Dynamic Capital Tax Competition under the Source Principle

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Abstract

In this paper we explore, theoretically and quantitatively, the short- and long-run implications of tax competition between jurisdictions in a neoclassical growth model under the assumption of perfect capital mobility. The government of each jurisdiction solves an optimal taxation problem under commitment, treating the other government’s policies as given. We provide a new theoretical perspective on the dynamic international capital-tax externalities that emerge in this model. Numerically, we find that source-based capital taxes are initially positive and slowly decline towards zero. The externalities associated with capital taxes are positive in the short run, then become slightly negative, and finally converge to zero.

*We thank participants at a seminar 2016 at Ryerson University, at the 2014 SED meetings in Toronto, Ontario, at the 2014 Barcelona GSE Summer Forum, at an Ensai workshop in Rennes, France and at a CIREQ workshop in Montréal, Québec, both in 2014. This paper subsumes and significantly extends earlier work by the third author previously circulated as “Dynamic Capital Tax Competition” and “Intertemporal Capital Tax Externalities and the ‘Race to the Bottom’”. The current work focuses on an infinite-horizon model and allows for asymmetric countries. It also includes a computational analysis that highlights the quantitative importance of the theoretical findings.

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1 Introduction

Capital tax competition has been a recurrent theme of an ongoing debate, and indeed a cause for concern, in developed countries for a long time. See, for instance, OECD (1998) for a call on countries to refrain from harmful tax competition, and European Commission (2001) for a similar call within the European Union (EU). Particularly in European policy circles, it is clearly a consensus view that tax competition tends to reduce capital taxes, and that this is an undesirable outcome; see Norman (2000a), Norman (2000b) and European Union (2003). The starting point of this view has traditionally been that it is hard to collect taxes on income from abroad, and that therefore capital income must be taxed at the source in order to generate much revenue. Meanwhile, if capital is mobile across borders, then taxing capital income at the source quite naturally leads to capital flight. Therefore, unless countries share information that would enable them to tax foreign-source income or coordinate (or harmonize) their source-based tax treatment of capital income, governments, so the argument goes, will engage in tax competition for capital inflows. This would eventually lead to a “race to the bottom” in source-based capital taxes, a decrease in capital tax revenue and, potentially, underprovision of public services. This belief is strikingly reflected in the most recent debate within the EU around plans for a minimum withholding tax on non-residents’ income; see, for instance, and, more recently, Holehouse and Williams (2015) and Lynch (2015).\(^1\) This belief has been informed by the received academic literature on the subject, which emphasizes the fiscal externality that emerges from the effect of source-based capital taxes on current capital flows across tax jurisdictions.\(^2\)

However, the empirical support for this traditional view on the effects of increased


\(^2\)For a highly informative contribution that situates the policy debate in the context of the theoretical literature, see Nicodème (2006).
capital mobility on capital tax rates and tax revenue shares is mixed. Some more recent theoretical literature has tried to reconcile this fact with theory. This strand of work argues that capital market integration might, in some circumstances, lead to an overtaxation of capital. This literature emphasizes the presence of alternative externalities that could counteract the aforementioned fiscal externality that lies behind the traditional view on tax competition. Nevertheless, this more recent theoretical work considers mainly static models and does not take into account the dynamic aspects of taxation. Consequently, it cannot account for the fact that statutory tax rates have been gradually decreasing for more than two decades now (Nicodème, 2006).

Our paper takes a fresh look at these issues by identifying and studying the cross-border tax externalities that emerge in a fully dynamic model as a consequence of endogenous capital accumulation. These dynamic externalities have so far received little or no attention in the literature. The main implications of our theory are that (i) capital taxes decrease over time and (ii) the relationship between the level of capital taxes and the degree of capital mobility is ambiguous: while initial capital taxes under perfect capital mobility are lower than those in a closed economy, capital taxes in the medium run are higher in an open economy than in a closed one, with long-run capital taxes be zero in both a closed and an open economy. At the same time, though, our results remain consistent with the view that, on average, governments tend to rely relatively less on capital taxation for tax revenues when there is capital mobility.

In more detail, what we do in this paper is to examine the implications of tax competition between jurisdictions in the context of a neoclassical growth model under the

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3See Devereux et al. (2008) and the discussions in Nicodème (2006) and Mendoza and Tesar (2005).
4See, for instance, the excellent reviews by Wilson (1999) and Wilson and Wildasin (2004), and, for more recent work, Keen and Kotsogiannis (2002), Kessler et al. (2002), Makris (2006), Lockwood and Makris (2006), Wooders et al. (2007), Bénassy-Quéré et al. (2007) and references therein. This literature has helped to identify in a neat and concrete way some very important issues involved in the taxation of mobile capital such as overlapping tax bases, mobile labour, amenities and the political determination of taxes.
assumption of perfect capital mobility. The government of each jurisdiction solves an optimal taxation problem under commitment, treating foreign policies as given. The instruments available to governments are time-dependent source-based proportional capital income taxes, proportional labour income taxes, and debt. Jurisdictions may differ with respect to population, total factor productivity, initial private assets and public debt, and the (exogenously given) amount of public spending, which implies that there are potential gains from capital mobility. We solve for the dynamic equilibrium numerically and examine a number of cases chosen for their theoretical interest and/or empirical relevance. We also discuss, in some detail, the underlying forces that together determine the equilibrium.

In particular, we stress what we call the savings externality, emphasizing the fact that our fully dynamic (infinite-horizon) setup allows us to consider the effects of capital taxes not only on the allocation of capital across space, but also its accumulation over time (and thus the global capital supply). In such a setup, the savings externality emerges because a higher tax rate results in less savings and hence a lower global capital stock, which affects all countries, not just the one levying it. Therefore, this negative cross-border intertemporal tax externality leads to an opposite effect to that analyzed in the seminal work of Zodrow and Mieszkowski (1986) and Wilson (1986). The deleterious consequences of tax competition are thus reduced, and potentially outweighed, in a dynamic model compared to a static model.

In the literature, the savings externality is mostly dominated by the fiscal externality. This predominant view is captured well by the following statement in Wilson (1999, p. 275): “We may conclude that allowing a variable supply of capital reduces, but does not eliminate, the tax competition problem.” However, this finding is driven from the fact that in Wilson (1999), as in many other papers, capital stems from a fixed endowment. In our model, only the initial capital stock is an endowment, and so the impact of capital taxes on the capital supply (and thus the savings externality) increases over time, as the importance of the initial capital endowment for the capital supply diminishes. In our numerical work, we quantify the importance of
the various externalities. There is a positive net externality in the short run—as in Wilson (1999)—but it converges to zero in the long term, and even turns (slightly) negative in the medium run. In striking contrast to the existing consensus, the savings externality does eliminate tax competition beyond the short run, and even turns it on its head for a while. This result has an obvious and profound implication for the policy debate discussed above.

Another result is that, as in the (static) model of De Pater and Myers (1994), the country which is capital-exporting has a tendency to set a lower capital tax rate than the country which is capital-importing; this is due to the incentive of tax jurisdictions to manipulate the terms of trade to their benefit. However, this effect is mitigated by intertemporal considerations, and so the difference in the capital taxes of capital-trading countries is smaller in a dynamic environment with endogenous savings than in a static setting. To understand this, recall that a higher capital tax leads to a reduction in savings and thus in the supply of worldwide capital, which, in turn, implies a higher world interest rate in the future. This indirect effect is beneficial to a capital-importing country, but is always outweighed by the direct, negative, effect of higher taxes on the current world interest rate. As a result, the incentive to manipulate the (current) terms of trade is smaller in an intertemporal setting with endogenous savings than with a fixed capital stock. The incentive to manipulate the terms of trade affects taxes only in the short run, though: in the long run, capital taxes are zero for both capital-exporting and importing countries.

Our analysis therefore suggests that results from the static/pseudo-dynamic tax competition literature should be interpreted as pertaining to the short run rather than the long run, pace Sørensen (2004, p. 1189), who writes that “My model of tax competition (called ‘TAXCOM’) is static, describing a stationary long-run equilibrium.”

Our work has an additional, more technical implication for the study of dynamic capital taxation problems. By way of background, Chamley (1986) shows that the
second-best outcome features high taxes on capital in the early periods and zero capital income taxes thereafter. Indeed, the result there is quite stark: if there are no restrictions at all on capital taxes, the only tax ever levied will be on capital income in the first period; the revenue from that is then used to finance all subsequent expenditure. This result is the well-known capital levy problem,\textsuperscript{5} which is present in the first period even under perfect commitment. Therefore, it is conventional to restrict at least the initial capital income tax rate to avoid trivializing the problem. Tax competition removes the temptation to impose an unlimited initial capital levy and therefore obviates the need to impose any exogenous restrictions on initial-period capital income taxes.\textsuperscript{6}

Our paper is organized as follows. Section 2 discusses some related literature, in addition to what we have already considered. Section 3 lays out the model framework, defines our equilibrium concept, and identifies the externalities stemming from capital taxes. In Section 4 we present our numerical exercises, chosen for their theoretical interest and/or empirical relevance. Section 5 concludes.

