Optimal Fiscal Policy in a Transfer Union

Till Gross*

March 25, 2016

Abstract

I study optimal fiscal policy in a transfer union, where every constituency has to pay a share of its tax revenues into a pool which then disburses the funds back to its members. Fiscal policy is composed of source-based capital taxes, labor taxes, government consumption, productive infrastructure, and bonds. I analyze both a static model with a fixed global capital stock and a dynamic model where the capital stock evolves endogenously due to optimal savings decisions as in a neoclassical growth model. I use a closed economy as a benchmark and compare it to an open economy with perfectly mobile capital and varying degrees of transfers. In a static open economy without transfers, capital taxes are too low from a global welfare perspective, whereas infrastructure spending is too high. Labor taxes, government consumption, and infrastructure are all declining functions of the share of government revenues which are transferred. Capital taxes on the other hand are increasing in transfers. This also applies to the short run of a dynamic open economy. In the long run, capital taxes and infrastructure spending are efficient without transfers; in the presence of transfers, capital taxes remain efficient, whereas infrastructure spending is too low and decreasing in transfers. The dampened capital-tax and infrastructure competition in the static model and during the transition in the dynamic model means that welfare increases for low levels of transfers, even though there are no redistributive gains from transfers.

JEL Classification: F42, H21, H87, E62
Keywords: Transfer Union, Dynamic Optimal Taxation, Tax Competition, Open Economy, Capital Taxes, Capital Mobility

1 Introduction

In countries with a federal structure, it is common that each of their composing jurisdictions may set some taxes on their own; on a supra-national level, each member state of the European Union sets

*Department of Economics, Carleton University, 1125 Colonel By Dr., Ottawa, ON, Canada, K1S 5B6. Tel: 613-520-3744, Fax: 613-520-3906. Email: `till.gross@carleton.ca`. I would like to thank conference participants at the 2015 meetings of the Canadian Economic Association, in particular Constantine Angyridis, and seminar attendees at the University of Windsor, in particular Marcelo Arbex, for their comments. All errors remain of course my own.

its own taxes independently. At the same time, some of the tax revenues from each constituency are transferred to the federal level and then partly transferred back to the sub-federal level. For instance, in the European Union each member state contributes a share of its gross national income and value-added tax revenues and receives in turn funding for agriculture, cohesion policies, research, and other projects. In the aftermath of the recent European financial crisis, there have been calls for large automatic transfers between governments of the European Union. The question this paper seeks to answer is how a government's incentives to set fiscal policy are affected by a transfer union, where every constituency has to pay a share of its tax revenues into a pool which then disburses the funds back to its members.

I adopt an optimal taxation approach, where each government optimally chooses its fiscal policy – capital and labor taxes, infrastructure, government consumption, and debt – taking into account how this influences the decisions of private agents. Since the focus is on an international (or inter-jurisdictional) context with several interacting governments, optimal fiscal policy considers also the impact on foreign private agents' behavior and is contingent on the belief of foreign policy. I analyze Nash equilibria where these beliefs are consistent with the actual foreign strategy. Capital is assumed to be mobile, whereas labor is not. I consider both a static model, in which the world capital stock is exogenously given, and a dynamic model, in which capital is accumulated through agents' optimal savings decisions. I restrict myself to a symmetric two-country economy, in which there are no distributional benefits from transfers in order to focus on the distortions for public policy (similar to a conventional representative-agent tax model in which tax revenues are rebated back in a lump-sum fashion). The model easily extends to any number of jurisdictions and almost any type of asymmetry, though, and most analytical results remain qualitatively unchanged.[1]

Casual intuition would suggest that in the presence of intergovernmental transfers which are based on actual tax revenues, not some form of fiscal capacity, there is a positive externality emanating from taxes and productive public capital (which I use synonymously for infrastructure). The benefits accruing to the home government decrease and the benefits to the other government increase in revenue sharing, so one would thus presume that taxes and infrastructure spending (and hence also government consumption) are a decreasing function of transfers. The welfare effects should then be unambiguously negative.

[1]The exception are the analytical results in section 4.2.3 on cooperative policies, which rely on the symmetry assumption.

This casual intuition is partially correct: Labor taxes and government consumption are lower the higher the transfers. Concerning capital taxes and infrastructure, this intuition is misleading, though. In a static world, the capital stock is an endowment and should be taxed as much as possible in a closed economy (say at 100%), as these taxes are non-distortionary. When the economy is open, each government has an incentive to lower capital taxes to attract capital from abroad, since the marginal social product of capital is higher than the private return to capital for foreign investors, creating a positive intratemporal externality for capital taxes. This leads to inefficient tax competition and a race to the bottom, which is a well-established result in the large literature on this subject.[2] With transfers, the benefits of attracting capital are diminished as only a fraction of the wedge between capital's marginal product and the investor's private net return flows to the home government and the rest goes abroad in transfers. Transfers thus reduce capital-tax competition.

Similarly, there is infrastructure competition in a static open economy without transfers; infrastructure attracts capital from abroad and due to the non-cooperative nature of the game, governments do not take this negative externality on the other country into account. With transfers, the cost of public funds is higher and governments provide less infrastructure, dampening the infrastructure competition. This implies that for lower levels of transfers, welfare increases in transfers. For higher levels of transfers, governments provide less infrastructure than what would be efficient, though.

In the dynamic version of the model, besides the positive intratemporal externality of capital taxes an additional *intertemporal* negative externality exists, as Klein and Makris (2014) show. Future capital taxes reduce the incentives to save and reduce the global capital-stock, and since this is shared by all countries, these effects are not fully internalized. Similarly, higher infrastructure spending increases the returns to capital and thereby encourages savings and expands the global capital stock. As I have argued above, the benefits of attracting capital are diminished by transfers, so the negative intertemporal externality of capital taxes is exacerbated by transfers (and the costs of infrastructure increase in transfers, diminishing the positive intertemporal externality of infrastructure).

[2]Zodrow and Mieszkowski (1986) and Wilson (1986) were the pioneering papers. Nicodème (2006) provides a review. If governments are not maximizing the welfare of their citizens, then capital-tax competition can discipline these leviathan governments and improve welfare, as Edwards and Keen (1996) and Eggert (2001) argue, so Wilson and Wildasin (2004) ask the question whether tax competition is a "Bane or Boon." In this paper I abstract from political-economy considerations and assume a benevolent government, although the results for infrastructure and long-run capital allocations are not affected by having self-interested governments.

In steady state, capital taxes and infrastructure are at their efficient levels without transfers. The externalities vanish in the long run, since lower capital taxes or higher infrastructure no longer attract capital from abroad, but instead create their own supply by encouraging savings. With perfect commitment and a complete tax system, long-run capital taxes are used to implement the efficient (first-best) capital allocation and not to raise revenues.[3] This carries over to open economies (Gross, 2014, 2015a). The long-run capital taxes in the present paper also implement the efficient capital allocation and since revenues are purely incidental, the fact that some of these revenues are transferred abroad is of no relevance. The logic is that in the short run, capital taxes are used to tax (in)directly the initial asset position; this motive disappears in the long run. Both the intratemporal and intertemporal externality hence converge to zero and transfers do not impact optimal capital taxes. However, for infrastructure the costs are in terms of public funds, which are higher with transfers – the long-run infrastructure allocation is therefore distorted downwards by transfers.

It is then not surprising that welfare gains from transfers are smaller and occur only at lower levels of transfers in a dynamic world as compared to a static one. To further study the welfare consequences of transfers, I consider two alternative transfer schemes and evaluate their effects on welfare: one in which infrastructure spending is deducted from the transferable tax revenues and another in which government consumption is deducted. Due to the infrastructure competition in the short run, the first is only doing better for higher levels of transfers than the baseline transfer scheme without deductions. The second generally leads to higher welfare than the baseline transfers and also fares better than the first.

I consider a one-shot game between governments, as each is able to commit perfectly. This is mainly important in relation to private agents, in the sense of committing to not expropriate their wealth in the future, and not in relation to other governments. For repeated games between governments, one would have to consider imperfect commitment (I briefly discuss this in section 5). The perfect-commitment case provides a benchmark, which is important when considering welfare implications (i.e. whether taxes and allocations are efficient or not). Repeated games and limited

[3] I discuss this in detail in Gross (2015b), where I argue that capital is an intertemporal intermediate good in the long run (the initial capital stock is obviously not an intermediate good). Intermediate goods should be provided efficiently and if taxes are necessary to implement the efficient allocation of an intermediate good, then the revenues thus generated are purely incidental. In this paper, capital taxes are necessary to tax away the firms' profits which go to capital owners, otherwise capital would be over-provided. Capital taxes can thus be seen similarly to Pigouvian taxes.

commitment could be interesting to study inter-governmental commitment problems of equalization transfers, though (as for example in Akai and Sato (2008) in a quasi-static model).

I discuss the related literature in the next subsection, but these are the two main contributions of this paper: (i) I present a general model of optimal fiscal policy with strategic interaction in a static context – consisting of capital and labor taxes, government consumption, and infrastructure provision – and discuss how revenue transfers affect the incentives to conduct fiscal policy, whereas the literature focuses on a subset of these policies. (ii) I extend this model to a dynamic context and show how the results deviate from a static model: In particular, for capital taxes and infrastructure the static model captures reasonably well the short-run but not the long run. As far as I know, the literature has not considered fully dynamic fiscal policy and transfers at all.

The remainder of the paper is organized as follows: In the following subsection I discuss the related literature, in section 2 I present the economic environment, and section 3 lays out the structure of the game between governments and agents. In section 4 I show the optimal policies, whereas section 5 discusses the results and different transfer schemes. The last section concludes and proposes avenues for future research. In the appendix I show the parametrizations and results for all parameter robustness checks and the alternative transfer schemes.

1.1 Related Literature

The result of dampened capital-tax competition in a static model is in line with previous work on equalization schemes, where transfers are based on a region's fiscal capacity and not on their actual tax revenues: Smart (1998) and Büttner (2006) show that distortionary taxes may actually increase as a function of transfers and Bucovetsky and Smart (2006) argue that this may improve efficiency under tax competition. The reason for this is different than in the current model, however: when transfers are based on fiscal capacity, then higher transfers imply there is less of an incentive to improve a jurisdiction's fiscal capacity and this applies to all factors of production, not just capital. In my model, transfers are based on actual tax revenues and transfers provide more incentives to tax capital, but less incentives to tax labor. This is similar to one setup in Köthenbürger (2002), which does not involve optimal taxation, though. Furthermore, the above papers do not consider dynamics or infrastructure provision.

Cai and Treisman (2005) study tax competition and infrastructure provision in a static model with heterogeneous regions and find that less productive countries may invest less in productive infrastructure and more productive countries invest more in an open economy as compared to a closed economy; there is only one available tax on output. The study by Liu (2014) is based on this and studies fiscal equalization but also does not consider optimal taxation – the tax rate is decided exogenously. Keen and Marchand (1997) examine small open economies and find that infrastructure is provided efficiently when all factors of production can be taxed.[4] They do not consider transfers or strategic interaction. Becker and Fuest (2010) study the coordination of transport infrastructure within a union with outside countries, but there is no optimal taxation and there are no transfers. Gomes and Pouget (2008) focus on optimal infrastructure provision and tax competition, but explicitly exclude optimal dynamic taxation, which the authors say is "well beyond the scope of our study" (p.15). Their tax competition is also somewhat different from the usual setup, in that it is about profit-shifting: corporate taxes are levied on reported profits and not on returns to capital, and it is costly for corporations to shift profits. Bayindir-Upmann (1998) considers two different games of competition between governments, one over tax rates and one over public goods – but not a game with optimal fiscal policy as a whole.

On transfers, Boadway (2004) provides an overview, which stresses the fact that equalizing transfers mostly occur when there is a federal government on top of the regional governments. It is thus strongly related to the theory of decentralization, Boadway (2001). Boadway distinguishes between gross equalization (with transfers from the federal level to the regions) and net equalization (with inter-regional direct transfers). The transfers in this paper can thus be classified as a net equalization scheme. Baretti, Huber, and Lichtblau (2002), Büttner (2006), and Egger, Köthenbürger, and Smart (2010) empirically study transfers in Germany and find that they tend to reduce tax revenues; Smart (2007) finds similar, although quantitatively larger, results for Canada. Breuillé, Madiès, and Taugourdeau (2010) compare the welfare consequences of gross as compared to net equalization transfers and find that the latter distort the tax incentives of regional governments less.

Hindriks, Peralta, and Weber (2008) set up a model of equalization transfers based on actual revenues, where governments choose public infrastructure and capital taxes. The analysis is confined to a static environment without optimal taxation of labor and government consumption and uses specific functional forms. They find that without transfers there is undertaxation and under-

[4]This contrasts with the results of static infrastructure competition in the current paper since their infrastructure is built from output, whereas I assume that it uses the initial capital stock. This is also discussed in section 5.

provision of infrastructure and higher transfers leave taxes unchanged, but decrease infrastructure investment, leading to a welfare improvement. These results are at odds with what I find, that short-run capital taxes rise. In my understanding, these differences are due to the fact that I consider the whole of optimal fiscal policy, including labor taxes and government consumption, chosen simultaneously, whereas Hindriks, Peralta, and Weber (2008) have governments decide sequentially their capital taxes and infrastructure investment. Related to this, Köthenbürger (2011) emphasizes that optimizing over taxes or expenditures for local governments may lead to different results. It can thus matter whether one is studying optimal fiscal policy as a whole or a subset of it.

The literature on equalizing transfers does not, to the best of my knowledge, extend to a fully dynamic environment.[5] This paper also relates to and builds on the small literature in dynamic optimal taxation in open economies.[6] Correia (1996) extended the Chamley-Judd result of zero long-run capital taxes to a small open economy; Gross (2014) does the same for large open economies. Angyridis (2007) studies a stochastic small open economy. Klein and Makris (2014) focus on a computational analysis of transition dynamics in a two-country model. Gross (2015a) shows that under certain assumptions the long-run capital allocations and qualitative capital-tax conclusions derived in closed-economy models transfer to open economies.

2 Economic Environment

I present a baseline economy with two jurisdictions which are part of a transfer union, i.e. a certain fraction of tax revenues from each jurisdiction flows into a common pool which is then transferred back. Both jurisdictions are identical and populated by a representative agent; there is no outside world in this model. These simplifications allow me to focus on the different incentives created by the transfer union as opposed to the potential welfare gains from redistribution between asymmetric countries. The analytic results can be generalized to a model with any number of

[5]The dissertation by Kim (2014) considers a dynamic economy with transfers similar to the one presented in this paper but does not show any analytical results. Moreover, the numerical implementation unfortunately does not take into account the transition path and so even in steady state it is not clear what the system of equations is actually solving for. Similarly, Gong and Zou (2002) have a government maximize steady-state welfare subject only to steady-state constraints. There are two state governments and one federal government, but there is no capital mobility and no interaction between state governments. Moreover, local consumption taxes are non-distortionary due to a perfectly inelastic labor supply.

[6]Wildasin (2003), Köthenbürger and Lockwood (2010), and Hatfield (2015) all consider dynamics in small open economies, but not dynamic optimal taxation in the sense of allowing for time-varying taxes and for the taxation of labor income, while precluding lump-sum taxes.

countries, including countries outside of the transfer union, with almost any type of asymmetry, and to heterogeneous agents with non-linear labor taxes.[7]

A fixed measure of perfectly competitive firms produce output in each country from labor and capital. There are constant returns to scale in these two private inputs and publicly-provided infrastructure, resulting in profits. These are returned to the firms' shareholders, which provide the capital; this is the reason why capital taxes are optimally positive in the long run.[8]

Capital investment stems from globally acting, perfectly competitive investment firms. They collect individuals' savings and invest them in government bonds and capital in both countries. Capital is perfectly mobile, while labor is immobile. The government in each country aims to maximize the home agent's utility and has capital and labor taxes at its disposal to finance public consumption and infrastructure spending. Capital taxes are paid according to the territorial principle, i.e. they are paid where the capital is employed. The two governments engage in a one-shot game with each other to which agents and firms then react.

The initial capital stock is exogenously given. The economic environment for the static and dynamic model is the same, except that in the latter capital after period zero is accumulated through agents' optimal savings decisions and the government may also issue bonds. In the dynamic model, the game-theoretic structure remains the same, i.e. a one-shot game, only that governments announce a sequence of taxes, spending decisions, and bond issues at time zero. The government can thus commit perfectly to its future actions.

I present the dynamic model and briefly outline what changes in the static model. The time horizon shrinks to period zero, so generally all intertemporal decisions disappear. Foreign prices and allocations are denoted by an asterisk.

[7]I do require a common discount factor, otherwise a stable non-degenerate long run does not exist. These results transfer easily from my previous work on international capital taxation, Gross (2014, 2015a). As mentioned before, the exception are the analytical results in section 4.2.3 on cooperative policies.

[8]This formulation allows for constant returns to scale in all production factors, but results would remain qualitatively unchanged if there were increasing returns to scale (however still assuming decreasing returns in accumulable factors, i.e. private and public capital, otherwise all capital could be attracted to only one country). It also does not matter qualitatively whether capital is optimally taxed in the long run or not.

