# Fiscal Competition and Public Debt[*]

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### Abstract

This paper explores the implications of high indebtedness for strategic tax setting in internationally integrated capital markets. When public borrowing is constrained due to default, a rise in a country's initial debt level lowers investment in public infrastructure and makes tax setting more aggressive in that country, while the opposite occurs elsewhere. On net a country with higher initial debt becomes a less attractive location. Using data from the universe of German municipalities in an event-study research design we present empirical evidence that is in line with the theoretical model. Our analysis sheds light on proposals to devolve taxing power to lower levels of governments which differ in initial debt levels.

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# 1 Introduction

The recent economic and financial crisis has led to substantial increases in government debt levels in many countries, which has raised concerns about the sustainability of government finances in general and fears about default in some countries (IMF, 2015). In the short-run, governments may need to increase taxes or cut spending to counter high indebtedness. At the same time fiscal policy also needs to stabilize output and must not become pro-cyclical. While academic research has extensively covered the effect of fiscal policy on economic stabilization and solvency (see DeLong & Summers, 2012; Auerbach & Gorodnichenko, 2012), the implications of high indebtedness for tax policy and strategic tax setting in internationally integrated capital markets have found much less attention.

In this paper, we propose a novel channel through which changes in initial debt levels, like the major pile up of debt during the recent economic and financial crisis, affect the policy and economic outcome. In particular, we show in a two-country model that in case of a binding constraint on public borrowing in one country, a rise in this country's initial debt level induces it to spend less on investment in public infrastructure and to set a lower business tax, while in the other country the opposite occurs. Thus, public policy diverges. On net the borrowing constrained country who experiences a debt shock becomes an unambiguously less attractive location for firms.

The result is driven by a government's limited ability to shift resources across time: A higher level of legacy debt reduces *ceteris paribus* a government's spending on public goods in the present. If taking on new public debt is not constrained by possible default, the optimal policy response is to increase public borrowing to smooth consumption across periods without affecting investment in public infrastructure. However, when default on new debt is an issue, the government's second best response is to partially reduce public infrastructure spending relative to the no default case. This affects the region's attractiveness for firms in the long-run due to the durable goods nature of public infrastructure. In addition, the government responds with a cut in its business tax to partially make up for the loss in competitiveness. Conceptually, our analysis is in the spirit of Cai & Treisman (2005) who argue that asymmetries in certain jurisdictional characteristics may have a substantial effect on how these jurisdictions behave in fiscal competition and how they react to an increase in tax base mobility. In this regard, initial debt levels may constitute an important but so far largely neglected factor.

Our mechanism assumes a direct link between the choice of government borrowing and adjustment of public investment in infrastructure. One might think that the government could respond to the problem of constrained borrowing by adjusting alternative instruments, in particular taxes. We show that this intuition is not correct because the alternative revenue source is optimally chosen even before the debt shock occurs. This finding is in line with Trabandt & Uhlig (2013) who report that shortly after the start of the economic and financial crisis in 2010 many industrialized countries were near the peaks of the Laffer curve regarding

their labor income tax.[1] In addition, Servén (2007) shows evidence for fiscal rules that limit government borrowing or debt to reduce spending on public infrastructure, a finding that is in line with a political economy explanation: Politicians reduce spending on durable goods like public infrastructure that has strong long-term consequences in order to please voters.

Two further results show when the link between initial debt and fiscal competition is further strengthened and when it is overturned. The main mechanism is reinforced when firm location choices become more flexible. An increase in capital mobility (by loosening firm attachment) does not only drive down tax rates on firms, a direct effect that is well known in the literature, but also tends to reinforce the impact of initial debt on fiscal competition. The latter represents a novel indirect effect. Higher initial debt levels are therefore more problematic when international capital markets are more integrated. The mechanism can be reversed, however, if higher initial debt is correlated with or even caused by higher initial public infrastructure. In that case, the affected region gains an advantage in fiscal competition early on when debt increases, which makes its government less rather than more constrained in its subsequent borrowing. The opposite holds when higher initial debt is correlated with more government consumption spending and thus less public infrastructure. Our finding thus complements the literature on the composition of public expenditure (e.g. Keen & Marchand, 1997).

In an empirical analysis using data from about 11,000 municipalities in Germany over the period of 1998 until 2013 we show evidence in line with the base model's theoretical predictions. We make use of an event study design and capture the change in initial debt by a well above average increase in the net repayment burden of a municipality. In line with the theoretical model, the municipality lowers its contemporaneous spending on public infrastructure by nearly 27%, which recovers within 5 years. In addition, the municipality decreases its local business tax by a small, but significant amount. The opposite behavior is found in localities who do not have a neighbor with a debt repayment shock and who increase slightly their tax rates.

Our analysis contributes to the debate on fiscal decentralization (Besley & Coate, 2003; Oates, 2005; Janeba & Wilson, 2011; Agrawal, 2012; Asatryan *et al.*, 2015). Many countries consider or have recently devolved powers from higher to lower levels of government, including the right to tax mobile tax bases like capital (Dziobek *et al.*, 2011). In Germany, for instance, federal states (Länder) may be granted the right to supplement the federal income tax with a state specific surcharge. Critics often fear that devolving taxation power leads to "unfair" fiscal competition and may aggravate existing spatial economic inequalities if regions differ economically and fiscally. We provide a rigorous framework to analyze this concern and show that it is justified if the default constraint on government borrowing is binding, for example due to a large initial debt levels.

It is perhaps surprising that despite the large body of research on inter-jurisdictional

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[1] Furthermore, quantitative results by Mendoza *et al.* (2014) suggest that capital tax increases would not have been sufficient to restore solvency in Europe after the financial crisis.

competition in taxes (see Keen & Konrad, 2013) and public infrastructure investment (e.g. Noiset, 1995; Bucovetsky, 2005), the theoretical literature in this field has mostly ignored public debt levels as a factor in inter-jurisdictional competition for business investment. One possible reason is that in the absence of government default there is no obvious reason why governments cannot separately optimize public borrowing and fiscal incentives for private investment, thus precluding any interaction between the initial debt level and business taxes. This notion also underlies the results of more comprehensive general equilibrium models such as in Mendoza & Tesar (2005).[2] However, in the light of public defaults and a surge in policy measures, such as fiscal rules designed to limit deficits and government debt, unconstrained public borrowing is an unrealistic assumption for some jurisdictions.[3]

We note two exceptions. Arcalean (2017) analyzes the effects of financial liberalization on capital and labor taxes as well as budget deficits in a multi-country world linked by capital mobility. In contrast to our analysis, he focuses on endogenous budget deficits that are affected by financial liberalization because permanently lower tax rates on capital due to more intensive tax competition lead to higher capital accumulation. This in turn makes it attractive for the median voter, who is a worker by assumption, to bring forward the higher benefits of capital taxation through government debt. The mechanism works at the early stages of financial liberalization when capital taxes are relatively high.

Jensen & Toma (1991) show in a two-period, two-jurisdiction model that a higher level of first-period debt leads to an increase in taxation in the following period and a lower level of public good provision in that jurisdiction. In the other jurisdiction, either a higher or a lower tax rate is set depending on whether tax rates are strategic complements or substitutes.[4] The present paper differs from this setting in three important aspects: First, we allow for a default on government debt which endogenously limits the maximum level of public debt. Second, we introduce public infrastructure investment, which is shown to play a key role. Finally, we assume a linear within-period utility function, which allows us to abstract from the intra-period transmission mechanism identified by Jensen & Toma (1991).

The paper is structured as follows. In Section 2, we describe the model framework. We then proceed to the equilibrium analysis in Section 3, which contains the main results for the situation with symmetric initial public infrastructure but possible differences in the public borrowing constraint. In Section 4, we consider a number of extensions, including an asymmetry that is due to differences in initial public infrastructure. In Section 5 we present our empirical analysis based on German municipal data. Section 6 provides the conclusion.

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[2] Mendoza & Tesar (2005) show in a setting without borrowing constraints that legacy debt provides an incentive for large economies to use capital taxes to manipulate interest rates but does not directly affect tax competition.

[3] By "unconstrained" we mean that the government can borrow as much as it wants at the current interest rate assuming no default.

[4] An interesting empirical application for this model in the case of interactions in borrowing decisions can be found in Borck *et al.* (2015). Krogstrup (2002) also analyzes the role of government debt in an otherwise standard ZMW (Zodrow & Mieszkowski, 1986; Wilson, 1986) model of tax competition. Higher interest payments on exogenous public debt lead to lower spending on public goods and higher taxes, similar to Jensen & Toma (1991).

# 2 The Model

We start with a brief overview of the model. The world consists of two jurisdictions, $i = 1, 2$, linked through the mobility of a tax base. The tax base is the outcome of the location decisions of a continuum of firms and generates private benefits and tax revenues that are used by the government for spending on a public consumption good, a public infrastructure good, and debt repayment. Better infrastructure makes a jurisdiction more attractive, while taxes work in the opposite direction. The economy lasts for two periods. Both jurisdictions start with an initial (legacy) debt level $b_{i0}$ and issue new debt in the first period in an international credit market at a given interest rate $r$. We pay particular attention to a government's willingness to repay its debt in period 2, which endogenously limits the maximum available credit in period 1.

The government is assumed to maximize a linear combination of the number of firms in its jurisdiction and the level of the public consumption good. There are two inter-temporal decisions for a government to be made in period 1: the level of borrowing and the spending on public infrastructure. The latter is modeled as a long-term decision to capture the durable good nature of infrastructure projects. Public investment is costly in period 1, but carries benefits only in period 2.

Fiscal competition has two dimensions: tax rate competition in periods 1 and 2, where governments set a tax on each firm in their jurisdiction, and competition in infrastructure spending. We consider a fiscal policy game between the two governments without commitment, that is, governments choose fiscal policy in each period non-cooperatively and cannot commit in period 1 to fiscal policy choices in period 2.

## 2.1 Firms

We begin the description of the model with the location of the tax base, which follows a simple Hotelling (1929) approach.[5] There is a continuum of firms with the total number of firms normalized to 1. Each firm chooses a jurisdiction to locate in and can switch its location between periods at no cost. Firms are heterogeneous in terms of their exogenous bias towards one of the two jurisdictions, which is captured by the firm-specific parameter $\alpha \in [0, 1]$. $\alpha$ comprises firm-specific characteristics that make it more attractive to locate in one or the other region such as existing production facilities or requirements for natural resources. Omitting the time index for the moment, a firm of type $\alpha$ receives a net benefit $\varphi_i(\alpha)$ in jurisdiction $i$ given by

$$\varphi_i(\alpha) = \begin{cases} \psi + \alpha\nu + \rho q_i - \tau_i & \text{for } i = 1 \\ \psi + (1-\alpha)\nu + \rho q_i - \tau_i & \text{for } i = 2. \end{cases} \tag{1}$$

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[5]Our model shares some features with classical models of tax competition as, for example, Zodrow & Mieszkowski (1986), Wilson (1986) and Kanbur & Keen (1993). Our approach is analytically simpler to handle, which is crucial in the presence of many government instruments and possible default on government debt.

The terms $\psi + \alpha\nu$ and $\psi + (1-\alpha)\nu$ represent the exogenous returns. The general return $\psi$ is assumed to be sufficiently positive so that overall return $\varphi_i$ is non-negative and the firm always prefers locating in one of the two jurisdictions rather than not operating at all. The second component of the private return is the firm-specific return in each jurisdiction weighted by $\nu > 0$. The parameter $\nu$ allows us to capture the strength of the exogenous component relative to the policy-induced one. Variation in $\nu$ changes the degree of fiscal competition, which we analyze below. The overall return to investment in a jurisdiction $i$ further increases when the jurisdiction has a stock of public infrastructure in place at level $q_i \geq 0$. The effectiveness of public infrastructure is captured by the parameter $\rho \geq 0$ and is not firm-specific.[6] Finally, the uniform tax $\tau_i$ reduces the return. We assume that the tax is not firm-specific, perhaps because the government cannot determine a firm's type or cannot choose a more sophisticated tax function for administrative reasons.

Let $\alpha \in [0,1]$ be uniformly distributed on the unit interval. There exists a marginal firm of type $\tilde{\alpha}$ that is indifferent between the two locations for the given policy parameters, that is $\varphi_1(\tilde{\alpha}) = \varphi_2(\tilde{\alpha})$. Under the assumption that the marginal firm is interior, $\tilde{\alpha} \in (0,1)$,[7] the number of firms in each jurisdiction is then given by $N_1 = 1 - \tilde{\alpha}$ and $N_2 = \tilde{\alpha}$ or, more generally,

$$N_i(\tau_i, \tau_{-i}, q_i, q_{-i}) = \frac{1}{2} + \frac{\rho\Delta q_i - \Delta\tau_i}{2\nu}, \tag{2}$$

where $\Delta q_i = q_i - q_{-i}$ and $\Delta\tau_i = \tau_i - \tau_{-i}$. The number of firms in a jurisdiction is a linear function of the tax and public infrastructure differentials. Firms split evenly between the two jurisdictions when both policies are symmetric across jurisdictions, that is $\Delta q_i = \Delta\tau_i = 0$. The sensitivity of a firm's location choice with respect to tax rates and infrastructure spending depends on the parameter $\nu$. Higher values of $\nu$ represent less sensitivity.