\section{Related literature}

To put our contribution in perspective, it is useful to situate our paper in the context of the received literature on capital tax competition. The seminal theoretical work on capital tax competition is by Zodrow and Mieszkowski (1986) and Wilson (1986) (ZMW hereafter). They emphasize that competition between identical tax jurisdictions for mobile capital leads governments to undercut each other in terms of source-based capital taxes, reducing tax rates to below what they would be in a closed-economy setting. The reason is straightforward. In the absence of cross-

\textsuperscript{5}The capital levy problem, i.e. the temptation on the part of governments to impose a one-time levy on the current capital stock, promising never to do that again, is discussed in Fischer (1980).

\textsuperscript{6}A similar result is obtained in Gervais and Mennuni (2014) by assuming that investment becomes productive immediately, without a period’s delay.
country spillovers, capital taxes in a closed economy are second-best efficient. When capital is mobile, however, an increase in the domestic tax leads to a decrease in the domestic net rate of return on capital and, thereby, to a capital outflow. This capital outflow translates into an increase in the capital employed in the other tax jurisdictions. Thus, an increase in the domestic tax leads to an increase in foreign capital tax-bases and, thereby, tax revenues abroad, for any given foreign taxes. Therefore, capital taxes under integrated capital markets give rise to a positive externality, and as such will in general be lower compared to the situation when capital is immobile.\textsuperscript{7} Importantly, the strength of this externality is positively related to the responsiveness of capital demand to its user-cost, whereas the supply of capital does not play a role, since it is fixed in ZMW.\textsuperscript{8}

In Bucovetsky and Wilson (1991) and later papers like Sørensen (2004), the capital stock derives endogenously from an endowment. Then the supply elasticity also matters, of course, in determining whether capital taxes are inefficiently high or low. However, as the quote in the introduction made clear, the consensus is that an endogenous capital supply cannot eliminate tax competition. Keen and Kotsogiannis (2002) deploy a two-period model with endogenous savings (out of an endowment), and show that capital taxes of competing jurisdictions may be too high due to a large capital supply elasticity, but the savings externality in their model arises from a common-pool problem between federal and provincial governments. Moreover, when states can fully tax rents, as we assume in our paper, then capital taxes of competing sub-federal governments are always too low.

An attempt to deal with equilibrium source-based capital taxes in a dynamic framework with capital accumulation is Mendoza and Tesar (2005), who, however, sim-

\textsuperscript{7}Even for the opponents of reducing tax competition, the existing consensus provides an unquestioned backdrop. For instance, Kehoe (1989), when making the case against capital tax policy coordination in the absence of commitment, argues that tax competition can serve as a substitute for a commitment device, driving down capital taxes to where they should have been in the first place.

\textsuperscript{8}Coates (1993) investigates a repeated version of ZMW, and thus maintains the ZMW assumption that the supply of capital (in each period) is exogenously fixed.
plify matters by forcing governments to levy time-invariant tax rates. Correia (1996) studies capital taxation in a small open economy, where the net world interest rate is exogenous and time-invariant. With source-based capital taxes, the transition to a steady state is immediate (after the initial period). A further step forward is found in Gross (2014) who studies large open economies, but confines his attention to long-run outcomes. In the same model environment as the one we study here, he finds that long-run capital taxes coincide with those of a closed economy and hence are equal to zero as in Chamley (1986). Therefore, whether by construction or focus of analysis, these papers do not study the time path of equilibrium time-varying source-based capital taxes, nor do they discuss the intertemporal capital-tax externalities we focus on here.\(^9\)

Wildasin (2003) discusses capital taxation in a small open economy, by recognizing the dynamics inherent in capital accumulation when capital inputs can only be adjusted by incurring adjustment costs. Here, instead, we assume zero capital adjustment costs, but we emphasize the interaction between non-cooperative capital taxes and the dynamics in capital accumulation that arises due to the dependence of endogenous savings on capital taxes. Other important differences are that in Wildasin (2003) the net world interest rate is, by assumption, exogenous and time-invariant, capital taxes are time-invariant and lump-sum taxes are available. One of the main results in Wildasin (2003) conforms with the traditional view: the capital tax decreases with the mobility of capital.\(^10\)

In the dynamic models of Lejour and Verbon (1997) and Koethenbuerger and Lockwood (2010) there is a negative cross-border tax externality, but as a result of a preference on the part of households for portfolio diversification. Importantly, the

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\(^9\)In Jensen and Toma (1991), a two-period model with public debt is discussed. Nevertheless, the analysis there takes place under a specific utility function which, crucially, implies (see their Lemma 1) that, in equilibrium, capital taxes do not affect future interest rates. Thus, the intertemporal capital tax externality that we focus on is absent in their paper. Batina (2009) has analyzed capital tax competition in a simple overlapping generations economy, but only in steady state.

\(^10\)See also Becker and Rauscher (2007) for an extension of Wildasin (2003) that incorporates public spending on infrastructure.
intertemporal externality we investigate here does not arise in their settings. In fact, in the absence of a preference for diversification, the standard “race-to-the-bottom” result survives in those models. Moreover, both Lejour and Verbon (1997) and Koethenbuerger and Lockwood (2010) consider only balanced growth paths and no alternative form of taxation, as well as a savings rate which is independent of the rate of return. In our paper, on the other hand, there is no portfolio diversification and the emphasis is on the externality that arises due to the negative effect of capital taxes on savings rates.

Finally, Klein et al. (2005) and Quadrini (2005) study optimal taxation in a fully dynamic open economy, but with limited commitment. Klein et al. (2005) focus on the use of different tax instruments (capital and labour taxes) in asymmetric countries in a steady state. Quadrini (2005) examines the implications of introducing capital mobility, and finds that as soon as capital mobility is allowed, there is a sudden decrease in capital taxes; this is in contrast to the gradual decline that our model implies.

In sum, as far as we know, we are the first to characterize the entire equilibrium path of a fully dynamic open economy with time-varying taxes under commitment, where both the savings rate and the rate of return are endogenous.\textsuperscript{12}

\textsuperscript{11} Koethenbuerger and Lockwood (2010) use a Markov-perfect equilibrium, which corresponds to limited commitment (also see below). Wrede (1999) uses the same equilibrium concept, but the savings rate is exogenously fixed, governments are of the revenue-maximizing Leviathan type, and the focus is on federalism.

\textsuperscript{12} In parallel work Gross (2016) studies optimal taxation in a fully dynamic open economy, but the focus is completely different, on intergovernmental transfers rather than capital-tax externalities.
3 The Model

Consider a world consisting of two countries. In each country there is a representative agent who maximizes her expected discounted utility, and takes prices and policies as given. Output is produced using capital, which is perfectly mobile across countries, and labour, which is immobile. We index time with \( t = 0, 1, 2, \ldots \).

We imagine that each government sets, independently of the other, public debt and labour and capital taxes from period zero until the end of time so as to maximize the welfare of its domestic representative agent subject to the constraints that (1) domestic and foreign private agents optimize and satisfy their budget constraints, (2) foreign taxes and public debt are given (at their equilibrium level), (3) markets clear, and that (4) its own intertemporal government budget constraint is satisfied. In doing so, it also takes as given past (i.e. prior to \( t = 0 \)) issues of public debt and past private asset holdings. Notice that we do not impose as a constraint on either country’s government that the other country balances its government budget constraint. This is in the spirit of the concept of a Nash equilibrium: when we define equilibrium policies, we do not allow for the possibility that a government may contemplate that the other government might react to its deviations; it takes instead

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13In our model, tax-jurisdictions could a priori be localities, provinces, cantons or countries; all that matters is that capital income cannot be taxed on a residence basis. To fix ideas we will use throughout the paradigm of countries. Note that allowing for more than two countries would not affect the main thrust of the theoretical discussion. It would complicate the exposition without adding further significant insights.

14Arguably, labour could also be mobile, though perhaps imperfectly, between countries. Our assumption then that capital is perfectly mobile while labour is immobile can be thought of as a simplifying assumption that tries to capture in a stylized manner this asymmetry between capital and labour, in order to enable us to restrict attention to the implications for tax competition of allowing for time-varying taxes in a neoclassical growth model. Moreover, we note that most of the literature we have discussed so far also assumes immobile labour. Maintaining this assumption here has the advantage of facilitating a comparison between our results and those found in this literature. For an exception that allows for labour to be imperfectly mobile across regions see Kessler et al. (2002). Note, however, that the dynamics inherent in the accumulation of capital, which we emphasize here, are given short shrift in their work, since the supply of capital is exogenously given. The model in Kim (2013) features an endogenous capital supply and labour mobility, but is restricted to a steady-state analysis.
the equilibrium policies of the other government as given. This means of course that, off the equilibrium path, the world may not be in competitive equilibrium. Note also that we do not impose the world resource constraint on either government. Having done so would imply, as a result of Walras’ law, that each government would, in effect, have regarded the other government’s budget constraint as also binding upon itself.

We now establish some notation. \(N\) denotes the population size of the “home” country, and \(N^*\) denotes the population size of the “foreign” country. The letter \(n\) denotes the relative population size of the of the “home” country, i.e. the ratio of its population to that of the “foreign” country so that \(n = N/N^*\).

We define domestic aggregate and per-capita labour supply and private assets, and private and public consumption, respectively, via \(L_t = Nh_t, J_t = Nj_t, C_t = Nc_t,\) and \(G_t = Ng_t,\) respectively. Lump-sum transfer payments are denoted by \(T_t\) and their per-capita counterpart is denoted by \(\bar{T}_t\) so that \(T_t = NT_t.\) Moreover, domestic aggregate capital and government bonds are denoted by \(K_t\) and \(B_t,\) respectively. Output is produced according to \(Af(K_t, L_t) + (1 - \delta)K_t,\) where \(A\) is home country total factor productivity (TFP) and \(\delta\) is the home country capital depreciation rate. The common function \(f\) is constant returns to scale (CRS). Let \(\beta\) be the common subjective discount factor. Foreign variables are denoted with an asterisk.