2.1 The Representative Agent

There is a measure one of agents in each country, taking prices and taxes as given and maximizing lifetime utility:

$$\sum_{t=0}^{\infty} \beta^t u(c_t, l_t, G_t). \tag{1}$$

$u(c_t, l_t, G_t)$ is a utility function that is strictly increasing and strictly concave in private consumption c_t, leisure l_t, and government consumption G_t (all terms here are in per-capita terms, which is equal to the aggregate, since the population size is unitized). $\beta \in (0, 1)$ is the discount factor. The household divides up its total unitized time between labor N_t and leisure. The per-period budget constraint is:

$$c_t = (1 - \tau_t^n) w_t N_t + (1 + R_t) a_t - a_{t+1}. \tag{2}$$

w_t is the domestic wage, τ_t^n are labor taxes, a_t are asset holdings, and R_t is the international net rate of return. Initial asset holdings a_0 are exogenously given.

Utility maximization implies the familiar labor-leisure trade-off and an Euler equation concerning the trade-off between consumption today versus tomorrow (subscripts denote derivatives, e.g. $u_c(t) = \partial u(c_t, l_t, G_t)/\partial c_t$):

$$u_l(t) = u_c(t)(1 - \tau_t^n) w_t \tag{3}$$

$$u_c(t) = \beta u_c(t + 1)(1 + R_{t+1}) \tag{4}$$

Equations (2), (3), and (4) characterize the household behavior together with initial asset holdings and no-Ponzi conditions (which I leave out for notational convenience). In the static model, there is no optimal savings decision to be done, so I set $a_1 = a_0$ and the Euler equation disappears.[9]

2.2 Firms and Production

There is a continuum of identical firms of measure one. Since they are perfectly competitive, I focus on a representative firm, which produces output used for private and public consumption and investment. To obtain an analytical expression for optimal capital taxes in the long run (and since a functional form has to be chosen anyway to run simulations), I assume the following Cobb-Douglas

[9] Letting $a_1 = a_0$ is to prevent the household from consuming the entire capital stock, but this does not affect results qualitatively.

production function:[10]

$$F(K_t, I_t, N_t) = ZK_t^{\alpha} I_t^{\iota} N_t^{1-\alpha-\iota}. \tag{5}$$

Z is the firm's productivity, K_t is the firm's capital, I_t is the country's infrastructure, and N_t the amount of labor the firm hires.

Firms are lent capital K_t by investors and aim to maximize total dividends, $r_t K_t$, where r_t is the dividend (or rate of return) per unit of capital, by choosing labor input N_t:

$$\begin{aligned} \max_{N_t} \quad & r_t K_t \\ \text{s.t.} \quad & F(K_t, I_t, N_t) - w_t N_t \geq r_t K_t. \end{aligned} \tag{6}$$

The wage and rate of return on capital are thus determined by

$$w_t = (1 - \alpha - \iota) F(K_t, I_t, N_t)/N_t \tag{7}$$

$$r_t = (\alpha + \iota) F(K_t, I_t, N_t)/K_t. \tag{8}$$

2.3 The Government

Each government decides its spending on government consumption G_t and the infrastructure level I_t, as well as taxes on capital and labor income, to maximize the discounted life-time utility of its citizens. It may also issue government bonds b_{t+1} at an interest rate $\tilde{r}$ (initial obligations are assumed to be zero, except in one alternative parametrization); in the static case, $b_{t+1} = b_t$. I assume that infrastructure is rented from capital markets in order to be able to keep the model general enough to incorporate the static and dynamic case in a symmetric manner; the cost of renting one unit of infrastructure is $\hat{r}_t$.[11] The government's per-period budget constraint can be

[10] The analytical results remain qualitatively unchanged for any well-behaved production function with decreasing returns in reproducible inputs, i.e. capital and infrastructure. Capital depreciation is included in the investors' problem below.

[11] Assuming that infrastructure is a stock which is owned by the government does not alter the long-run results in the dynamic model. In the static model, this assumption would obviously lead to the problem that infrastructure is not a choice variable.

written as

$$G_t + I_t\hat{r}_t + b_t(1+\tilde{r}_t) = \tag{9}$$
$$(1-T)[\tau_t^k r_t K_t + \tau_t^n w_t N_t] + TH[\tau_t^k r_t K_t + \tau_t^n w_t N_t + \tau_t^{*k} r_t^* K_t^* + \tau_t^{*n} w_t^* N_t^*] + b_{t+1}.$$

$0 \leq T < 1$ is the fraction of government revenues which is channeled into the common pool and $0 < H \leq 1$ is the share of the funds in this pool which are given back to the home country (in the symmetric case considered here, $H = 1/2$). I assume that capital taxes are bounded above by 1 and that taxing initial capital at this rate is not enough to achieve first-best government consumption and infrastructure provision with zero taxes. This constraint is only relevant for the closed-economy benchmark and the static case of cooperative policies, so I generally suppress mentioning it.

2.4 Investors

Investors allocate savings from agents into firm capital, infrastructure, and government bonds to maximize their profits (which are zero in equilibrium). Capital returns are taxed at source in each country and private capital depreciates at rate δ_K.[12] Public capital depreciates at rate $\delta_I = \delta_K$. The representative investor's profit maximization problem is

$$\max_{K_t,K_t^*,I_t,I_t^*,b_t,b_t^*,a_t,a_t^*} [r_t(1-\tau_t^k) - \delta_K]K_t + [r_t^*(1-\tau_t^{*k}) - \delta_K]K_t^* + [\hat{r}_t - \delta_I]I_t + [\hat{r}_t^* - \delta_I]I_t^* \tag{10}$$
$$+ b_t\tilde{r}_t + b_t^*\tilde{r}_t^* - (a_t + a_t^*)R_t$$
$$\text{s.t.}\ a + a^* = K + K^* + I + I^* + b + b^*. \tag{11}$$

[12] Capital depreciation is not tax-deductible in order to generate a clean optimal capital tax; this does not affect the analytical results, though. Also, I implicitly assume that returns on government bonds, and thus infrastructure lending, are not taxed. As shown below, no-arbitrage requires that returns on government bonds have to be equal to dividends from firms. It therefore does not matter whether bond returns are taxed or not.

The first-order conditions are the common no-arbitrage conditions.[13] The net returns on each asset have to be equal to each other and the international rate of return:

$$R_t = r_t(1 - \tau_t^k) - \delta_K \tag{12}$$

$$\begin{aligned} R_t &= r_t^*(1 - \tau_t^{*k}) - \delta_K \\ &= \hat{r}_t - \delta_I \\ &= \hat{r}_t^* - \delta_I \\ &= \tilde{r}_t \\ &= \tilde{r}_t^*. \end{aligned} \tag{13}$$

From here on I will replace $\hat{r}_t$ and $\hat{r}_t^*$ by $R_t + \delta_I$ and $\tilde{r}_t$ and $\tilde{r}_t^*$ by R_t.

3 The Game Structure

Governments are able to commit perfectly and announce their policies simultaneously at time zero for the infinite future. With internationally involved governments, perfect commitment corresponds to a one-shot game between governments and repeated games correspond to imperfect commitment. The perfect commitment case is a benchmark and one can deduce the effects of imperfect commitment from there; I discuss this in section 5.

Households, firms, and investors then react optimally to the announced policies. Incorporating their optimality conditions as constraints allows the government to directly use all of the private sector's choice variables as its own control variables. The other government is a strategic actor and chooses its policy at the same time. The foreign policy can therefore not be chosen by the home government. For any belief of foreign policy, the home government determines its best-response. This is a generalized game where the equilibrium is feasible, but off-equilibrium behavior is generally not (that is, the worldwide resource constraint will hold only in equilibrium).[14] The

[13] I assume that even in the limit, when capital taxes approach one, these no-arbitrage conditions still hold; this is purely to keep the discussion of cooperative policies simpler and has no impact on the non-cooperative game.

[14] A more detailed discussion of the equilibrium concepts for large open economies without transfers can be found in Gross (2014), where I also show how a different equilibrium concept can be used to allow for feasible off-equilibrium behavior. While this alternative equilibrium concept does not affect results in Gross (2014), it would do so in the presence of transfers.

domestic government's Lagrangean is

$$
\begin{aligned}
\pounds = & \sum_{t=0}^{\infty} \beta^t \{u(c_t, l_t, G_t) \\
& +\psi_t[(1-T)(\tau_t^k r_t K_t + \tau_t^n w_t N_t) + TH(\tau_t^k r_t K_t + \tau_t^n w_t N_t + \tau_t^{*k} r_t^* K_t^* + \tau_t^{*n} w_t^* N_t^*) + \\
& \quad b_{t+1} - G_t - I_t(R_t + \delta_I) - b_t(1+R_t)] \\
& +\theta_t[(1-\tau_t^n) w_t N_t + (1+R_t) a_t - a_{t+1} - c_t] \\
& +\mu_t[(1-\tau_t^n) w_t u_c(t) - u_l(t)] \\
& +\zeta_{t|t>0}[(1+R_t) - u_c(t-1)/(\beta u_c(t))] \\
& +\theta_t^*[(1-\tau_t^{n*}) w_t^* N_t^* + (1+R_t) a_t^* - a_{t+1}^* - c_t^*] \\
& +\mu_t^*[(1-\tau_t^{n*}) w_t^* u_c^*(t) - u_l^*(t)] \\
& +\zeta_{t|t>0}^*[(1+R_t) - u_c^*(t-1)/(\beta u_c^*(t))] \\
& +\gamma_t[r_t(1-\tau_t^k) - \delta_K - R_t] \\
& +\gamma_t^*[r_t^*(1-\tau_t^{k*}) - \delta_K - R_t] \\
& +\omega_t[a_t + a_t^* - (K_t + K_t^* + I_t + I_t^* + b_t + b_t^*)]\},
\end{aligned}
\tag{14}
$$

where w and r are functions of K and n as described in equations (7) and (8) and $l_t = 1 - n_t$ (and similarly for abroad). The set of control variables in the dynamic world is

$$X = \{c_t, c_t^*, N_t, N_t^*, K_t, K_t^*, a_{t+1}, a_{t+1}^*, b_{t+1}, \tau_t^k, \tau_t^n, G_t, I_t, R_t\}_{t=0}^{\infty}. \tag{15}$$

In the static world, this reduces to $\{c, c^*, N, N^*, K, K^*, \tau^k, \tau^n, G, I, R\}$.

Definition 1 (Optimal Response Function)**.** *An optimal response function is a sequence of taxes* $\{\tau_t^k, \tau_t^n\}_{t=0}^{\infty}$*, government spending and infrastructure levels* $\{G_t, I_t\}_{t=0}^{\infty}$*, and bond issues* $\{b_t\}_{t=1}^{\infty}$ *(*τ^k*,* τ^n*,* G*, and* I *in the static case) for any belief of foreign policy* $\{\tau_t^{k*}, \tau_t^{n*}, G_t^*, I_t^*, b_{t+1}^*\}_{t=0}^{\infty}$ *(*τ^{k*}*,* τ^{n*}*,* G^**, and* I^* *in the static case) maximizing the agent's discounted lifetime utility such that the government budget constraint holds every period. The resulting allocations are such that*

1. *agents at home and abroad choose consumption, labor supply, and asset holdings to maximize their utility subject to their budget constraint, taking prices and taxes as given;*

2. *firms at home and abroad choose labor to maximize dividends, taking capital and wages as given;*

3. *investors choose asset borrowing and bond, infrastructure, and capital lending at home and abroad to maximize profits, taking prices and taxes as given.*

A strategy specifies the action taken at each information node of a game; since it is a one-shot game, a strategy corresponds to choosing a policy sequence.

Definition 2 (Tax Competition Equilibrium)**.** *A tax-competition equilibrium is a sequence of prices* $\{w_t, r_t, w_t^*, r_t^*, R_t\}_{t=0}^{\infty}$ *(w, r, w^*, r^*, R in the static case), government policies* $\{\tau_t^n, \tau_t^{n*}, \tau_t^k, \tau_t^{k*}, G_t, G_t^*, I_{t+1}, I_{t+1}^*, b_{t+1}, b_{t+1}^*\}_{t=0}^{\infty}$ *($\tau^n, \tau^{n*}, \tau^k, \tau^{k*}, G, G^*, I, I^*$ in the static case), and allocations* $\{c_t, c_t^*, N_t, N_t^*, K_t, K_t^*, a_{t+1}, a_{t+1}^*\}_{t=0}^{\infty}$ *(c, c^*, N, N^*, K, K^* in the static case) such that each government's equilibrium policy is an optimal response function to the other government's equilibrium policy.*

If an equilibrium exists, it will satisfy the worldwide resource constraint. In an equilibrium, each country plays an optimal response to the other country's policy; thus, each country's government budget constraint has to hold. Moreover, the budget constraints of both households and the capital market equation (with Lagrange multiplier ω) also hold. Combining these equations and using the fact that $w_t n_t + r_t K_t = F(K_t, I_t, N_t)$, yields the worldwide resource constraint:

$$\begin{aligned} &F(K_t, I_t, N_t) + K_t(1-\delta_K) - K_{t+1} + I_t(1-\delta_I) - I_{t+1} - c_t - G_t + \\ &F^*(K_t^*, I_t^*, N_t^*) + K_t^*(1-\delta_K) - K_{t+1}^* + I_t^*(1-\delta_I) - I_{t+1}^* - c_t^* - G_t^* = 0. \end{aligned} \tag{16}$$

This worldwide resource constraint also illustrates that infrastructure is a stock just like capital, even though it is modeled somewhat unconventionally in that it is rented by governments from capital markets. In a static setting, $K_1 = K_0$ and similarly for infrastructure and the corresponding variables abroad.

4 Optimal Fiscal Policy

In this section I characterize the optimal fiscal policy for a static and a dynamic world. Analytical results can only be obtained concerning capital and infrastructure, which is why I also resort to numerical simulations. I first define a closed-economy benchmark and then show results for the static and dynamic open-economy setting. The interpretation and discussion of the results are left to the next section.

4.1 Closed-economy Benchmark

It is useful to define a closed economy as a benchmark, where the government does not have to deal with strategic issues between countries: Under the assumption of symmetry, this also corresponds to the solution for a global social planner in an open economy (with equal weights for each country's welfare). In technical terms, one can still use the previous Lagrangean, equation (14), by simply setting all variables with an asterisk to zero and excluding them as choice variables where applicable; the transfers T are obviously zero in this case.

Proposition 1. *In a closed static economy, optimal capital taxes are set to the maximum,* $\tau^k = 1$*, and the optimal infrastructure allocation is characterized by* $F_I(K, I, N) = F_K(K, I, N)$*.*

The proof is in the appendix. The proposition is straightforward from an optimal-taxation perspective: The initial capital stock is an endowment and should be taxed as much as possible. Since the net return to capital is driven down to zero, the cost of infrastructure is equal to the opportunity cost of having less capital and hence the marginal products should be equalized. This corresponds to the first-best efficient infrastructure allocation when the government has access to lump-sum taxes (note that government consumption is not at its first-best level, though).

Corollary 1. *In a closed static economy, when capital taxes are constrained to be less than one,* $\tau^k < 1$*, then the optimal infrastructure allocation satisfies* $F_I(K, I, N) > F_K(K, I, N)$*.*

The proof is in the appendix. Again, this is straightforward: If the initial capital stock cannot be taxed at 100%, then the fiscal costs of public capital (infrastructure) compared to private capital matter and the marginal product of infrastructure is higher than that of capital, i.e. infrastructure is at less than the first-best level.

For the long run I focus on steady states, but the qualitative results also apply on average to any stable non-degenerate long run, which transfers from earlier work: Judd (1999) for a closed economy and Gross (2014, 2015a) for open economies.

Proposition 2. *In a closed dynamic economy, the optimal steady-state capital and infrastructure allocations are characterized by* $1 - \delta_K + F_K(K_{SS}, I_{SS}, N_{SS}) = 1/\beta$ *and* $F_I(K_{SS}, I_{SS}, N_{SS}) =$

$F_K(K_{SS}, I_{SS}, N_{SS})$, respectively. The optimal capital tax is $\tau^k_{SS} = \iota/(\alpha + \iota)$.

The proof is in the appendix. This is a simple extension of the work by Chamley (1986) and Judd (1999). The capital and infrastructure allocations follow the modified golden rule and capital taxes are used to implement this by reducing the super-returns of capital to its marginal product. Capital tax revenues are therefore purely incidental. In the long run, the capital stock is determined endogenously (unlike the initial capital endowment) and public and private capital are thus intertemporal intermediate goods. These are provided without distortions, even when the public capital has to be paid for through distortionary taxes.

4.2 Static World

I first present the analytic results, which are useful to understand the factors at play and since this facilitates comparison to the dynamic case. Moreover, the analytic results of the Nash game can be put in contrast with cooperative policies, revealing that non-cooperative capital taxes and infrastructure provision are lower than with cooperation. To illustrate optimal policy in general, I use numerical simulations. I graphically show how fiscal policy changes as a function of transfers.

