Dissertation

Interjurisdictional Competition and Public-Sector Modernisation - Theory and Empirics

Daniel Becker

Universität Rostock, Wirtschafts- und Sozialwissenschaftliche Fakultät

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Dekan: Prof. Dr. Stefan Göbel, seit dem WS 2008/09: Prof. Dr. Doris Neuberger
Erstgutachter / Betreuer: Prof. Dr. Michael Rauscher (Universität Rostock)
Zweitgutachter: Prof. Dr. Wolfgang Peters (Europa Universität Viadrina, Frankfurt (Oder))

Vorgelegt von

Daniel Becker

daniel.becker@uni-rostock.de
http://www.wiwi.uni-rostock.de/~wsf8545/
http://www.wiwi.uni-rostock.de/vwl/aussenwirtschaft/becker/

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Danke an alle, die mich unterstützt haben!

Contents

List of Abbreviations

billion	1 000 000 000
DEA	Data Envelopment Analysis
DFG	Deutsche Forschungsgemeinschaft
DOI	Digital Object Identifier
FDH	Free Disposable Hull
GDP	Gross Domestic Product
IDA	International Development Association (World Bank)
ISBN	International Standard Book Number
million	1 000 000
OECD	Organisation for Economic Co-operation and Development
PWT	Penn World Tables
SNA	System of National Accounts
trillion	1 000 000 000 000
UNESCO	United Nations Educational, Scientific and Cultural Organization
URL	Uniform Resource Locator (address of a Webpage)
WDI	World Development Indicators

Chapter 1

Introduction

The existence of a public sector that raises tax revenue and provides public goods and services almost naturally justifies that the issue of public-sector modernisation is on the political agenda. Taxation of households and firms has opportunity costs: foregone consumption and investment. Hence, politicians (should) always have the goal to organise the public-sector efficiently: either by delivering more goods and services with a given tax revenue or by holding the level of public goods and services constant while cutting expenditure and eventually – at least in an intertemporal sense – taxation.[1]

This thesis contributes to the analysis of the relationship between interjurisdictional competition and public-sector modernisation. It hence tries to clarify whether there is a "market-solution" for the task of public-sector modernisation. Inspired by the welfare implications of perfect competition in microeconomic theory, one might be tempted to see the lack of competition between jurisdictions and their governments as the underlying cause of public-sector inefficiency.

Both theoretical and empirical work is presented in the following chapters. These chapters are at the same time independent research papers, dealing with selected topics in the fields of interjurisdictional competition and public-sector modernisation. The relevant literature is introduced subsequently in the context of my own research presented below.

In the course of the research project "Interjurisdictional competition and public-sector modernisation" – see the acknowledgements for more details about this project – it turned out that the modelling of interjurisdictional competition in a dynamic context is very challenging. Hence, the theoretical chapters are dealing with this question, in particular chapters 2 and 4. In chapter 3, it is argued that public-sector modernisation should be modelled in a dynamically (as it is obviously a dynamic process). Furthermore, the dynamic modelling of interjurisdictional competition allows to develop a consistent concept of the intensity of interjurisdictional competition that is used in all theoretical chapters. Alternatives are rare in the literature about fiscal competition.

The empirical part (chapter 5) applies a state-of-the-art method of efficiency measurement to the public sector of national countries. A summary of the most important results and a research agenda can be found in chapter 6.

[1] The OECD, in a series of policy briefings, reviews real world initiatives to modernise the public sector [OECD 2003, 2004a,b,c, 2005a,b,c].

Chapter 2

Comparative dynamics in a fiscal competition model

This chapter is based on Becker [2007].

2.1 Introduction

Fiscal competition often occurs in the form of tax competition for a mobile tax base. It is often assumed that productive capital is the mobile tax base. Capital accumulation is a process where the stock of capital for a given point of time is the result of investment flows in the past. A natural task on the research agenda therefore is: the analysis of the dynamics of capital tax competition. Almost all models of tax competition are static and therefore their results are limited to the "long run" or steady state situations. Wildasin's [2003] paper shows that this limit matters when capital accumulation is a time consuming process.