In what follows we adopt the dual approach to optimal taxation, treating tax rates (and public debt) as the formal choice variables of each government. This has expository advantages in this context of strategic interaction. Not coincidentally, it also has a decisive conceptual advantage in that it allows us to make transparent assumptions about precisely what each government can control, what it takes as given, and what conditions are treated as binding constraints as opposed to other conditions that must be true in an equilibrium but which governments imagine that they could violate at will (though in equilibrium they choose not to).
The home government maximizes

\[
\sum_{t=0}^{\infty} \beta^t [u(c_t) + \nu(h_t)]
\]

subject to

\[
\begin{align*}
uc_t(1 - \tau_t)Af_{L,t} + \nu_{h,t} &= 0, \\
uc_{t}(1 - \tau_t^*)A^*f_{L^*,t} + \nu_{h^*,t} &= 0,
\end{align*}
\]

\[
\begin{align*}
\beta uc_{t+1} [1 + (1 - \theta_{t+1})(Af_{K,t+1} - \delta)] - uc_t &= 0, \\
\beta uc_{t+1} [1 + (1 - \theta_{t+1}^*)(A^*f_{K^*,t+1} - \delta^*)] - uc_{t}^{*} &= 0,
\end{align*}
\]

\[
(1 - \theta_t) (Af_{K,t} - \delta) - (1 - \theta_t^*) (A^*f_{K^*,t} - \delta^*) = 0,
\]

\[
J_t + J_t^* - (B_t + B_t^* + K_t + K_t^*) = 0,
\]

\[
[1 + (1 - \theta_t)(Af_{K,t} - \delta)]j_t + (1 - \tau_t)Af_{L,t}h_t + T_t - c_t - j_{t+1} = 0,
\]

\[
B_{t+1} - [1 + (1 - \theta_t)(Af_{K,t} - \delta)]B_t + \tau_t Af_{L,t}L_t + \theta_t(Af_{K,t} - \delta)K_t - T_t - G_t = 0,
\]

and

\[
[1 + (1 - \theta_t^*)(A^*f_{K^*,t} - \delta^*)]j_{t}^* + (1 - \tau_t^*)A^*f_{L^*,t}h_t^* + T_t^* - c_t^* - j_{t+1}^* = 0
\]

for all \(t = 0, 1, \ldots\), where \(B_0, J_0, B_0^*, J_0^*\), and hence the initial global capital stock, are given.

Equations (1), (3) and (7) describe the optimal behaviour of the domestic agent, whereas Equations (2), (4) and (9) describe the optimal behaviour of the foreign agent (together with the initial and transversality conditions). In particular, Equations (1) and (2) relate the optimal consumption-leisure trade-off for the domestic and foreign agent, respectively. Equations (3) and (4) are the conditions for an optimal intertemporal trade-off, while Equations (7) and (9) are the private budget constraints. Equation (5) is the familiar no-arbitrage condition, and (6) is the capital market-clearing condition. Finally, equation (8) is the domestic government budget constraint.
The set of choice variables $X$ is

$$X = \{c_t, c^*_t, h_t, h^*_t, j_{t+1}, j^*_{t+1}, K_t, K^*_t, B_{t+1}, \tau_t, \theta^*_t\}_{t=0}^{\infty}. \quad (10)$$

The following two equations also have to hold in equilibrium, but are not regarded by the home government to be constraints of its optimization problem. Specifically, the world resource constraint, which is

$$Af(K_t, L_t) + A^*f(K^*_t, L^*_t) + (1 - \delta)(K_t + K^*_t) = C_t + C^*_t + K_{t+1} + G_t + G^*_t \quad (11)$$

and the foreign government budget constraint, which is

$$B^*_{t+1} = [1 + (1 - \theta^*_t)(A^*f_{K^*_t, t} - \delta^*)]B^*_t - \tau^*_t A^*f_{L^*_t, t} - \theta^*_t(A^*f_{K^*_t, t} - \delta^*)]K^*_t + T^*_t + G^*_t. \quad (12)$$

We note here that, by Walras’s law, one of the six equations given by (6)-(9), (11), and (12) is redundant: it is implied by adding up the rest. To ensure that the foreign government budget constraint is not a constraint for the home government, we therefore impose neither (11) nor (12) as constraints on the home government (and analogously for the foreign government).

### 3.1 Non-cooperative Policies

We now characterize the equilibrium. The full derivation can be found in Appendix A. Here we confine our attention to the key equations, namely the (domestic) optimality conditions for the (domestic) capital stock, the (domestic) labour tax rate, the (domestic) source-based capital income tax rate and, only for $t > 0$, the (domestic) private assets. These equations will involve Lagrange multipliers; specifically, the multipliers $\lambda_{1,t}$ to $\lambda_{9,t}$ are associated with the constraints (1)-(9), respectively, where we set $\lambda_{1,-1} = ... = \lambda_{9,-1} = 0$. We also normalize the home country population to one and, to preserve the ratio between them, the foreign country population to $n^*$. Meanwhile, we redefine the multiplier $\lambda^*_{9,t}$ so that it is in fact the product of
the actual multiplier and the foreign population size. All multipliers are defined in current value terms, which means that we need to multiply them by $\beta^t$ to get the present-value multipliers. The optimality conditions in question are:

$$
\lambda_{1,t}u_{c,t}(1 - \tau_t)Af_{KL,t} + \\
\lambda_{3,t-1}u_{c,t}(1 - \theta_t)Af_{KK,t} + \lambda_{5,t}(1 - \theta_t)Af_{KK,t} - \lambda_{6,t} + \\
\lambda_{7,t}A[(1 - \tau_t)Af_{KL,t}L_t + (1 - \theta_t)Af_{KK,t}J_t] + \\
\lambda_{8,t}A[\tau_tAf_{KL,t}L_t + \theta_t[f_{KK,t}K_t + f_{K,t} - \delta/A] - (1 - \theta_t)f_{KK,t}B_t] = 0.
$$

and

$$
-\lambda_{1,t}u_{c,t} - \lambda_{7,t}L_t + \lambda_{8,t}L_t = 0
$$

$$
-\lambda_{3,t-1}u_{c,t} - \lambda_{7,t}J_t + \\
\lambda_{8,t}(K_t + B_t) - \lambda_{5,t} = 0
$$

and

$$
-\lambda_{7,t-1}/\beta + \lambda_{6,t} + \lambda_{7,t}[1 + (1 - \theta_t)(Af_{K,t} - \delta)] = 0.
$$

Our aim now is to use these equations to investigate the relationship between the closed-economy and open-economy capital taxes. It should be clear that the closed-economy capital tax (i.e. when capital is immobile) is second-best efficient. Meanwhile, there is no reason to believe that the open-economy capital tax is second-best efficient.

An obvious way in which tax rates in closed and open economies are different is that, in the presence of capital mobility, there is no temptation on the part of either government to impose a confiscatory initial-period capital tax rate, because if it did,
capital would immediately flow out and domestic wages would plummet. This is confirmed by our numerical exercise in Section 4. We confine capital taxes to be less than 1, a constraint that is binding in a closed economy for a finite number of periods. In an open economy, however, this constraint never binds and governments tax capital at a rate that is very far from confiscatory.

Another source of differences between the closed and the open economy is the presence of capital-tax externalities under capital mobility. These externalities arise in our model because capital taxes affect the allocation of capital between countries and across time, and thereby foreign welfare. These externalities tend to operate in different directions. We discuss this further below.

Now we show that the steady-state capital tax coincides with that in a closed economy, i.e. it is equal to zero (as in Chamley, 1986). That is, any capital-tax externalities cancel each other out at the steady state, and the capital tax is second-best efficient. To see this, we use Equations (τ) and (θ) to eliminate $\lambda_{1,t}$ and $\lambda_{5,t}$ from Equation (K), and using that $f_{KK,t}K_t + f_{KL,t}L_t = 0$ for a CRS technology, we have that (K) reduces to

$$\lambda_{8,t}\theta_t(Af_{K,t} - \delta) = \lambda_{6,t}. \quad (13)$$

In steady state, we have $1 = \beta[1 + (1 - \theta)(Af_{K} - \delta)]$, an implication of Equation (3) when evaluated at steady state. Combining this result with the steady-state condition $\lambda_{7,t} = \lambda_{7,t-1}$ and applying what we have found so far to Equation (j), we conclude that, in a steady state, $\lambda_{6,t} = 0$. Moreover, the shadow cost of (wasteful) public expenditures, $\lambda_{8,t}$, is greater than zero. Thus, we confirm the Gross (2014) result that in the long run, the capital tax is the same as the closed-economy one.\(^{15}\)

\(^{15}\)The apparent alternative possibility, $Af_{K} - \delta = 0$, is not a real one, because it implies that $\beta = 1$.\(^{15}\)
3.2 Cooperative policies

Of course, it is possible to improve upon the welfare gains from optimal policy reform of the open economy at period $t = 0$ by coordinating policy. A coordinated policy is one that maximizes the weighted sum of welfares across the two jurisdictions subject to the constraint that both jurisdictions are in a competitive equilibrium. We rule out intergovernmental transfers, i.e. taxes paid in one country can only be used to finance government expenditures (for consumption, transfers to citizens, or debt service) in that same country. We use population sizes (in terms of efficiency units) as Pareto weights, so that the objective function is

$$\sum_{t=0}^{\infty} \beta^t \left( A[u(c_t) + v(h_t)] + n^* A^*[u(c_t^*) + v(h_t^*)] \right).$$

The set of constraints is the same as in the domestic government’s uncoordinated problem, equations (1) - (9), except that we also have to add the foreign government budget constraint, equation (12). We also need to impose the constraint that capital taxes may not exceed 100% for each country, which is binding in some periods.