4.2.1 Analytical results

The first-order conditions with respect to capital, infrastructure, and labor and capital taxes are

$$K\colon\ \psi[1-T(1-H)]\left[\tau^k r + \tau^k K\frac{\partial r}{\partial K} + \tau^n N\frac{\partial w}{\partial K}\right] + \theta(1-\tau^n)N\frac{\partial w}{\partial K} \tag{17}$$
$$+\,\mu u_c(1-\tau^n)\frac{\partial w}{\partial K} + \gamma(1-\tau^k)\frac{\partial r}{\partial K} = \omega,$$
$$I\colon\ \psi[1-T(1-H)]\left[\tau^k K\frac{\partial r}{\partial I} + \tau^n N\frac{\partial w}{\partial I}\right] + \theta(1-\tau^n)N\frac{\partial w}{\partial I} \tag{18}$$
$$+\,\mu u_c(1-\tau^n)\frac{\partial w}{\partial I} + \gamma(1-\tau^k)\frac{\partial r}{\partial I} = \omega + \psi(R+\delta_I),$$
$$\tau^n\colon\ \psi[1-T(1-H)]Nw = \theta N w + \mu u_c w, \tag{19}$$
$$\tau^k\colon\ \psi[1-T(1-H)]Kr = \gamma r. \tag{20}$$

Inserting equations (19) and (20) into equations (17) and (18) yields

$$\psi[1-T(1-H)]\left[\tau^k r + K\frac{\partial r}{\partial K} + N\frac{\partial w}{\partial K}\right] = \omega \tag{21}$$

$$\psi[1-T(1-H)]\left[K\frac{\partial r}{\partial I} + n\frac{\partial w}{\partial I}\right] = \omega + \psi(R+\delta_I). \tag{22}$$

Furthermore, total production has to equal total factor remuneration $F(\cdot) = Kr + Nw$. Differentiating this identity with respect to capital leads to $F_K = K(\partial r)/(\partial K) + r + N(\partial w)/(\partial K)$. Equation (21) then becomes

$$\psi[1-T(1-H)][F_K - \delta_K - R] = \omega. \tag{23}$$

Equation (23) shows the benefits from an additional unit of capital on the left and the costs on the right. The benefits are expressed (using the optimality of taxes) in terms of fiscal gains. $F_K - \delta_K - R$ is the capital wedge, i.e. the difference between social and private returns to capital, $F_K - \delta_K$ and R respectively. At the optimum, the value of the wedge (its size multiplied by the value per unit, $\psi[1-T(1-H)]$) is equal to the shadow value of one unit of the stock of global assets ω. This implies somewhat paradoxically that a higher $T(1-H)$ should result in a larger capital wedge. The Lagrange multipliers ψ and ω are of course also changing with transfers, but as the numerical simulations below confirm, the direct effect is always stronger than the indirect effects through the Lagrange multipliers. Optimal capital taxes can be expressed as

$$\tau^k = \frac{\iota}{\alpha+\iota} + \frac{\omega}{\psi[1-T(1-H)]}\frac{1}{r}. \tag{24}$$

The first term on the right in equation (24) is the (efficient) optimal steady-state capital tax in a dynamic world with endogenous savings (see below). The second term is larger the more the home government can influence the global rate of return.[15] As explained above for the capital wedge, capital taxes in a static environment are higher the larger the revenue sharing.

For the optimal infrastructure decision, one can substitute F_I for $K(\partial r)/(\partial I) + N(\partial w)/(\partial I)$

[15] From the perspective of a small open economy, the relative size of the global asset stock is infinite, so $\omega = 0$. Note that as is well documented in the tax-competition literature, the positive externality of capital taxes implies that a larger country is worse off than a smaller country.

and from equation (23) $\psi[1-T(1-H)][F_K-\delta_K-R]$ for ω into equation (22) to obtain

$$F_I(K,I,N) = F_K(K,I,N) + r(1-\tau^k)\frac{T(1-H)}{1-T(1-H)}. \tag{25}$$

In equation (25), the first term on the right is how infrastructure is provided in first-best, i.e. where the marginal product of public infrastructure is equal to the marginal product of capital. The second term captures how revenue-sharing influences infrastructure provision: the higher $T(1-H)$, the larger the term (the interest rate net of taxes $r(1-\tau^k)$ is also a function of $T(1-H)$, but the numerical results show again that these indirect effects do not outweigh the direct effects). We can thus conclude that the higher the revenue-sharing, the higher the marginal product of infrastructure relative to the marginal product of capital and thus the lower the level of infrastructure.

Comparing these results with zero transfers to the second-best solution in a closed economy, it becomes apparent that capital taxes are lower in an open economy and that given these capital taxes, infrastructure provision is higher:

Proposition 3. *In the absence of transfers, capital taxes are lower in an open than a closed economy in a static environment, while infrastructure levels are higher given these capital taxes.*

4.2.2 Numerical results

In this section I present the results for simulations of open economies with different degrees of revenue sharing. For the parametrization I use a closed economy where the capital tax rate is set to the long-run efficient rate. I set the capital coefficient in the production function to $\alpha = 0.3$ and the infrastructure one to $\iota = 0.05$. This results in a share of roughly 1/3 of total income going to capital owners, which is the common estimate. The infrastructure share is in line with results for the United States from a meta study by Bom and Ligthart (2014). Depreciation is $\delta_K = \delta_I = 0.08$. The utility function takes the form $u(c,l,G) = ln(c) - e(1-l)^\sigma + gln(G)$, similar to Klein and Makris (2014), with $e = 7.1$ and $\sigma = 3$ resulting in time worked being 0.33 (the corresponding labor-supply elasticity is 0.5).[16] Unlike Gomes and Pouget (2008) I do not include infrastructure in the utility function, so as to be able to cleanly separate the implications of transfers for the provision of a government consumption good versus public capital. Productivity is normalized to

[16]It is well understood that all parameters are calibrated jointly and that one cannot attribute meeting one target to one specific parameter; I still portray it in such a way to illustrate what the calibration goals were and which parameters influence which target the most.

one. The parameter for government consumption is $g = 0.55$, with total government expenditures $G + (R + \delta_I)I$ being 40% of output, in accordance with values reported for the United States. The initial asset endowment is $a_0 = 1.32$ so that the return to capital net of depreciation and taxes is 4.0%.

The main results are embedded in figure 1. It shows the optimal fiscal policy as a function of the degree of revenue sharing T, normalized to be a fraction of the policy when $T = 0$. The higher the revenue-sharing, the lower the labor taxes and the expenditures (both consumption and infrastructure), but the higher the capital taxes.

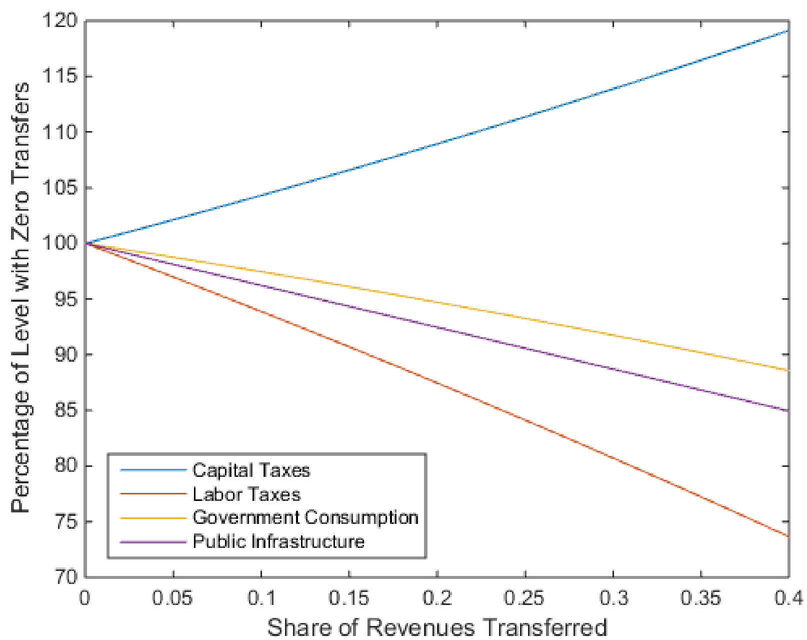


Figure 1: Optimal Fiscal Policy as a function of Transfers

It is instructive to compare these results to optimal policy in a closed economy for which the capital-tax rate is exogenously fixed at the equilibrium level from an open economy with transfers. Due to symmetry, the only change from a closed to an open economy is the externality of the common capital stock. Figure 2 shows that in an open economy without transfers, infrastructure is over-provided, but that infrastructure is decreasing in transfers and at some point under-provided (in this calibration, from around 30% of revenues transferred onwards).

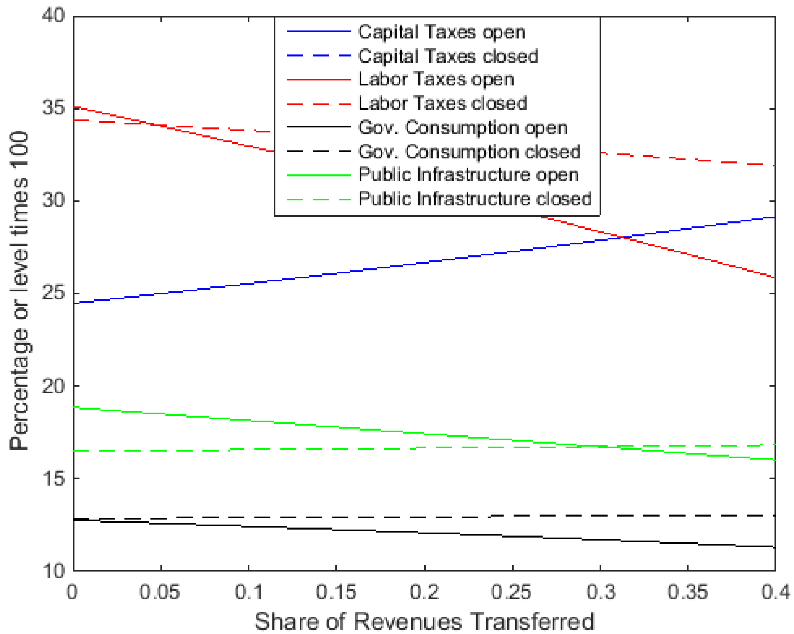


Figure 2: Comparison of Policy in Open and Closed Economies

Welfare is at first, for low levels of transfers, an increasing function of the size of transfers but then decreases. This is illustrated in figure 3, where I plot the consumption equivalent. This is defined as the percentage of private consumption that is needed to achieve the same utility as in an open economy without transfers.[17] A lower consumption equivalent thus implies higher welfare. While it may come as a surprise that transfers can increase welfare, it is also interesting to note that the welfare costs remain relatively low even for high levels of transfers. For example, for 40% of revenues transferred (which appears very high) the welfare costs are still below 0.2% of private consumption.

[17]Formally, I define the consumption equivalent $x_{(T=y)}$ for transfer level $T = y$ implicitly as the x that solves $U_{T=0} = ln(C_{T=y}x) - e(1 - l_{T=y})^{\sigma} + gln(G_{T=y})$, which can then be simplified to $x_{T=y} = \exp(U_{T=0} - U_{T=y})$. To obtain a percentage, I multiply this by 100.

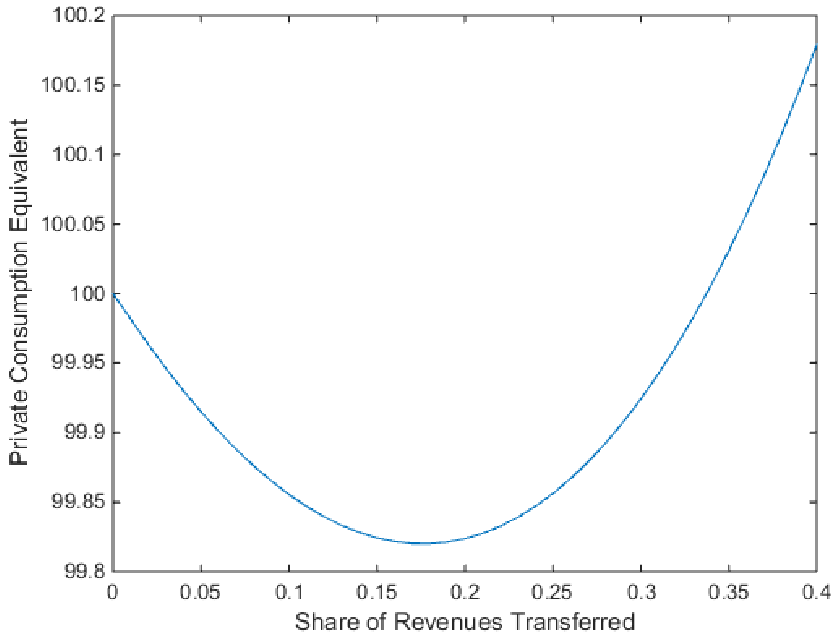


Figure 3: Consumption Equivalents as a function of Transfers

The results are qualitatively robust to different parameter specifications (in fact, I have not found any specifications for which results differed): I have run robustness checks for a higher infrastructure share ($\alpha = 0.25$ and $\iota = 0.1$), for a higher sigma ($\sigma = 3.5$), for a lower sigma ($\sigma = 2.5$), and for an initial government debt of 60% of output, where in each case e, g, and $a0$ adjust to meet the targets of $l = 0.33$, $(G + (R + \delta_I)I)/(F(K, N, I) - \delta_K K - \delta_I I) = 0.40$, and $r(1 - \tau^k) - \delta_K = 0.040$. I have also run a simulation as in the baseline, where I set the target for the share of government expenditures to 20% of output instead, as in Klein and Makris (2014). All parametrizations and results are presented in the appendix.

4.2.3 Cooperative Policies

When countries cooperate, they can implement an efficient allocation of infrastructure and set capital taxes to the globally optimal level, independent of revenue sharing. Formally, one can model this the same as before, except that the objective function includes the utility of the foreign agent and that the foreign fiscal policy is now part of the choice variables (which means adding the foreign government's budget constraint with a Lagrange multiplier ψ^*). Cooperative policies generate the same results as in a closed economy, i.e. full capital taxation and efficient infrastructure provision:

Proposition 4. *When governments cooperate, they set capital taxes to one and provide infrastructure efficiently, both of which are higher than in the non-cooperative game with transfers.*

Proof. Taking the first-order condition with respect to the global rate of return R yields

$$\theta a + \theta^* a^* = \psi(I + b) + \psi^*(I^* + b) + \gamma + \gamma^*. \tag{26}$$

The first-order conditions with respect to the domestic and foreign capital tax rate now imply $\gamma = \psi K$ and $\gamma^* = \psi^* K^*$ (using symmetry: $\psi = \psi^*$). Furthermore, $\theta = \theta^*$ and by capital-market clearing, $a^* = a = K + I + b$, which means that condition (26) implies $\theta = \psi$. This would suggest that lump-sum taxes on capital are so high that the economy is in first-best, where the value of resources for the government (ψ) is equal to that for private households (θ). Since this is ruled out by assumption, then taxes are as high as possible, i.e. the constraint that $\tau^k \leq 1$ is binding now.

Concerning the efficiency of infrastructure provision, the equations (21) and (22) now become[18]

$$(\psi[1 - T(1-H)] + \psi^* T(1-H)) \left[\tau^k r + K\frac{\partial r}{\partial K} + N\frac{\partial w}{\partial K}\right] = \omega \tag{27}$$

$$(\psi[1 - T(1-H)] + \psi^* T(1-H)) \left[K\frac{\partial r}{\partial I} + N\frac{\partial w}{\partial I}\right] = \omega + \psi(R + \delta_I). \tag{28}$$

Again, due to symmetry $\psi = \psi^*$ and since $\tau^k = 1$ it follows that $\omega = \psi F_K$ from equation (27). Combining this with equation (28) then leads to the conclusion that $F_I = F_K$, which is the efficient infrastructure allocation. This follows even though capital taxation is not enough to reduce the excess burden of taxation to zero, i.e. $\psi > \theta$.

Capital taxes in a non-cooperative game are below one (otherwise one country could lower capital taxes by ϵ and attract all the capital from the other country), so cooperative taxes are higher than that. Furthermore, the infrastructure level in the non-cooperative game is determined by $F_I(K, I, N) = F_K(K, I, N) + r(1 - \tau^k)\frac{T(1-H)}{1-T(1-H)}$, implying that the marginal product of infrastructure is higher than the marginal product of capital (since $r(1 - \tau^k)\frac{T(1-H)}{1-T(1-H)} > 0$), and thus

[18] One cannot use the optimality of capital taxes as before, but one can use the fact that $\tau^k = 1$ instead.

infrastructure is lower than with cooperation.[19] □

What can explain that despite infrastructure competition in a non-cooperative game, infrastructure is optimally higher in a cooperative game? In the non-cooperative game, infrastructure provision is too high *given the level of capital taxes* and since cooperation leads to higher capital taxes, the optimal level of infrastructure is higher than in the non-cooperative game.