## 2.2  Governments

Government $i$ takes several decisions in each period. In both periods, it sets a uniform tax $\tau_{it}$ and provides a public consumption good $g_{it}$, which can be produced by transforming one unit of the private good into one unit of the public good. In the first period, the government pays back initial debt $b_{i0}$ (no default by assumption), and decides on public infrastructure investment $m_{it}$ as well as the level of newly issued debt $b_{i1}$. If the government honors the debt contract, $b_{i1}$ is repaid in period 2. We denote the government's default decision with the binary variable $\kappa_i = \{0,1\}$, where 0 stands for no default and 1 for default.

Public investment raises the existing stock of public infrastructure $q_{it}$. In each period, a share $\delta \in [0,1]$ of $q_{it}$ depreciates so that the law of motion for $q_{it}$ is denoted by

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[6]We could let the firm-specific component and the effectiveness of public infrastructure interact. This would lead to a less tractable framework without providing additional insights.

[7]Similarly to Hindriks *et al.* (2008), we make this assumption to avoid the less interesting case of a concentration of all firms in one of the two jurisdictions.

$$q_{it} = (1 - \delta) \, q_{it-1} + m_{it-1}. \tag{3}$$

In period 1 jurisdictions are endowed with an exogenous level of public infrastructure $q_{i0} = \bar{q}_i$.[8] The cost for public infrastructure investment is denoted by $c(m_i)$, which is an increasing, strictly convex function: $c'(m_i) > 0$, $c''(m_i) > 0$. To simplify notation, we suppress the time subscript in $m_i$, since it is effectively only chosen in period 1.

The period-specific budget constraints for the government in $i = 1, 2$ can be stated as follows:

$$g_{i1} = \tau_{i1} N_{i1} - c(m_i) - (1 + r) \, b_{i0} + b_{i1} \tag{4}$$

$$g_{i2} = \tau_{i2} N_{i2} - (1 - \kappa_i) \, (1 + r) \, b_{i1}. \tag{5}$$

In these expressions, the set of available revenue-generating instruments is limited to the business tax. In practice, governments may use a wide range of taxes, including levies on consumption and labor. In the base version we consider only the taxation of firms. In Appendix A.5 we demonstrate that the main insights of the base model are qualitatively not affected by introducing a second tax instrument.

Government borrowing takes place on the international credit market at the constant interest rate $r$. We assume for the time being that government debt is repaid. In our subsequent analysis we pay attention to the possibility of default in period 2.[9]

Each government is assumed to maximize the discounted benefit arising from attracting firms and government spending on a public consumption good according to the following specification:

$$U^i = h_1 \, (u_{i1}) + \beta h_2(u_{i2}) = h_1 \, (N_{i1} + \gamma g_{i1}) + \beta h_2 \, (N_{i2} + \gamma g_{i2}) \,. \tag{6}$$

We think of (6) as the utility function of a representative citizen who benefits from attracting firms because this generates private benefits such as income and employment. Here, we simply use the number of firms in jurisdiction $i$, $N_i$, as an indicator of this benefit. In addition, attracting firms increases the tax base and generates higher tax revenues.[10] The marginal benefit of the public good, $\gamma > 1$, implicitly determines the relative weight attached to the private benefit and public consumption. The linear structure of the within-period utility function is in line with earlier literature (e.g. Brueckner, 1998) in order to solve for Nash tax rates explicitly. This assumption makes the model different from Jensen & Toma (1991) who assume a strictly concave function for the benefit of the public good (within the function $h_2$). As mentioned earlier, our approach is more tractable in the context of

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[8]A jurisdiction's level of public infrastructure may be correlated with its initial level of government debt. We consider this aspect in Section 4.2.

[9]We ignore the possibility of bailouts, which have been relevant in the financial crisis in some cases, but go beyond the scope of this paper.

[10]Our utility function is qualitatively similar to standard models of tax competition. In Section 4.4 we argue that a micro-founded model in the spirit of Hindriks *et al.* (2008) generates also very similar results.

multiple government instruments and possible default on debt, and allows us to demonstrate the novel mechanism at work. $\beta$ is the discount factor which we set equal to $\frac{1}{1+r}$. The intertemporal structure of the utility function assumes that the functions $h_1$ and $h_2$ are concave, and at least one of them is strictly concave. We assume this for $h_1$, such that $h_1' > 0$, $h_2' > 0$, $h_1'' < 0$, $h_2'' \leq 0$.

So far, we assumed that public debt is repaid in both periods, such that creditors have no reason to restrict lending to the government. We now consider default on debt in period 2 through a willingness-to-pay constraint. A government honors the debt contract when the net benefit of defaulting is smaller than the net benefit of paying back the debt. While the former is related to the size of the existing debt level, the latter involves a loss of access to the international credit market and possibly other disturbances. The two-period time horizon allows us, similar to Acharya & Rajan (2013), to take a shortcut for modeling such disturbances. Default in period 2 causes a utility loss of size $z$ in that period, representing the discounted value from being unable to borrow in the future among other possible disadvantages. The period 2 utility in jurisdiction $i$ is given by

$$u_{i2} = N_{i2} + \gamma g_{i2} - \kappa_i z.$$

Two comments are in order. First, we do not model the default decision on government debt regarding initial (legacy) debt $b_{i0}$ in period 1. Legacy debt levels may accumulate due to unforeseen shocks as in the recent European financial and economic crisis, or may play a role when switching to a more decentralized tax system (as is considered in the reform debate on fiscal federalism in Germany).[11]

In a second comment we like to highlight a particular modeling choice. In our model, the fixed interest rate and the binary government default decision are separated. Alternatively, one could assume that the interest rate on debt depends positively on the size of debt $b_{i1}$ due to default risk. In that case the government would face an increasing marginal cost of borrowing. By contrast, in our model default prohibits any borrowing beyond a certain level. This approach has certain advantages in terms of tractability and captures explicitly that the rising cost of borrowing originate from the possibility of default. We return to the role of this assumption in Section 4.4.

## 2.3 Equilibrium

The equilibrium definition has two components. The economic equilibrium is straightforward, as this refers only to the location decision of firms. There is no linkage across periods because relocation costs for firms are zero. An economic equilibrium in period $t = 1, 2$ is

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[11]Our assumption of repayment of legacy debt is reasonable if its size is small enough so that default in period 1 is not attractive. Even if a government default was attractive in period 1, it would not occur in equilibrium, since creditors would not have given any loans in the first place. We checked that there exists a set of sufficiently small initial debt levels that does not lead to default in period 1 but still influences the subsequent choice of fiscal instruments.

fully characterized in Section 2.1 as a profit-maximizing location choice of each firm for given levels of taxes and infrastructure in that period.

The second component comprises the policy game between governments. We assume the following timing of events. In period 1, governments simultaneously decide on how much to invest (i.e. set $m_i$), set new debt $b_{i1}$, choose the tax rate $\tau_{i1}$ and the public good $g_{i1}$, assuming that they pay back the legacy debt $b_{i0}$. Then firms decide where to invest. In period 2, governments simultaneously choose tax rate $\tau_{i2}$, as well as the public good $g_{i2}$, and decide on the default of existing debt $b_{i1}$. Subsequently, firms again make their location choices. Governments observe previous decisions and no commitment is possible. We consider a sub-game perfect Nash equilibrium and solve the model by backward induction.

# 3 Results

## 3.1 Period 2

We begin with analyzing the government decision making in period 2. At that stage, a government decides on its tax rate, the public consumption good level and default, taking as given the policy choices of period 1, that is, the debt levels $b_{i1}$ and the public infrastructure $q_{i2}$ in both jurisdictions $i = 1, 2$. A period 2 Nash equilibrium is a vector of tax rates, public good levels and default decisions such that each government maximizes its period 2 sub-utility, taking the other government's fiscal policy decisions in that period as given, and anticipating correctly the subsequent locational equilibrium .

Government $i$ maximizes period 2 utility as given by equation (6). We analyze the tax and default decisions sequentially, making sure that in the end a global maximum is reached. We start with the choice of the tax rate, which affects the number of firms $N_{i2}$, given by (2) adding time subscripts. The first-order condition is given by

$$U^i_{\tau_{i2}} := \frac{\partial U^i}{\partial \tau_{i2}} = h'_2 \frac{\partial \left(N_{i2}\left(1 + \gamma \tau_{i2}\right)\right)}{\partial \tau_{i2}} = 0, \ i = 1, 2 \tag{7}$$

For the period 2 decision the outer utility function $h_2$ can be ignored as long as $h'_2 > 0$, which we assume. Solving the system of two equations (one for each jurisdiction) with two unknowns, we obtain $\tau_{12}$ and $\tau_{22}$.[12]

Next, we analyze the default decision in period 2, holding tax rates in both jurisdictions constant for the moment. For this purpose, we need to compare the utilities under default and under no default, which defines a willingness-to-pay threshold $b^{wtp}$ at which the

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[12]The second-order condition is fulfilled because $N_{i2}$ is a linear function of tax rates and depends negatively on the own tax rate.

government is indifferent:

$$u_{i2}\left(\kappa_i = 1\right) = u_{i2}\left(\kappa_i = 0\right) \Leftrightarrow N_{i2} + \gamma N_{i2}\tau_{i2} - z = N_{i2} + \gamma\left(N_{i2}\tau_{i2} - b^{wtp}\left(1+r\right)\right)$$
$$\Leftrightarrow b^{wtp} = \frac{z}{\gamma\left(1+r\right)}.$$

If $b_{i1} > b^{wtp}$, a jurisdiction does not repay its debt as the benefits from default outweigh the related costs, and vice versa.[13]

The additive structure of the within period 2 utility allows us to separate the tax and default decisions. The government could choose a different tax rate in case of default than when honoring debt contracts. There is no incentive to do so, however, as tax rate choices are best responses that do not depend on default, as long as the level of public good provision is strictly positive, that is, tax revenue exceeds the repayment burden resulting from debt in period 1. The latter holds as long as the willingness-to-pay threshold is sufficiently strict, which is fulfilled for a sufficiently small $z$.[14]

Taken together, the first-order conditions (7) and the willingness-to-pay condition define the government's optimal decision in period 2. Inserting these candidate tax rates into (2), we find the marginal firm to be of type $\tilde{\alpha} = \frac{1}{2} - \frac{\rho\Delta q_{i2}}{6\nu}$, from which we can derive the number of firms $N_{i2} = \frac{1}{2} + \frac{\rho\Delta q_{i2}}{6\nu}$. Note that $\Delta q_{i2} = \Delta q_{i2}\left(m_i, m_{-i}\right) = \Delta\bar{q}_i\left(1-\delta\right) + \Delta m_i$ is a linear function of the inter-jurisdictional differences in existing public infrastructure $\Delta\bar{q}_i = \bar{q}_i - \bar{q}_{-i}$ and additional investment in public infrastructure $\Delta m_i = m_i - m_{-i}$. We summarize the results for period 2 in the following Proposition.

**Proposition 1.** *Let $\gamma\nu > 1$. For given public infrastructure investment levels $(m_1, m_2)$ and borrowing in period 1 $(b_{11}, b_{21})$, there exists a unique Nash equilibrium for the period 2 fiscal policy game with*

$$\tilde{\tau}_{i2}\left(m_i, m_{-i}\right) = \nu + \frac{\rho\Delta q_{i2}}{3} - \frac{1}{\gamma},$$

$$\tilde{\kappa}_i\left(b_{i1}\right) = \begin{cases} 0 & \text{if } b_{i1} \leq b^{wtp} \\ 1 & \text{if } b_{i1} > b^{wtp} \end{cases}$$

$$\tilde{g}_{i2}\left(m_i, m_{-i}, b_{i1}\right) = \tilde{\tau}_{i2}\tilde{N}_{i2} - (1-\tilde{\kappa}_i)(1+r)b_{i1},$$

*and the number of firms in $i = 1, 2$ given by $\tilde{N}_{i2}\left(m_i, m_{-i}\right) = \frac{1}{2} + \frac{\rho\Delta q_{i2}}{6\nu}$.*

Proposition 1 carries several implications. First, the equilibrium tax rate of jurisdiction $i$ increases with the value of the gross location benefit $\nu$, the own investment in infrastruc-

[13]$b^{wtp}$ is identical across jurisdictions because they face the same $z$. This assumption simplifies the derivation but is not crucial for our results. In fact, heterogeneous utility losses in case of default are one of the reasons why the Willingness-to-pay Condition that we derive below may be binding in one jurisdiction and not the other. We describe this situation as Case II below.

[14]When inserting $b^{wtp}$ as the maximum debt level for $b_{i1}$ into (5), it becomes obvious that $g_{i0}^* > 0 \iff \frac{z}{\gamma} < \tau_{i2}^* N_{i2}^*$.

ture $m_i$, and the marginal benefit of the public good $\gamma$, while the tax rate decreases with infrastructure spending by the other government $m_{-i}$. Better infrastructure provides more benefits to firms that are partially taxed. The tax rate is positive if $\nu$ and $\gamma$ are sufficiently large ($\gamma\nu > 1$). Moreover, any divergence in tax rates stems solely from differences in public infrastructure, $\Delta q_{i2}$. Second, the average tax rate across jurisdictions $\bar{\tau}_2 = \frac{\tau_{12}^* + \tau_{22}^*}{2} = \nu - \frac{1}{\gamma}$ is independent of public infrastructure levels, as the terms involving public infrastructure offset each other, but decreases when the general location benefit $\nu$ declines, making firms more sensitive to policy differences.