The set of choice variables $X_{\text{coord}}$ is the same as $X$ except that we add the foreign government’s policy variables, $B_{t+1}^*, \tau_t^*, \theta_t^*$:

$$X_{\text{coord}} = \{c_t, c_t^*, h_t, h_t^*, j_{t+1}^*, j_{t+1}^*, K_t, K_t^*, B_{t+1}^*, \tau_t, \theta_t, B_{t+1}, \tau_t^*, \theta_t^* \}_{t=0}^{\infty}. \quad (14)$$

In the symmetric case, the solution to the coordinated problem is (obviously) identical to the closed-economy solution.\(^{16}\) It is easy to show that the steady-state capital taxes will still be zero with coordination, using the first-order conditions with respect to $\tau_t^*, \theta_t^*$, and $j_{t+1}^*$ in addition to the ones used in the last section.

\(^{16}\)With asymmetry, however, coordination does not guarantee that both countries are even weakly better off than in a closed economy. In principle, coordinated policy with our Pareto weights does not even guarantee that each country is better off than without coordination. Since we have not come close to this possibility in our quantitative exercises, we ignore this theoretical problem, though.
3.3 Discussion of Capital-Tax Externalities

We now discuss the welfare effects on the home country for a hypothetical small deviation in the foreign country’s (non-cooperative) equilibrium policy, namely a small shift from labour to capital taxes in one period. The goal is to identify and decompose the overall externality of capital taxes.

Specifically, we increase foreign capital taxes by a small amount \( \Delta \theta^*_t \) in a given period \( t \), which we call the period of intervention. This results of course in a different allocation in that period \( t \), as well as all other periods. Therefore, we let foreign government debt adjust in each period \( s > 0 \) by \( \Delta B^*_s \) in order to satisfy the foreign government flow budget constraint each period, and the foreign labour tax in period \( t \) by \( \Delta \tau^*_t \) to satisfy the foreign intertemporal government budget constraint. We note that while per-period public spending remains unchanged the net present value of public expenditures may change following such intervention. As a result tax revenues and hence disposable income in period \( t \) may also change. These changes take into account how the domestic and foreign households react to them, while keeping the domestic policies unchanged at their non-cooperative equilibrium level. This exercise is therefore well-specified in terms of the game outlined above.

We thus differentiate the home government’s Lagrangian (see Appendix A), evaluated at the non-cooperative equilibrium, with respect to \( \theta^*_t, \tau^*_t \) and \( B^*_s \quad \forall s > 0 \). We omit the factor \( \beta^t \) which multiplies all of it in order to have a comparable expression in current value terms at the time period of intervention, otherwise the measured externality would trivially tend to zero as time goes to infinity. The externality of the foreign government substituting from labour to capital taxes at time period \( t \) is then:

\[
E(\Delta \theta^*_t) = r^*_t (-\lambda_{4,t-1} u_{c^*,t} + \lambda_{5,t} - \lambda_{9,t} J^*_t) \Delta \theta^*_t + w^*_t (-\lambda_{2,t} u_{c^*,t} - \lambda_{9,t} L^*_t) \Delta \tau^*_t - \sum_{s=1}^{\infty} \beta^{s-t} \lambda_{6,s} \Delta B^*_s.
\]

\[15\]

It follows that, as a result of the intervention, the global resource constraint will be violated.
From the first-order condition with respect to domestic capital taxes, equation (θ), we substitute out for Λ₅₄ and use the fact that \( B_t + K_t - J_t = -(B^*_t + K^*_t - J^*_t) \) to obtain

\[
E(\Delta \theta^*_t) = -r^*_t (\lambda_{3,t-1} u_{c,t} + \lambda_{4,t-1} u_{c^*,t}) \Delta \theta^*_t
\]

Savings Externality

\[
+ r^*_t (\lambda_{8,t} - \lambda_{7,t}) J_t \Delta \theta^*_t
\]

Fiscal Externality

\[
+ r^*_t (\lambda_{8,t} - \lambda_{9,t}) (B_t + K_t - J_t) \Delta \theta^*_t
\]

Terms of Trade Externality

\[
- w^*_t \left( \lambda_{2,t} u_{c^*,t} + \lambda_{9,t} L_t^* \left( 1 + r^*_t \frac{K_t^* + B_t^* \Delta \theta^*_t}{L_t^* \Delta \tau^*_t} \right) \right) \Delta \tau^*_t
\]

Foreign Labour Externality

\[
- \sum_{s=1}^{\infty} \beta^{s-t} \lambda_{6,s} \Delta B^*_s.
\]

Debt Externality

We can identify five externalities from here: (i) the savings externality, (ii) the fiscal externality, (iii) the terms-of-trade externality, (iv) the foreign-labour externality, and (v) the debt externality. Unlike the traditional public finance literature, we present these externalities in terms of Lagrange multipliers, since the technique of expressing them purely in terms of quantities and prices is obviously not possible in an infinite horizon setting. Moreover, the savings externality is usually subsumed in the fiscal externality, but in our model we can neatly separate the two.

The sign of the savings externality is determined by \(-\lambda_{3,t-1} u_{c,t} - \lambda_{4,t-1} u_{c^*,t}\). \(\lambda_{3,t-1}\) and \(\lambda_{4,t-1}\) are the multipliers for the domestic and foreign household’s intertemporal optimality condition, respectively. These are naturally absent in static models and reflect how an increase in capital taxes decreases savings.\(^{18}\) Lower savings

\(^{18}\)Since net returns equalize across countries, as shown in the no-arbitrage condition, an increase in one country’s capital taxes means that the net rate of return decreases in both countries. This implies that the marginal utility of consumption in the previous period has to fall, resulting in higher consumption and lower savings.
imply a smaller future capital stock and therefore reduce the worldwide potential future output. While the foreign government takes into account how its taxes affect worldwide savings, it does not incorporate the implications of this for domestic welfare. Since the global capital stock is shared, lower savings and less capital affect both countries in a negative way and we thus have a dynamic negative externality. \[19\]

The fiscal externality, represented by the term \((\lambda_{8,t} - \lambda_{7,t}) J_t\), is the effect at the centre of the analysis in ZMW. As long as \(\lambda_{8,t} > \lambda_{7,t} > 0\), i.e. that resources are valued and more so in the government’s coffers than in private hands (due to distortionary taxation), then this is a positive externality. If governments had access to lump-sum taxes, then this externality would of course be zero. To better understand this effect in our context, note that an increase in foreign capital taxes leads to a lower return on savings for domestic private households, but at the same time more capital flows into the country (via the no-arbitrage condition), thereby boosting tax revenues. This externality captures all fiscal effects together: the tax basis for both capital and labour taxes is increased, and debt becomes less expensive to finance.

The terms-of-trade externality is seen in the expression \((\lambda_{8,t} - \lambda_{9,t}) (K_t + B_t - J_t)\), which is positive for a “capital-importing” country, i.e. if \(K_t + B_t > J_t\). (The Lagrange multiplier on the government budget constraint, \(\lambda_{8,t}\), is naturally always larger than the one on the foreign household’s budget constraint, \(\lambda_{9,t}\).) It represents the welfare gain (resp. loss) of a capital-importing (resp. capital-exporting) country due to the fact that a lower world interest rate decreases the interest payments to (resp. from) foreigners, see also De Pater and Myers (1994). Similar results are well-known from international trade, where countries can benefit from manipulating world prices of commodities they import or export. This externality vanishes in a symmetric equilibrium with no capital flows between countries, as in the ZMW

\[19\] The Lagrange multipliers \(\lambda_{3,t-1}\) and \(\lambda_{4,t-1}\) are positive. To see this, it is easiest to consider the first-order condition with respect to capital taxes in a closed economy: 

\[-\lambda_{3,t-1} u_{c,t} + (\lambda_{8,t} - \lambda_{7,t}) J_t = 0,\]

where we used the fact that \(J_t = K_t + B_t\). Since \(\lambda_{8,t} > \lambda_{7,t}\) in the absence of lump-sum taxes, it has to be that \(\lambda_{3,t-1} > 0\). Put in a different way, if \(\lambda_{3,t-1}\) were not strictly positive, then capital taxes would be non-distortionary.
model where countries are identical.

The foreign-labour externality is captured by the term
\[ -w_t^* \lambda_{2,t} u_{c^*,t} - \lambda_{t} (w_t^* L_t^* + r_t^* (K_t^* + B_t^*)) \Delta \theta_t^* \Delta \tau_t^* \].