4.3 Dynamic World

The results which hold in the steady state of a world with endogenous capital accumulation are quite different for capital taxes and private capital allocations. As I have shown in previous work without revenue transfers (Gross, 2014, 2015a), capital is provided efficiently in the long run when governments pursue uncooperative policies (and when they do cooperate); the externality of a common capital market disappears in the long run and capital taxes in a closed and an open economy are equal to each other. Surprisingly, this also holds in the presence of revenue-sharing:

Proposition 5. *The optimal steady-state capital taxes are independent of the degree of revenue-sharing and identical to a closed economy; the steady-state allocation of private capital follows the modified golden rule.*

Proof. The first-order conditions taken above are valid for any t in a dynamic world and can thus be used here. The main difference is that assets are accumulated endogenously; the first-order condition for next-period government bonds is

$$\psi_{t+1}(1 + R_{t+1}) + \omega_{t+1} = \psi_t/\beta. \tag{29}$$

In steady-state, the Lagrange multipliers ψ_t and ω_t are equal across time periods (see appendix A) and I thus suppress time subscripts and replace them with SS. From the household's Euler equation (4) it follows that $1 + R_{SS} = 1/\beta$ and the equation above hence implies that $\omega_{SS} = 0$.

[19]It is well understood that the levels of K, I, and N are not the same across the two cases. In order to be precise, one would need to state that the marginal product of infrastructure relative to that of capital is higher in a non-cooperative game than in the cooperative game. In all the simulations I have run, the absolute infrastructure levels were following this and so were higher in the cooperative game than in the non-cooperative game, so this disclaimer does not apply there.

Equation (24) then shows that the optimal steady-state tax is the same as in a closed economy:

$$\tau^k_{SS} = \frac{\iota}{\alpha + \iota} \tag{30}$$

It follows that $R_{SS} = F_K(SS) - \delta_K$. Using again the Euler equation leads to the modified golden rule:

$$1 - \delta_K + F_K(SS) = 1/\beta. \tag{31}$$

□

Concerning infrastructure on the other hand, results align with the static model in the sense that infrastructure provision is a decreasing function of transfers. At the same time, without transfers steady-state infrastructure is at the efficient level – following the same modified golden rule as in a closed economy – whereas in a static open economy, it is inefficiently high:

Proposition 6. *Infrastructure provision follows the modified golden rule in steady state in the absence of revenue sharing. Otherwise infrastructure is provided inefficiently, the more so the higher the revenue sharing.*

Proof. Using the result above that $R_{SS} = F_K(SS) - \delta_K$ and substituting this into equation (25) yields

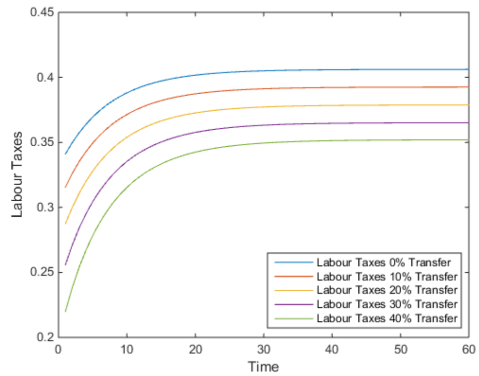
$$F_I(SS) = \frac{F_K(SS)}{1 - T(1 - H)}. \tag{32}$$

It follows that if there is no revenue sharing and $T = 0$, then infrastructure provision is efficient (and follows the same modified golden rule rule as in a closed economy), whereas it is inefficient and a decreasing function of T otherwise. □

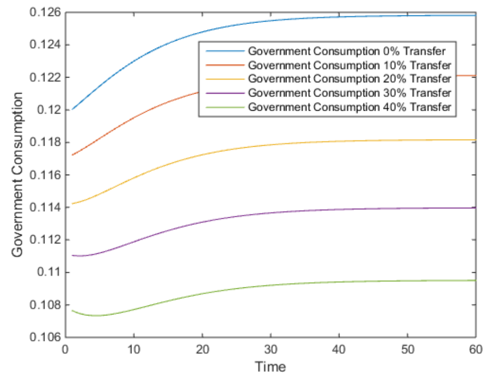
Following the logic in section 4.2.3, it is easy to see that cooperative policies lead to an efficient provision of public infrastructure in the presence of transfers.

4.3.1 Numerical results

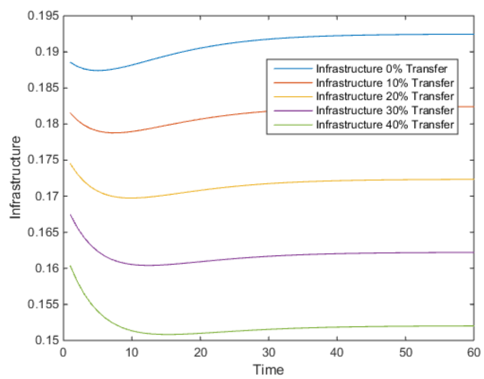
I use the same parameters as in the static setting and set the time discount factor to $\beta = 0.96$, which is consistent with a steady-state net rate of return on capital of 4%. The numerical results show that similar to the static setting, labor taxes, government spending, and infrastructure are lower at any moment in time when transfers are higher, see panels (a), (b), and (c) of figure 4. The time path of public debt is higher the bigger the transfers, as seen in panel (d).



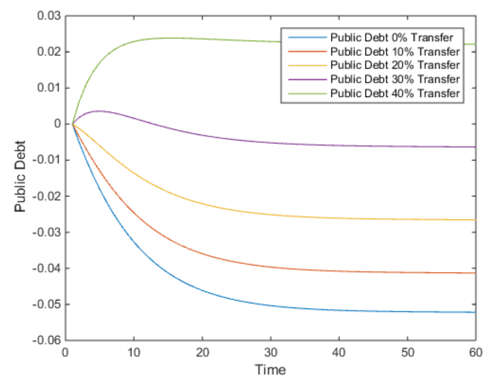
(a) Labor Taxes



(b) Government Consumption



(c) Infrastructure



(d) Debt

Figure 4: Optimal Dynamic Fiscal Policy

Figure 5 shows that capital taxes during the transition are higher the larger the transfers, while always converging to the same efficient steady-state solution, as predicted by the theory.

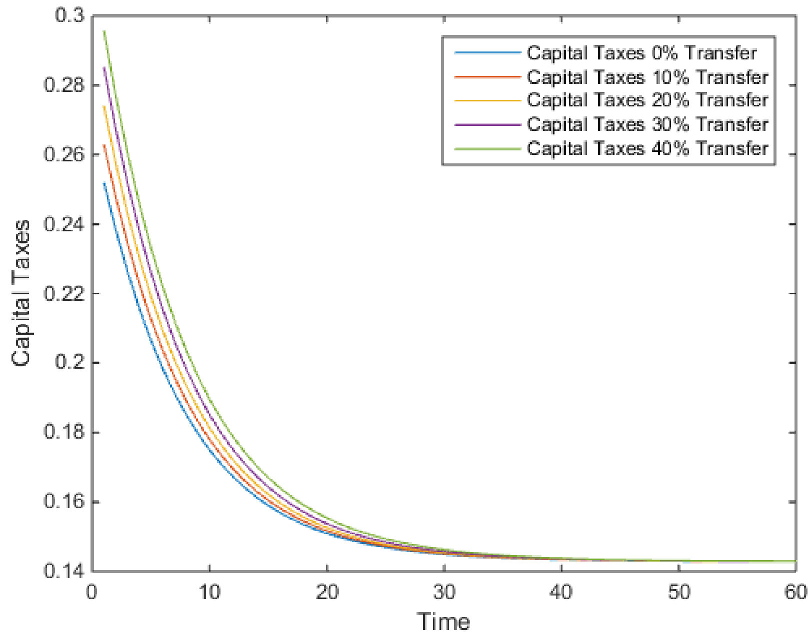


Figure 5: Optimal Capital Taxes over Time as a function of Transfers

The welfare effects of transfers are more negative than in the static setting; only for very low levels of transfers does welfare increase slightly, while the welfare costs rise quickly. Similar to the static sections, I show in figure 6 which percentage of actual private consumption in each period would be needed to attain the same utility as in an open economy without transfers.[20] The welfare costs of transfers reach almost one percent when 40% of revenues are transferred.

[20]Analogue to the static definition, the consumption equivalent x for transfer level $T = y$ is given by $U_{T=0} = \sum_{t=0}^{\infty} \beta^t [ln(C_{T=y}(t)x_{T=y}) - e(1 - l_{T=y})(t)^{\sigma} + gln(G_{T=y}(t)]$, or $x = \exp([U_{T=0} - U_{T=y}][1 - \beta])$.

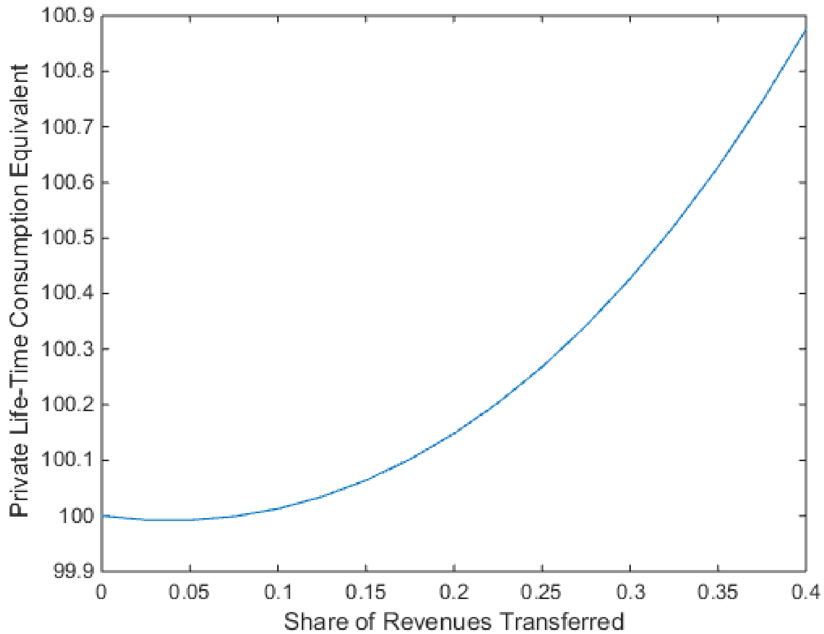


Figure 6: Lifetime Consumption Equivalents as a function of Transfers

Just as for the static setting, I have run the same robustness checks regarding the parametrization. The results are qualitatively the same and the quantitative departures follow the same pattern as for the static world. All results are reported in the appendix.

5 Discussion

In this section, I discuss the results. I start out with the static case and then explain how results differ in a dynamic setting.

5.1 Static World

As mentioned before, the shared asset (or capital) market is what links open economies. In the static model (or to a lesser extent in the short run of the dynamic model) the asset endowment is fixed and a tax on capital indirectly taxes the initial asset endowment. It is globally optimal to tax this endowment at 100%, since it amounts to a lump-sum tax and other tax instruments, such as labor taxes, are distortionary.[21] The ability to tax this endowment is obstructed by international capital mobility and in an uncooperative Nash game capital taxes are inefficiently low. This has been shown by the large tax-competition literature, starting with Zodrow and Mieszkowski (1986) and Wilson (1986). The idea is that each country aims to attract foreign capital, since the marginal product of capital is higher than the net return to the investor; the tools to attract capital are lower capital taxes. Capital taxes thus have an intratemporal positive externality. With transfers, the benefits of attracting capital are lower than without transfers, since some of the gained resources are sent abroad, and hence capital taxes are higher the larger the transfers. Tax competition is dampened and this effect leads to higher welfare.

In an open static economy, there is also infrastructure competition, in consonance with Keen and Marchand (1997):[22] in order to attract scarce capital from abroad, governments spend more on infrastructure in an open economy than they would in a closed economy (holding fixed the capital tax rate). Using public capital draws from the common asset market and individual governments do not take into account how this negatively affects the other country. Infrastructure thus has an intratemporal negative externality. With transfers, the marginal cost of infrastructure is higher, since it is paid through public funds: For one dollar spent on infrastructure, $1/(1-T(1-H))$ dollars have to be raised in tax revenues. Therefore, at lower levels of transfers, infrastructure competition is dampened, which leads to higher welfare; however, at higher levels of transfers, infrastructure provision is below what it would be in a closed economy with the same capital taxes, leading to a decline in welfare.

Public consumption is always negatively affected by revenue sharing, since the marginal cost of public funds is higher the bigger the proportion of revenues transferred. This effect naturally implies a lower welfare. Taken together, the three effects of dampened tax competition, initially improving infrastructure competition which then turns to sub-optimal infrastructure provision, and too low public consumption explain the U-shaped welfare effects: for lower levels of transfers, welfare increases, but then decreases in transfers. Unlike in the taxation of individuals, a tax rate of 100%

[21] A capital tax of 100% is the outcome in a closed economy or the cooperative solution to a game between governments in an open economy. I have set a cap on taxes at 100% for illustrative purposes; if there were no cap, capital taxes would be even higher.

[22] They consider static small open economies without transfers, where infrastructure is provided efficiently when profits can be fully taxed (even though government consumption is still inefficiently low). In the present model, infrastructure is not provided efficiently, even though the same rule as in first-best holds (that the marginal products of public and private capital are equal). The difference arises from the modeling assumptions: “their” infrastructure is produced from output, whereas “my” infrastructure uses the capital stock.

for governments (i.e. $T = 1$) would not lead to a complete breakdown of government services, as governments are strategic and take into account that they receive a fraction H of it back.[23]

5.2 Dynamic World

In a dynamic world, the negative externalities of capital-tax and infrastructure competition still hold in the short run, but to a lesser extent. The initial capital stock is exogenously given as in a static world, but on top of the *intratemporal* externalities mentioned above, there is an opposing *intertemporal* externality for both capital taxes and infrastructure: while lower capital taxes and higher infrastructure hurt the other country by attracting capital from there, it also encourages capital formation and thus benefits the other country in the future. Klein and Makris (2014) pointed this out for capital taxes, but it also applies to infrastructure.

In the long run, though, countries are no longer competing for a fixed capital stock: if one country lowers its steady-state capital-tax rate (or increases infrastructure), it does not "steal" the capital from abroad, but new capital is instead generated through savings. The intratemporal (and also intertemporal) externalities vanish in the long run. It follows that without transfers capital is provided efficiently in the long run – according to the modified golden rule – and capital taxes implement this allocation, while revenues are purely incidental, in consonance with my previous findings in Gross (2014, 2015a). The last point is crucial to understand why transfers do not affect the long-run capital allocation and taxes. Capital is privately provided and its costs are therefore not affected by transfers; since revenues are purely incidental, the fact that part of these revenues are transferred abroad is irrelevant.

In the long run without transfers, infrastructure provision is efficient in an open economy. At all times, it follows the rule that the marginal products of capital and infrastructure are equal to each other. This is inefficient in the short run, since it comes at the expense of less private capital, but in the long run more infrastructure comes from higher savings and not from "stealing" capital from abroad. In the presence of transfers, the costs of infrastructure are covered by tax dollars and $1/(1 - T(1 - H))$ dollars have to be raised in tax revenues for one dollar of spending. Therefore, infrastructure provision is below what it would be in a closed economy, leading to a decline in welfare in the long run.

[23] Of course this would change if the number of symmetric countries went to infinity or more generally if the relative size of an individual country compared to the transfer union went to zero.

Welfare in a dynamic world is thus much more negatively affected by transfers than in a static world: while the short-run effects roughly mimic the static world (even though the intertemporal externality pulls in the opposite direction), the long-run effects are purely negative. In the long run there is no capital-tax or infrastructure competition and so only the negative effects of transfers on infrastructure provision and government consumption remain.

Cooperation between governments naturally leads to a more efficient allocation, where the externalities of an open economy and the transfer system are completely neutralized (this is due to the symmetry assumption: with asymmetric countries, the externalities are reduced but not entirely eliminated). In fact, cooperation between symmetric countries is equivalent to a closed economy.

5.3 Imperfect Commitment

The perfect commitment assumed in this paper generates a benchmark; it is well-known that with imperfect commitment equilibrium capital taxes are too high.[24] The reason is that governments take the current capital stock as given, but it is determined endogenously through agents' rational expectations of taxes. That is, governments perceive capital to be an endowment whereas it is accumulated endogenously; in other words, instead of an endowment it is an (intertemporal) intermediate good and should thus be taxed differently. Tax competition is then welfare-improving, as it drives rates down towards the efficient level, see Quadrini (2005). Therefore, with imperfect commitment transfers clearly affect welfare (in the long-run equilibrium) in a negative way: first, through the distortion of incentives to provide infrastructure and government consumption, and second through the dampened tax competition, which produces higher rates of inefficient capital taxes. In this case, cooperation actually harms welfare, as first pointed out by Kehoe (1989).

5.4 Alternative Transfer Mechanisms

As the U-shaped welfare curve and the previous discussion show, transfers have both positive and negative incentive effects for welfare, even when there are no allocational or insurance gains from transferring resources from richer to poorer regions. The positive effect is to reduce capital-tax and at first instrastructure competition, the negative effect is a downward distortion of government consumption and, for higher levels of transfers, infrastructure.

[24] This relates to the famous time-inconsistency problem first established by Kydland and Prescott (1977).

