log(1+\lambda_{DPV}) + U_t^{CT}.$$

Expressing the welfare benefit of a tax cut as the percentage of consumption (instead of a fraction) and solving for λ_{DPV} yields

$$\lambda_{DPV} = 100 \times [\exp(1-\beta)(U_t^{TC} - U_t^{CT}) - 1]. \tag{35}$$

A first-order Taylor expansion of the utility function implies that the change in utility in period t is given by

$$dU_t = U_t - U_0 = (\hat{C}_s - l_0 \hat{l}_s^2). \tag{36}$$

The welfare level realized in the model is the one with a tax cut ($U_t^{TC} = U_t$). In the case where the tax rates are constant, welfare would be in the initial level welfare implying that $U_t^{CT} = U_0$. Making use of equation (36), equation (35) can be written as:

$$\lambda_t = 100 \times [\exp(1-\beta)(\hat{C}_s - l_0 \hat{l}_s^2) - 1]. \tag{37}$$

Equation (37) measures the DPV of the welfare benefit of a tax cut as the percentage of initial consumption. Table 3 shows that a domestic income tax cut increases utility in both countries. Imperfect competition and distortionary taxes imply that the level of consumption and output is inefficiently low in the initial steady state. A domestic tax cut brings domestic

[10] We neglect, as customary in the literature, the utility derived from real balances.

consumption closer to its efficient level, increasing utility. In the foreign country, the improvement in the foreign terms of trade increases consumption in real terms. This causes an increase in foreign utility.

Table 3

Income Tax Rate Cut: Welfare Effects

λ_{DPV}	λ^*_{DPV}
26.0	5.9

The responses of macroeconomic variables to tax cuts presented in this section are broadly consistent with findings of the empirical literature. The result that domestic activity is stimulated in response to a tax reduction is a standard one in studies of the US economy (see for example Blanchard and Perotti (2002)). Empirical studies on the international transmission of tax changes are scarce. One exception is IMF (2010, chapter 3), in which a tax-based fiscal consolidation (an *increase* in taxation) causes a fall in output and domestic demand, an increase in unemployment and increase in net exports and a depreciation of the (real) exchange rate in the short term. In our model, a *fall* in taxation causes an increase in output and employment (excluding in the short run), an increase in consumption, a fall in net export that is reflected in a fall in the bond holdings of domestic households and an appreciation of the (nominal) exchange rate. Therefore, our model is roughly consistent with the empirical results of IMF (2010), because the effects of a tax increase in our model would be mirror images of those reported in this section.

Both IMF (2010) and Arin and Koray (2009) find that a tax shock changes output with a delay and the initial response is close to zero, while in our model domestic output falls in the short run. This difference is due to the strong short-run expenditure switching effect in our model, which has a negative impact on domestic output. This result is sensitive to the assumptions on the degree of nominal rigidity in the economy. Our baseline parameterization is characterized by relatively sticky prices, a high elasticity of substitution between domestic and foreign goods, and a steady-state import share of 50 percent. In the sensitivity analysis below we show that, if prices are more flexible, domestic output increases also in the short run.

5. Consumption Tax Cuts

In this section we analyze the degree of self-financing in the case of a consumption tax cut. In the policy experiment that we present here τ_t^I is therefore kept constant at its initial steady-state level (a 28 percent income tax rate) while the consumption tax rate τ_t^C is reduced from 5 to 4 percent (which amounts to a 20 percent decrease in the rate). The results of this exercise are summarized in Figure 2 and in Tables 4-6.