We start our discussion of this externality by focusing on the first part of the term: when the foreign country increases its capital taxes and lowers, as a result, its labour taxes to balance its budget, then it takes into account that this affects the labour supply of its own citizens. However, the change in labour supply also has an impact on domestic welfare; observe that \( \lambda_{2,t} \) is the Lagrange multiplier of the domestic government for the foreign household’s labour-leisure decision. Lower foreign labour taxes will lead (in this model) to an increase in foreign labour supply and this may in principle have a positive or negative impact on domestic welfare. Specifically, more foreign labour increases the world rate of return on capital and increases savings (positive effects), but at the same time it also results in a higher marginal product of capital abroad, thereby attracting capital from the home country, a negative effect.

We now turn to the second part of the above term. This part describes a “wealth effect” for the foreign household and how this affects domestic welfare. To understand this, recall from our description of the intervention that a shift from labour to capital taxes may change tax revenues and thereby the disposable income of foreign households. This influences of course the decisions of foreign households, which in turn affects domestic welfare; this is what constitutes an externality. However, we expect the wealth effect to be of minor importance: a small change from the optimal equilibrium policy should not lead to significant changes in the income available to the household.\(^{20}\)

The (foreign) debt externality is represented by \(- \sum_{s=1}^{\infty} \beta^{s-1} \lambda_{6,s} \Delta B_s^*\). It arises from

\(^{20}\)Notice also that if public spending was valued by consumers and endogenous (as it is the case in ZMW and a big part of the ensuing literature), then the foreign-labour externality would not emerge as long as the level of foreign public spending was absorbing the change in tax revenues induced by the small change in foreign capital taxes. Only the part \(-r_t^* \lambda_{t} (K_t^* + B_t^*) \Delta \theta_t^* \Delta \tau_t^*\) would remain, which captures the fact that the foreign household would have less resources at its disposal after a tax increase.

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the adjustment of foreign government debt in order to satisfy the foreign government budget constraint in each period. We expect this term to be small in the short run and zero in the long run: The small policy deviation is likely to lead to an increase in debt before the tax hike and a decrease afterwards, so that the effects would roughly cancel out. Moreover, in the long run $\lambda_{6, s} = 0$ as shown in Section 3.1.

Since the fiscal, terms-of-trade, and foreign-labour externalities are all present in a static model, we expect that a dynamic model with the additional negative savings externality will feature relatively higher capital taxes than a static model (or any model in which the capital stock does not evolve endogenously through savings). In other words, models with an exogenous capital stock will exaggerate the negative effects of tax competition. In fact, in the medium run capital taxes may even be too high, rather than too low. In the long run, we expect capital taxes to have no externality, since we have shown analytically that steady-state capital taxes in an open economy coincide with those in a closed one.

It is worth emphasizing that while only the savings and debt externality are dynamic in the sense that they are new compared to a static model, the fiscal, terms-of-trade, and foreign-labour externalities are all also dynamic in nature and will differ quantitatively and potentially even qualitatively from those in a static model. The reason is that an increase in foreign capital taxes will have an impact on the whole path of the price of capital. To explain this, let us consider the example of the terms-of-trade externality: A higher foreign capital tax negatively affects the home country if it is a capital exporter in the same time period, as it drives down the price of capital, as explained above. But since the tax also discourages the accumulation of capital, the home country is positively affected in the future since a lower global capital supply will increase the price of capital. For the foreign-labour externality, as we explained above, there is also a static and dynamic component to it. Since the importance of each effect can change over time, the sign of the externality may change, and this is indeed what we find in our quantitative exercises.
4 Quantitative results

The main purpose of this section is to explore the quantitative implications of the model for a range of parameter values, which are chosen so as to make the results broadly speaking empirically relevant. Rather than attempting to account for any particular historical episode, we will investigate capital tax paths for a range of scenarios designed to shed light on the mechanisms involved. We also carry out an applied exercise, calibrating our model to capture some key features of Germany and the Netherlands.

In each computational experiment, we consider the following scenario. We imagine that the world economy has existed for a long time with exogenously given (source-based) capital income taxes and debt, and no capital mobility. This situation (henceforth, we call this the “initial steady state”) is generated by the steady states of two closed economies implied by exogenously given constant capital tax rates and debt levels. At time \( t = 0 \), each of the two governments simultaneously and independently choose their policies so as to maximize the welfare of the representative citizen under its jurisdiction, given the policies of the other government. From period \( t = 0 \) and onwards, depending on the scenario, capital may either be perfectly mobile (open economies) or perfectly immobile (closed economies). We impose an upper bound of 100 percent on capital taxes, which is non-binding in the open economy equilibrium without coordination.

The initial steady state determines the following variables that we use to initialize the equilibrium with optimal policy and tax competition: the initial world capital stock, the initial stock of government debt in each country, and the initial asset holdings of inhabitants of each country.

\(^{21}\)The initial steady-state labour tax rate in each jurisdiction is determined endogenously so as to balance the budget.
4.1 Calibration and computation

We now describe the benchmark parameterization of a symmetric two-country model. (Asymmetric cases will be described later.) We calibrate the initial level of government debt to be 60 percent of GDP in both jurisdictions, corresponding roughly to the (unweighted) EU average in 1995 according to the OECD.\textsuperscript{22} Government revenue (and hence spending) is set to equal the EU average as it was in 2012, and reported in Graph 1 in Eurostat (2015), i.e. 40 percent of GDP. Somewhat arbitrarily, but not unreasonably, we assume that half of that spending is government consumption and the rest consists of lump-sum transfer payments.

The per-period utility function is assumed to take the following form:

\[ u(c, h) = \frac{c^{1-\sigma} - 1}{1 - \sigma} - \psi \cdot \frac{h^{1+\frac{1}{\sigma}}}{1+\frac{1}{\epsilon}} \]

where \(1/\sigma\) is the (constant) intertemporal elasticity of substitution and \(\epsilon\) is the (constant) Frisch elasticity of labour supply. We set \(\sigma = 1\), \(\epsilon = 1/2\) and \(\psi = 30\); the latter is a normalization implying that labour supply \(h\) is about a third. The subjective discount factor, \(\beta\), is set equal to 0.96 so that each period can be thought of as one year.

The production function is assumed to be Cobb-Douglas so that

\[ f(K, L) = K^{\alpha}L^{1-\alpha} \]

where \(\alpha = 1/3\), which is an empirically plausible value for the capital share.

Every transition path is solved for in the following conceptually straightforward way.\textsuperscript{23} We fix a time horizon \(T\) after which we conjecture that the economy has come very close to the long-run allocation. We then stack the equilibrium conditions up until period \(T\) and then force the solution to converge to some steady state, whose

\textsuperscript{22}See https://data.oecd.org/gga/general-government-debt.htm.
\textsuperscript{23}The method is known in the literature as the extended path method and was first described in Fair and Taylor (1983).
properties are not specified but will emerge endogenously. An approximate solution to the resulting system of equations is then found by using the Gauss-Newton method of minimizing the sum of squared deviations. (Minimization allows us to impose a large number of convergence criteria so that we avoid solutions that do not converge to a steady state.)

4.2 Symmetric countries

We begin by considering a case where the two jurisdictions are identical: they are equally productive \( A = A^* \) and equally populous \( N = N^* \), and also spend the same time-invariant amount on public consumption, \( G_t = G_t^* = G \) and on transfer payments, \( T_t = T_t^* = T \). As we have already mentioned, the initial conditions are defined from the initial steady state of the economies; in this symmetric case, that means \( \theta = \theta^* = 0.4 \). Meanwhile, \( G_t \) is set so that the ratio of government consumption to output is 20 percent and \( T_t \) is set so that the ratio of lump sum transfers to output is also 0.2. This in turn implies that labour tax rates in the initial steady state are about 55 percent.

Given these parameter values and these initial conditions, there appears to be a unique equilibrium, and it is symmetric.\(^{24}\) Because of the symmetry, there is no terms-of-trade externality.

The implications for capital tax rates of this symmetric case are shown in Table 1 and Figure 1. The first result we immediately see here is that the period-0 open-economy capital tax rate is most definitely not confiscatory. In contrast to the closed economy, there is no need to impose any constraint on what capital income taxes can be; tax competition provides enough discipline to keep them in check. Notice also that capital taxes are about 40 percent in the initial period. This is not too far from what we saw in the European Union when the 1992 program was completed.

\(^{24}\)We have found no evidence of multiple equilibria once we make sure to impose convergence criteria on all variables, including Lagrange multipliers.
and full freedom of movement of capital was realized.\textsuperscript{25}

Moreover, capital tax rates in an open economy only very gradually fall towards zero; in year 30, they are still at 2 percent. This is in contrast to the closed economy, where the transition from 100 percent to 2 percent takes only 14 years. While capital tax rates are initially higher in the closed than the open economy, this reverses from year 7 on, when tax rates are at 23 percent in an open economy and 17 percent in a closed economy. Thus, a rather natural extension of the seminal ZMW model—namely, allowing for capital accumulation—is sufficient to completely overturn its prediction from year 7 onwards, at least under the parameter values considered here. However, it is worth emphasizing that the overall reliance on capital taxes, as measured by the fraction of the discounted revenues they raise, is still significantly lower in an open (4.4\%) than a closed economy (10.8\%).