One could therefore envisage two modifications of the transfer scheme: one in which infrastructure spending is "deductible" from revenue sharing, i.e. that only tax revenues net of infrastructure spending are considered for transfers, and another in which government consumption is deductible.[25] Formally, in the first case the government budget constraint would be

$$
\begin{aligned}
&G_t + b_t(1+R_t) = (1-T)[\tau_t^k r_t K_t + \tau_t^n w_t N_t - I_t(R_t+\delta_I)] + \\
&TH[\tau_t^k r_t K_t + \tau_t^n w_t N_t - I_t(R_t+\delta_I) + \tau_t^{*k} r_t^* K_t^* + \tau_t^{*n} w_t^* N_t^* - I_t^*(R_t+\delta_I)] + b_{t+1},
\end{aligned} \tag{33}
$$

and in the second case it would be

$$
\begin{aligned}
&I_t(R_t+\delta_I) + b_t(1+R_t) = (1-T)[\tau_t^k r_t K_t + \tau_t^n w_t N_t - G_t] + \\
&TH[\tau_t^k r_t K_t + \tau_t^n w_t N_t - G_t + \tau_t^{*k} r_t^* K_t^* + \tau_t^{*n} w_t^* N_t^* - G_t^*] + b_{t+1}.
\end{aligned} \tag{34}
$$

Casual intuition might suggest that with intergovernmental transfers, infrastructure spending should be encouraged and government consumption discouraged (also in line with the reasoning from capacity-based transfers that capacity-building is harmed by transfers). It might then come as a surprise that with revenue-based transfers, deducing government consumption expenditures fares much better than deducing infrastructure expenditures in a static setting. However, in light of the above analysis, it becomes apparent that infrastructure is in fact over-provided in the absence of transfers in a static setting and there is an under-provision of government consumption – therefore, infrastructure should (to some degree) be discouraged and consumption encouraged.

Figures 7 and 8 show optimal static policy as a function of transfers for the cases when infrastructure expenditures and government consumption are deductible, respectively.[26] In the first case, infrastructure provision is substantially higher compared to the baseline and capital and labor taxes are somewhat higher, while government consumption remains virtually unchanged. In the second case, government consumption, capital taxes, and labor taxes are substantially higher, while infrastructure spending remains virtually unchanged.

[25] If both were deductible, transfers would be effectively eliminated, so I will not consider this. In the static setting, all expenditures and revenues would then be subject to transfers and transfers thus do not affect policy when countries are symmetric. In the dynamic setting, government debt would not be subject to transfers, so transfers would still affect policy to some degree.

[26] All computations in this section are based on the parameters in the baseline parametrization.

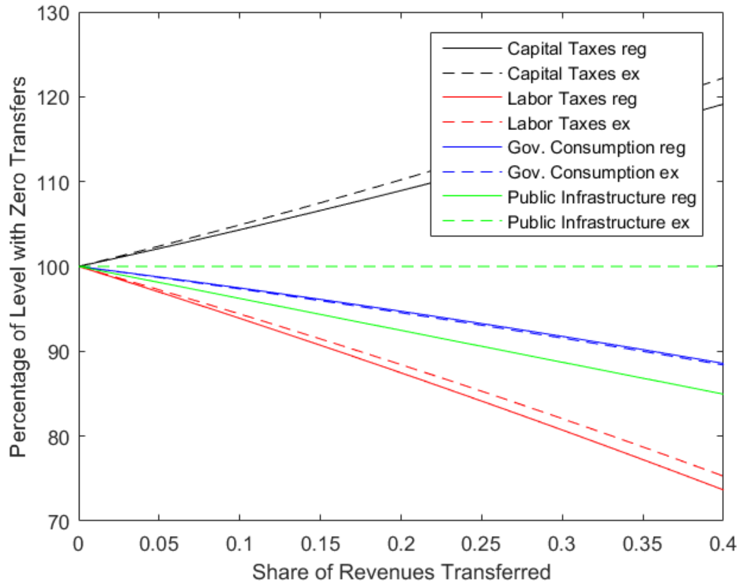


Figure 7: Optimal Fiscal Policy as a function of Transfers – Infrastructure Deduction

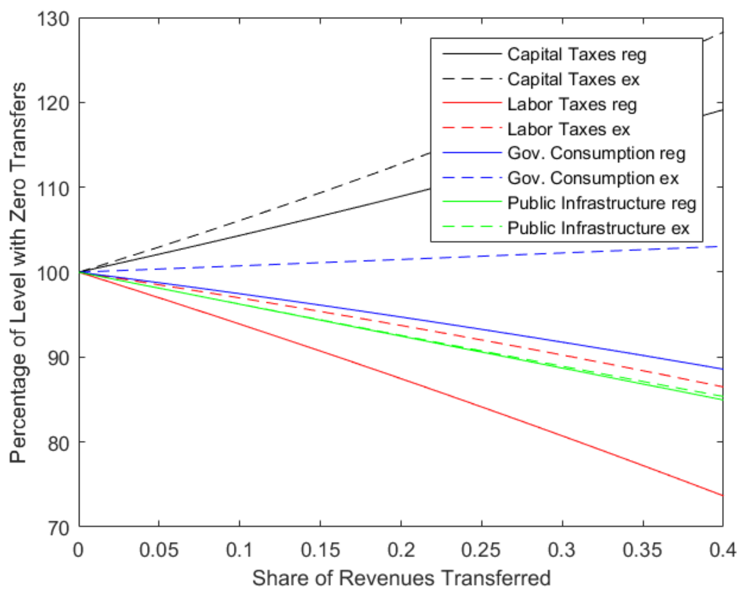


Figure 8: Optimal Fiscal Policy as a function of Transfers – Government Consumption Deduction

One can compare the welfare consequences by inspecting Figure 9. The regime where government consumption is deductible fares better than the baseline without deductions, whereas the regime where infrastructure spending is deductible does worse than the baseline for lower levels of transfers and does better at higher levels of transfers. This is in line with the previous observations that government consumption is always too low in the presence of transfers, while infrastructure spending is too high at a lower T and too low at a higher T.

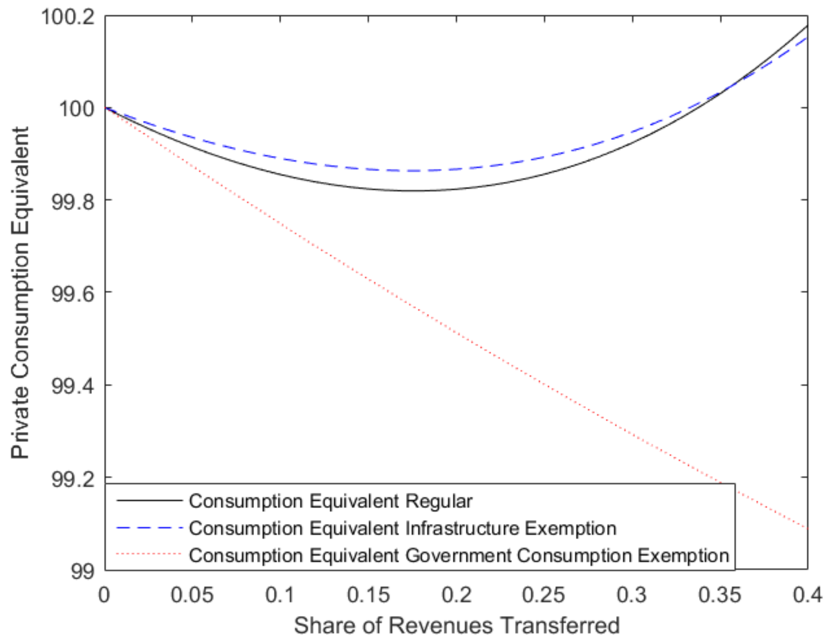


Figure 9: Consumption Equivalents as a function of Transfers: Comparison of Transfer Regimes

In a dynamic setting, these conclusions are modified in an important way: the long-run infrastructure allocation is efficient in the absence of transfers and is sub-optimal in their presence. Therefore, the case for an infrastructure deduction is stronger in a dynamic setting than a static one. However, the deduction for government consumption still leads to higher welfare. I do not show the optimal dynamic policy here (it can be found in the appendix, though), since the implications are similar to the static case, but the welfare properties of the different transfer regimes are depicted in 10.

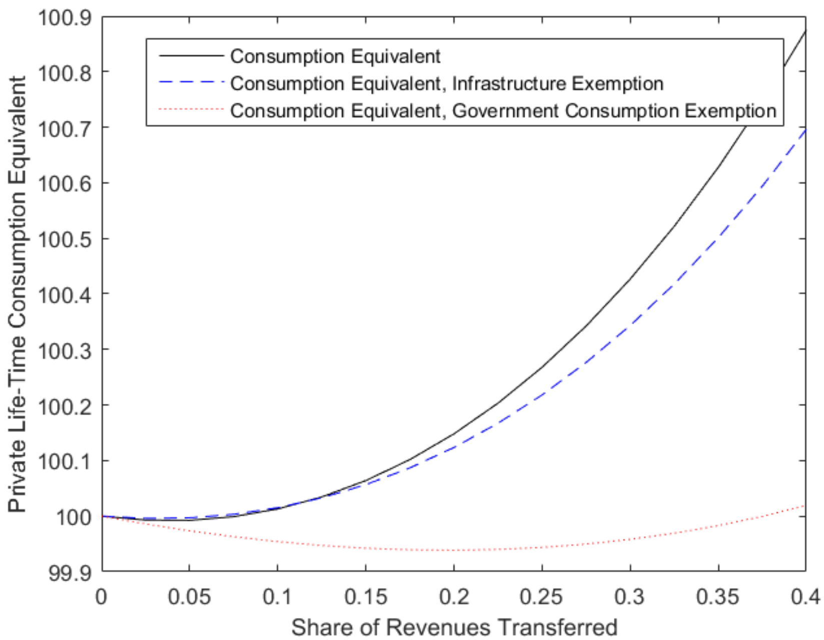


Figure 10: Lifetime Consumption Equivalents as a function of Transfers: Comparison of Transfer Regimes

6 Conclusion

In this paper I develop a model of optimal fiscal policy with capital mobility and transfers between governments. I analyze a static setting with an exogenous capital stock and a dynamic setting where households optimally choose their asset position and thus determine the size of the capital stock. For both the static and dynamic world, government consumption and labor taxes are decreasing functions of transfers. This represents a negative welfare effect of transfers. The within-period incentives to attract capital from abroad by lowering capital taxes or providing infrastructure – traditionally referred to as capital-tax and infrastructure competition – are dampened and this positively affects welfare, so that low levels of transfers increase welfare. However, the incentives to accumulate capital across periods are negatively affected by transfers, so that in the dynamic world transfers only lead to very small welfare gains at very low transfer levels, whereas welfare losses rise quickly. In the long run, capital is provided efficiently; since capital taxes are then only used to implement this efficient capital allocation and not to raise revenues, they are independent of transfers. The long-run infrastructure provision is efficient without transfers and inefficiently low with them.

In light of these results, a transfer scheme with a deduction for government consumption improves welfare compared to the baseline transfers, whereas a deduction for infrastructure investment does worse than the baseline for lower levels of transfers. This is in contrast to conventional thinking about transfers (whereby investment should be encouraged and government consumption discouraged), but it is important to bear in mind that the analysis in this paper abstracts from political-economy considerations, limited commitment, government default, and many other important real-world aspects.

I believe there are many interesting avenues for future research on this subject: One would be to investigate how transfers affect government consumption, labor taxes, and short-run capital taxes differently when countries are asymmetric; in that case, transfers will serve as a vehicle to shift resources from richer to poorer jurisdictions (which Bargain, Dolls, Fuest, Neumann, Peichl, Pestel, and Siegloch (2013) studied in a static context and without optimal taxation). Moreover, transfers could also be used as some sort of insurance device, for instance if productivity were not deterministic as in the present model, but stochastic as in Chari, Christiano, and Kehoe (1994). This is computationally difficult, though. It could also be interesting to compute the welfare costs of transfers in a repeated game with imperfect commitment. Modeling countries outside of the transfer union does not affect the analytical results presented in this paper, but does of course change equilibrium values. Comparing policies within and outside the union and finding the optimal transfer rate, similar in spirit to Becker and Fuest (2010), could yield interesting insights. One could also contrast equalization schemes based on capacity vs. actual revenues – similar to Köthenbürger (2002) – or investigate what an optimal equalization scheme might look like, similar to Bucovetsky and Smart (2006). Considering transfers in a federation with an additional layer of government would allow one to study the different incentive effects on a horizontal and vertical level.

References

Akai, N., and M. Sato (2008): "Too big or too small? A synthetic view of the commitment problem of interregional transfers," *Journal of Urban Economics*, 64(3), 551 – 559.

Angyridis, C. (2007): "Optimal capital income taxation in a small open economy," *Economics Letters*, 95(1), 73 – 79.

Baretti, C., B. Huber, and K. Lichtblau (2002): "A Tax on Tax Revenue: The Incentive Effects of Equalizing Transfers: Evidence from Germany," *International Tax and Public Finance*, 9(6), 631–649.

Bargain, O., M. Dolls, C. Fuest, D. Neumann, A. Peichl, N. Pestel, and S. Siegloch (2013): "Fiscal union in Europe? Redistributive and stabilizing effects of a European tax-benefit system and fiscal equalization mechanism," *Economic Policy*, 28(75), 375–422.

Bayindir-Upmann, T. (1998): "Two Games of Interjurisdictional Competition When Local Governments Provide Industrial Public Goods," *International Tax and Public Finance*, 5(4), 471–487.

Becker, J., and C. Fuest (2010): "EU regional policy and tax competition," *European Economic Review*, 54(1), 150 – 161.

Boadway, R. (2001): "Inter-Governmental Fiscal Relations: The Facilitator of Fiscal Decentralization," *Constitutional Political Economy*, 12(2), 93–121.

——— (2004): "The Theory and Practice of Equalization," *CESifo Economic Studies*, 50(1), 211–254.

Bom, P. R., and J. E. Ligthart (2014): "What have we learned from three decades of research on the productivity of public capital?," *Journal of Economic Surveys*, 28(5), 889–916.

Breuillé, M.-L., T. Madiès, and E. Taugourdeau (2010): "Gross versus net equalization scheme in a federation with decentralized leadership," *Journal of Urban Economics*, 68(2), 205 – 214.

Bucovetsky, S., and M. Smart (2006): "The Efficiency Consequences of Local Revenue Equalization: Tax Competition and Tax Distortions," *Journal of Public Economic Theory*, 8(1), 119–144.

Büttner, T. (2006): "The incentive effect of fiscal equalization transfers on tax policy," *Journal of Public Economics*, 90(3), 477 – 497, Special issue published in cooperation with the National Bureau of Economic Research: Proceedings of the Trans-Atlantic Public Economics Seminar on Fiscal Federalism 20-22 May 2004.

Cai, H., and D. Treisman (2005): "Does Competition for Capital Discipline Governments? Decentralization, Globalization, and Public Policy," *American Economic Review*, 95(3), 817–830.

Chamley, C. (1986): "Optimal Taxation of Capital Income in General Equilibrium with Infinite Lives," *Econometrica*, 54(3), 607–622.

Chari, V. V., L. J. Christiano, and P. J. Kehoe (1994): "Optimal Fiscal Policy in a Business Cycle Model," *Journal of Political Economy*, 102(4), 617–52.

Correia, I. H. (1996): "Dynamic Optimal Taxation in Small Open Economies," *Journal of Economic Dynamics and Control*, 20(4), 691–708.

Edwards, J., and M. Keen (1996): "Tax competition and Leviathan," *European Economic Review*, 40(1), 113–134.

Egger, P., M. Köthenbürger, and M. Smart (2010): "Do fiscal transfers alleviate business tax competition? Evidence from Germany," *Journal of Public Economics*, 94(3-4), 235–246.

Eggert, W. (2001): "Capital tax competition with socially wasteful government consumption," *European Journal of Political Economy*, 17(3), 517 – 529.

Gomes, P., and F. Pouget (2008): "Corporate Tax Competition and the Decline of Public Investment," CESifo Working Paper Series 2384, CESifo Group Munich.

Gong, L., and H. Zou (2002): "Optimal taxation and intergovernmental transfer in a dynamic model with multiple levels of government," *Journal of Economic Dynamics and Control*, 26(12), 1975 – 2003.

Gross, T. (2014): "Equilibrium Capital Taxation in Open Economies under Commitment," *European Economic Review*, 70(0), 75 – 87.

——— (2015a): "On the Relevance of Tax Competition when it is Optimal to Tax Capital Income in the Long Run," Carleton University Working Paper.

——— (2015b): "Undistorted Capital Allocations and Non-zero Capital Taxes," Carleton University Working Paper.

Hatfield, J. W. (2015): "Federalism, Taxation, and Economic Growth," *Journal of Urban Economics*, 87, 114 – 125.

Hindriks, J., S. Peralta, and S. Weber (2008): "Competing in taxes and investment under fiscal equalization," *Journal of Public Economics*, 92(12), 2392 – 2402, New Directions in Fiscal Federalism.

Judd, K. L. (1999): "Optimal taxation and spending in general competitive growth models," *Journal of Public Economics*, 71(1), 1–26.

Keen, M., and M. Marchand (1997): "Fiscal competition and the pattern of public spending," *Journal of Public Economics*, 66(1), 33 – 53.

Kehoe, P. J. (1989): "Policy Cooperation Among Benevolent Governments May Be Undesirable," *The Review of Economic Studies*, 56(2), pp. 289–296.