He shows that a government that has to decide about the taxation of mobile capital faces a trade-off. As has been known in the literature for a long time, capital taxation hurts workers. Less capital means that labor is less productive and this in turn depresses wages. But this disadvantage from the perspective of workers matters only in the long run. Capital taxation has also beneficial effects as it generates revenue that can be redistributed in favor of workers. Wildasin shows that the speed of capital de-accumulation in response of capital taxation – i.e. how promptly the deterioration of productivity of workers comes into effect – is crucial for the decision of a government that has to weigh immediate benefits against future disadvantages.

To introduce dynamics into the model, Wildasin uses a standard adjustment cost function for investment. In his model, a convex adjustment cost function has the effect that the adjustment of the capital allocation across jurisdictions after a change in capital taxation is not immediate. From a normative point of view, this means that the tax rate chosen by a local jurisdiction is positive.

From a technical point of view, Wildasin [2003] is a paper in comparative dynamics. The point that comparative static models may be misleading for the analysis of tax incidence has been made earlier by Boadway [1979, p. 505]: "Since the process of tax shifting through a change in capital accumulation takes time, comparative steady-state analysis may be quite inappropriate for considering the effects of tax changes over more limited time horizons." Boadway studies "... the effect of tax changes on the growth path of an economy between two arbitrary points of time in a single-sector neoclassical model ...". Wildasin uses a similar methodology and applies it to the problem of fiscal competition. Fiscal or tax competition here means a situation where the possibility for capital owners to shift capital to another jurisdiction results in lower tax rates than those that would occur in the case of a closed economy. The analysis in Wildasin [2003] is about the optimal policy of a local jurisdiction, given this constraint. Wildasin does not solve for the Nash equilibrium for a system of jurisdictions. This note doesn't do that, either.

The main motivation for this note is to state clearly the basics of comparative dynamics in a fiscal competition model in which dynamics are driven by the accumulation of capital like in traditional Ramsey-type models of optimal growth. It hopefully has helped to improve the author's understanding of the methodology of comparative dynamics in this special context. And maybe it is useful for others that have the intention to work in the field of dynamic models in fiscal competition.

2.2 The model

For a detailed introduction of variables and the model setup, the reader is referred to Wildasin [2003]. The model is very similar to the model of an open-economy with an exogenous interest rate that is discussed in Barro / Sala-i-Martin [1995, ch. 3.5]. I will keep the description of the model setup and assumptions very brief.

A representative firm chooses its investment rate $i(t)$ in the local capital stock $k(t)$. The initial value of the capital stock in $t = 0$ is labeled k_0. The alternative investment opportunity is to invest in assets that bear an interest at rate r. The interest rate is assumed to be exogenous to the jurisdiction. The firm produces with a neoclassical production function $f(k(t))$, where the size of the labor force has been normalized to one. The firm's investment decision is determined in part by the local tax rate on capital, τ, which is assumed to be a constant flat-rate tax. Hence, the tax rate is a parameter in the dynamic optimization problem. The other major determinant of firm's behavior is a convex adjustment cost function $c\left(i(t)\right)$. It will turn out that it is its curvature that determines the speed of a capitalist's reaction to a variation in the capital tax rate.

The current-value Hamiltonian for the decision problem of the firm is:

$$\mathcal{H} = f(k(t)) - c\left(i(t)\right)k(t) - \tau k(t) - i(t)k(t) - w(t) + \lambda(t)\left(i(t) - \delta\right)k(t)\ , \tag{2.1}$$

where $\lambda(t)$ is the costate variable of capital, δ is the depreciation rate and $w(t)$ is the wage rate of workers.