Quantitative analysis of externalities  Here we consider the effects on welfare in the home country of marginal changes to capital taxes in the foreign country (or vice versa), taking into account the implied change, via the foreign government’s budget constraint, in the labour tax and public debt sequence abroad. The numbers we compute, and show in Figure 2, can be thought of as numerical derivatives; they are literally ratios of small changes. That figure displays the various components of the capital tax externality, as defined in Section 3.3: the fiscal externality, the savings externality, and the foreign labour externality.\textsuperscript{26}

This quantitative analysis clearly reveals the importance of introducing capital accumulation. All components of the externality are affected by dynamics, but the effect is most striking in the savings externality, which is obviously absent in a static model. It is zero at time zero (naturally capital taxes at time zero cannot affect the


\textsuperscript{26}The debt externality is only of minor importance and is left out so as to avoid cluttering the figure; the same applies to the terms-of-trade externality, which is obviously zero in a symmetric environment.
capital accumulation in previous periods) but then grows in magnitude over time and, in the long run, completely offsets the fiscal and other externalities. The intuition is simple, but powerful: In the long run, lower capital tax rates do not “steal” capital from abroad anymore, but instead increased savings fill the higher demand for capital.

The fiscal externality shrinks somewhat over time, but remains important at any period of intervention. From the perspective of introducing dynamics, the foreign-labour externality—even though small in size—exhibits interesting behavior: It starts off negative at time zero, but then becomes positive in the long run. What this shows is that a static model may not only differ in predicting a different magnitude of the externalities but even a different sign as compared to a dynamic model.

Crucially, this also becomes apparent when we look at the total externality: There is a large positive externality at time zero driven by the fiscal externality, in line with the findings of ZMW. Then the total externality shrinks to zero as we approach steady state, in consonance with the result in Gross (2014) that the capital distortions of a closed and open economy coincide in the long run. However, as a zoom in on the total externality (see Figure 3) shows, the convergence is non-monotonic and the externality in fact becomes negative from year 43 onwards. Governments could therefore improve welfare by jointly lowering taxes in the medium run, whereas the policy prescription of ZMW, to jointly increase taxes, only applies in the short run.27

The welfare implications in our main model are worth noting as well. The benefit, relative to the initial steady state, from optimal tax reform in period \( t = 0 \), when economies are closed, corresponds to a consumption increase of about 2.8 percent. If instead the economies are open from \( t = 0 \) and onwards, and there is no policy coordination, then the welfare gain is just 0.9 percent. It is not surprising that in this case there are losses from capital-market integration in the absence of coordination.

27Note, however, that the short run in our baseline case is about 40 years and that the long run kicks in after roughly 100-120 years.
There are two reasons for this. First, there is no upside from capital-market integration: because the two countries are identical, there are no potential gains from trade in capital. Second, in the absence of coordination, the tax externalities that emerge when the capital market is integrated, are not internalized.

4.3 Asymmetric countries

We now turn to cases where countries are not identical and there are potential gains from trade in capital. In these cases the terms-of-trade externality emerges alongside the fiscal externality, affecting the paths of capital taxes.

4.3.1 Differences in initial asset positions

Here we assume that the initial steady state features a capital tax rate of 0 percent at home and 40 percent abroad, implying that the domestic stock of assets is initially 29 percent greater than the foreign one. Meanwhile, government spending (equally split into purchases and transfer payments) is the same in both countries, calibrated to be 40 percent of the foreign country’s initial steady state GDP. Again, convergence to zero is a protracted affair; see Table 2 and Figure 4.

Notice that the home country taxes capital less than the foreign country under capital mobility, even though in autarky it taxes capital more heavily than the foreign country. The reason is that the home country is a net capital exporter, as indicated by the positive net foreign asset position of the home country (NFAP) in Table 2. As a result, each country attempts to manipulate the terms of trade in its favor. The capital exporter lowers capital taxes and thereby increases the worldwide rate of return, whereas it is the opposite for the capital importer. The resulting terms-of-trade externality is now positive as we can see in Figure 5, which shows how the foreign country is affected by an increase in capital taxes in the home country. It is inter-
esting to see that the savings and foreign-labour externality have roughly the same magnitude as in the previous section, while the fiscal externality is smaller.\textsuperscript{28}

While the sign of the externality is in line with the results in De Pater and Myers (1994) for a static model, we do observe a difference in the magnitude.\textsuperscript{29} In our fully dynamic model the home country’s capital tax is two percentage points lower than in the foreign one, whereas the corresponding difference in an otherwise similar static world\textsuperscript{30} economy is about three percentage points. As mentioned in the Introduction, the terms-of-trade externality has both a static component and a dynamic one. In more detail, a decrease in the capital tax rate in the capital-exporting country leads to an increase in the current rate of return as well as, in a dynamic setting, to an increase in savings. The latter of course leads to a higher capital stock in the future, which, in turn, lowers the future rate of return. While this accumulation-induced effect never outweighs the direct effect (present also in a static setting), it decreases the magnitude of the overall terms-of-trade externality.

The welfare effects of optimal policy reform for a closed economy are very similar to the symmetric case, 2.9% for the home country and 2.8% for the foreign country. However, the welfare effects in the open economy differ markedly: The home country only gains 0.2%, while the foreign country gains 2.6%. In this sense, our results are in consonance with the results by Mendoza and Tesar (2005). They find that the United Kingdom, which had initially higher capital taxes and a lower capital-output

\textsuperscript{28}Repeating the analogous exercise for the home country, we find that the terms-of-trade externality of an increase in foreign capital taxes is negative and the fiscal externality is larger than with symmetry.

\textsuperscript{29}De Pater and Myers (1994) deal in their model only with the case of exogenously fixed labour supply. Here, however, we confirm that the effect they identify is valid in our computations regardless of whether labour supply is endogenous or not.

\textsuperscript{30}This static model economy is a one-period economy whose exogenously given capital stock as well as government debt is the same as in period 0 of the dynamic economy; government spending needs are also the same. The main difference is that everyone knows that there is no tomorrow, and so there is no investment and government debt is paid off immediately. The only other difference is that the capital stock is not available for consuming. Instead the assumption is that it must be maintained, so a fraction δ of the capital stock in each country is subtracted from output and not available for consumption. This assumption is for comparability with the dynamic economy.
ratio, has much more to gain from capital market integration than continental Europe.

4.3.2 Differences in population size and TFP

Next we assume that the home country is twice as populous as the foreign country. The parameterization is otherwise the same as in the baseline (symmetric) set up. The implications for capital taxes are shown in Table 3 and Figure 6. Convergence to zero is again a rather protracted matter, with domestic capital taxes remaining at 10 percent or above for more than 15 years. As we can also see in Table 3, optimal capital taxes in the open economy start out at 51 percent at home and 33 percent abroad. In addition, they are consistently higher at home than abroad, even though each country would have had the same capital taxes in a closed economy. This reflects the results from the static literature, that larger countries have more “market power” and as a consequence set higher capital taxes than smaller countries, see e.g. Wilson (1991). The intuition is simple: In the short run, an increase in capital taxes in the home country leads to a relatively smaller outflow of capital than in the foreign country. However, since the home country sets higher capital taxes than the foreign country, the home country’s net foreign asset position is positive in the early periods (despite both countries having identical initial asset endowments). This implies that there is an incentive on the part of the home government to lower its capital taxes to manipulate the terms-of-trade to its benefit. This partially counteracts the incentives to tax capital more due to the greater market power. As the gap between the two countries’ tax rates is closing, the home country’s net foreign asset position gradually

\[31\text{ Since the foreign country is smaller, an outflow of, say, one percent of domestic capital would decrease the foreign rate of return by more than an outflow of one percent of foreign capital would decrease the domestic rate of return. In other words, in the short run, the home capital stock is less elastic with respect to domestic capital taxes than the foreign one. In the long run, this logic no longer applies, and both countries set a zero capital-tax rate, as the global capital supply is not fixed but in fact perfectly elastic at the discount rate.}\]
shrinks, almost to zero.

The welfare gains from optimal policy reform at $t = 0$ are again greater in each closed economy (still 2.8 percent) than in the open economy, but, interestingly, in the open economy, the smaller country gains more (1.6 percent) than the bigger one (0.8 percent). This reflects the fact that the total externality from capital taxes is large and positive in the early periods, and mirrors in this respect the conclusions from the received tax competition literature.

A further case to consider is one where the home country is more productive than the foreign one in the sense that its TFP is higher. However, this case is completely isomorphic to the one where the home country is more populous (if we calibrate government consumption and transfers per efficiency units of population to be equal across countries), so there is no need to go into detail.

**Going to the limit** As a sidenote, it is interesting to consider the question of what happens as one country becomes arbitrarily larger than the other, either in terms of population or TFP or both. It is tempting to say that the smaller country then becomes a small open economy that cannot tax capital income at all, and the larger economy becomes a closed economy and behaves accordingly. That turns out not to be quite right. Instead, what happens is that, in the initial period (and indeed several periods beyond that), both jurisdictions tax net capital income at exactly 100 percent. After a few periods, the larger country gradually reduces the tax rate towards zero. As soon as the larger country stops taxing capital income at exactly 100 percent, the smaller country cuts its tax rate on capital to zero. So the smaller country can tax capital at the initial high rate only because the rest of the world taxes capital at 100 percent, which implies that the domestic rate of return before taxes is driven down to zero in the absence of a 100 percent tax rate. This is an artifact of our otherwise innocuous assumption that there are only two countries, however: If we assumed that two or more large countries engaged in tax competition as well as
an arbitrary number of smaller countries, then the smaller countries would indeed set capital taxes to zero at all times, in consonance with Correia (1996).