Kim, J. W. (2014): "Three Essays on Equalization Transfers in a Fiscal Federalism," Ph.D. thesis, University of Ottawa, Department of Economics.

Klein, P., and M. Makris (2014): "Dynamic Capital Tax Competition in a Two-country Model," Working Paper.

Köthenbürger, M. (2002): "Tax Competition and Fiscal Equalization," *International Tax and Public Finance*, 9(4), 391–408.

——— (2011): "How do local governments decide on public policy in fiscal federalism? Tax vs. expenditure optimization," *Journal of Public Economics*, 95(1112), 1516 – 1522, Special Issue: International Seminar for Public Economics on Normative Tax Theory.

Köthenbürger, M., and B. Lockwood (2010): "Does Tax Competition Really Promote Growth?," *Journal of Economic Dynamics and Control*, 34(2), 191 – 206.

Kydland, F. E., and E. C. Prescott (1977): "Rules Rather Than Discretion: The Inconsistency of Optimal Plans," *Journal of Political Economy*, 85(3), 473–91.

LIU, Y. (2014): "Does competition for capital discipline governments? The role of fiscal equalization," *International Tax and Public Finance*, 21(3), 345–374.

NICODÈME, G. (2006): "Corporate Tax Competition and Coordination in the European Union: What do we know? Where do we stand?," European Economy, Economic Papers 250, European Commission.

QUADRINI, V. (2005): "Policy commitment and the welfare gains from capital market liberalization," *European Economic Review*, 49(8), 1927 – 1951.

SMART, M. (1998): "Taxation and Deadweight Loss in a System of Intergovernmental Transfers," *Canadian Journal of Economics*, 31(1), pp. 189–206.

——— (2007): "Raising taxes through equalization," *Canadian Journal of Economics*, 40(4), 1188–1212.

WILDASIN, D. E. (2003): "Fiscal competition in space and time," *Journal of Public Economics*, 87(11), 2571–2588.

WILSON, J. D. (1986): "A theory of interregional tax competition," *Journal of Urban Economics*, 19(3), 296–315.

WILSON, J. D., AND D. E. WILDASIN (2004): "Capital tax competition: bane or boon," *Journal of Public Economics*, 88(6), 1065–1091.

ZODROW, G. R., AND P. MIESZKOWSKI (1986): "Pigou, Tiebout, property taxation, and the underprovision of local public goods," *Journal of Urban Economics*, 19(3), 356–370.

Appendix A: Proofs

In a closed static economy, optimal capital taxes are set to the maximum, $\tau^k = 1$, and the optimal infrastructure allocation is characterized by $F_I(K, I, N) = F_K(K, I, N)$.

Proof. In a static economy, the household Euler equation does not apply and substituting in for R reveals that the first-order condition for τ^k would imply $\psi = \theta$. This would suggest that taxes on capital are so high that the economy is in first-best, where the value of resources for the government (ψ) is equal to that for private households (θ). Since I have ruled out this uninteresting possibility by assumption, taxes are as high as possible, i.e. the constraint that $\tau^k \leq 1$ is binding now (which I generally ignore otherwise). We thus have $\tau^k = 1$ and $\psi > \theta$.

The first-order conditions with respect to capital, infrastructure, and labor taxes are similar to those in the main part of the paper:

$$K\colon\ \psi\left[\tau^k r + \tau^k K\frac{\partial r}{\partial K} + \tau^n N\frac{\partial w}{\partial K}\right] + \theta(1-\tau^n)N\frac{\partial w}{\partial K} \tag{35}$$
$$+\,\mu u_c(1-\tau^n)\frac{\partial w}{\partial K} + \gamma(1-\tau^k)\frac{\partial r}{\partial K} = \omega,$$
$$I\colon\ \psi\left[\tau^k K\frac{\partial r}{\partial I} + \tau^n N\frac{\partial w}{\partial I}\right] + \theta(1-\tau^n)N\frac{\partial w}{\partial I} \tag{36}$$
$$+\,\mu u_c(1-\tau^n)\frac{\partial w}{\partial I} + \gamma(1-\tau^k)\frac{\partial r}{\partial I} = \omega + \psi(R+\delta_I),$$
$$\tau^n\colon\ \psi[1-T(1-H)]Nw = \theta Nw + \mu u_c w, \tag{37}$$

Using $K(\partial r)/(\partial K) + N(\partial w)/(\partial K) = F_K - r$ and $K(\partial r)/(\partial I) + N(\partial w)/(\partial I) = F_I$ and inserting equation (37) into equations (35) and (36) yields

$$\psi F_K - (1-\tau^k)\left[\psi r + \psi K\frac{\partial r}{\partial K} - \gamma\frac{\partial r}{\partial K}\right] = \omega \tag{38}$$
$$\psi F_I - (1-\tau^k)\left[\psi r + \psi K\frac{\partial r}{\partial I} - \gamma\frac{\partial r}{\partial I}\right] = \omega. \tag{39}$$

Also note that $R = r(1-\tau^k) - \delta_K$. Using $\tau^k = 1$, it follows that $F_I = F_K$. □

In a closed static economy, when capital taxes are constrained to be less than one, $\tau^k < 1$, then the optimal infrastructure allocation satisfies $F_I(K, I, N) > F_K(K, I, N)$.

Proof. If $\tau^k < 1$, equations (38) and (39) combine to

$$\psi F_I = \psi F_K + (1-\tau^k)\left[\frac{\partial r}{\partial I} - \frac{\partial r}{\partial K}\right][\psi K - \gamma]\,. \tag{40}$$

The first-order condition with respect to R shows that $\psi K - \gamma = a(\psi - \theta) > 0$. It is clear that $\frac{\partial r}{\partial I} = (\alpha+\iota)\iota F/(KI) > 0$ and $\frac{\partial r}{\partial K} = -(\alpha+\iota)(1-\alpha)F/K^2 < 0$, and hence $F_I > F_K$. □

In a closed dynamic economy, the optimal steady-state capital and infrastructure allocations are characterized by $1-\delta_K + F_K(K_{SS}, I_{SS}, N_{SS}) = 1/\beta$ and $F_I(K_{SS}, I_{SS}, N_{SS}) = F_K(K_{SS}, I_{SS}, N_{SS})$, respectively. The optimal capital tax is $\tau^k_{SS} = \iota/(\alpha+\iota)$.

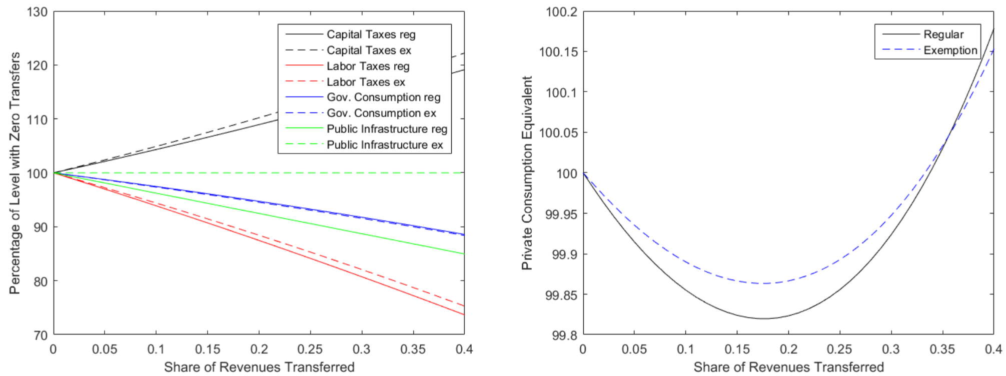
Proof. The first-order condition with respect to capital taxes at time t is $\psi_t K_t = \gamma_t$ (since $r_t > 0$) and therefore equation (38) leads to $\psi_t[F_K(t) - (1-\tau^k_t)r_t] = \omega_t$. The first-order conditions for b_{t+1} and G_t are

$$\psi_{t+1}(1+R_{t+1}) + \omega_{t+1} = \psi_t/\beta \tag{41}$$

$$\psi_t = u_G(t). \tag{42}$$

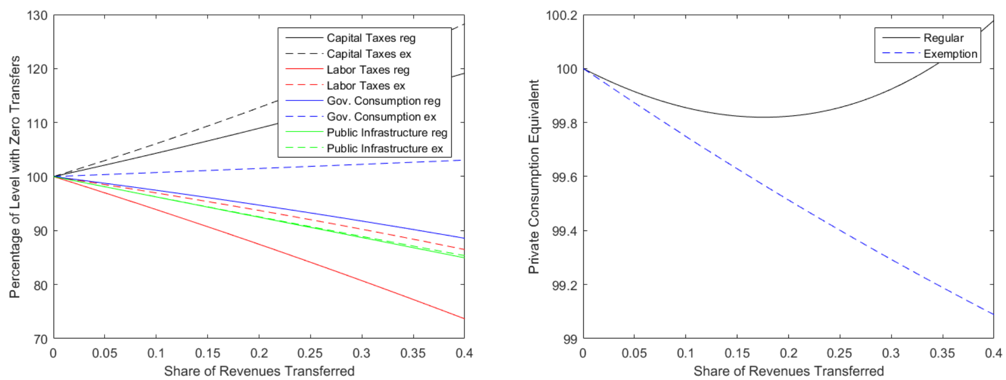
In steady state, $G_t = G_{t+1}$ and Lagrange multipliers for the government budget constraint are thus equal across time periods, $\psi_t = \psi_{t+1}$. The household's Euler equation in steady state implies that $1 + R_{SS} = 1/\beta$ and hence $\omega_{SS} = 0$. It follows that $F_K(SS) = (1-\tau^k_{SS})r_{SS}$, which is equivalent to $R_{SS} = F_K(SS) - \delta_K$ and thus $1 - \delta_K + F_K(SS) = 1/\beta$. From equation (40) and the optimality of the capital tax, it is evident that $F_I(t) = F_K(t)\,\forall t$ and hence $F_I(SS) = F_K(SS)$. Simple algebraic manipulations show that $F_K(SS) = (1-\tau^k_{SS})r_{SS}$ implies that $\tau^k_{SS} = \iota/(\alpha+\iota)$. □

Appendix B: Optimal Fiscal Policy under Alternative Transfer Mechanisms



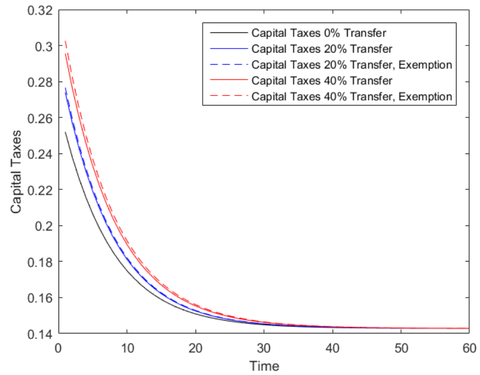
(a) Policy (b) Welfare

Figure 11: Static Policy and Welfare with Infrastructure Exemption

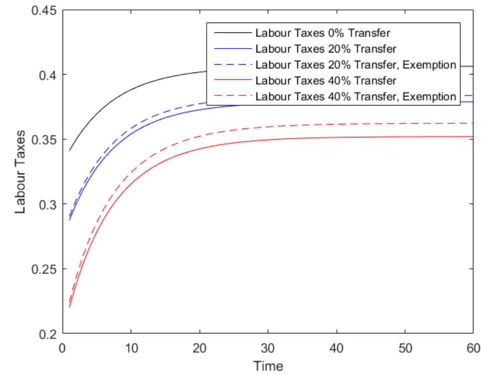


(a) Policy (b) Welfare

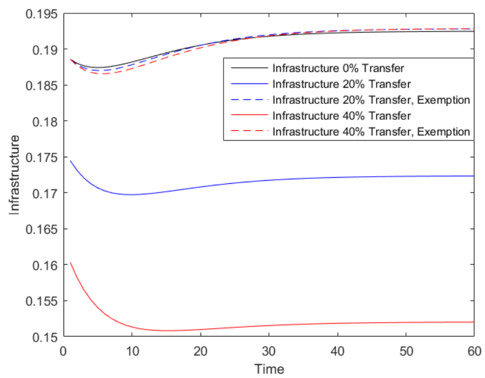
Figure 12: Static Policy and Welfare with Government-Consumption Exemption



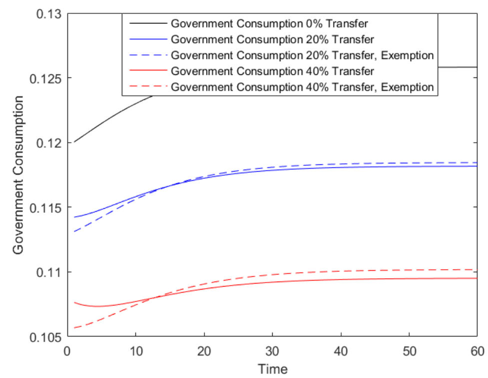
(a) Capital Taxes



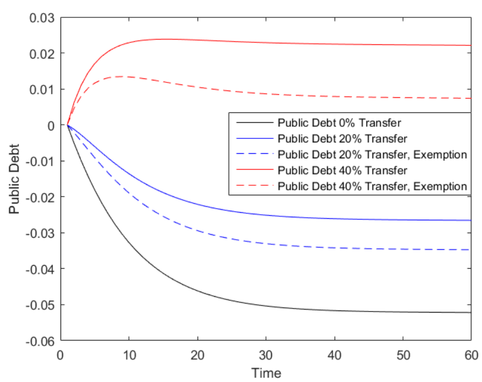
(b) Labor Taxes



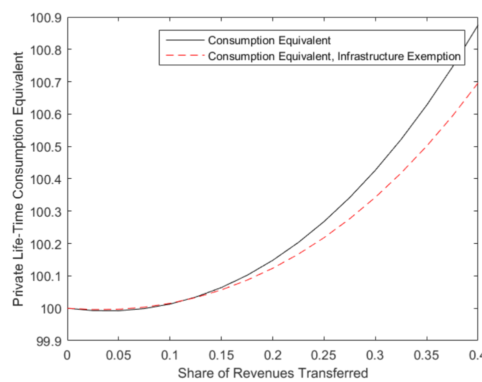
(c) Infrastructure



(d) Government Consumption

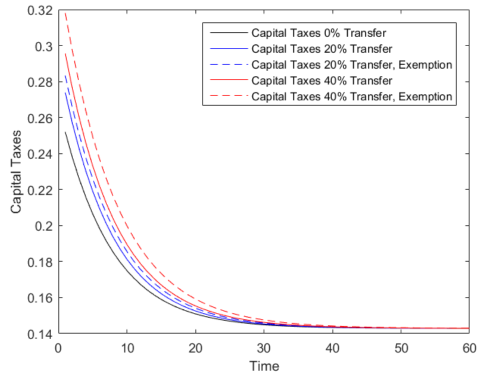


(e) Debt

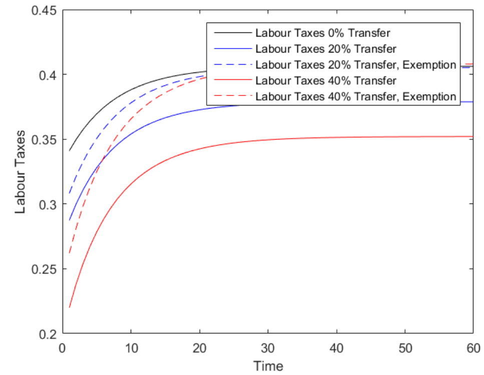


(f) Welfare

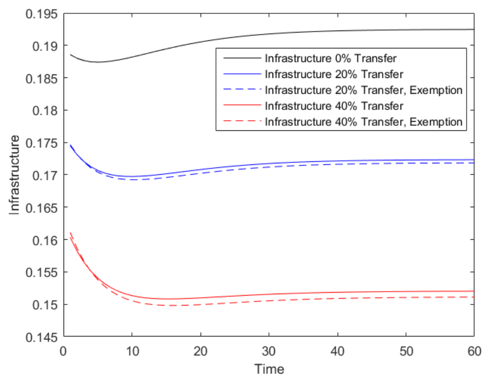
Figure 13: Dynamic Policy and Welfare with Infrastructure Exemption



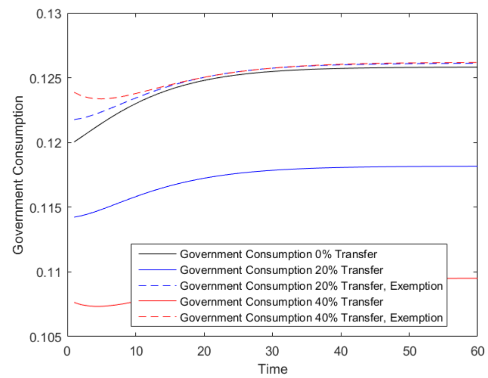
(a) Capital Taxes



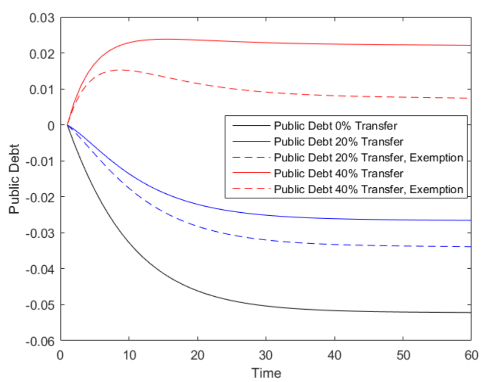
(b) Labor Taxes



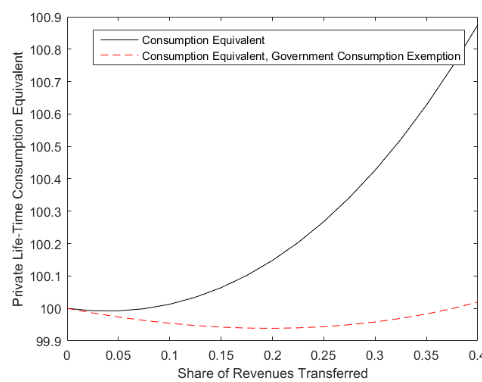
(c) Infrastructure



(d) Government Consumption



(e) Debt



(f) Welfare

Figure 14: Dynamic Policy and Welfare with Government-Consumption Exemption

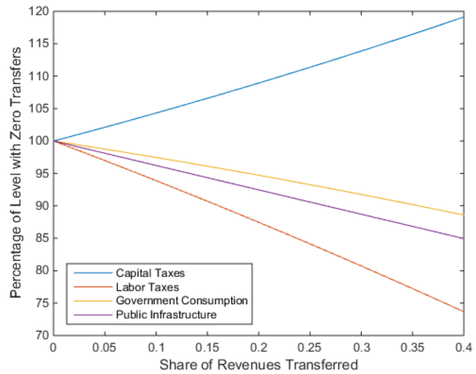
Appendix C: Alternative Parametrizations

The targets for the parametrizations were $l = 0.33$, i.e. the time spent working is 1/3 of the total time endowment; $[G + (R + \delta_I)I]/(F(K, N, I) - \delta_K K - \delta_I I) = 0.40$, i.e. government expenditures (not including potential interest payments on debt) are 40% of output; and $r(1 - \tilde{\tau}^k) - \delta_K = 0.040$, i.e. the net rate of return on capital is 4% when the tax rate is at its efficient level. Government debt is set to zero, except in the "Government Debt" scenario, where it is targeted to be 60% of output, i.e. $b_0/(F(K, N, I) - \delta_K K - \delta_I I) = 0.60$. In the "Low Government Share" scenario, $[G + (R + \delta_I)I]/(F(K, N, I) - \delta_K K - \delta_I I) = 0.20$, i.e. government expenditures are 20% of output instead of 40%.