Using the Maximum Principle, the process of capital accumulation by an optimizing firm can be described as follows.

$$\dot{k}(t) = \left(i(t) - \delta\right)k(t) \tag{2.2a}$$

$$\dot{\lambda}(t) = -f'(k(t)) + \Psi\left(\lambda(t)\right) + \tau + \lambda(t)\left(r + \delta\right) \tag{2.2b}$$

$$\lambda(t) = 1 + c'\left(i(t)\right) \tag{2.2c}$$

$$k(0) = k_0 > 0 \text{ is given}; \quad \lim_{t\to\infty}\left(\lambda(t)e^{-rt}k(t)\right) = 0, \tag{2.2d}$$

where (2.2c) has been used to substitute for λ and $\Psi = c(i(t)) + i(t)(1-\lambda(t)) = c(i(t)) + i(t)c'(i(t))$. The investment rate $i(t)$ can implicitly be determined by the first-order condition (2.2c). The boundary conditions in (2.2d) are standard.[1] (2.2a) and (2.2b) together are the canonical equations.

To simplify the notation, assume the following quadratic specification of adjustment costs:

$$c(i(t))\,k(t) = \frac{b}{2} i(t)^2 k(t), \tag{2.3}$$

where $c(0) = 0$, $c' = bi(t)$, $c'' = b$. Parameter b can be interpreted as a measure of the mobility of capital: The lower b, the cheaper it is to adjust the capital stock. The total costs of investing one unit of capital are $i(t)(1 + c(i(t))k(t)) = i(t)\left(1 + \frac{b}{2}i(t)^2 k(t)\right)$. This implies that the investment rate can be expressed as a function of the costate variable λ, using the first-order condition (2.2c):

$$\lambda(t) = 1 + c'(i(t)) \Leftrightarrow \lambda(t) = 1 + bi(t) \Leftrightarrow$$

$$i(t) = \frac{\lambda(t) - 1}{b}\,, \tag{2.4}$$

and this in turn

$$c(i) = \left(\frac{\lambda - 1}{b}\right)^2 \frac{b}{2}$$

$$c'(i) = \lambda - 1$$

$$\Psi = \frac{(\lambda - 1)^2}{2b}\,.$$

(2.2) is a system of ordinary differential equations. Its solution $\{k(t,\tau), \lambda(t,\tau)\}$ depends on the parameter τ. Rewrite (2.2) for the functional form of the adjustment cost function defined in (2.3) and get

$$\dot{k}(t) = \left(\frac{\lambda(t) - 1}{b} - \delta\right) k(t) \tag{2.5a}$$

$$\dot{\lambda}(t) = -f'(k(t)) + \tau + \lambda(t)(r + \delta) + \frac{(\lambda - 1)^2}{2b} \tag{2.5b}$$

$$k(0) = k_0 > 0 \text{ is given;} \quad \lim_{t\to\infty}\left(\lambda(t)e^{-rt}k(t)\right) = 0\,. \tag{2.5c}$$

Given all parameters and the initial value of $k_0 = k(0)$, the economy grows towards a steady state $\{K_{SS}(\tau), \lambda_{SS}(\tau)\}$, that is defined by

$$\delta b + 1 = \lambda_{SS} \tag{2.6a}$$

$$\tau + (\delta b + 1)(r + \delta) + \frac{\delta^2 b}{2} = f'(k_{SS})\,. \tag{2.6b}$$

The system is saddle-point stable. See figure 2.1, which displays the phase diagram.[2]

[1] The initial value of the capital stock, k_0, is given historically. The other condition is not an initial condition but a terminal or transversality condition. From an economic perspective, the following condition is more intuitive: $\lim_{t\to\infty}\left[k(t)e^{-rt}\right] \geq 0$. It states that the discounted capital stock must be non-negative at the end of time. But this can be rewritten – given that a few conditions discussed in the literature hold – as in (2.2d). The intuition is that the value of capital must be asymptotically zero as it would be irrational not to make use of something valuable. This is achieved if the shadow price of capital λ is zero asymptotically (when capital is positive for $t \to \infty$). See the mathematical appendix in Barro / Sala-i-Martin [1995] or Caputo [2005, ch. 14] for references on the topic of transversality conditions in control problems with an infinite time horizon. See also Feichtinger / Hartl [1986, ch. 2.6], who discuss the conditions for $\lim_{t\to\infty} e^{-rt}\lambda(t)$ being a necessary condition for an optimal solution.