Figure 2

The Effects of a Domestic Consumption Tax Reduction

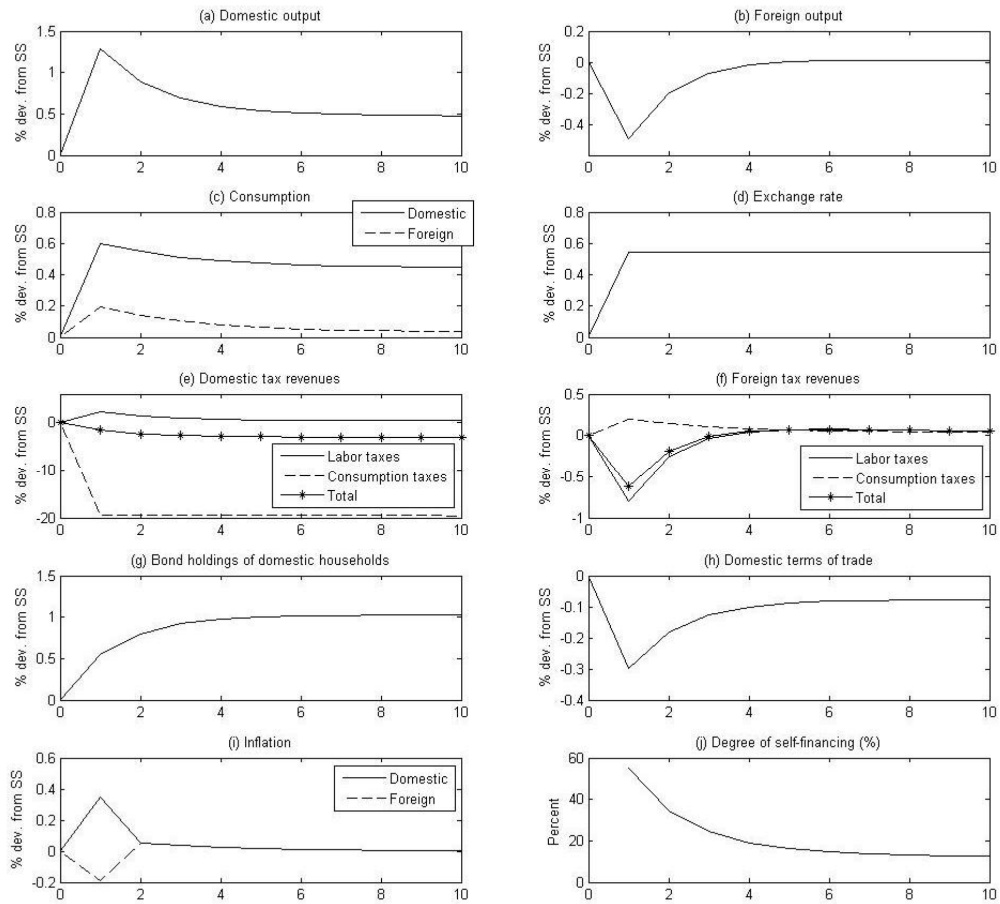


Table 4

Consumption Tax Rate Cut: Domestic Tax Revenues Collection Changes 1/

t = 1	t = 3	t = 5	steady state
-1.6	-2.7	-3.0	-3.1

1/Percentage changes with respect to the initial steady state.

Table 5

Consumption Tax Rate Cut: The Degree of Self-Financing

t = 1	t =3	t = 5	steady state	present value
54.9	24.4	16.1	12.3	13.2

One important difference between income and consumption tax reductions is that they have opposite effects on the nominal exchange rate. While in the case of an income tax cut the domestic exchange rate appreciates (Figure1(d)), a consumption tax cut results in a domestic depreciation (Figure 2(d)). The intuition for this result is the money demand effect already discussed in section 4. Since money demand is a positive function of consumption including taxes, the reduction in the consumption tax rate has a negative effect on domestic money demand, which for our parameterization is stronger than the effect of the increase in real consumption excluding taxes. The negative impact on money demand implies a transmission mechanism symmetric to the one described in section 4, resulting here in an exchange rate depreciation. The fact that the domestic exchange rate depreciates instead of appreciating implies that the main spillover channels through which the domestic tax reduction affects the foreign country—the expenditure switching effect, the terms of trade in the short run, and the accumulation of external surplus/deficit—are now reversed compared to those presented in section 4. This result in a dynamics of foreign output and consumption following domestic consumption tax cuts which is almost a mirror mage of the one stemming from domestic income tax cuts (compare Figure 1(b,c) with figure 2(b,c)). In particular, foreign output falls and foreign consumption increases in the short run when the domestic country cuts consumption taxes.

A result that can be clearly seen in Figure 2 and Table 4 is that, even in the case of consumption tax cuts, no dynamic Laffer effects emerge in our model. Domestic income tax collection increases in this case, because domestic households increase their labor supply at an unchanged income tax rate. The increase in income tax collection, however, is not large enough to compensate for the reduction in consumption tax collection. As a result, total revenue collection in real terms drops by 3.1 percent in the steady-state. Furthermore, the present value of the degree of self-financing in terms in the new steady state is 13.2 percent (Table 5), which is lower than the 20.2 percent derived for the case of income tax reductions (Table 2).