4.3.3 Differences in government spending and debt

We now turn to the case where the home country spends 7 percent less on purchases and transfers than the “foreign” country does; the latter still spending 20 percent of initial steady state GDP on each. Notice that the home country sets a lower capital tax rate than the “foreign” country in every period; see Table 4 and Figure 7. Convergence to zero is, again, protracted.

The results are straightforward: the home government has lower revenue needs and therefore sets (weakly) lower capital (and labour) taxes than the foreign one, both in a closed and an open economy. However, this difference in capital-tax rates leads to a negative net foreign asset position of the home country, which pushes the incentives to tax capital in the opposite direction in order to manipulate the terms-of-trade to its benefit. As with population size differences, these secondary effects of course do not outweigh the primary effects.

Regarding the welfare effects of optimal policy reform at period $t = 0$, the gains are again higher in the closed economy than in the open economy; in the closed economy the home country gain is equivalent to a consumption increase of 2.2 percent (2.8 percent in the foreign country), while in the open economy the welfare gain corresponds to an increase in consumption equal to 0.9 percent (1.0 percent in the foreign country).

Similarly, when the home country has a higher initial government debt (we set foreign debt to zero in this experiment and keep the domestic debt at the same level as in the symmetric case), it needs to raise more tax revenues than the foreign country, and so it sets higher capital taxes and, thus, has a positive net foreign asset position; see Table 5 and Figure 8. Again, the resulting terms-of-trade effect pushes in the
opposite direction, but without outweighing the need to set higher capital taxes to finance the higher tax revenue requirements. Finally, the welfare gains from optimal policy reform at period \( t = 0 \) are 2.8% and 2.0% in a closed economy for the home and foreign country, respectively, but 0.6% and 1.1% in an open economy.

### 4.4 Coordination

In this section, we report some results on how the solution changes in a cooperative equilibrium as compared to the non-cooperative equilibrium studied so far. We refer to exactly the same scenarios as previously described.

Our first result is unsurprising: As mentioned before, the coordinated solution in a symmetric environment is identical to the solution in a closed economy, which is the second-best policy. Therefore, coordinated capital taxes are higher than the non-cooperative ones in the short-run, but lower in the medium-run. The latter is in contrast to common beliefs that have influenced policy debates in Europe and elsewhere. The gains from coordination—relative to the non-cooperative outcome under capital mobility—are 1.9% of life-time consumption in each country. Capital taxes are initially at the maximum 100% for years 0 to 6 and then converge relatively quickly to zero. Notice that despite the additive separability of utility in consumption and labour, capital taxes do not immediately switch from 100% to zero with only one intermediate period, as in Atkeson et al. (1999). The reason for this is that we assume (exogenously given) lump-sum transfer payments from the governments to their citizens. One can readily confirm that the implementability constraint then no longer satisfies the conditions set out by Atkeson et al. (1999).

More interestingly, if one country is more populous or more productive than the other, then the coordinated solution is still identical to the closed-economy solution. While the uncoordinated game features different policies between the larger and the smaller countries, the coordinated solution has identical policies for both countries.
The larger country gains more from coordination than the smaller country, 2.1% and 1.3% of life-time consumption respectively.

When one country has more initial assets than the other (as specified in the previous section), then optimal coordinated policies differ by country, as one may expect. Interestingly, though, the main difference is in the labour tax rates: The country with more assets sets higher labour taxes, since its citizens are richer and therefore supply less labour at the same net wage. Capital-tax rates, however, are virtually indistinguishable between countries, see Figure 9. We observe the same pattern for asymmetries in government spending and transfers as well as in initial debt. Coordination thus roughly preserves production efficiency, i.e. that the marginal products of capital are the same in both countries. An unexpected and possibly highly policy-relevant implication of this result is that capital tax-harmonization is (roughly) optimal, even when countries are not symmetric.

While both countries gain from coordination, 1.8% and 1.4% of life-time consumption for the home and the foreign country respectively, the capital-exporting country (the home country here) would prefer the closed-economy outcome to the coordinated outcome (and vice versa for the capital-importing country). The intuition is that the home-country suffers relatively more from tax competition in the sense that part of its capital migrates abroad; moreover, it suffers relatively more from the inability to efficiently tax the initial capital stock.

When countries differ in government spending or initial debt as specified above, the country with lower spending or debt gains less from coordination than the country

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32 It is generally not true, however, that a coordinated solution satisfies production efficiency; in fact, one can show that if there are per-capita asymmetries (and the government budget constraint Lagrange multipliers differ between countries), then production efficiency will be violated. A similar point has been made in Kotsogiannis and Makris (2002) and Keen and Wildasin (2004) in static models. The first paper discusses optimal federal tax policy when the federal government is a Stackelberg leader vis-vis asymmetric state tax authorities, while the second paper discusses Pareto-improving reforms. In both papers, there are no transfers to redistribute tax revenues between (state) tax jurisdictions.

33 The overall gains from coordination are lower than in the symmetric case since the world is richer and taxation is not as distortionary.
with higher spending. There are two reinforcing reasons for this. First, a country with lower spending/debt sets lower capital taxes and enjoys capital inflows in the non-cooperative setting, while the other country experiences capital outflows. Second, the distortions from taxes are lower for the country with lower spending, so the inability to efficiently tax the initial capital stock in a non-cooperative setting harms it less than the other country.

4.5 Germany vs the Netherlands

In this section we describe the results from calibrating the model in order to roughly match some key observations about Germany and the Netherlands. We are aware that tax competition did not only take place between these two countries, but also involved the rest of the European Union (and to a lesser degree the rest of the world). Nonetheless, it seems to us to be an interesting exercise, because it puts together all of the asymmetries discussed above in a fairly realistic setting.

According to the OECD, the debt/GDP ratio in 1995 in the Netherlands was about 86 percent, while in Germany it was 54 percent. According to Eurostat (2015), Germany’s government revenue share of GDP was 39 percent of GDP in 2012 and that of the Netherlands was about the same. So we set the government consumption share to 19 percent of GDP and the ratio of transfers to GDP to 20 percent in both countries. Meanwhile, according to PWT 9.0, the 1995-2014 average ratio of Dutch to German GDP/capita was about 1.12. Germany’s population was, on average between 1995 and 2014, about five times bigger than that of the Netherlands. Their initial asset positions are determined by solving for the steady state of a model calibrated to match observations in 1995, including capital tax rates (from 1992) and government debt/GDP ratios.

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34 See https://data.oecd.org/gga-general-government-debt.htm. 1995 is a reasonably good starting point, because (i) this is when the OECD data series on debt starts and (ii) it is only a few years after the completion of the European Single Market, mandating the free mobility of capital.

35 See http://www.rug.nl/ggdc/productivity/pwt/.
As can be seen in Table 6 and Figure 10, our model predicts an initial German capital tax rate of 60 percent and an initial Dutch capital tax rate of 25 percent; subsequently, of course, the taxes are predicted to be on a declining trajectory. Looking at the data, we see that, in 1995, Germany’s corporate tax rate was about 55 percent, the corresponding Dutch number was about 35 percent. Today, in 2016, Germany’s corporate income tax is about 30 percent whereas in the Netherlands it is 25 percent; higher than the model predicts, but noticeably lower than in 1995.

In terms of the externalities, the Netherlands benefit from a large inflow of capital from Germany, as evidenced by the positive German net foreign asset position. This is driven largely by the difference in population size, but mitigated by the Dutch TFP advantage and higher initial debt.

Note that after 30 years, the NFAP changes sign and becomes negative. The effect is driven by the faster accumulation of capital in the Netherlands. The dynamics can thus lead to a reversal of conditions.

5 Concluding remarks

In this paper, we examine the implications for capital tax policy of capital mobility across borders. We consider a model economy where two benevolent (but nationalist) governments, each independently of the other, commit simultaneously, at the beginning of time, to a tax policy that applies until the end of time. Our main finding is that, though as in Chamley (1986) and Gross (2014), capital taxes tend to zero in the long run, they may in empirically relevant scenarios be high and positive during a highly protracted transition to that long run. We show that the cross-border externalities from capital taxes are positive in the short run, zero in the long run, and negative (though small in size per period but for many periods) in the medium run. This implies that a coordinated decrease in capital taxes over some periods

\(^{36}\text{See http://www.oecd.org/tax/tax-policy/tax-database.htm.}\)
may be welfare-improving. This is in contrast to a common belief to the contrary among many researchers and practitioners, which has motivated frequent calls for a coordinated increase in capital taxes.

We have deployed the simplest possible model for the task in hand, and one that extends existing work in a minimal way. In particular, the choice of the representative agent paradigm is consistent with the framework in ZMW and most of the literature that it spawned, and it is instructive to be able to directly compare our results with those of this canonical model. Allowing for heterogeneous agents and ensuing political economy considerations such as those in Lockwood and Makris (2006) in a dynamic set-up is an interesting task for future research. Fully understanding the net externalities involved in taxing mobile capital in the presence of heterogeneous consumers would also require the study of alternative dynamic environments such as overlapping-generation models. The reason is that, as our analysis makes clear, the specifics of capital accumulation are important for intertemporal capital tax externalities.