## 3.2 Period 1

We first abstract from any confounding asymmetries and let initial levels of public infrastructure be the same ($\bar{q}_1 = \bar{q}_2$). We relax this assumption below. Beginning with the second stage of period 1, firms choose their location in the same way as in period 2 because location decisions are reversible between periods at no cost. In the first stage of period 1 fiscal policy is determined. Recall that default on debt from period 0 is not considered. However, new borrowing in period 1 is constrained by default in period 2. Proposition 1 shows that a government defaults when its debt level exceeds $b^{wtp}$. Therefore, no lender gives loans above this threshold. We thus have an upper limit on borrowing in the form of a willingness-to-pay condition which is defined as follows.

**Condition 1** (Willingness-to-pay Condition). $b_{i1} \leq b^{wtp} = \frac{z}{\gamma(1+r)}$.

The advantage of Condition 1 is its simplicity, as it does not depend on public investment and legacy debt levels.

We denote by $b_{i1}^{des}$ the desired level of borrowing in period 1 if the default problem in period 2 is ignored. If utility is strictly concave in $b_{i1}$, and assuming an interior level of the public consumption good, the optimal period 1 debt is given by

$$b_{i1}^* = \min\left\{b_{i1}^{des}, b^{wtp}\right\}.$$

We now consider two separate cases. First, we assume that the willingness-to-pay condition is not binding in either of the jurisdictions. The assumption is correct if, for example, the default cost $z$ and thus $b^{wtp}$ are very large, so that $b_{i1}^* = b_{i1}^{des} < b^{wtp}$. In this case we can derive and use the first-order conditions for all fiscal variables in period 1, taking into account the variables' impact on period 2 equilibrium values. In a second step, we turn to the case where Condition 1 is binding in jurisdiction 1 only, that is $b_{11}^* = b^{wtp}$. The set of first-order conditions of the government in jurisdiction 1 is reduced by one because it is constrained in its borrowing (or more precisely, the first-order condition for $b_{11}$ does not hold with equality).[15]

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[15] We have checked the consistency of all assumptions and the working of the model using a numerical example with quasi-linear utility. We let $h_{i1}(u_{i1}) = \ln(u_{i1})$, $h_{i2}(u_{i2}) = u_{i2}$, $c(m_i) = m_i^2$, $\bar{q}_i = \bar{q}_j$ and set parameter values $\rho = 1.4$, $\nu = 1.4$, $\gamma = 1.3$, $\delta = 1$, $z = 0.25$, $r = 0.01$ such that $\beta = 0.99$ and $b^{wtp} = 0.19$.

**Case I: The Willingness-to-pay Condition is not binding in both jurisdictions**

After inserting budget constraints, both governments $i = 1, 2$ solve the following maximization problem

$$\max_{\tau_{i1}, m_i, b_{i1}} U^i = h_1 \left( N_{i1} + \gamma \left( \tau_{i1} N_{i1} - c - (1 + r) b_{i0} + b_{i1} \right) \right) \tag{8}$$
$$+ \beta h_2 \left( \tilde{N}_{i2} + \gamma \left( \tilde{\tau}_{i2} \tilde{N}_{i2} - (1 + r) b_{i1} \right) \right) \text{ s.t. } g_{i1} \geq 0, \, m_i \geq 0.$$

This maximization problem is similar to the one discussed by the tax-smoothing literature that also considers inter-temporal aspects of fiscal policy (e.g. Barro, 1979). As before, we assume a positive level of public good provision $g_{i1} \geq 0$.[16] The values for period 2 ($\tilde{\tau}_{i2}, \tilde{\kappa}_i,$ $\tilde{N}_{i2}$), as given in Proposition 1, are correctly anticipated. Condition 1 ensures that debt contracts are always honored, as shown in expression (8). The first-order conditions for $i = 1, 2$ are

$$\frac{\partial U^i}{\partial \tau_{i1}} = h'_{i1} \frac{\partial \left( N_{i1} \left( 1 + \gamma \tau_{i1} \right) \right)}{\partial \tau_{i1}} = 0, \tag{9}$$

$$\frac{\partial U^i}{\partial m_{i1}} = -h'_{i1} \gamma c' + \beta h'_{i2} \frac{\partial \left( \tilde{N}_{i2} \left( 1 + \gamma \tilde{\tau}_{i2} \right) \right)}{\partial m_i} = 0, \tag{10}$$

$$\frac{\partial U^i}{\partial b_{i1}} = \gamma h'_{i1} - \beta \gamma (1 + r) h'_{i2} = h'_{i1} - h'_{i2} = 0. \tag{11}$$

In the first-order condition (11), we make use of the assumption $\beta = \frac{1}{1+r}$. We derive the full set of second-order conditions in Appendix A.1.[17] Note that $U^i$ is strictly concave in $b_{i1}$, as long as at least one of the two functions $h_{i1}$ or $h_{i2}$ is strictly concave.

We solve the system of six first-order conditions (three for each jurisdiction) as follows: Assuming that public consumption good levels are strictly positive, the first-order conditions for tax rates (9) for both jurisdictions are independent of infrastructure investment as well as debt levels, and can be solved in a similar way as above in period 1, yielding

$$\tau_{i1}^* = \nu - \frac{1}{\gamma}, \, N_{i1}^* = \frac{1}{2}, \, i = 1, 2 \tag{12}$$

Since by assumption the public infrastructure differential is zero in period 1, the tax base is split in half between the two jurisdictions. As in period 2, the more footloose firms are (i.e. the lower $\nu$ is), the lower are equilibrium tax rates. This corresponds to the standard result that increasing capital mobility drives down equilibrium tax rates.

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We solve the example using a simple iterative algorithm and obtain results that are consistent with our general analysis.

[16] The relevant parameter restriction depends on the functional form of $U^i$. For example, if $U^i$ is quasi-linear, that is $h''_2 = 0$, one obtains a positive public good level $g_{i1}^* = \frac{1}{2\gamma} > 0$ in equilibrium.

[17] The second-order conditions are always satisfied if the cost function for infrastructure investment is sufficiently convex.

Using the condition for period 1 borrowing (11), $h'_{i1} = h'_{i2}$, we can simplify the condition for optimal infrastructure investment (10) to $\beta\frac{\partial\left(\tilde{N}_{i2}(1+\gamma\bar{\tau}_{i2})\right)}{\partial m_i} = \gamma c'(m_i)$. We use the period 2 equilibrium values to obtain

$$c'(m_i) = \frac{\beta\rho}{3}\left(1 + \frac{\rho\Delta m_i}{3\nu}\right),\ i = 1, 2. \tag{13}$$

A symmetric equilibrium $m_1 = m_2 = m^*$ always exists. It is unique if the cost function for public infrastructure $c$ is quadratic because then the first-order conditions are linear. Asymmetric equilibria may exist though.[18] The combined results from the first-order conditions for taxes and infrastructure spending can now be used to determine the optimal borrowing level, as all other variables entering the arguments of $h_{i1}$ and $h_{i2}$ are determined via (10) and (11).

An interesting property of (13) is that it is independent of the initial debt level, which leads to a neutrality result: The choice of $m_i$ is not affected by $b_{i0}$ if the willingness-to-pay condition is not binding. We summarize our insights from the equilibrium under non-binding debt constraints in the Proposition below.

**Proposition 2.** *Let $\gamma\nu > 1$. Assume Condition 1 is not binding in both jurisdictions and initial public infrastructure levels are symmetric $\bar{q}_1 = \bar{q}_2$.*

   *a) A subgame perfect Nash equilibrium with symmetric infrastructure spending exists, in which first-period tax rates are $\tau^*_{i1} = \nu - \frac{1}{\gamma}$ and infrastructure spending and first period borrowing are implicitly given by $c'(m^*) = \frac{\beta\rho}{3}$ and condition (11).*

   *b) Changes in a jurisdiction's legacy debt ($b_{i0}$) affect its period 1 borrowing and its period 2 public consumption good, but do not affect fiscal competition (tax rates and public infrastructure). The firms' location decisions in both periods are unaffected.*

   *c) Lower $\nu$ (i.e. firms are more footloose) implies lower tax rates in both jurisdictions in both periods.*

Underlying the debt neutrality result is the following intuition: When governments can choose their desired borrowing level, the unconstrained decision on period 1 debt leads to the equalization of marginal utilities across periods. This frees the infrastructure spending decision from doing this. Infrastructure spending serves to equalize the marginal benefit of an improved economic outcome in period 2 (number of firms and public consumption good) and the marginal cost from spending in period 1 that implies forgone public good consumption in that period. The neutrality result with respect to inter-temporal aspects of fiscal competition may explain why the existing literature has not much addressed the link between fiscal competition and public legacy debt.[19] However, endogenous constraints on

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[18]For example, a corner solution with one jurisdiction not investing at all exists if $c(m_i) = \frac{m_i^2}{2}$ and $2\beta\rho^2 > 9\nu > \beta\rho^2$. The first inequality ensures that one jurisdiction cannot benefit from infrastructure investment, while the second inequality makes sure that the jurisdiction finds a positive level of infrastructure $m_i^* = \frac{3\beta\rho\nu}{9\nu - \beta\rho^2}$ optimal.

[19]We abstract from inefficiencies in public good provision and thus ignore the intra-period transmission channel highlighted by Jensen & Toma (1991) to focus on the inter-temporal effect of initial public debt.

borrowing change this conclusion.

**Case II: The Willingness-to-pay Condition is binding in one jurisdiction**

We now turn to the case where Condition 1 is binding in jurisdiction 1, but not in the other jurisdiction. In this scenario, jurisdiction 1 would like to run a higher debt level than lenders are willing to provide, as the latter correctly anticipate the default problem in period 2, that is $b_{11}^{des} > b^{wtp}$. In equilibrium, the first-order condition for period 1 debt, (11), does not hold with equality. Instead the optimal borrowing level equals the maximum feasible level given by $b^{wtp}$ due to the strict concavity of $U^1$ with respect to $b_{11}$. First-order condition (9) still holds and together for both jurisdictions the two conditions determine the Nash tax rates in period 1, which are identical to Case I. As before, we make the appropriate assumption that the level of the public consumption good is positive and thus an interior solution is obtained.[20] In this case, legacy debt does not affect period 1 taxes.

We are left with the two jurisdictions' first-order conditions for public infrastructure investment, (10). The absence of condition (11), however, now implies that the marginal utilities in periods 1 and 2 are typically not equalized for jurisdiction 1, $h'_{11} \neq h'_{12}$. In particular, $h'_{11}$ in (10) depends on the level of infrastructure investment. This is the key difference to Case I.

We are interested in the effect of legacy debt on fiscal competition, that is period 2 taxes and public infrastructure. We cannot solve explicitly for public investment levels, as the two conditions are nonlinear functions of $m_1$ and $m_2$. We can undertake comparative statics, however, by totally differentiating the first-order conditions for public infrastructure, assuming an interior solution for the public consumption good and making sure that tax rates for period 1 are determined in isolation from the other relevant first-order conditions.

The sign of the comparative static effects can be partially determined when we assume that the Nash equilibrium is stable, as suggested by Dixit (1986). In this case, the sign of the own second-order derivative regarding infrastructure spending is negative, $\frac{\partial^2 U^i}{\partial m_i^2} < 0$, $i = 1, 2$, and importantly, the own effects dominate the cross effects, that is $\frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^{-i}}{\partial m_{-i}^2} > \frac{\partial^2 U^{-i}}{\partial m_{-i} \partial m_i} \frac{\partial^2 U^i}{\partial m_i \partial m_{-i}}$. A detailed derivation of the comparative static analysis is relegated to Appendix A.2. Making use of the Dixit (1986) stability assumptions, we obtain

$$\frac{\mathrm{d}m_1}{\mathrm{d}b_{10}} = -\frac{1}{\phi} \frac{\partial^2 U^2}{\partial m_2^2} \frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0, \tag{14}$$

$$\frac{\mathrm{d}m_2}{\mathrm{d}b_{10}} = \frac{1}{\phi} \frac{\partial^2 U^2}{\partial m_2 \partial m_1} \frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} > 0, \tag{15}$$

with $\phi = \frac{\partial^2 U^1}{\partial m_1^2} \frac{\partial^2 U^2}{\partial m_2^2} - \frac{\partial^2 U^2}{\partial m_2 \partial m_1} \frac{\partial^2 U^1}{\partial m_1 \partial m_2} > 0$ and $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} = h''_{11} \frac{\gamma^2}{\beta} c' < 0$. The latter inequality means that the incentive to invest in infrastructure declines with higher legacy debt, as the

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[20] Using the numerical example described in footnote 15 we verify that such an equilibrium may indeed be obtained.

marginal utility of consumption rises when $h_1'' < 0$. Thus, solution (14) contains our second important result: If a jurisdiction is constrained in its borrowing, an increase in legacy debt leads unambiguously to a decline in its infrastructure investment. The cross effect of an increase in legacy debt on the infrastructure investment in the other jurisdiction is positive. Furthermore, since $\frac{\partial^2 U^i}{\partial m_i \partial b_{i0}}$ depends on $\nu$, capital mobility clearly affects the size of the effect of legacy debt on public infrastructure investments. We summarize these results in the following proposition and discuss them in detail below.