Table 6

Consumption Tax Rate Cut: Welfare Effects

λ_{DPV}	λ^*_{DPV}
18.0	4.1

Table 6 shows that the welfare effects of a reduction in the domestic consumption tax rate go in the same direction as those following income tax cuts: utility increases in both countries. A domestic consumption tax cut brings domestic consumption closer to its efficient level, increasing utility. In the foreign country, the improvement in the foreign terms of trade increases foreign utility.

Table 5 also shows that the short-run degree of self-financing, at 54.9 percent, is substantially larger than the steady-state value of 12.3 percent. This result is partly due to the expenditure switching effect, which now goes in the opposite direction compared to the case of income taxes. Under a consumption tax cut, the domestic exchange rate depreciates, thus lowering the relative price of domestic goods in the short term. This shifts demand towards domestic goods thus increasing domestic income tax collection in the short run. Therefore, domestic tax revenue collection is temporarily higher and the degree of self-financing is higher in the short run.

The expenditure switching effect is not, however, the only reason why the degree of self-financing is the highest in the short run. The fact that domestic output increases more in the short run than in the long run (Figure 2(a)) can be partly explained by the behavior of the real wage. While in the long run prices increase, due to the increase in wages, in the short run prices are sticky and they do not immediately increase. As a consequence, the domestic real wage is temporarily high. This increases labor supply in the short run. This effect reinforces the expenditure switching effect and partly explains why domestic output increases more in the short run than in the long run. These effects together imply that the degree of self-financing is the highest in the short run.

In summary, consumption tax cuts do not generate a "free lunch" for the budget. In addition, the degree of self-financing of consumption tax cuts is, in our model, lower than the one observed for income tax cuts. While previous literature did not delve into the study of the self-financing features of consumption tax cuts, our results are broadly consistent with the findings of the endogenous growth model of Novales and Ruiz (2002), in which no dynamic Laffer effects emerge for consumption tax reductions.

6. Sensitivity Analysis

In this section we carry out an analysis of how sensitive the degree of self-financing is to changes in key parameter values. Trabandt and Uhlig (2010) show that the degree of self-financing depends on the Frisch elasticity of labor supply. In addition, our results discussed in sections 4 and 5 above suggest that the degree of self-financing in the short term depends on the strength of the expenditure switching effect. Therefore, we analyze how sensitive the main results are to changes in the degree of nominal rigidity (γ), the labor disutility parameter (ν), the consumption elasticity of money demand $(1/\varepsilon)$, the degree of openness (n) and the currency of export pricing. Overall, our sensitivity analysis confirms the robustness of the results that we have discussed in sections 4 and 5, although varying some of the parameters has some impact on the magnitude of short-run effects.

6.1 Income Tax Cut: Sensitivity Analysis

6.1.1 Price Rigidities

Figure 3(a,b) and rows 1-3 in Table 7 shows the consequences of varying the Calvo parameter. The solid lines in Figure 3(a,b) show the case of our benchmark parameterization presented in section 3. In the benchmark case (row 1 in Table 7 and solid line in Figure 3(a)) the degree of self-financing is set to γ =0.75, which implies an average delay of one year between price changes, consistently with evidence by Gopinath and Rigobon (2008) for the US). The dashed lines in Figure 3 (a,b) illustrate the case where γ = 0.5, which implies and average delay of six months, based on estimates by Bils and Klenow (2004).