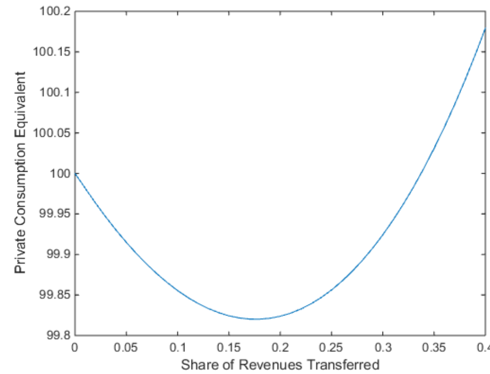
Table 1: Alternative Parametrizations

Parametrization	α	ι	e	σ	g	b_0	a_0
Baseline	0.3	0.05	7.1	3	0.55	0	1.32
High Infrastructure Share	0.25	0.1	7.2	3	0.42	0	1.16
Government Debt	0.3	0.05	6.7	3	0.57	0.217	1.53
High Sigma	0.3	0.05	10.5	3.5	0.55	0	1.33
Low Sigma	0.3	0.05	4.8	2.5	0.57	0	1.33
Low Government Share	0.3	0.05	7.4	3	0.16	0	1.37

α is the exponent of capital in the production function, ι is the exponent of infrastructure in the production function, e multiplies the disutility from labor in the utility function, σ is the exponent on labor in the utility function, g multiplies the utility from government consumption in the utility function, b_0 is the initial public debt position, and a_0 is the initial total asset position of the private household. The depreciation of capital and infrastructure is $\delta_K = \delta_I = 0.08$ in all specifications.

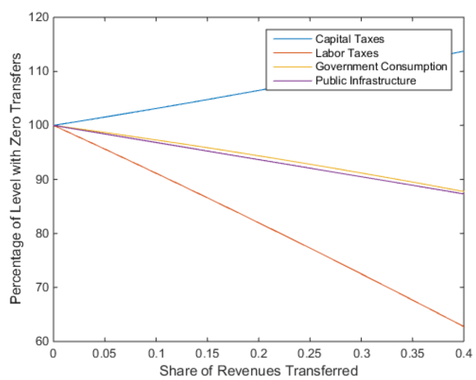


(a) Policy

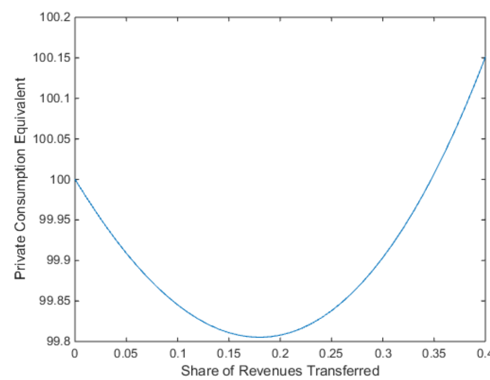


(b) Welfare

Figure 15: Static Policy and Welfare under “Baseline”

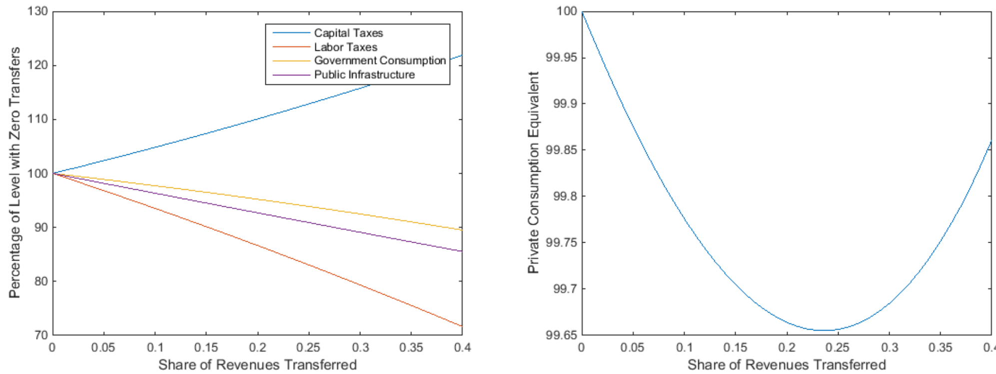


(a) Policy



(b) Welfare

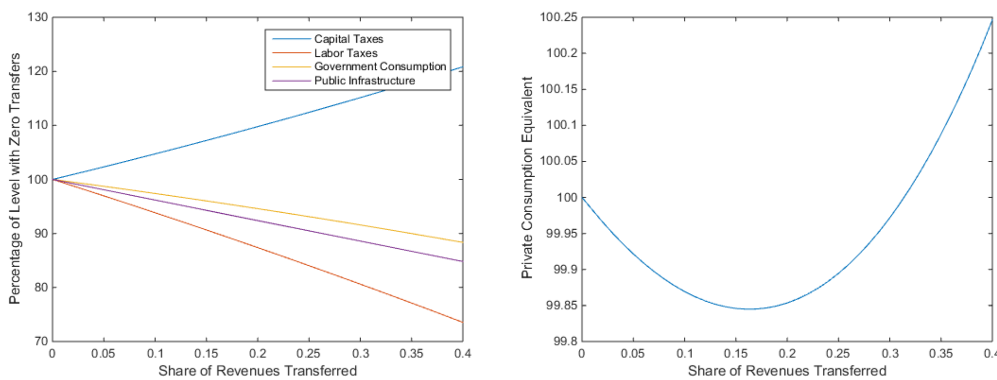
Figure 16: Static Policy and Welfare under “High Infrastructure Share”



(a) Policy

(b) Welfare

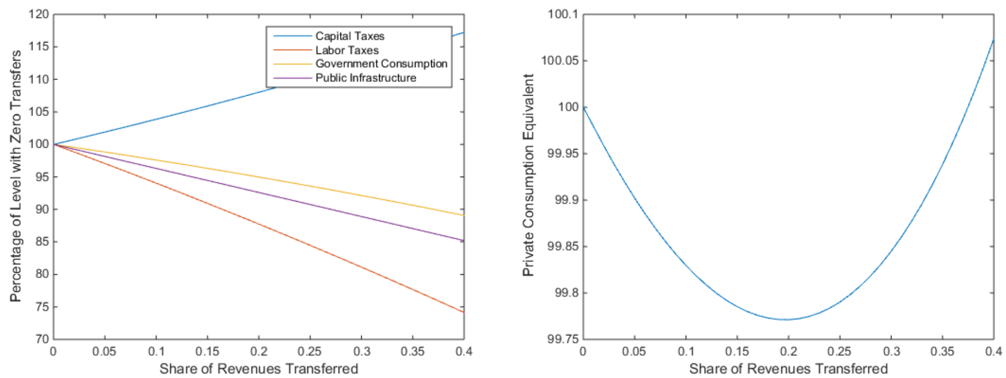
Figure 17: Static Policy and Welfare under “Government Debt”



(a) Policy

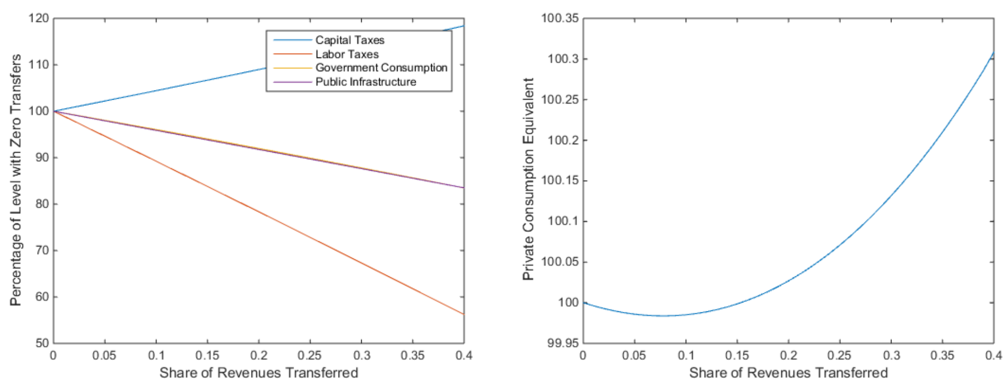
(b) Welfare

Figure 18: Static Policy and Welfare under “High Sigma”



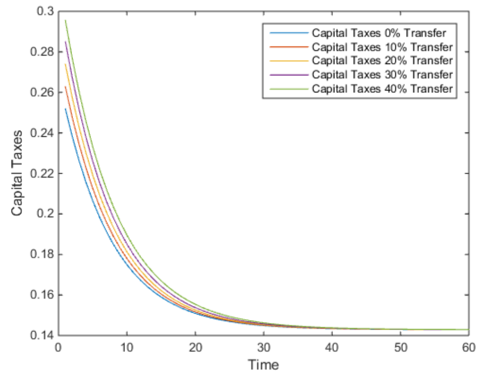
(a) Policy (b) Welfare

Figure 19: Static Policy and Welfare under "Low Sigma"

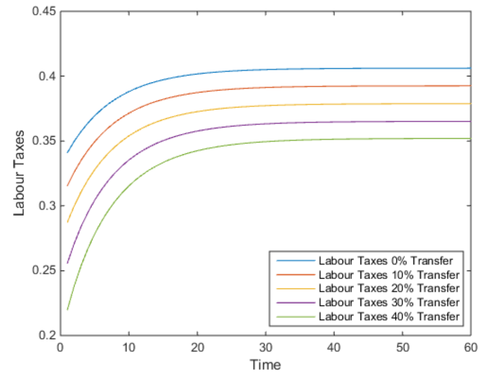


(a) Policy (b) Welfare

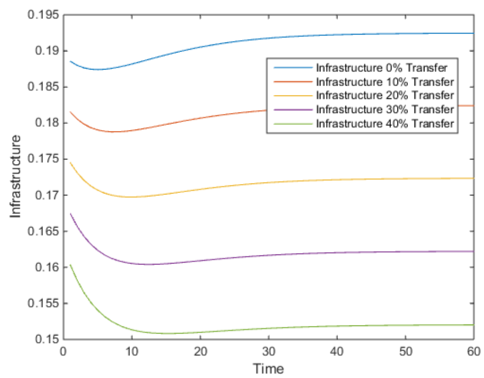
Figure 20: Static Policy and Welfare under "Low Government Share"



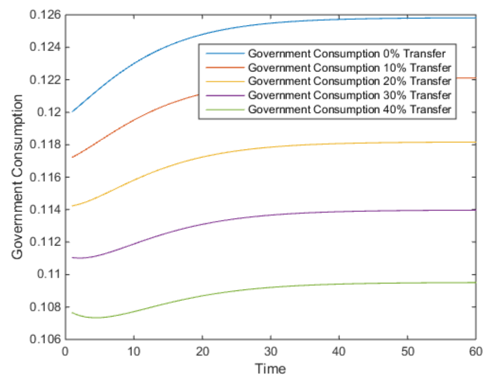
(a) Capital Taxes



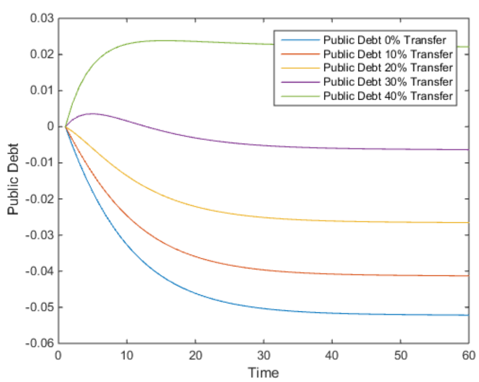
(b) Labor Taxes



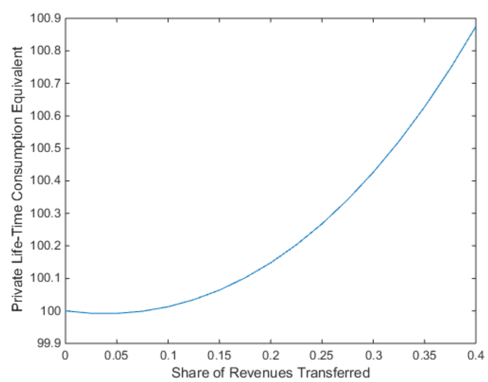
(c) Infrastructure



(d) Government Consumption

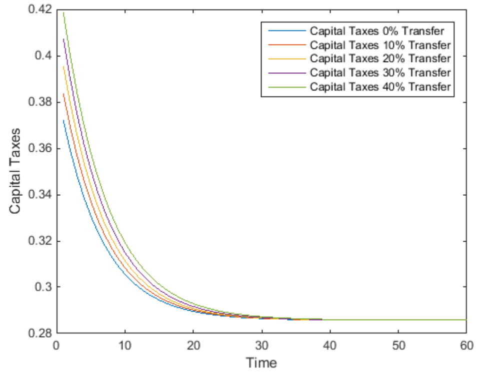


(e) Debt

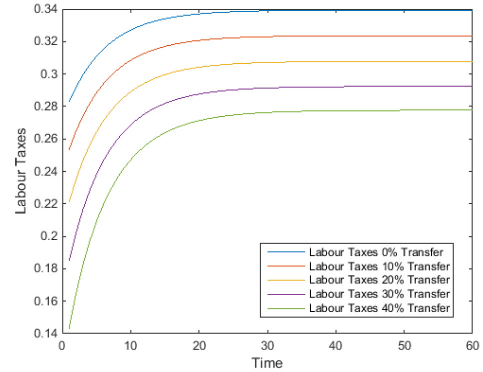


(f) Welfare

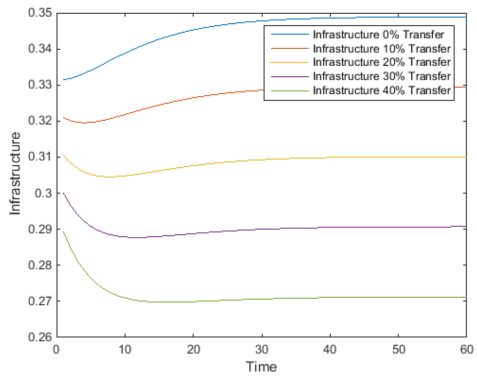
Figure 21: Dynamic Policy and Welfare under “Baseline”