**Proposition 3.** *Let $\gamma\nu > 1$. Assume that jurisdiction 1 is constrained in its borrowing decision in period 1 and initial public infrastructure levels are symmetric $\bar{q}_1 = \bar{q}_2$.*

  a) *If the Nash equilibrium in infrastructure spending is stable, an increase in the legacy debt of jurisdiction 1 ($b_{10}$) leads to a decline in infrastructure investment ($m_1$) and also reduces i's period 2 tax rate ($\tau_{12}$). In jurisdiction 2, it raises the tax rate ($\tau_{22}$) and infrastructure spending ($m_2$). As a consequence, the number of firms decreases in jurisdiction 1 and increases in jurisdiction 2.*
  b) *Lower $\nu$ (i.e. firms are more footloose) implies lower tax rates in both jurisdictions in both periods. In addition, if $h_1''' > 0$, the effect of legacy debt on the public investment level and period 2 tax rates is the stronger in magnitude the larger is $\nu$.*

The interaction of public infrastructure investment and tax setting both within jurisdictions and over time, as well as, between competing governments implies that an increase in legacy debt in one jurisdiction affects various fiscal policy instruments. Table 1 summarizes these effects for unrestricted (Case I) and restricted (Case II) public borrowing in period 1.

Table 1: Change in Legacy Debt ($b_{10}$), Impact on Fiscal Policy

| Willingness-to-pay Condition | Jurisdiction 1 ($db_{10} > 0$) | | | | Jurisdiction 2 ($db_{20} = 0$) | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Period 1 | | Period 2 | | Period 1 | | Period 2 | |
| | $m_1$ | $b_{11}$ | $\tau_{12}$ | $N_{12}$ | $m_2$ | $b_{21}$ | $\tau_{22}$ | $N_{22}$ |
| Case I (non-binding) | - | ↑ | - | - | - | - | - | - |
| Case II (binding in 1) | ↓ | - | ↓ | ↓ | ↑ | ↑ | ↑ | ↑ |

The main reason for the negative effect of legacy debt $b_{10}$ on public investment $m_1$ is that borrowing cannot be increased to smooth consumption if the willingness-to-pay condition is binding. The burden from higher legacy debt falls *ceteris paribus* on period 1 and raises the marginal utility of consumption in period 1, thus making a transfer of resources from period 2 to period 1 more desirable. Because higher government debt is impossible, a second best government response is to reduce investment in public infrastructure in that jurisdiction. This in turn lowers government spending in period 1 and increases the space for public good consumption. At the same time, the constrained government makes up for reduced competitiveness in period 2 by lowering its tax rate in the long run.

The increase in $b_{10}$ also affects public investment policy in jurisdiction 2. The decrease in $m_1$ provides an incentive for jurisdiction 2 to increase public investment because of the strategic advantage arising from this situation.[21] As a consequence, jurisdiction 2 becomes more attractive in period 2.

A policy divergence occurs also in the period 2 tax equilibrium. Starting from a stable equilibrium, an increase in a jurisdiction's initial debt leads to a lower tax rate for this jurisdiction in period 2, while the opposite holds in the other jurisdiction. The latter can afford a higher tax because the better relative standing in public infrastructure partially offsets higher taxes. Overall, we conclude that an exogenous increase in government debt leads to policy divergence across jurisdictions regarding fiscal competition instruments.

The second part of Proposition 3 refers to the impact of capital mobility. As in the case with no restriction on public borrowing, higher capital mobility, captured by a decrease in $\nu$, puts downward pressure on equilibrium tax rates. However, in addition to this direct effect, an additional indirect effect from capital mobility arises when public borrowing in period 1 is restricted. Intuitively, higher capital mobility reduces the government's revenue from taxing firms in period 1. This makes the government even more sensitive in period 1 to increases in legacy debt. It becomes even less attractive to shift resources to the future by investing in public infrastructure. Consequently, a government sets an even lower tax rate in period 2. Analytically, by affecting the level of tax rates in period 1, $\nu$ changes $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}$. In particular, $\frac{d}{d\nu}\left(\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\right) = h'''_{11}(1+r)\gamma^3 c'$ is positive if and only if $h'''_{11} > 0$, which holds for many strictly concave functions such as natural logarithm and square root.

It is interesting to put our main results in the context of the scarce literature on tax competition and public debt. As noted in the introduction, Arcalean (2017) is close to but different from our work. In his model government, debt is always repaid. Financial liberalization puts pressure on tax rates which in turn leads to more capital accumulation. The gains from an increase in future tax bases can be brought forward through higher initial budget deficits. This incentive works because the median voter, who has labor income only, redistributes through capital taxation to herself intra-temporally and through debt intertemporally. In our paper, we emphasize the role of initial (legacy) debt and focus on a different inter-temporal mechanism through investment in public infrastructure. Our results can also be related to Jensen & Toma (1991), who show that period 1 debt affects period 2 capital tax rates even in the absence of default. While the models are different in some other aspects, the non-linear within-period utility function in Jensen & Toma (1991) drives this difference. In contrast, our simplifying assumption is useful in order to clearly identify the role of default which we obtain by comparing the results from Case I and Case II, respectively.

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[21]Since jurisdiction 2 is not constrained in its borrowing, the increase in $m_2$ is financed by an increase in $b_{21}$, see Appendix A.2.

# 4 Robustness and Extensions

We have made several simplifying assumptions to ease presentation and direct attention to the main insights and underlying mechanisms. In this section we discuss other settings. For example, we consider the case where both competing jurisdictions may not be able to borrow at their desired level. Furthermore, we analyze the effect of structural differences in initial infrastructure across competing jurisdictions which are a frequent phenomenon and may be correlated with the legacy debt level. Finally, we consider a tax on an immobile tax base. We also discuss more general modeling choices including the exogenous interest rate. We summarize the main findings and relegate a more formal derivation to the Appendix.

## 4.1 Constrained Borrowing in Both Jurisdictions

We begin by considering an alternative case where the Willingness-to-pay Condition is binding in both jurisdictions. In this case, the set of first-order conditions in period 1 is reduced to (9) and (10) (see Appendix A.3). The first-order condition with respect to $b_{i1}$ does not hold with equality for both jurisdictions. Thus, the maximization problem of each jurisdiction is identical to the constrained jurisdiction in Case II (see derivation in Appendix A.2). It follows that the direction of the response to a marginal increase in $b_{i0}$ is also the same: Jurisdiction $i$ lowers public infrastructure investment in period 1 and also reduces its period 2 tax rate to mitigate the resulting loss in attractiveness.

The effect of a change in legacy debt in one jurisdiction on the infrastructure investment in the other jurisdiction is less clear cut and depends on the strategic interaction of public infrastructure investment. If public investments are strategic substitutes[22] jurisdiction 2 reacts to jurisdiction 1's decrease in $m_1$ with an increase in $m_2$. Such an unambiguous result is, for example, obtained if we assume that the inter-temporal utility function is of the quasi-linear type ($h_2'' = 0$). In this case $\frac{\partial^2 U^2}{\partial m_2 \partial m_1}$, which is the change in the net benefit of public infrastructure investment in one jurisdiction if the government in the other jurisdiction invests more (or less), is negative and $\frac{dm_2}{db_{10}} > 0$.

With regard to tax policy, the increase in initial debt in jurisdiction 1 leads to a divergence in the period 2 tax equilibrium similar to Case II. The tax rate of jurisdiction 1 decreases relative to the tax rate in jurisdiction 2. This effect is independent of the infrastructure spending response in region 2 because in the fiscal competition game the best response of jurisdiction 2 when deviating from the initial Nash equilibrium is to adjust fiscal policy instruments in such a way that its attractiveness increases relative to jurisdiction 1. Thus, even if it lowers $m_2$, it will do so only to the extent that it still turns out to be more attractive than jurisdiction 1. As a consequence, jurisdiction 2 can afford a higher tax rate without reducing its mobile tax base.

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[22] This a standard feature in fiscal competition models (e.g. Hindriks *et al.*, 2008). For a discussion on the role of public inputs in fiscal competition, see Matsumoto (1998).

## 4.2 Interaction Between Initial Public Infrastructure and Initial Public Debt

A potential feed-back mechanism of legacy debt differentials may occur if these are related to differences in initial infrastructure levels, $\bar{q}_1 \neq \bar{q}_2$. Public debt that results from large public infrastructure investments in the past has a different impact on the subsequent fiscal competition game than one that has mostly been caused by public consumption.

To understand the mechanism at work, note that an asymmetric level of initial public infrastructure has two implications. First, *ceteris paribus* it causes the better endowed and thus generally more attractive jurisdiction to set higher taxes because its better infrastructure offsets weaker tax conditions. This effect takes place in period 1, and also in period 2 if public infrastructure does not fully depreciate ($\delta < 1$). Second, asymmetric equilibria in the tax competition game feed into the inter-temporal fiscal variables. A higher level of public infrastructure attracts more firms, which in turn raises the incentive for additional public infrastructure spending as long as public investment is a strategic substitute.[23] More public infrastructure investment also raises the level of desired public borrowing in period 1, $b_{i1}^{des}$, both in order to compensate for an otherwise lower public good provision in that period, and because the better endowed jurisdiction intertemporally shifts part of the benefits from a higher level of period 2 tax revenues to period 1. A higher level of existing public infrastructure thus improves a jurisdiction's position in the subsequent fiscal competition game. This relates to the polarization effect described by Cai & Treisman (2005).

We consider an asymmetry in initial infrastructure ($\bar{q}_1 \neq \bar{q}_2$) that is caused by legacy debt differentials. In particular, suppose that the initial level of public infrastructure is a function of legacy debt, $\bar{q}_i = f(b_{i0})$. Intuitively, there are two forms in which such a relation appears reasonable. For example, Poterba (1995) points out that debt financing of public infrastructure spending can make it easier to obtain support for government investment projects as they appear less costly to the public. Thus, if higher legacy debt levels are an indicator of more public infrastructure spending in the past, the relationship is positive, that is, $f' > 0$. High legacy debt levels may, however, also be caused by public consumption spending. In this case, the level of existing infrastructure may be negatively related to the observed legacy debt, and therefore $f' < 0$.

In Appendix A.4, we insert $\bar{q}_i = f(b_{i0})$ into our model and analyze the equilibria for Cases I and II. In both scenarios, the negative effect of an increase in initial public debt on infrastructure investment in period 1 is reinforced when there is a negative relation between legacy debt and initial public infrastructure ($f' < 0$). A positive relation between $b_{i0}$ and $\bar{q}_i$ ($f' > 0$) leads to more nuanced results. If legacy debt has no effect on inter-temporal redistribution (Case I), only the polarization effect of public infrastructure spending is present. This additional mechanism generates a link between $b_{i0}$ and $m_i$ even in the case of unrestricted public borrowing. Higher $b_{i0}$ leads to more infrastructure spending in period 1

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[23] In our model this is generally the case for quasi-linear inter-temporal utility functions.

if higher legacy debt is associated with more public investment in the past ($f' > 0$).[24]

Inter-temporal considerations are relevant, if public borrowing is restricted (Case II). The benchmark result in Proposition 3 remains relevant as the government's desire to smooth utility across periods induces it to lower public investment when the legacy debt burden is higher. At the same time, the polarization effect that results from the (potentially positive) relation between $b_{i0}$ and $\bar{q}_i$ works in the opposite direction if public investment is a strategic substitute. The effect described in Proposition 3 is thus mitigated. In extreme scenarios, the results may even be reversed. This is, however, only the case if public infrastructure spending is indeed a strategic substitute and the polarization effect dominates the coinciding mechanism of Proposition 3.

## 4.3 A Tax on Domestic Income

In the base model we restrict tax policy to the taxation of capital at source. In reality, governments have various revenue sources, which may include a tax on a less mobile base such as labor income. Would the introduction of such a tax affect the results with regard to the role of legacy debt in our fiscal competition model? The short answer is basically no. In Appendix A.5, we prove this result in a model with an additional tax on domestic income: the government can tax a share of the local benefit of foreign investment, which can be interpreted as a wage tax on labor income that citizens receive from the firms that locate in their jurisdiction. The tax is distortive by assuming that the government incurs a convex administrative cost when collecting revenue from this source.

We repeat our analysis and show that the results with regard to legacy debt prevail. An additional tax raises government revenue in both periods but does not affect the nature of inter-temporal redistribution that induces governments to react to an increase in the initial debt repayment burden with a cut in public investment spending and a subsequent reduction in the tax rate on the mobile income. The result is obtained precisely because the additional tax instrument relates to the immobile, local tax base and thus has no effect for the fiscal competition game that drives our main results. The tax is optimized separately in any case. We note, however, that the additional revenue from a labor tax can make it less likely that governments face binding constraints with regard to their borrowing.

## 4.4 Model Robustness

Two further modeling choices are worth being discussed in more detail. In the base model the number of firms in a region enters directly into the region's utility function. In comparison to a standard micro-founded model, this simplifies notation while still keeping the main idea: firms generate private benefits in form of wages and employment. As discussed above, introducing an additional immobile income source does not alter the results of our analysis, even if it is related to the level of firm investment. Furthermore, we are able to confirm

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[24]This result is formalized in condition (A.17) in the Appendix.

our results in a micro-founded model similar to Hindriks *et al.* (2008).[25] More generally, our results hold for any form of economy for which a jurisdiction's within-period utility is a concave function of its own tax rate.