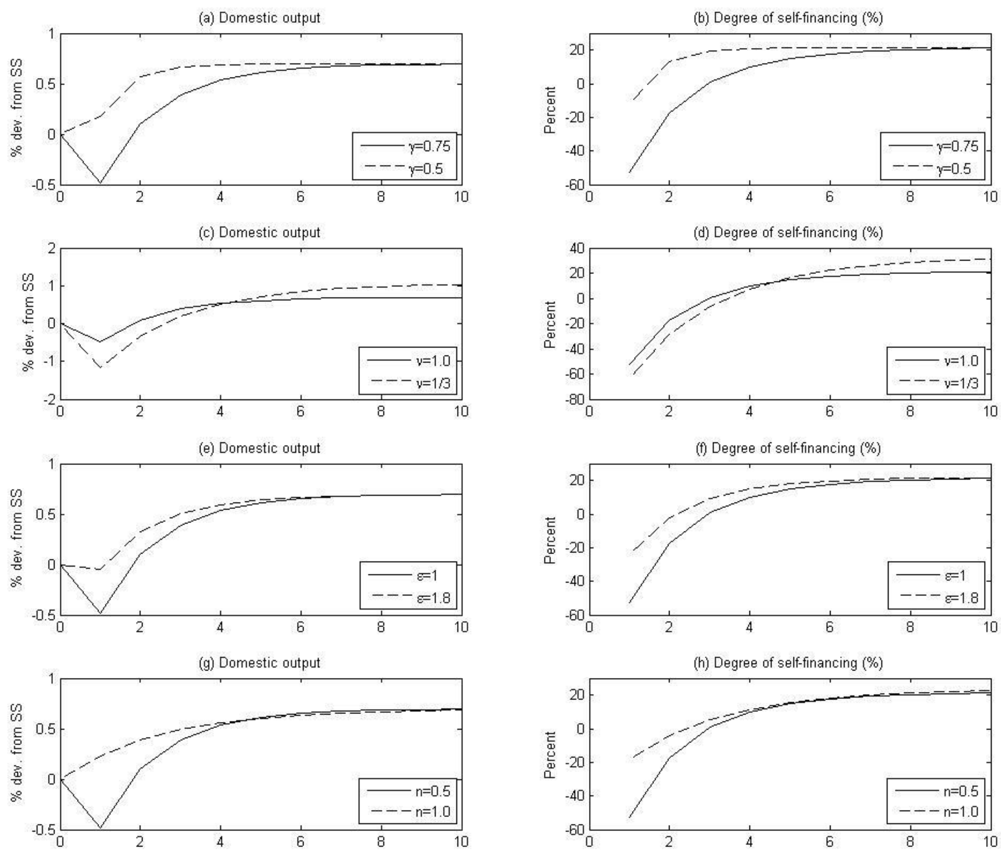
Table 7

Income Tax Rate Cut: Sensitivity Analysis

		Degree of self-financing (%)				
Row	Parameters	t=1	t=3	t=5	Steady state	Present value
1	Benchmark: ε=ν=1, γ=0.75, n=0.5, b=0	-52.8	0.665	15.1	21.8	20.2
2	γ =0.5	-12.0	19.2	21.4	21.7	21.2
3	γ = 0	21.6	21.6	21.6	21.6	21.6
4	ν = 1/3	-63.2	-6.31	16.4	33.1	30.4
5	ν = 2	-43.8	2.80	11.5	14.5	13.4
6	ε = 1.8	-24.2	9.0	17.8	21.7	20.7
7	Closed economy (n=1)	-18.0	5.20	15.5	23.6	22.4
8	LCP (b=1)	-15.7	6.30	14.8	21.7	20.6

Figure 3(a,b) and Table 7 show that the results regarding on the degree of self-financing in the short run are sensitive to changes in the degree of nominal rigidity. As expected, the short-run impact of the expenditure switching effect is stronger when prices are more rigid (row 1 in Table 5) and becomes weaker as we move toward a flexible-price economy (rows 2 and 3 in Table 5). In the long run, however, the role of price rigidities vanishes and the degree of self-financing is virtually the same under sticky and flexible prices. In addition, nominal rigidities have also a minor effect on the present value of the degree of self-financing.

Figure 3
Income Tax Cut: The Effects of Varying Key Parameter Values



6.1.2 Labor Supply

Trabandt and Uhlig (2010) show that the Frisch elasticity of labor supply is a key parameter governing the size of the degree of self-financing. In their model, if the Frisch elasticity is high, then the degree of self-financing is high. This is because, with a higher elasticity of labor supply, households respond to a tax cut by increasing their labor supply more, which in turns generates higher revenue collection compared to a lower elasticity.

Table 7 and panels (c)-(d) in Figure 3 show how the degree of self-financing changes when the Frisch elasticity—which in our model is given by $1/\nu$—is changed. Our long-run results are consistent with Trabandt and Uhlig (2010): a Frisch elasticity of 3 ($\nu = 1/3$) compared to the benchmark of 1 ($\nu = 1$) implies a higher degree of self-financing. If the Frisch elasticity is 3 ($\nu = 1/3$), the present value of the degree of self-financing increases to 30.4 percent (compared to 20.2 in the benchmark parameterization). In comparison, Trabandt and Uhlig (2010) find that when the Frisch elasticity of labor supply is increased from 1 to 3 the degree of self-financing increases from 27 to 38 percent. Table 7 also shows that the Frisch elasticity is the only parameter which has a significant effect on the present value of the degree of self-financing.