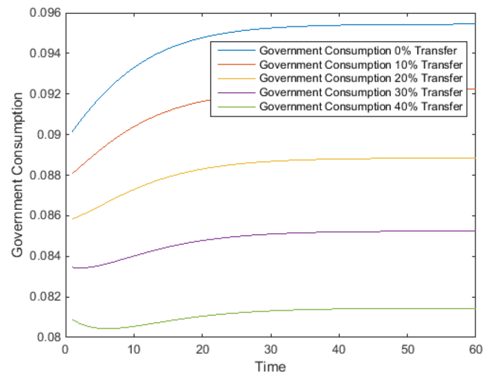
(a) Capital Taxes



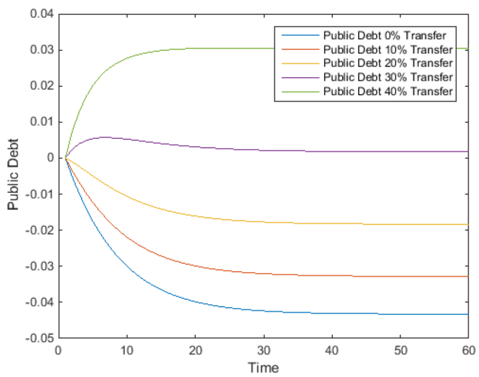
(b) Labor Taxes



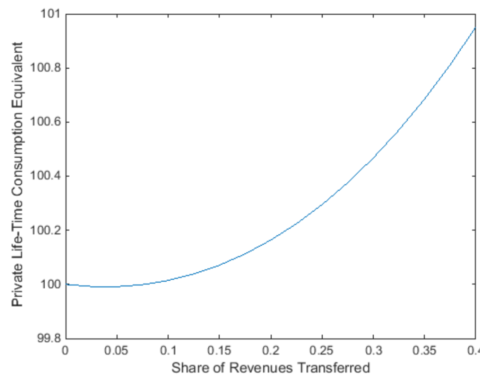
(c) Infrastructure



(d) Government Consumption

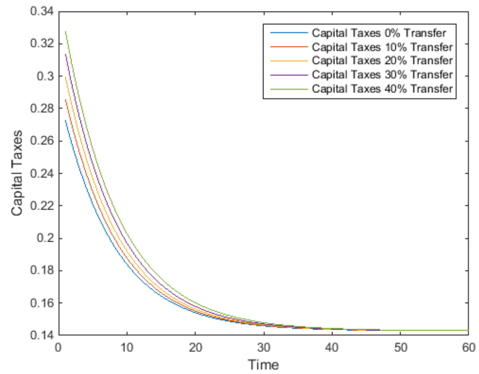


(e) Debt

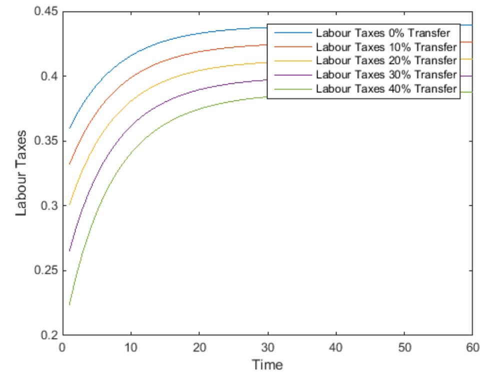


(f) Welfare

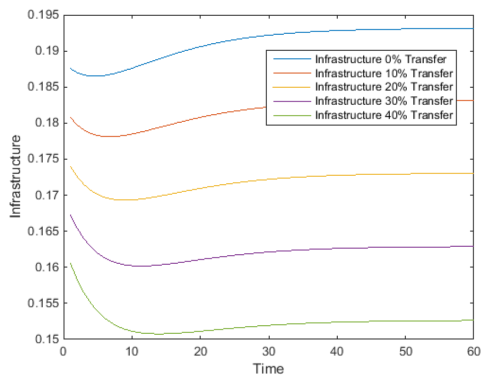
Figure 22: Dynamic Policy and Welfare under “High Infrastructure Share”



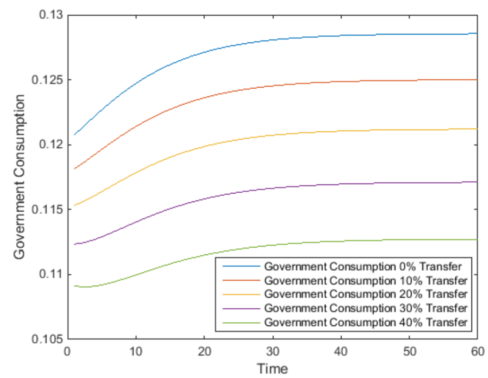
(a) Capital Taxes



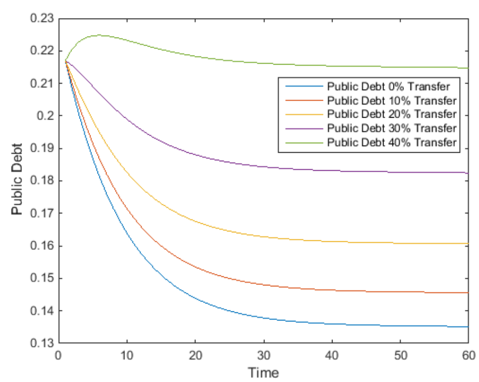
(b) Labor Taxes



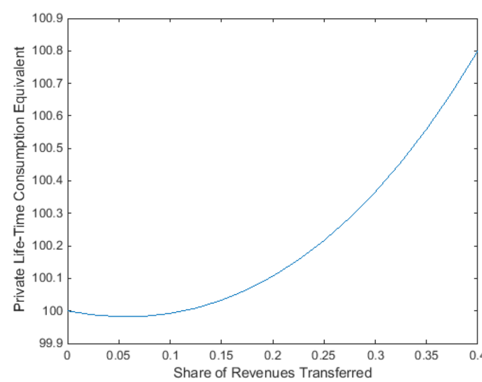
(c) Infrastructure



(d) Government Consumption

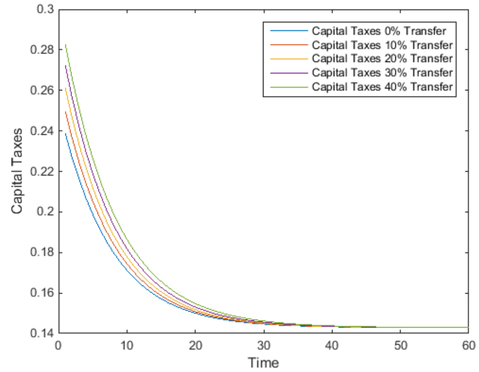


(e) Debt

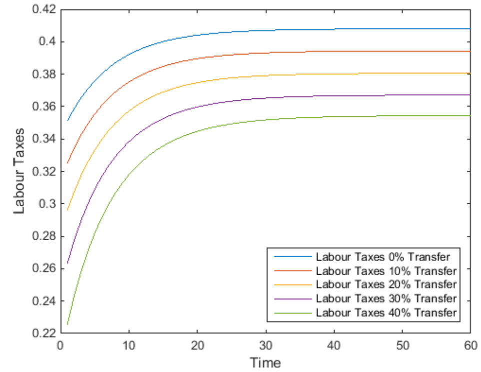


(f) Welfare

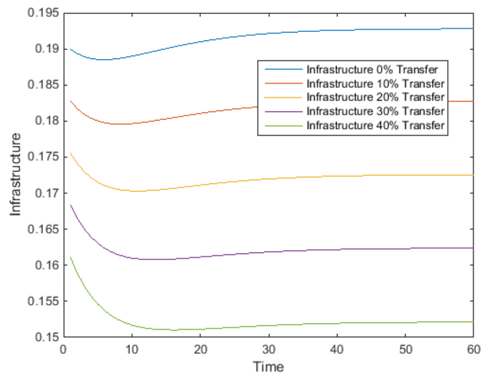
Figure 23: Dynamic Policy and Welfare under "Government Debt"



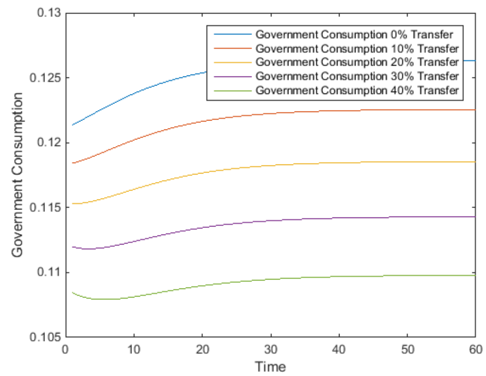
(a) Capital Taxes



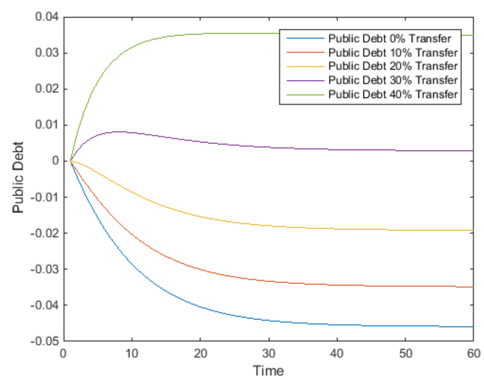
(b) Labor Taxes



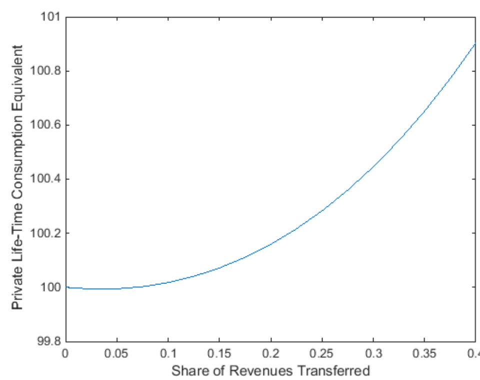
(c) Infrastructure



(d) Government Consumption

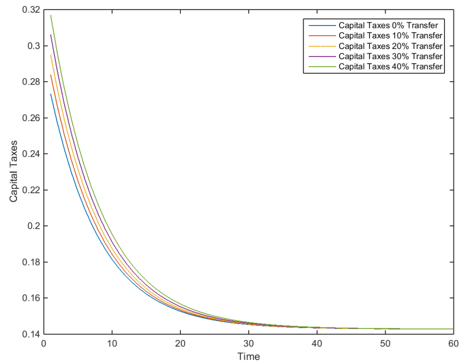


(e) Debt

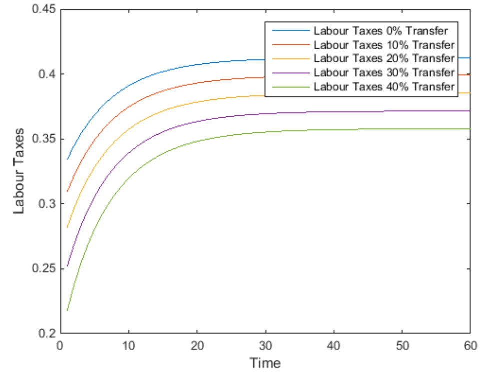


(f) Welfare

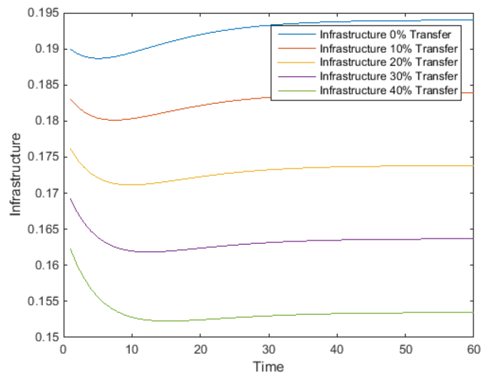
Figure 24: Dynamic Policy and Welfare under "High Sigma"



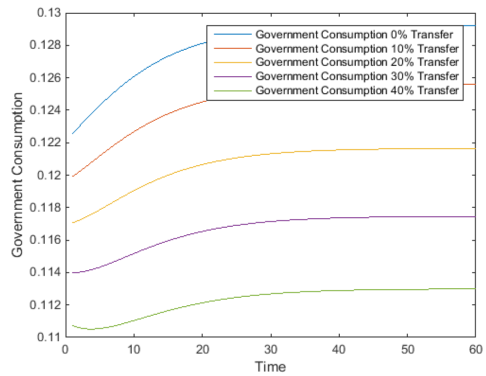
(a) Capital Taxes



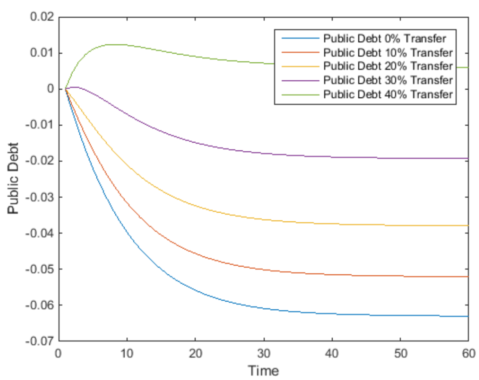
(b) Labor Taxes



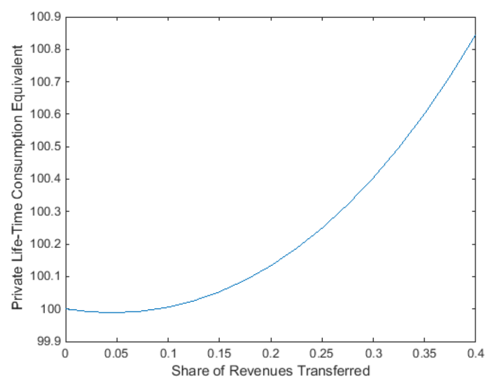
(c) Infrastructure



(d) Government Consumption

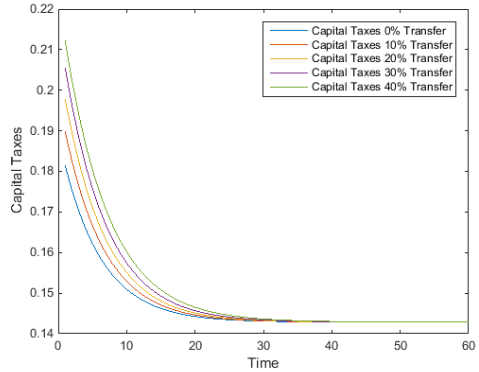


(e) Debt

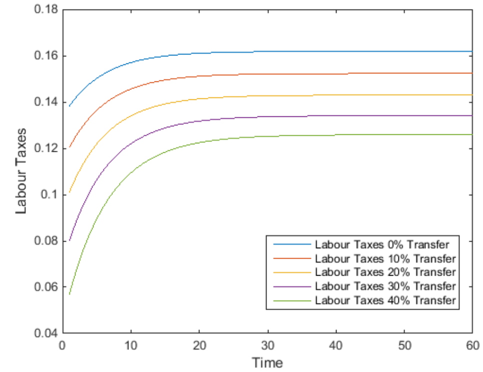


(f) Welfare

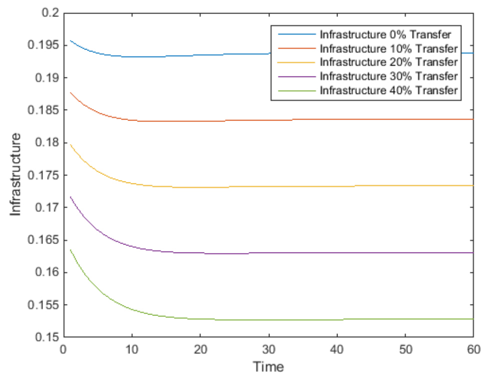
Figure 25: Dynamic Policy and Welfare under "Low Sigma"



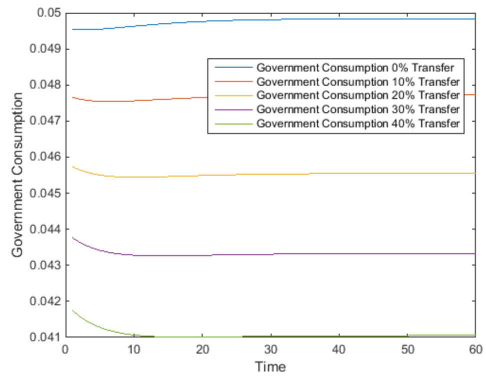
(a) Capital Taxes



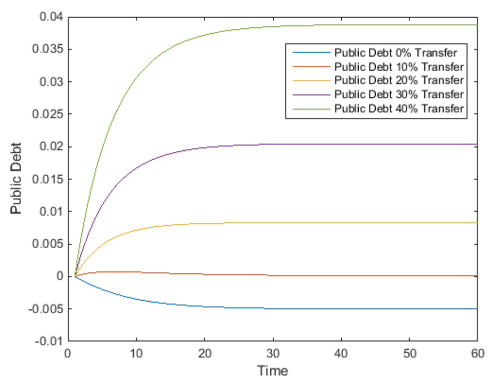
(b) Labor Taxes



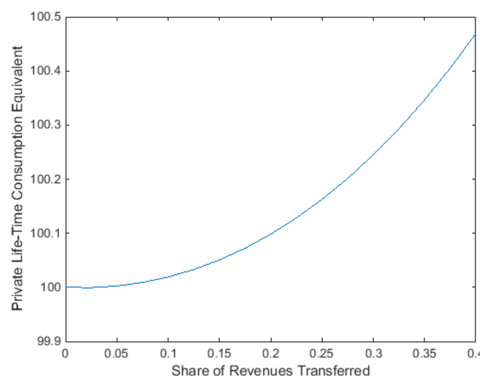
(c) Infrastructure



(d) Government Consumption



(e) Debt



(f) Welfare

Figure 26: Dynamic Policy and Welfare under “Low Government Share”