[2] The $\dot{k} = 0$ locus is given from (2.5a) by $\lambda = \delta b + 1$. The $\dot{\lambda} = 0$ locus is given implicitly from (2.5b) by $0 = \frac{\lambda^2}{2b} + \lambda\left(r + \delta - \frac{1}{b}\right) - f'(k) + \tau + \frac{1}{2b}$.

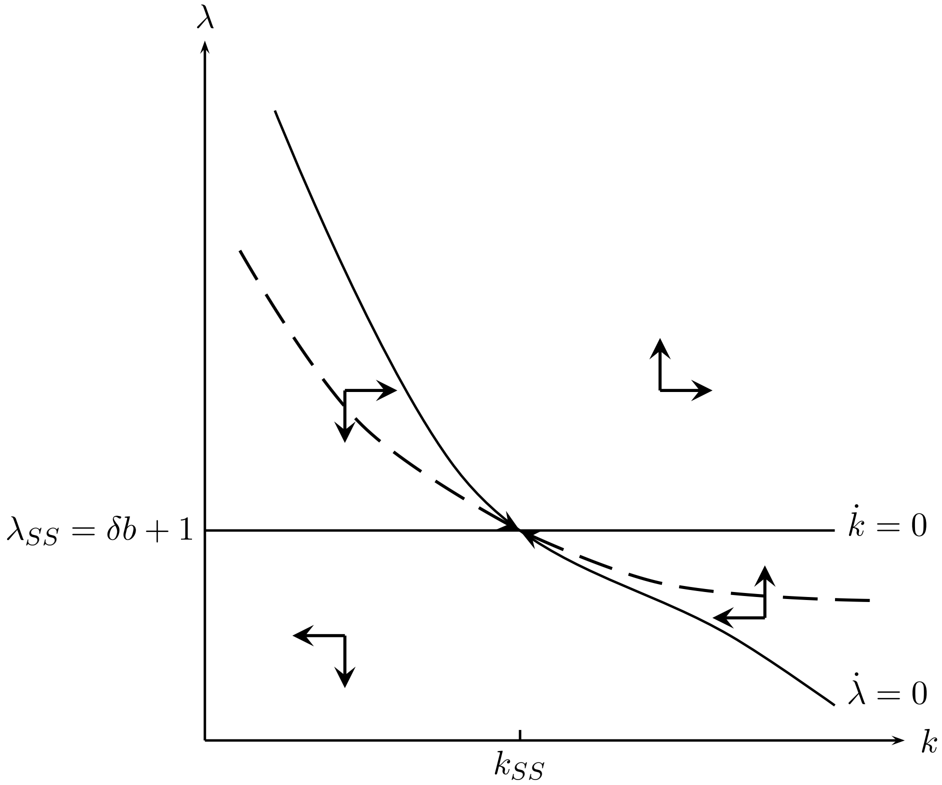
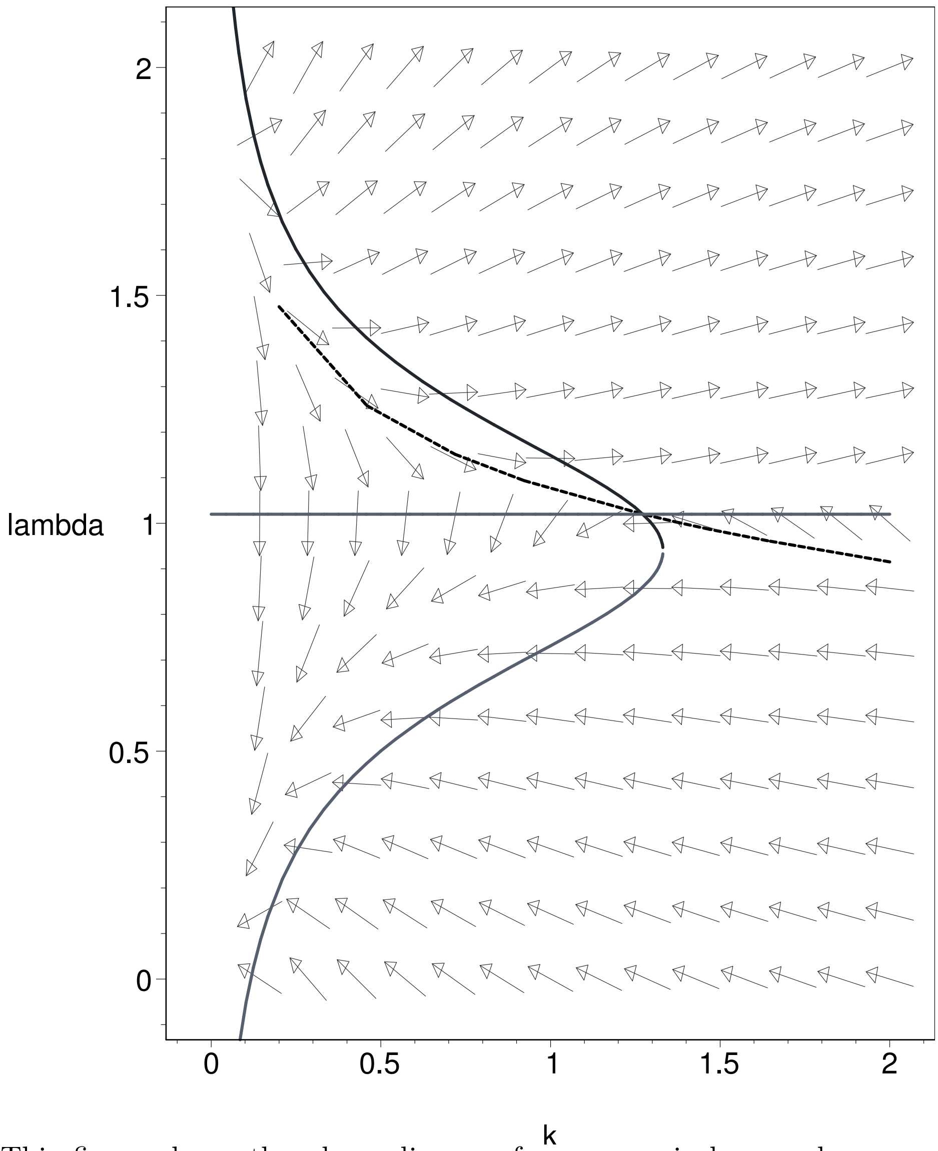