The other important modeling choice refers to the market for government bonds. Public borrowing is assumed to take place on an international debt market with an exogenous interest rate. Both assumptions may not hold in reality. For example, governments may largely borrow domestically. In this case, the repayment burden in period one is a simple transfer between the government and its citizens. We note, however, that $\gamma > 1$ ensures that an increase in the debt repayment burden affects the marginal utility of public infrastructure investment and thus triggers the mechanism described above. Finally, private borrowing may serve as a substitute for inter-temporal redistribution by the government. This appears feasible with regard to the consumption of the private good. Public goods are, however, generally provided more efficiently by the government[26] such that private borrowing is, at best, an imperfect substitute for public redistribution across periods.[27] Thus, inter-temporal adjustments via reductions in public infrastructure spending remain relevant. Furthermore, some citizens are likely to borrow at a higher cost, this cannot completely compensate for the public borrowing restriction.

Another important assumption we made is that the interest rate is exogenous. Alternatively, one could allow for a positive, possibly convex relation between the interest rate and the level of public borrowing in the current or the previous period. The case of a contemporaneous relationship turns out to be a simple extension to our model in which the marginal increase in the initial public debt burden is reinforced by its effect on the interest paid.[28] The case with a lagged relationship introduces a cost on the inter-temporal redistribution via public borrowing. If the relation between past borrowing and the current interest rate is non-linear (e.g. convex), this precludes the friction-less reallocation of resources between periods through additional borrowing. As a consequence, more borrowing is not necessarily the best option for inter-temporal redistribution since the corresponding costs must be compared to the cost of redistribution between periods via an adjustment in long-run public infrastructure investment. Our results thus rely on the assumption that public borrowing is generally used as the best option for inter-temporal utility-smoothing in the sense of Barro (1979).

# 5   Empirical Evidence

We test the main implications of our theoretical analysis using administrative data from German municipalities. We do not aim at fully identifying the causal relationships suggested

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[25] Results are available from the authors upon request.

[26] In this regard, the simplifying assumption of a representative citizen in our model constitutes an exemption which would need to be relaxed to determine the optimal way of public goods provision.

[27] An additional requirement for private borrowing to completely compensate for the public borrowing restriction is that, on average, citizens do not borrow at a cost above the one faced by the government.

[28] Formally, $\frac{\partial^2 U^i}{\partial m_i \partial b_{i0}} = h''_{i1} \gamma^2 \left(1 + r + \frac{\partial r}{\partial b_{i0}} b_{i0}\right) c' < h''_{i1} \gamma^2 (1 + r) c' < 0.$

in the model as this would require further information which is hard to obtain. For example, we do not know whether and to what extent jurisdictions are constrained in their public borrowing. Still, the empirical analysis is an important first step towards verifying the mechanism proposed in our theoretical model.

The case of Germany is a good testing ground as the constitution provides municipalities with substantial discretion in fiscal policy. Each municipality approves its own budget, which includes decisions on public borrowing and public investment expenditure. Furthermore, several tax rates are set at the municipal level such as the taxation of business profits ("Gewerbesteuer"). Most importantly, fiscal policy in German municipalities varies substantially both with respect to the tax rates applied and in terms of the debt ratio.

## 5.1 Empirical Specification

To test the main results of our theoretical analysis, we apply an event study design. Originally developed by Fama *et al.* (1969) for the analysis of stock market responses, this methodology is now also widely used in the area of public economics (e.g. Hoynes & Schanzenbach, 2012; Chetty *et al.*, 2014; Hoynes *et al.*, 2016). In our context, we measure the responses of jurisdictions within a pre-defined time window around a particular event of interest. In this way, event studies allow for a precise analysis of the timing of responses which is crucial for our purposes as we test an inter-temporal model with policy responses that are not necessarily contemporaneous.

We estimate the response of two fiscal policy instruments to shocks in the debt-repayment burden of individual municipalities. The latter are defined as years in which the level of net redemption payments of a municipality is extraordinarily high. Net redemption payments are defined as the difference between the total debt redemption payment and additional revenue obtained from issuing new debt in the same period. We set the value of net redemption payments to zero whenever newly issued credit exceeds redemption payments.[29] We then compute the share of net redemption payments in the net expenditure of a municipality for each individual year and also the average of this share within a municipality across the observation period. We define a shock as a municipal-year observation in which the share is at least three times as high as its average within the municipality. Therefore a shock constitutes a substantial increase in the debt repayment burden of a municipality and corresponds to an increase in the initial debt burden, $b_{i0}$, in our theoretical model, which in turn results in a net repayment burden in period 1 of $b_{i1} - (1 + r)b_{i0}$.

An alternative specification would be to regress the fiscal policy variables of interest on the lagged level of public debt. Instead, we analyze debt-repayment shocks for three reasons. First, by focusing on unit-specific events we avoid a number of endogeneity issues related to the inter-temporal correlation of fiscal variables and other equilibrium effects that would arise in a framework with lagged variables. Second, within a region public debt levels of

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[29]This avoids classifying temporary reductions of municipal borrowing with a continuing increase in public debt as debt repayment shocks.

neighboring municipalities are likely to be correlated (e.g. see Borck *et al.*, 2015). This aspect makes it difficult to identify fiscal competition effects, which only occur when initial debt levels diverge. In contrast, the debt repayment shocks that we observe are confined to individual municipalities and thus constitute an asymmetry in a competitive environment. Finally, in order to apply an event study design with its various econometric and conceptual advantages, we need to define changes in the initial debt repayment burden as events. A feasible way to do this is to look at debt repayment shocks.

Our empirical model takes the following form:

$$
y_{i,t} = \alpha_{-4} \sum_{n=4}^{t-1998} s_{i,t+n} + \sum_{n=-3}^{-2} \alpha_n s_{i,t-n} + \sum_{n=0}^{4} \alpha_n s_{i,t-n} + \alpha_5 \sum_{n=5}^{2012-t} s_{i,t-n}
$$
$$
+ \boldsymbol{\beta_2 x_{i,t}} + \boldsymbol{\psi} + \epsilon_{i,t}. \quad (16)
$$

$y_{i,t}$ is the fiscal policy variable of interest in municipality $i$ at year $t$, and $s_{i,t}$ is a dummy that indicates whether in year $t$ municipality $i$ experienced a debt repayment shock as described above. Within the first and last year in our sample, 1998 and 2012, we define an event window of 10 years, that is, we observe 4 years before and 5 years after the repayment shock as well as the shock year itself.[30] In each year, we thus compare the treated municipalities to those that did not experience a debt repayment shock in this particular period. Following Kline (2012) we adjust the end points of the event window to indicate whether a debt repayment shock has occurred 4 or more years before (upper window limit) and 5 or more years after a given year (lower window limit) in order to mitigate collinearity with the year-fixed effects. The resulting coefficients, however, do not assign the same weights to municipalities with events early and late in our observation period since the sample is generally unbalanced in event time. As in Kline (2012), the interpretation of the results thus focuses on the coefficients for indicators within the event window. To avoid perfect collinearity among the shock indicators, the regressor in the year before the repayment shock is dropped and normalized to zero. As a consequence, the remaining coefficients $\alpha_t$ are interpreted as the effect of the shock on $y_{i,t}$ relative to the pre-shock year.

We test the theoretical predictions by analyzing the response of local business tax rates and local public investment expenditure to the debt repayment shocks. Both measures are decided by the municipal council and may be adjusted each year. Local public investment is measured as the logarithm of investment expenditure of the municipality.

We complement our model by a vector of lagged control variables, $\boldsymbol{x_{i,t}}$, including the logarithm of total population and the logarithm of GDP per capita in the district of the municipality. Furthermore, we intend to capture unobserved confounding factors by including a set of fixed effects which comprises municipality-fixed effects, year-fixed effects and state-year-fixed effects. The latter take into account that time trends may vary across states

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[30]Expanding or contracting the event window by up to 2 years leads to virtually the same results.

(*Länder*).

Since our fiscal competition model relies on the interaction between competing jurisdictions, we are not only interested in the response of the municipality that experiences the debt repayment shock but also in the response of its competing neighbors. We therefore rerun the model described above replacing the variables $y_{i,t}$ and $\boldsymbol{x_{i,t}}$ with the weighted average of the respective variables across the neighboring municipalities that are within 10 kilometers of municipality $i$. Using inverse distance weights in terms of the difference in total population between the municipality and its neighbor[31], we observe how fiscal policy evolves in the neighboring jurisdictions of a municipality when it experiences a debt repayment shock.

The effect is identified by comparing the neighbors of treated and untreated municipalities in each year. Note that the control group includes the whole sample in both regressions. Following our theoretical analysis, fiscal competition implies that the neighboring localities are affected by the debt repayment shock as well and are thus analyzed in a separate regression.

## 5.2   Data

The data set contains information on fiscal variables, including local tax rates, of all municipalities in Germany from 1998 to 2013. In total, there are 11,064 municipalities in our sample. The effective business tax rates are obtained by multiplying the base rate ("Steuermesszahl") of 3.5% (5% until 2007) with the local tax rate ("Hebesatz"), which is determined each year by the municipal council. The base rates are determined at the federal level and are therefore not a local choice variable. The effective business tax rates in our sample range from 0% to 45% with an average of 14.9%. About 17.2% of municipalities change their local business tax rate within the sample period. 57.5% of the municipalities in our sample experience a debt repayment shock in the sample period. Only 3.5% of municipalities have more than two shocks. The empirical framework described above accounts for the occurrence of more than one event within a unit. The full set of descriptive statistics can be found in Appendix A.6.
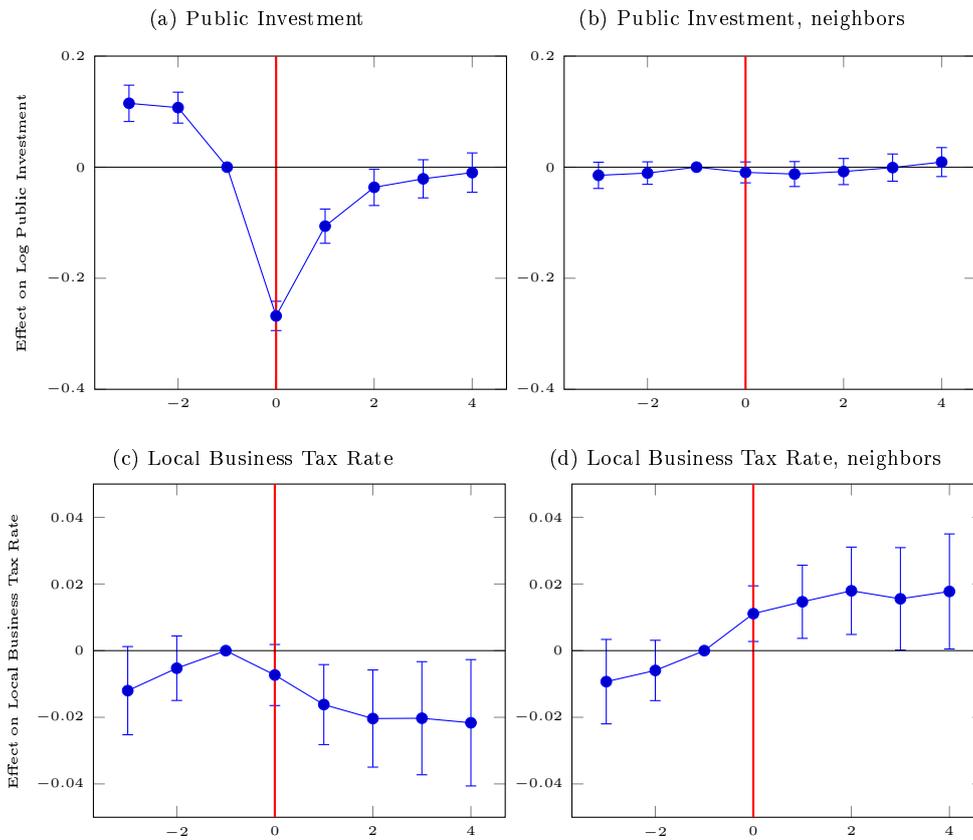
## 5.3   Results

We present our results in the form of event-study graphs. Figure 1 displays graphs for the response of both the municipality itself (panels a and c) and the neighboring municipalities (panels b and d). We first explore the response of municipalities that experience a debt repayment shock. Results displayed in panel (a) of Figure 1 show that, relative to the pre-shock year, the treated jurisdictions substantially reduce their investment expenditure in the year of the shock and also in the years immediately after the shock.[32] The main effect

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[31]In a robustness check we have used distance weights in terms of geographical distance in kilometers and obtained very similar outcomes. Results are available from the authors upon request.

[32]Since several highly indebted municipalities in Germany have eliminated their debt burden by selling municipal assets such as real estate to repay outstanding debt, one might be concerned that these events

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occurs instantly, with a decrease of public investment expenditure of 26.8% in the year of the shock. The negative effect is smaller in later years and diminishes to an insignificant decrease of 0.1% five years after the shock. This is consistent with our theoretical analysis. Note that the level of public investment is also higher prior to the shock. This positive effect does not match the negative effect after the repayment shock. Yet the finding suggests that at least part of the increase in initial debt burden may be related to an earlier increase in public infrastructure investment. We have considered this aspect in our theoretical model in Section 4.2.