6.1.3 Money Demand Elasticity

Figure 3 (e,f) and rows 6 in Table 7 show the consequences of varying the consumption elasticity of money demand. As mentioned, our choice for the benchmark value of this parameter is based on Mankiw and Summers (1986), who find it to be close to one for the US. As a sensitivity test, we now set ε=1.8, which implies a consumption elasticity of money demand equal to 0.55, the value estimated by Helliwell et al. (1990) for Japan.

A lower consumption elasticity of money demand implies a smaller relative demand for domestic money following the same change in consumption. This in turn means that the exchange rate appreciates by less (a 0.32 percent appreciation in the case of ε=1.8, compared to 0.56 percent in the benchmark of ε=1). As a consequence, the expenditure switching effect is weaker and consequently short-run domestic output is now higher than in the benchmark. This implies that the degree of self-financing is higher.

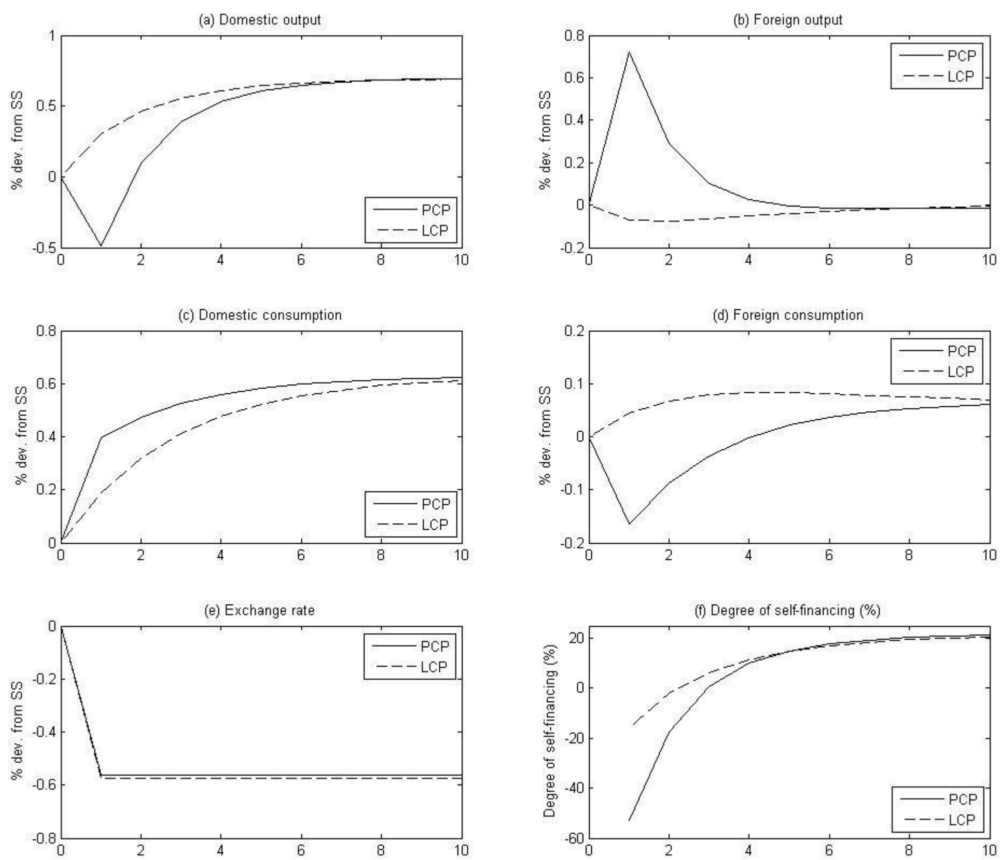
6.1.4 Country Size

Row 7 of Table 7 and Figure 3(g,h) compare our benchmark case of an open economy (n=0.5) with a closed economy (n=1). The closed economy is analyzed by setting the relative size of the home economy to 1. As Table 7 and Figure 3(h) show, the degree of openness is crucial only for the short-run results. In the closed economy, there is no expenditure switching effect moving consumption away from domestic goods towards foreign goods. This explains why, in the closed economy case, the short-run degree of self-financing is higher than in our benchmark case n=0.5, in which the expenditure switching effect is at work. In the short run, prices do not adjust downwards immediately. Insufficient aggregate demand due to sticky prices account for the sluggish response of output to a tax cut. Output increases gradually as prices can be adjusted. Consequently, the degree of self-financing increases over time.