The large public finance literature discussed in the Introduction and Section 2 has highlighted many interesting additional mechanisms through which tax policy in one country affects welfare in other countries. Here we have also studied one of these mechanisms, the terms-of-trade externality, which is discussed in the context of a static model in De Pater and Myers (1994). Naturally, then, another avenue for future research would be to revisit other mechanisms, e.g. publicly provided amenities or federal structures, while recognizing the intertemporal tax externalities we emphasize here.

Which externalities dominate in reality is ultimately an empirical matter. However, we believe it is helpful for both policy debates and empirical research on the topic to be informed of the main channels at work that could affect non-cooperative capital tax setting. An objective of this paper has been to bring attention to one such channel that has largely been neglected in the received (theoretical and empirical) literature.
Namely, that source-based capital taxation gives rise to \textit{inter-temporal} tax externalities that go in the opposite direction to those of the familiar tax externalities, which have been analyzed in static and two-period models, and have influenced policy debates in Europe and elsewhere.
6 Tables

Table 1: Capital taxes when the countries are symmetric

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Note: $\theta$ is the home capital tax rate, $\theta^*$ is the foreign counterpart. NFAP is the net foreign asset position from the point of view of the home country.
Table 2: Capital taxes when the home country has a stronger initial asset position

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Note: θ is the home capital tax rate, θ* is the foreign counterpart. NFAP is the net foreign asset position from the point of view of the home country.
Table 3: Capital taxes when the home country is twice as populous

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Note: θ is the home capital tax rate, θ* is the foreign counterpart. NFAP is the net foreign asset position from the point of view of the home country.
Table 4: Capital taxes when the home country gov’t spends 25% less on purchases and transfers

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Note: $\theta$ is the home capital tax rate, $\theta^*$ is the foreign counterpart. NFAP is the net foreign asset position from the point of view of the home country.
Table 5: Capital taxes when the home country has more initial gov’t debt

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Note: $\theta$ is the home capital tax rate, $\theta^*$ is the foreign counterpart. NFAP is the net foreign asset position from the point of view of the home country.
Table 6: Capital taxes and net foreign asset position (NFAP) in Germany/Netherlands experiment

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7 Figures

Figure 1: Capital taxes when countries are symmetric
Figure 2: Capital tax externalities when countries are symmetric
Figure 3: Capital tax externalities when countries are symmetric, enlarged
Figure 4: Capital taxes when the home country’s initial asset position is higher than the foreign country’s
Figure 5: Capital tax externalities when the home country’s initial asset position is higher than the foreign country’s
Figure 6: Capital taxes when the home country is twice as populous
Figure 7: Capital taxes when the home country gov’t spends 7 percent less
Figure 8: Capital taxes when the home country has positive initial government debt and the foreign country has none.
Figure 9: Capital taxes when initial assets are asymmetric and policies are coordinated
Figure 10: Capital taxes in the Germany/Netherlands experiment
A Derivation of the equilibrium conditions

In this section we characterize the equilibrium in detail. Associating the Lagrange multipliers $\lambda_{1,t} - \lambda_{9,t}$ to the constraints (1)-(9), we have the following domestic Lagrangian:

$$L = \sum_{t=0}^{\infty} \beta^t \left[ u(c_t) + \nu(h_t) \right] + \lambda_{1,t} \left[ u_{c,t}(1 - \tau_t)A^L_{t+1} + \nu_{h_t} \right] + \lambda_{2,t} \left[ u_{c^*,t}(1 - \tau^*_t)A^L_{t+1} + \nu_{h^*,t} \right] + \lambda_{3,t} \left[ \beta u_{c,t+1}[1 + (1 - \theta_{t+1})(A^K_{t+1} - \delta)] - u_{c,t} \right] + \lambda_{4,t} \left[ \beta u_{c^*,t+1}[1 + (1 - \theta^*_{t+1})(A^K_{t+1} - \delta^*)] - u_{c^*,t} \right] + \lambda_{5,t} \left[ (1 - \theta_t)(A^K_{t} - \delta) - (1 - \theta^*_t)(A^K_{t} - \delta^*) \right] + \lambda_{6,t} \left[ j_t + j^*_t - (B_t + B^*_t + K_t + K^*_t) \right] + \lambda_{7,t} \left[ (1 - \tau_t)A^L_t h_t + [1 + (1 - \theta_t)(A^K_t - \delta)]j_t + T_t - c_t - j_{t+1} \right] + \lambda_{8,t} \left[ B_{t+1} - [1 + (1 - \theta_t)(A^K_t - \delta)]B_t + \tau_t A^L_{t+1} L_t + \theta_t (A^K_t - \delta)K_t - T_t - G_t \right] + \lambda_{9,t} n^* \left[ (1 - \tau^*_t)A^K_{t} h^*_t + [1 + (1 - \theta^*_t)(A^K_{t} - \delta^*)]j^*_t + T^*_t - c^*_t - j^*_{t+1} \right]$$

As a reminder, we defined $\lambda_{i,t} = 0$ for $i \in \{1, \ldots, 9\}$. Differentiating with respect to all of the domestic government’s choice variables, the first order conditions for the home country are given by:

$$u_{c,t} + \lambda_{1,t} u_{cc,t}(1 - \tau_t)A^L_t + \beta \lambda_{3,t-1} u_{cc,t}[1 + (1 - \theta_t)(A^K_t - \delta)] - \lambda_{3,t} u_{cc,t} - \lambda_{7,t} = 0$$

$$\nu_{h,t} + \beta \lambda_{3,t-1} u_{c,t}(1 - \theta_t)A^L_t$$

$$\lambda_{1,t} u_{c,t}(1 - \tau_t)A^L_t + \nu_{h,t} + \lambda_{5,t}(1 - \theta_t)A^K_t +$$
\[ \lambda_{7,t} A\{(1 - \tau_t) [f_{LL,t} L_t + f_{L,t}] + (1 - \theta_t) f_{KL,t} j_t]\] 
\[ \lambda_{8,t} A\{\tau_t [f_{LL,t} L_t + f_{L,t}] + f_{KL,t} [\theta_t K_t - (1 - \theta_t) B_t]\} = 0 \]

\[ + \beta \lambda_{3,t-1} u_{c,t} (1 - \theta_t) A f_{KK,t} + \]  
(K)

\[ \lambda_{1,t} u_{c,t} (1 - \tau_t) A f_{KL,t} + \lambda_{5,t} (1 - \theta_t) A f_{KK,t} - \lambda_{6,t} + \]

\[ \lambda_{7,t} A\{(1 - \tau_t) f_{KL,t} L_t + (1 - \theta_t) f_{KK,t} j_t\} + \]

\[ \lambda_{8,t} A\{\tau_t f_{KL,t} h_t + \theta_t [f_{KK,t} K_t + f_{K,t} - \delta/A] - (1 - \theta_t) f_{KK,t} B_t\} = 0 \]

\[ - \lambda_{1,t} u_{c,t} - \lambda_{7,t} L_t + \lambda_{8,t} L_t = 0 \]  
(τ)

\[ - \beta \lambda_{3,t-1} u_{c,t} - \lambda_{7,t} J_t + \]  
(θ)

\[ \lambda_{8,t} (K_t + B_t) - \lambda_{5,t} = 0 \]

\[ \lambda_{2,t} u_{cc^{*},t} (1 - \tau_t^*) A f_{L^{*},t} + \beta \lambda_{4,t-1} u_{cc^{*},t} [1 + (1 - \theta_t^*) (A^* f_{K^{*},t} - \delta^*)] - \]
(c*)

\[ \lambda_{4,t} u_{cc^{*},t} - \lambda_{9,t} n^* = 0 \]

\[ \beta \lambda_{4,t-1} u_{c^{*},t} (1 - \theta_t^*) A^* f_{KL^{*},t} + \]  
(h*)

\[ \lambda_{2,t} (u_{c^{*},t} (1 - \tau_t^*) A^* f_{LL^{*},t} + v_{hh^{*},t} / n^*) - \lambda_{5,t} (1 - \theta_t^*) A^* f_{KL^{*},t} + \]

\[ \lambda_{9,t} A^*\{(1 - \tau_t^*) [f_{LL^{*},t} L_t^* + f_{L^{*},t}] + (1 - \theta_t^*) f_{KL^{*},t} J_t^]\} = 0 \]

\[ \beta \lambda_{4,t-1} u_{c^{*},t} (1 - \theta_t^*) A^* f_{KK^{*},t} + \]  
(K*)

\[ \lambda_{2,t} u_{c^{*},t} (1 - \tau_t^*) A^* f_{KL^{*},t} - \lambda_{5,t} (1 - \theta_t^*) A^* f_{KK^{*},t} - \lambda_{6,t} + \]

55
\[ \lambda_{9,t}A^*[(1 - \tau^*_t)f_{KL^*,t}L^*_t + (1 - \theta^*_t)f_{KK^*,t}J^*_t] = 0 \]

and only for \( t > 0 \)

\[ \lambda_{8,t-1}/\beta - \lambda_{6,t} - \lambda_{8,t}[1 + (1 - \theta_t)(Af_{K,t} - \delta)] = 0 \] (B)

\[ -\lambda_{7,t-1}/\beta + \lambda_{6,t} + \lambda_{7,t}[1 + (1 - \theta_t)(Af_{K,t} - \delta)] = 0 \] (j)

\[ -\lambda_{9,t-1}/\beta + \lambda_{6,t} + \lambda_{9,t}[1 + (1 - \theta^*_t)(A^*f_{K^*,t} - \delta^*)] = 0 \] (j*)
References