Figure 1: Event Study



(a) Public Investment

(b) Public Investment, neighbors

(c) Local Business Tax Rate

(d) Local Business Tax Rate, neighbors

Standard errors are clustered on firm level. 95% confidence intervals are reported. Estimations include municipality-fixed, year-fixed and state-year-fixed effects.

We now turn to the response of municipal tax rates. Panel (c) depicts the impact of the repayment shock on the local business tax rate. We find no effect directly in the year of the shock but the tax rate is about 0.02 percentage points lower in each of the following four years. The delayed response mirrors the dynamics in the theoretical analysis. While

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drive our results. In particular, the reduction in the stock of public capital induced by the assets sales might have also triggered the subsequent decrease in public investment. We ensure that this is not the case by repeating the analysis excluding all municipalities involved in substantial real estate privatizations during the observation period. Information for this exercise has been provided by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). We obtain virtually the same results when excluding these municipalities.

the reduction in investment expenditure is immediate, the tax rate cut - that is aimed at restoring the jurisdiction's attractiveness - only occurs in later periods when a lower level of past investment and thus less public infrastructure becomes effective. The estimated tax cut is significant but in absolute size relatively small. We attribute this finding to a generally low level of tax competition among German municipalities. The lack of fiscal competition among German municipalities has mainly been explained by the existence of equalization grants for municipalities in many German states (Baretti *et al.*, 2002; Buettner, 2006; Egger *et al.*, 2010). Furthermore, previous studies have found only small cross-border effects of local tax rates in Germany (e.g. Buettner, 2003).

How do competing municipalities react to debt repayment shocks affecting their neighbors? As described above, we approach this issue in an additional estimation involving the weighted average of a municipality's neighbors. Results are presented with red squares in Figure 1. Again, we begin with the response of public infrastructure investment. Our results suggest that competing neighbors of municipalities that experience a strong increase in the debt repayment burden do not alter their level of public investment expenditure. This suggests that in our sample the strategic interaction in infrastructure expenditure is not very strong. One explanation is that an upward adjustment in infrastructure, as suggested by our theoretical model, is not easily achieved in practice as new investment opportunities have to be developed first. In contrast, municipalities can easily reduce current investment expenditure by postponing or canceling planned investment projects.

With respect to local taxation, our results suggest that neighboring governments increase their tax rates for local business profits. This finding is consistent with our theoretical model and is an indicator of tax competition. The decrease in public investment in the municipality experiencing a debt repayment shock induces its neighbor to increase business taxes. Neighboring municipalities thus exploit the relative decrease in the attractiveness of the treated municipality to increase local revenue from business taxes without reducing the local tax base. Again, the absolute effect is relatively small.

# 6 Conclusion

In this paper, we have used a two-jurisdiction, two-period model to analyze a fiscal competition game with asymmetric initial public debt levels. We first show that in the absence of government default the level of legacy public debt does not affect the fiscal competition game. Governments merely shift the repayment burden to future generations by increasing additional borrowing one by one. We then allow for government default which endogenously imposes an upper bound on public debt. This restricts inter-temporal redistribution of governments and provides an important theoretical link between legacy debt and fiscal competition.

In the presence of restricted public borrowing the government's decision on long-term infrastructure investment is shaped by its desire to optimally allocate resources between

periods. A higher level of legacy debt causes the government to decrease public investment in the first period, making the jurisdiction a less attractive location for private investment in the following period. Governments partly compensate this disadvantage by setting lower tax rates in the second period. In our two-jurisdiction model, the jurisdiction experiencing an increase in legacy debt therefore invests less and sets a lower tax on capital, while the opposite occurs in the other (unconstrained) jurisdiction. Under mild assumptions, this mechanism is the stronger the higher is the level of capital mobility. Capital mobility, therefore, leads not only to downward pressure on tax rates, as is well known, but tends to reinforce the effect of initial debt.

We show that the fiscal behavior of municipalities in Germany is broadly in line with the theoretical model predictions. Tax rates diverge when a municipality experiences a debt repayment shock. While the response is statistically significant, it is relatively small in value, which may be explained by the strong fiscal equalization scheme and the large number of interacting municipalities. We also find a strong negative public investment response by the municipality experiencing the shock. Neighboring regions, however, do not adjust in a significant way their public investment, as our benchmark result predicts, perhaps because increases in investment take more time compared to cuts.

Our results provide insights into current policy debates. For example, in Germany the federal states (Länder) have little tax autonomy. Some policy makers and many academics support more tax autonomy for states such as a state income and business tax. Given that states differ widely in existing debt levels, it is not clear whether and how existing debt would influence the competitiveness in a subsequent fiscal competition game. Our model suggests that default on government debt plays a crucial role and would disadvantage highly indebted regions. Among German states per capita debt levels differ significantly, including a few with very high levels. Opponents of more tax autonomy may therefore find support for their view in our model. So far, however, German states do not appear to be substantially constrained in their borrowing, as an implicit bail-out guarantee by the German federal government and the collection of all states is provided in the German constitution.

Our model sheds also light on the efforts to harmonize taxes in the European Union, which in the area of business taxation have proven to be difficult. The economic and financial crisis has led to a substantial increase in debt levels, which in some countries still prevail while others have reduced to them back to near pre-crisis levels. Attempts to harmonize tax rates may have become more difficult now. Countries with a high debt repayment burden may have very different fiscal policy strategies than governments with a low level of consolidation requirement.

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# Appendix

## A.1  Second-Order Conditions for Case I

The Hessian for the system of first-order conditions (9) to (11) for jurisdiction $i$ is given by

$$\boldsymbol{H} = \begin{pmatrix} \frac{\partial^2 U^i}{\partial m_i^2} & \frac{\partial^2 U^i}{\partial \tau_{i1}\partial m_i} & \frac{\partial^2 U^i}{\partial b_{i1}\partial m_i} \\[2mm] \frac{\partial^2 U^i}{\partial m_i\partial \tau_i} & \frac{\partial^2 U^i}{\partial \tau_{i1}^2} & \frac{\partial^2 U^i}{\partial b_{i1}\partial \tau_i} \\[2mm] \frac{\partial^2 U^i}{\partial m_i\partial b_{i1}} & \frac{\partial^2 U^i}{\partial \tau_{i1}\partial b_{i1}} & \frac{\partial^2 U^i}{\partial b_{i1}^2} \end{pmatrix} = \begin{pmatrix} \frac{\partial^2 U^i}{\partial m_i^2} & 0 & \frac{\partial^2 U^i}{\partial b_{i1}\partial m_i} \\[2mm] 0 & \frac{\partial^2 U^i}{\partial \tau_{i1}^2} & 0 \\[2mm] \frac{\partial^2 U^i}{\partial m_i\partial b_{i1}} & 0 & \frac{\partial^2 U^i}{\partial b_{i1}^2} \end{pmatrix}$$

In the second term, we insert the first-order condition for taxes (9) to verify that $\frac{\partial^2 U^i}{\partial m_i\partial \tau_i} = -h_{i1}''\frac{\partial(N_{i1}(1+\gamma\tau_{i1}))}{\partial \tau_{i1}}\gamma c' = 0$ and $\frac{\partial^2 U^i}{\partial b_{i1}\partial \tau_i} = \gamma h_{i1}''\frac{\partial(N_{i1}(1+\gamma\tau_{i1}))}{\partial \tau_{i1}} = 0$. For (9)-(11) to yield a maximum, $\boldsymbol{H}$ must be negative definite which is the case if and only if

$$\frac{\partial^2 U^i}{\partial m_i^2} = h_{i1}''\left(\gamma c'\right)^2 - h_{i1}'\gamma c'' + \beta h_{i2}''\left(\frac{\partial \tilde{N}_{i2}\left(1+\gamma\tilde{\tau}_{i2}\right)}{\partial m_i}\right)^2 + \beta h_{i2}'\frac{\gamma \rho^2}{9\nu} < 0, \qquad (A.1)$$

$$\frac{\partial^2 U^i}{\partial m_i^2}\frac{\partial^2 U^i}{\partial \tau_{i1}^2} > 0, \qquad (A.2)$$

$$\frac{\partial^2 U^i}{\partial \tau_{i1}^2}\left(\frac{\partial^2 U^i}{\partial m_i^2}\frac{\partial^2 U^i}{\partial b_{i1}^2} - \left(\frac{\partial^2 U^i}{\partial b_{i1}\partial m_i}\right)^2\right) < 0. \qquad (A.3)$$

Condition (A.1) is fulfilled for any sufficiently convex public investment cost function $c\left(m_i\right)$. In particular, noting from (11) that $h_{i2}' = h_{i1}'$, we know that $c''\left(m_i\right) > \frac{\beta\gamma\rho^2}{9\nu}$ is a sufficient condition for (A.1) to be satisfied. This relation holds for a wide range of parameters and functional forms. Since $\frac{\partial^2 U^i}{\partial \tau_{i1}^2} = -h_{i1}'\frac{\gamma}{\nu} < 0$, (A.2) must hold whenever (A.1) holds. Furthermore, note that $\frac{\partial^2 U^i}{\partial b_{i1}^2} = \left(h_{i1}'' + \frac{1}{\beta}h_{i2}''\right)\gamma < 0$ and $\frac{\partial^2 U^i}{\partial b_{i1}\partial m_i} = -\gamma^2 h_{i1}''c' - \gamma h_{i2}''\left(\frac{\partial \tilde{N}_{i2}(1+\gamma\tilde{\tau}_{i2})}{\partial m_i}\right) > 0$ such that for (A.3) to hold, we must have $\frac{\partial^2 U^i}{\partial m_i^2}\frac{\partial^2 U^i}{\partial b_{i1}^2} > \left(\frac{\partial^2 U^i}{\partial b_{i1}\partial m_i}\right)^2$. Inserting the first-order conditions (10) and (11), it is straightforward to show that this condition is satisfied if $c''\left(m_i\right) > \frac{\beta\gamma\rho^2}{9\nu}$ (i.e. the cost function must be sufficiently convex) such that condition (A.3) holds whenever (A.1) is fulfilled.

## A.2  Comparative Statics for Case II

If Condition 1 is binding in jurisdiction 1, the system of first-order conditions is given by

$$\frac{\partial U^i}{\partial \tau_{i1}} = h_{i1}'\frac{\partial\left(N_{i1}\left(1+\gamma\tau_{i1}\right)\right)}{\partial \tau_{i1}} = 0, \; i = 1,2 \qquad (A.4)$$

$$\frac{\partial U^1}{\partial m_1} = -h_{11}'\gamma c' + \beta h_{12}'\frac{\partial\left(\tilde{N}_{12}\left(1+\gamma\tilde{\tau}_{12}\right)\right)}{\partial m_1} = 0 \qquad (A.5)$$

$$\frac{\partial U^2}{\partial m_2} = -\gamma c' + \beta\frac{\partial\left(\tilde{N}_{22}\left(1+\gamma\tilde{\tau}_{22}\right)\right)}{\partial m_2} = 0 \qquad (A.6)$$

Condition (A.6) is obtained by inserting the first-order condition for $b_{21}$, (11), into the first order condition for $m_2$, (10), as in Case I. The Hessian for the system of first-order conditions

for jurisdiction 1 (A.4), and (A.5) given by

$$\boldsymbol{H} = \begin{pmatrix} \frac{\partial^2 U^1}{\partial m_1^2} & \frac{\partial^2 U^1}{\partial \tau_{11} \partial m_1} \\[2ex] \frac{\partial^2 U^1}{\partial m_1 \partial \tau_{11}} & \frac{\partial^2 U^1}{\partial \tau_{11}^2} \end{pmatrix} = \begin{pmatrix} \frac{\partial^2 U^1}{\partial m_1^2} & 0 \\[2ex] 0 & \frac{\partial^2 U^1}{\partial \tau_{11}^2} \end{pmatrix}$$

In the second term, we insert the first-order condition for taxes (A.4) to verify that $\frac{\partial^2 U^1}{\partial m_1 \partial \tau_{11}} = 0$. For (A.4) and (A.5) to yield a maximum, $\boldsymbol{H}$ must be negative definite which is the case if and only if

$$\frac{\partial^2 U^1}{\partial m_1^2} = h_{11}'' \left( \gamma c' \right)^2 - h_{11}' \gamma c'' + \beta h_{12}'' \left( \frac{\partial \tilde{N}_{12} \left( 1 + \gamma \tilde{\tau}_{12} \right)}{\partial m_1} \right)^2 + \beta h_{12}' \frac{\gamma \rho^2}{9\nu} < 0, \qquad \text{(A.7)}$$

$$\frac{\partial^2 U^1}{\partial m_1^2} \frac{\partial^2 U^1}{\partial \tau_{11}^2} > 0, \qquad \text{(A.8)}$$

Condition (A.7) holds if $-\frac{\partial \left( \tilde{N}_{12}(1 + \gamma \tilde{\tau}_{12}) \right)}{\partial m_1} \frac{c''}{c'} < \frac{\gamma \rho^2}{9\nu}$ which is true for any convex function $c$. Since $\frac{\partial^2 U^1}{\partial \tau_{11}^2} < 0$, (A.8) must hold whenever (A.7) holds. The first-order conditions for taxes (A.4) yield again (12). The Dixit (1986) stability conditions are

$$\frac{\partial^2 U^i}{\partial m_i^2} < 0, \ \frac{\partial^2 U^{-i}}{\partial m_{-i}^2} < 0, \ \frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^{-i}}{\partial m_{-i}^2} > \frac{\partial^2 U^{-i}}{\partial m_{-i} \partial m_i} \frac{\partial^2 U^i}{\partial m_i \partial m_{-i}}. \qquad \text{(A.9)}$$