Table 7 and Figure 3(h), however, show that the open economy dimension does not matter much for the degree of self-financing in the long run, because in the long run prices are flexible and therefore the expenditure switching effect is not at work. In addition, the present value of self-financing is very similar in a closed and open economy. In summary, the impact of the open economy dimension on the degree of self-financing is limited to short-run effects, with no significant implication for the long run and the present value. One policy implications is that evaluating the degree of self-financing over time, and its link to openness to trade, should be an important element of carefully implemented fiscal policy. Even though the long run effects dominate, the degree of openness of the economy has important short-run implications in terms of the degree of self-financing.

Figure 4

Income Tax Rate Cut: The Role of the Currency of Export Pricing



6.1.5 Local Currency Pricing

We have also checked the sensitivity of the results to our PCP assumption, by examining the effect of an income tax shock under full LCP (b = 1). The results are shown in Figure 4 and row 8 of Table 7. In Figure 4, the solid lines plot the effects under PCP and the dashed lines show the LCP case.

Under LCP, the exchange rate pass-through into import price is zero and nominal exchange rate movements carry no expenditure switching effect. Consequently, an exchange rate appreciation does not switch demand from domestic goods to foreign goods. Instead, it generates a redistribution of income. Compared to the PCP case, setting export prices in foreign currency reduces domestic firms' profits measured in terms of domestic currency (see equation (15)). On the other hand, LCP raises the profits of foreign firms measured in foreign currency terms, increasing foreign consumption. The absence of the expenditure switching effect implies that domestic output increases in the short run following an income tax cut. The short-run degree of self-financing is therefore higher compared to the PCP case. Table 7 and Figure 4(f) show that the currency of export pricing has notable consequences for the international transmission of tax cuts and the degree of self-financing in the short run. However, they also show that it has very limited effects on the present value of the degree of self-financing.

In summary, for the case of income tax cuts the sensitivity of our results to changes in key parameters is limited to the short run. Our findings regarding the present value of the degree of self-financing are robust, since only changes in the Frisch elasticity of labor supply have notable consequences for it.

6.1.6 Consumption Tax Cut: Sensitivity Analysis

Table 8

Consumption Tax Rate Cut: Sensitivity Analysis

		Degree of self-financing (%)				
Row	Parameters	t=1	t=3	t=5	Steady state	Present value
1	Benchmark: ε=ν=1, γ=0.75, n=0.5, b=0	54.9	24.4	16.1	12.3	13.2
2	γ=0.5	31.6	13.8	12.5	12.3	12.6
3	γ=0	12.4	12.4	12.4	12.4	12.4
4	ν=1/3	36.8	26.0	21.6	18.4	19.0
5	ν=2	74.9	21.6	11.6	8.22	9.44
6	ε=1.8	34.0	18.6	14.4	12.3	12.8
7	Closed economy (n=1)	37.3	24.0	18.2	13.5	14.2
8	LCP (b=1)	25.0	19.8	16.3	12.4	12.9

In Table 8 we present sensitivity results for changes in γ and ν in the case of the consumption tax cut. Table 8 shows that when prices are more flexible compared to the benchmark (columns 2 and 3) there is a smaller degree of self-financing in the short run. This is due to a weaker (compared to the benchmark) expenditure switching towards domestic goods, which implies a smaller increase in domestic output, and therefore lower tax collection. Overall, our results are robust to changes in the degree of nominal rigidity. The impact of changes in ν is similar to the one discussed above in the case of income tax cuts. The degree of self-financing in real terms increases for lower levels of the labor disutility parameter but remains below 20 percent (Table 8, rows 4 and 5). Table 8 also shows the sensitivity of the results to the degree of openness. The short-run degree of self-financing is smaller for an open economy. As in the case of income tax cuts, this is due to the fact that the expenditure switching effect does not operate in a closed economy.

7. Conclusions

This paper focuses on the impact of income and consumption tax cuts in an open economy New Keynesian model. Our results show that in our framework tax cuts cannot be considered a "free lunch", because both income and consumption unilateral tax rates reductions have negative budgetary consequences for the country which implements them. Given the absence of dynamic Laffer effects, most of our analysis is focused on the degree of self-financing of tax cuts.

We find that the long-run degree of self-financing of an income tax cut is about 22 percent, a value of the same order of magnitude as those calculated in closed economy models such as Mankiw and Weinzierl (2006) and Trabandt and Uhlig (2010). While the degree of self-financing is negative on impact, it quickly becomes positive (from the third period after the tax reduction) and the negative short-run degree of self-financing has a relatively weak impact on its present value. One conclusion that we can draw from our analysis is that the open economy dimension does not matter much for the degree of self-financing of labor income tax cuts in the steady state. This is because the main channel through which the open economy dimension affects the results, the expenditure switching effect, is not active in the new steady state, when all firms are free to adjust their prices in response to the initial shock and the economy reaches a new flexible-price equilibrium.

In the case of domestic consumption tax cuts, dynamic Laffer effects also do not emerge. Contrary to the case of income tax cuts, in the case of consumption tax cuts the degree of self-financing is always positive. Furthermore, it is higher (around 55 percent) in the short run and lower (around 12 percent) in the new steady state. The explanation for this dynamics is that in the case of consumption tax cuts we observe a depreciation of the nominal exchange rate (rather than an appreciation like in the case of income tax cuts). As a consequence, in the case of consumption tax cuts the expenditure switching effect, which is more relevant in the short run due to nominal rigidities, works in favor of the domestic country, shifting demand in the short-run towards its goods and therefore increasing the short-run degree of self-financing (compared to the long-run one).

Our results are robust to sensitivity analysis on various parameters and assumptions, such as the degree of nominal rigidity, the Frisch elastcity of labor supply, the consumption elasticity of money demand, the country size, and the currency of invoicing of exports.

Interesting extension for future research would be the introduction of capital and capital income taxation, modelling a balanced growht path, as well as allowing for public debt and government spending.

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Appendix 1: Derivation of initial share of income taxes on total taxes.

In the initial steady state we have the following equations:

$$y_0 = C_0 = l_0 = [(\frac{1-\tau_0^I}{1+\tau_0^C})(\frac{\theta-1}{\theta})]^{\frac{1}{\nu+1}} \tag{A1.1}$$

$$P_0 = \frac{\theta}{\theta-1} w_0 \tag{A1.2}$$

$$T_0 = \tau_0^I \frac{w_0}{P_0} l_0 + \tau_0^C C_0 = (\tau_0^I \frac{w_0}{P_0} + \tau_0^C) l_0 \tag{A1.3}$$

We can therefore express the share of initial labor income taxes on total taxes as

$$u = \frac{\tau_0^I \frac{w_0}{P_0} l_0}{(\tau_0^I \frac{w_0}{P_0} + \tau_0^C) l_0} = \frac{\tau_0^I \frac{w_0}{P_0}}{(\tau_0^I \frac{w_0}{P_0} + \tau_0^C)} \tag{A1.4}$$

Using the initial nominal wage as a numeraire $(w_0 = 1)$ our benchmark parameterization $(\tau_0^I = 0.28; \tau_0^C = 0.05; \theta = 6; \nu = 1)$ implies that $u = 0.82$.

Appendix 2: Log-linear equations in the case of PCP

$$\hat{\delta}_t + \frac{\tau_0^C}{1+\tau_0^C}\hat{\tau}_{t+1}^C + \hat{P}_{t+1} + \hat{C}_{t+1} = \frac{\tau_0^C}{1+\tau_0^C}\hat{\tau}_t^C + \hat{P}_t + \hat{C}_t \qquad \text{(A2.1)}$$

$$\hat{\delta}_t + \frac{\tau_0^C}{1+\tau_0^C}\hat{\tau}_0^{C*} + \hat{P}_{t+1}^* + \hat{C}_{t+1}^* + \hat{E}_{t+1} = \frac{\tau_0^C}{1+\tau_0^C}\hat{\tau}_0^{C*} + \hat{P}_t^* + \hat{C}_t^* + \hat{E}_t \qquad \text{(A2.2)}$$

$$\nu\hat{l}_t = -\frac{\tau_0^I}{1-\tau_0^I}\hat{\tau}_0^I - \frac{\tau_0^C}{1+\tau_0^C}\hat{\tau}_0^C + \hat{w}_t - \hat{C}_t - \hat{P}_t \qquad \text{(A2.3)}$$