Taking the total differential of the first-order conditions with respect to $b_{10}$ we arrive at the following system of equations

$$\begin{pmatrix} \frac{\partial^2 U^1}{\partial m_1^2} & \frac{\partial^2 U^1}{\partial m_1 \partial m_2} \\[2ex] \frac{\partial^2 U^2}{\partial m_2 \partial m_1} & \frac{\partial^2 U^2}{\partial m_2^2} \end{pmatrix} \begin{pmatrix} \mathrm{d}m_1 \\[2ex] \mathrm{d}m_2 \end{pmatrix} + \begin{pmatrix} \frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} \\[2ex] 0 \end{pmatrix} \mathrm{d}b_{10} = \begin{pmatrix} 0 \\[2ex] 0 \end{pmatrix} \qquad \text{(A.10)}$$

which can be rearranged to yield

$$\frac{\mathrm{d}m_1}{\mathrm{d}b_{10}} = -\frac{1}{\phi} \frac{\partial^2 U^2}{\partial m_2^2} \frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0, \ \frac{\mathrm{d}m_2}{\mathrm{d}b_{10}} = \frac{1}{\phi} \frac{\partial^2 U^2}{\partial m_2 \partial m_1} \frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} > 0 \qquad \text{(A.11)}$$

with $\phi = \frac{\partial^2 U^1}{\partial m_1^2} \frac{\partial^2 U^2}{\partial m_2^2} - \frac{\partial^2 U^2}{\partial m_2 \partial m_1} \frac{\partial^2 U^1}{\partial m_1 \partial m_2} > 0$. The first effect is obtained because of the Dixit (1986) stability conditions and since $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0$. The second effect results from $\frac{\partial^2 U^2}{\partial m_2 \partial m_1} = -\frac{\gamma \rho^2}{9\nu} < 0$. From Proposition 1 we know that the effect of a change in $b_{i0}$ on $\tau_{i2}^*$ and $N_{i2}^*$ is given by

$$\frac{d\tau_{i2}^*}{db_{i0}} = \frac{\rho}{3} \frac{d\Delta q_{i2}}{db_{i0}} = \frac{\rho}{3} \left( \frac{dm_i}{db_{i0}} - \frac{dm_{-i}}{db_{i0}} \right), \ \frac{dN_{i2}^*}{db_{i0}} = \frac{\rho}{6\nu} \frac{d\Delta q_{i2}}{db_{i0}} = \frac{\rho}{6\nu} \left( \frac{dm_i}{db_{i0}} - \frac{dm_{-i}}{db_{i0}} \right) \qquad \text{(A.12)}$$

where $\Delta q_{i2} = m_i - m_{-i}$ (assuming that $\bar{q}_1 = \bar{q}_2$). It follows from (A.11) that $\frac{d\tau_{12}^*}{db_{10}} < 0$, $\frac{dN_{12}^*}{db_{10}} < 0$, $\frac{d\tau_{22}^*}{db_{20}} > 0$ and $\frac{dN_{22}^*}{db_{20}} > 0$.

Adjustment in period 1 borrowing only occurs in jurisdiction 2 as jurisdiction 1 is constrained. We derive jurisdiction 2's borrowing response by totally differentiating the corresponding first order condition for $b_{12}$ (11) with respect to $m_1$, $m_2$ and $b_{12}$ which yields

$$\frac{\partial^2 U^2}{\partial b_{21}^2} db_{21} + \frac{\partial U^2}{\partial b_{21} \partial m_2} dm_2 + \frac{\partial U^2}{\partial b_{21} \partial m_1} dm_1 = 0. \tag{A.13}$$

Substituting (14) and (15) for $dm_1$ and $dm_2$ we solve for

$$\frac{db_{21}}{db_{10}} = \frac{1}{\phi} \left( \frac{\partial U^2}{\partial b_{21} \partial m_1} \frac{\partial^2 U^2}{\partial m_2^2} - \frac{\partial U^2}{\partial b_{21} \partial m_2} \frac{\partial^2 U^2}{\partial m_2 \partial m_1} \right) \frac{\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}}{\frac{\partial^2 U^2}{\partial b_{21}^2}} > 0 \tag{A.14}$$

where the inequality follows because $\frac{\partial U^2}{\partial b_{21} \partial m_2} > 0$, $\frac{\partial^2 U^2}{\partial m_2 \partial m_1} < 0$, $\frac{\partial^2 U^2}{\partial m_2^2} < 0$, $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0$, $\frac{\partial^2 U^2}{\partial b_{21}^2} < 0$ (see Section A.1) and $\frac{\partial U^2}{\partial b_{21} \partial m_1} = -\gamma h_{i2}'' \left( \frac{\partial \tilde{N}_{22}(1 + \gamma \tilde{\tau}_{22})}{\partial m_1} \right) < 0$.

## A.3 Comparative Statics for Constrained Borrowing in Both Jurisdictions

Taking the total differential of the first-order conditions we arrive at the same system of equations as in (A.10) which can be rearranged to yield expressions for $\frac{dm_2}{db_{10}}$ and $\frac{dm_1}{db_{10}}$ as in (A.11). Since $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} < 0$, the Dixit (1986) stability conditions (A.9) again imply $\frac{dm_1}{db_{10}} < 0$. However, since the first-order condition for $b_{20}$ does not necessarily hold, it cannot be substituted to yield $\frac{\partial^2 U^2}{\partial m_2 \partial m_1} < 0$ which leads to the unambiguous result obtained for jurisdiction 2 in (A.11). If $h_2'' = 0$ such that $U^2$ is quasi-linear, we can show that $\frac{dm_2}{db_{20}} < 0$ by verifying that in this case

$$\frac{\partial^2 U^2}{\partial m_2 \partial m_1} = -\beta h_{22}'' \left( \frac{\rho}{6\nu} + \frac{\gamma \rho}{3} \left( \frac{1}{2\nu} \tau_{12} + N_{12} \right) \right)^2 - \frac{\gamma \rho^2}{9\nu} \beta h_{22}' = -\frac{\gamma \rho^2}{9\nu} \beta h_{22}' < 0.$$

The effect of a marginal increase in $b_{10}$ on tax rates and the number of firms is again given by (A.12). Substituting from (14) and (15) and noting that

$$\frac{\partial^2 U^2}{\partial m_2 \partial m_1} = -\beta h_{22}' \frac{\gamma \rho^2}{9\nu} - \beta h_{22}'' \left( \frac{\rho}{6\nu} (1 + \gamma \tau_{22}) + \frac{\rho}{3} N_{22} \right)^2,$$
$$\frac{\partial^2 U^2}{\partial m_2^2} = h_{21}'' (\gamma c')^2 - h_{21}' \gamma c'' - \frac{\partial^2 U^2}{\partial m_2 \partial m_1}$$

allows us to rewrite the effect of a marginal increase in legacy debt on taxes and the number of firms in period 2 as

$$\frac{d\tau_{12}^*}{db_{10}} = -\frac{1}{\phi}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\frac{\rho}{3}\left(h_{21}''\left(\gamma c'\right)^2 - h_{21}'\gamma c''\right) < 0,$$

$$\frac{dN_{12}^*}{db_{10}} = -\frac{1}{\phi}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\frac{\rho}{6\nu}\left(h_{21}''\left(\gamma c'\right)^2 - h_{21}'\gamma c''\right) < 0,$$

$$\frac{d\tau_{22}^*}{db_{10}} = \frac{1}{\phi}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\frac{\rho}{3}\left(h_{21}''\left(\gamma c'\right)^2 - h_{21}'\gamma c''\right) > 0,$$

$$\frac{dN_{22}^*}{db_{10}} = \frac{1}{\phi}\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}\frac{\rho}{6\nu}\left(h_{21}''\left(\gamma c'\right)^2 - h_{21}'\gamma c''\right) > 0.$$

The inequality is a result of the convexity of $c$ and the strict concavity of $h_1$. Note that in the derivation above, the indices for jurisdiction 1 and 2 are interchangeable because, with both jurisdictions constrained in their borrowing, it is irrelevant where the marginal increase in initial public debt that we investigate in the comparative static analysis occurs.

## A.4 Interaction Between Initial Public Infrastructure and Initial Public Debt

**Unrestricted Borrowing**  Let $\bar{q}_i = \bar{q}_i\left(b_{i0}\right)$, $i = 1, 2$. Condition (13) must be modified and reads

$$c'\left(m_i\right) = \frac{\beta\rho}{3}\left(1 + \frac{\rho}{3\nu}\Delta m_i + \frac{\rho}{3\nu}\Delta\bar{q}_i\left(1 - \delta\right)\right), \ i = 1, 2. \tag{A.15}$$

Taking the total differential of (A.15) with respect to $m_i$ and $b_{i0}$ we obtain

$$\frac{dm_i}{db_{i0}} = \frac{\frac{\beta\rho^2}{9\nu}\left(1 - \delta\right)}{c''\left(m_i\right) - \frac{\beta\rho^2}{9\nu}}\bar{q}_i', \ i = 1, 2 \tag{A.16}$$

where $\bar{q}_i' = \frac{\partial\bar{q}_i'}{\partial b_{i0}}$. Again, we assume that the cost function is sufficiently convex, $c''\left(m_i\right) > \frac{\beta\gamma\rho^2}{9\nu}$, such that the second-order conditions are fulfilled. Then (A.16) implies

$$\frac{dm_i}{db_{i0}} \lesseqgtr 0 \iff \bar{q}_i' \lesseqgtr 0. \tag{A.17}$$

**Restricted Borrowing in Jurisdiction 1**  The sign of (14) depends on $\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}}$. Let $\bar{q}_1 = \bar{q}_1\left(b_{10}\right)$ and differentiate (A.5) w.r.t $b_{10}$ to obtain

$$\frac{\partial^2 U^1}{\partial m_1 \partial b_{10}} = h_{11}''\frac{\gamma^2}{\beta}c' + \left(\beta\left(1 - \delta\right)\eta_{12} + \eta_{11}\right)\bar{q}_1',$$

$$\eta_{11} = -h_{11}''\gamma c'\frac{\partial\left(N_{11}\left(1 + \gamma\tau_{11}\right)\right)}{\partial\bar{q}_1} > 0, \ \eta_{12} = h_{12}''\left(\frac{\partial\left(N_{12}\left(1 + \gamma\tau_{12}\right)\right)}{\partial m_1}\right)^2 + h_{12}'\frac{\gamma\rho^2}{9\nu}. \tag{A.18}$$

The first term in (A.18) captures the effect of $b_{10}$ on the marginal utility of public infrastructure investment ($\frac{\partial U^1}{\partial m_1}$) that results from its impact on the incentives for inter-temporal

redistribution as described in Proposition 3. The second term $(\beta (1 - \delta) \eta_{12} + \eta_{11}) \bar{q}'_1$ represents the change in $\frac{\partial U^1}{\partial m_1}$ caused by a change in $\bar{q}_1 = \bar{q}_1 (b_{10})$ that is due to the variation in the marginal utility of public infrastructure investment in period 1, $\eta_{11}$, and period 2, $\eta_{12}$. In order to obtain a reversal of the result in Proposition 3, such that a rise in jurisdiction $i$'s legacy debt $(b_{i0})$ leads to an increase in i's infrastructure investment $(m_i)$ and period 2 tax rate $(\tau_{i2})$, the following assumption must hold.

**Assumption 1.** *An increase in initial public infrastructure $\bar{q}_i$ raises the marginal utility of public infrastructure investment in period 1. It does so at a rate greater in magnitude than the coinciding marginal change in the repayment burden.*

The first part of Assumption 1 ensures that a higher level of initial public infrastructure incentivizes governments to raise infrastructure investment in period 1. This holds if public investments are strategic substitutes. In the reverse case, any positive relation between initial infrastructure and initial debt would merely reinforce the effect described in Proposition 2 as an increase in $b_{i0}$ would unambiguously reduce the marginal utility of public infrastructure investment in period 1. The second part of Assumption 1 states that the positive effect of $\bar{q}_i$ on the marginal utility of public infrastructure investment dominates the overall effect.

The effect of initial infrastructure investment depends on the sign of the second term in (A.18), $(\beta (1 - \delta) \eta_{12} + \eta_{11}) \bar{q}'_1$. It is assumed to be positive (first part of Assumption 1). The assumption is satisfied in the quasi-linear case with $h''_{12} = 0$, because then $\eta_{12} = h'_{12} \frac{\gamma \rho^2}{9\nu} > 0$. If $(\beta (1 - \delta) \eta_{12} + \eta_{11}) \bar{q}'_1 > 0$, and $\left| h''_{11} \frac{\gamma^2}{\beta} c' \right| < |(\beta (1 - \delta) \eta_{12} + \eta_{11}) \bar{q}'_1|$, as stated in the second part of Assumption 1, we have

$$\frac{dm_1}{db_{10}} \lessgtr 0 \iff \bar{q}'_1 \lessgtr 0. \tag{A.19}$$

Under Assumption 1 the negative effect of an increase in initial public debt on infrastructure investment in period 1 is reinforced when there is a negative relationship between legacy debt and initial public infrastructure ($f' < 0 \implies \bar{q}'_1 < 0$).