$$\nu\hat{l}_t^* = -\frac{\tau_0^{I*}}{1-\tau_0^{I*}}\hat{\tau}_0^{I*} - \frac{\tau_0^{C*}}{1+\tau_0^{C*}}\hat{\tau}_0^{C*} + \hat{w}_t^* - \hat{C}_t^* - \hat{P}_t^* \qquad \text{(A2.4)}$$

$$-P_t = \frac{1}{\varepsilon}\hat{C}_t - \frac{1}{\varepsilon}\frac{\tau_0^C}{1+\tau_0^C}\hat{\tau}_0^C + \frac{\beta}{\varepsilon(1-\beta)}\hat{\delta}_t \qquad \text{(A2.5)}$$

$$-P_t^* = \frac{1}{\varepsilon}\hat{C}_t^* - \frac{1}{\varepsilon}\frac{\tau_0^{C*}}{1+\tau_0^{C*}}\hat{\tau}_0^{C*} + \frac{\beta}{\varepsilon(1-\beta)}(\hat{\delta}_t + \hat{E}_{t+1} - \hat{E}_t) \qquad \text{(A2.6)}$$

$$\hat{\tau}_t^I = \rho_I\hat{\tau}_{t-1}^I + \varphi_{I,t} \qquad \text{(A2.7)}$$

$$\hat{\tau}_t^C = \rho_C\hat{\tau}_{t-1}^C + \varphi_{C,t} \qquad \text{(A2.8)}$$

$$\hat{\tau}_t^{I*} = \rho_I\hat{\tau}_{t-1}^{I*} + \varphi_{I,t}^* \qquad \text{(A2.9)}$$

$$\hat{\tau}_t^{C*} = \rho_C\hat{\tau}_{t-1}^{C*} + \varphi_{C,t}^* \qquad \text{(A2.10)}$$

$$\hat{y}_t = \hat{l}_t \qquad \text{(A2.11)}$$

$$\hat{y}_t^* = \hat{l}_t^* \qquad \text{(A2.12)}$$

$$\hat{y}_t = -\theta(\hat{b}_t(z) - \hat{P}_t) + n\hat{C}_t + (1-n)\hat{C}_t^* \qquad \text{(A2.13)}$$

$$\hat{y}_t^* = -\theta(\hat{b}_t^*(z) - \hat{P}_t^*) + n\hat{C}_t + (1-n)\hat{C}_t^* \qquad \text{(A2.14)}$$

$$P_t = n\hat{b}_t(z) + (1-n)\hat{b}_t^*(z) + (1-n)\hat{E}_t(z) \qquad \text{(A2.15)}$$

$$P_t^* = n\hat{b}_t(z) - n\hat{E}_t + (1-n)\hat{b}_t^*(z) \qquad \text{(A2.16)}$$

$$b_t(z) = \gamma\hat{b}_{t-1}(z) + (1-\gamma)\hat{p}_t(z) \qquad \text{(A2.17)}$$

$$b_t^*(z) = \gamma\hat{b}_{t-1}^*(z) + (1-\gamma)\hat{q}_t^*(z) \qquad \text{(A2.18)}$$

$$\hat{p}_t(z) = \beta\gamma\hat{p}_{t-1}(z) + (1-\gamma)\hat{w}_t \qquad \text{(A2.19)}$$

$$\hat{q}_t^*(z) = \beta\gamma\hat{p}_{t-1}^*(z) + (1-\gamma)\hat{w}_t^* \tag{A2.20}$$

$$\beta\hat{D}_t = \hat{y}_t - \hat{b}_t(z) + \hat{C}_t - \hat{P}_t + \hat{D}_{t-1} \tag{A2.21}$$

Equations (A2.1)-(A2.6) are the log-linearized versions of the first-order conditions. Equations (A2.7)-(A2.10) are the tax rates. Equations (A2.11) and (A2.12) are the production functions. Equations (A2.13) and (A2.14) show demand for goods. Equations (A2.15) and (A2.16) are the aggregate price indexes. Equations (A2.17) and (A2.18) are the Calvo-weighted price indexes. Equations (A2.19) and (A2.20) are the optimal pricing rules. Equation (A2.21) is the concolidate budget constraint of the domestci country. The PCP version of the model contains 21 unknown variables that are determined by these 21 equations. The foreign budget constraint is left out because one equation is redundant by Walras' law.