## A.5   A Tax on Domestic Income

We consider an additional tax on an immobile tax base. We assume that a fraction $0 \leq \omega \leq 1$ of the local benefit of firm investment $N_{it}$ is taxed at $\tau^w_{i1}$. One may think of $\omega N_{it}$ as a wage which is taxed with a labor tax. We also introduce a welfare loss from taxation by assuming that the corresponding tax revenue is reduced by administrative costs which are a convex function of $\tau^w_{i1}$.[33] The budget constraints thus read

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[33] Ignoring administrative costs yields an equilibrium where $\tau^w_{i1} = 1$ since $\gamma > 1$ and the results of the main analysis are immediately obtained.

$$g_{i1} = \tau_{i1} N_{i1} + \left( \tau_{i1}^w - \xi \frac{(\tau_{i1}^w)^2}{2} \right) \omega N_{i1} - c(m_i) - (1+r) b_{i0} + b_{i1} \tag{A.20}$$

$$g_{i2} = \tau_{i2} N_{i2} + \left( \tau_{i2}^w - \xi \frac{(\tau_{i2}^w)^2}{2} \right) \omega N_{i2} - (1+r) b_{i1}, \tag{A.21}$$

and governments maximize

$$\begin{aligned} U^i = h_1 \left( u_{i1} \right) + \beta h_2(u_{i2}) = & h_1 \left( (1-\omega) N_{i1} + (1-\tau_{i1}^w) \omega N_{i1} + \gamma g_{i1} \right) \\ & + \beta h_2 \left( (1-\omega) N_{i2} + (1-\tau_{i2}^w) \omega N_{i2} + \gamma g_{i2} \right). \end{aligned} \tag{A.22}$$

Solving by backward induction, the set of first-order conditions in period 2 - given by (7) - is extended by the optimal choice of $\tau_{i2}^w$:

$$U_{\tau_{i2}^w}^i := \frac{\partial U^i}{\partial \tau_{i2}^w} = h_2' \frac{\partial u_{i2}}{\partial \tau_{i2}^w} = 0. \tag{A.23}$$

The optimal labor tax equals $\tau_{i2}^{w*} = \frac{\gamma-1}{\gamma\xi}$. Substituting into (7), we can determine capital tax rates and the number of firms in a similar way as stated in Proposition 1:

$$\tilde{\tau}_{i2} \left( m_i, m_{-i} \right) = \nu - \frac{1}{\gamma} + \frac{\rho \Delta q_i}{3} - \frac{(\gamma-1)^2}{2\gamma^2 \xi} \omega \tag{A.24}$$

$$\tilde{N}_{i2} \left( m_i, m_{-i} \right) = \frac{1}{2} + \frac{\rho \Delta q_i}{6\nu} \tag{A.25}$$

$$\tau_{i2}^{w*} = \frac{\gamma-1}{\gamma\xi} \tag{A.26}$$

$$\tilde{\kappa}_i \left( b_{i1} \right) = \begin{cases} 0 & \text{if } b_{i1} \leq b^{wtp} \\ 1 & \text{if } b_{i1} > b^{wtp} \end{cases} \tag{A.27}$$

$$\tilde{g}_{i2} \left( m_i, m_{-i}, b_{i1} \right) = \tilde{\tau}_{i2} \tilde{N}_{i2} - (1 - \tilde{\kappa}_i)(1+r) b_{i1}, \tag{A.28}$$

Solving period 2, we begin with the case where the Willingness-to-pay Condition is not binding in both jurisdictions. The maximization problem of jurisdiction $i$ is given by

$$\begin{aligned} \max_{\tau_{i1}, m_i, b_{i1}, \tau_{i1}^w} U^i = & h_1 \left( (1-\omega) N_{i1} + (1-\tau_{i1}^w) \omega N_{i1} + \gamma g_{i1} \right) \\ & + \beta h_2 \left( (1-\omega) \tilde{N}_{i2} + (1-\tau_{i2}^{w*}) \omega \tilde{N}_{i2} + \gamma \tilde{g}_{i2} \right) \end{aligned} \tag{A.29}$$

which leads to the first-order conditions

$$\frac{\partial U^i}{\partial \tau_{i1}} = h'_1 \frac{\partial u_{i1}}{\partial \tau_{i1}} = 0, \tag{A.30}$$

$$\frac{\partial U^i}{\partial m_{i1}} = -h'_1 \gamma c' + \beta h'_2 \frac{\partial \tilde{u}_{i2}}{\partial m_i} = 0, \tag{A.31}$$

$$\frac{\partial U^i}{\partial b_{i1}} = \gamma h'_1 - \beta \gamma (1 + r) h'_2 = h'_1 - h'_2 = 0, \tag{A.32}$$

$$\frac{\partial U^i}{\partial \tau_{i1}^w} = h'_2 \frac{\partial u_{i1}}{\partial \tau_{i1}^w} = 0. \tag{A.33}$$

The Hessian for the system of first-order conditions (A.30) to (A.33) for jurisdiction $i$ is given by

$$\boldsymbol{H} = \begin{pmatrix} \frac{\partial^2 U^i}{\partial m_i^2} & \frac{\partial^2 U^i}{\partial \tau_{i1} \partial m_i} & \frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} & \frac{\partial^2 U^i}{\partial \tau_{i1}^w \partial m_i} \\ \frac{\partial^2 U^i}{\partial m_i \partial \tau_{i1}} & \frac{\partial^2 U^i}{\partial \tau_{i1}^2} & \frac{\partial^2 U^i}{\partial b_{i1} \partial \tau_i} & \frac{\partial^2 U^i}{\partial \tau_{i1}^w \partial \tau_i} \\ \frac{\partial^2 U^i}{\partial m_i \partial b_{i1}} & \frac{\partial^2 U^i}{\partial \tau_{i1} \partial b_{i1}} & \frac{\partial^2 U^i}{\partial b_{i1}^2} & \frac{\partial^2 U^i}{\partial \tau_{i1}^w \partial b_{i1}} \\ \frac{\partial^2 U^i}{\partial m_i \partial \tau_{i1}^w} & \frac{\partial^2 U^i}{\partial \tau_{i1} \partial \tau_{i1}^w} & \frac{\partial^2 U^i}{\partial \tau_{i1}^w} & \frac{\partial^2 U^i}{\partial (\tau_{i1}^w)^2} \end{pmatrix} = \begin{pmatrix} \frac{\partial^2 U^i}{\partial m_i^2} & 0 & \frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} & 0 \\ 0 & \frac{\partial^2 U^i}{\partial \tau_{i1}^2} & 0 & 0 \\ \frac{\partial^2 U^i}{\partial m_i \partial b_{i1}} & 0 & \frac{\partial^2 U^i}{\partial b_{i1}^2} & 0 \\ 0 & 0 & 0 & \frac{\partial^2 U^i}{\partial (\tau_{i1}^w)^2} \end{pmatrix}$$

In the second term, we insert the first-order condition for taxes (A.30) to verify that $\frac{\partial^2 U^i}{\partial m_i \partial \tau_i} = -h''_{i1} \frac{\partial (N_{i1}(1+\gamma \tau_{i1}))}{\partial \tau_{i1}} \gamma c' = 0$ and $\frac{\partial^2 U^i}{\partial b_{i1} \partial \tau_i} = \gamma h''_{i1} \frac{\partial (N_{i1}(1+\gamma \tau_{i1}))}{\partial \tau_{i1}} = 0$. For (A.30)-(A.33) to yield a maximum, $\boldsymbol{H}$ must be negative definite which is the case if and only if

$$\frac{\partial^2 U^i}{\partial m_i^2} < 0, \tag{A.34}$$

$$\frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^i}{\partial \tau_{i1}^2} > 0, \tag{A.35}$$

$$\frac{\partial^2 U^i}{\partial \tau_{i1}^2} \left( \frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^i}{\partial b_{i1}^2} - \left( \frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} \right)^2 \right) < 0. \tag{A.36}$$

$$\frac{\partial^2 U^i}{\partial \tau_{i1}^2} \frac{\partial^2 U^i}{\partial (\tau_{i1}^w)^2} \left( \frac{\partial^2 U^i}{\partial m_i^2} \frac{\partial^2 U^i}{\partial b_{i1}^2} - \left( \frac{\partial^2 U^i}{\partial b_{i1} \partial m_i} \right)^2 \right) > 0. \tag{A.37}$$

Conditions (A.34), (A.35), and (A.36) are identical to the benchmark model (see Section A.1). Condition (A.37) holds whenever (A.36) holds because $\frac{\partial^2 U^i}{\partial \tau_{i1}^2} < 0$ and $\frac{\partial^2 U^i}{\partial (\tau_{i1}^w)^2} = -\gamma \xi < 0$.

The system of first-order conditions (A.30)-(A.33) can be solved to obtain equilibrium tax rates and the number of investments in period 1:

$$\tau_{i1}^* = \nu - \frac{1}{\gamma} - \frac{(\gamma - 1)^2}{2\gamma^2 \xi} \phi, \ \tau_{i1}^{w*} = \frac{\gamma - 1}{\gamma \xi}, \ N_{i1}^* = \frac{1}{2}. \tag{A.38}$$

Noting that $\frac{\partial \tilde{u}_{i2}}{\partial m_i} = \frac{\gamma \rho}{3} \left(1 + \frac{\rho \Delta m_i}{3\nu}\right)$, we can substitute (A.32) into (A.31) to obtain the modified first-order condition for infrastructure investment $c'(m_i) = \frac{\beta \rho}{3} \left(1 + \frac{\rho \Delta m_i}{3\nu}\right)$ which is identical to (13) such that the results stated in Proposition 2 prevail.

Turning to the case where borrowing is constrained in jurisdiction 2, we note that the comparative static analysis is unaffected by the introduction of the additional tax instrument because $\frac{\partial \tilde{u}_{i2}^{w}}{\partial m_i}$ is independent of the choice of $\tau_{i1}^{w}$. As a consequence, the results stated in Proposition 3 are also valid with a tax on the immobile tax base.

## A.6   Empirical Evidence: Additional Tables

Table A.1: Summary Statistics: Firms

| Variable | Observations | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|---|
| Business Tax Rate | 165,873 | 14.880 | 2.698 | 0 | 45 |
| Property Tax Rate | 165,878 | 1.451 | 0.670 | 0 | 4.55 |
| Log Local Public Investment Expenditure | 151,360 | 12.819 | 2.071 | 1.138 | 20.416 |
| Shock ($s_{i,t}$) | 165,880 | 0.054 | 0.225 | 0 | 1 |
| Log GDP p.c. | 121,985 | 10.075 | 0.227 | 9.484 | 11.580 |
| Log Population | 165,880 | 7.568 | 1.491 | 1.099 | 15.073 |

## Table A.2: Event Study: Regression Results

This table contains the regression results of the event study design. All regressions contain year, municipality and state-year fixed effects. The dependent variable is the logarithm of public investment expenditure in columns (1)-(2) and the local business tax rate in columns (3)-(4). In columns (2) and (4), the dependent variable and the control variables refer to the corresponding inverse distance weighted average (weighted according to difference in population) of all neighboring municipalities of municipality within 10km. Cluster robust standard errors (clustered at the municipality level) are provided in parentheses. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

| | Public Investment Expenditure | | Business Tax Rate | |
| --- | --- | --- | --- | --- |
| | (1) | (2) | (3) | (4) |
| | Treated | Neighbor | Treated | Neighbor |
| $s_{i,t+4}$ | 0.031** | -0.016 | -0.023** | 0.005 |
| | (0.015) | (0.011) | (0.010) | (0.008) |
| $s_{i,t+3}$ | 0.115*** | -0.015 | -0.012* | -0.009 |
| | (0.017) | (0.012) | (0.007) | (0.006) |
| $s_{i,t+2}$ | 0.107*** | -0.011 | -0.005 | -0.006 |
| | (0.014) | (0.010) | (0.005) | (0.005) |
| $s_{i,t}$ | -0.268*** | -0.009 | -0.007 | 0.011*** |
| | (0.013) | (0.010) | (0.005) | (0.004) |
| $s_{i,t-1}$ | -0.106*** | -0.012 | -0.016*** | 0.015*** |
| | (0.016) | (0.011) | (0.006) | (0.006) |
| $s_{i,t-2}$ | -0.036** | -0.008 | -0.020*** | 0.018*** |
| | (0.017) | (0.012) | (0.007) | (0.007) |
| $s_{i,t-3}$ | -0.021 | -0.001 | -0.020** | 0.016** |
| | (0.017) | (0.012) | (0.009) | (0.008) |
| $s_{i,t-4}$ | -0.010 | 0.009 | -0.022** | 0.018** |
| | (0.018) | (0.013) | (0.010) | (0.009) |
| $s_{i,t-5}$ | -0.022 | -0.015 | -0.039*** | 0.011 |
| | (0.015) | (0.011) | (0.011) | (0.010) |
| Log GDP p.c. | 0.404*** | 0.269*** | -0.123* | -0.141*** |
| | (0.091) | (0.083) | (0.072) | (0.044) |
| Log Population | 0.106 | 1.107*** | -0.206** | 0.144 |
| | (0.133) | (0.071) | (0.102) | (0.118) |
| Observations | 116,463 | 103,103 | 121,985 | 104,666 |
| Municipalities | 8,132 | 6,979 | 8,137. | 6,981 |
| $R^2$ | 0.110 | 0.206 | 0.957 | 0.972 |