Figure 2.1: Phase diagram



This figure shows the phase diagram for a numerical example corresponding to (2.5). For the production function, I use a Cobb-Douglas specification: $f(k) = k^{\alpha}$ with $\alpha = 0.3$. The other parameters have been set to: $\delta = 0.05, r = 0.1, \tau := 0.1, b = 0.4$. The saddle-path (indicated by the dashed line) is drawn for an initial capital stock of $k(0) = 0.2$ (to the left from the equilibrium point) and for $k(0) = 2$ (right). In both cases, the second condition used to define the boundary-value problem is that λ reaches its equilibrium value $\lambda_{SS} = 1.475$ after 100 Periods. This defines a boundary-value problem that has been solved with numerical methods. The corresponding Maple 9.5 workfile is available from the author on request.

Figure 2.2: *Phase diagram - numerical example.*

2.3 Comparative Dynamics

The next step is to characterize the comparative dynamic behavior of the system described in the preceding section.

In a comparative *static* analysis, one is interested in the comparison of an initial equilibrium with another equilibrium that results from the change of a parameter of the model. In a comparative *dynamic* analysis of an optimal control problem, the focus is on the effect of a parameter variation not only on the difference between an "old" steady state equilibrium and a "new" one, which corresponds to the new value of a parameter. Comparative dynamic analysis aims also to show how the optimal solution of the control problem is altered due to the parameter change.

There are several ways to perform a comparative dynamic analysis. Caputo [1990b] distinguishes three different approaches:

The first approach is to investigate (or assume) stability of a dynamic system and linearize it around its steady state.[3] For the linearized system, a closed-form solution can then be calculated and the effect of a parameter change investigated. The result is an approximation of the comparative dynamics in a small neighborhood of the steady state. This procedure is only possible for control problems with an infinite time horizon and when they are autonomous in either current-value or present-value terms.[4]

The second approach is to do a comparative dynamic analysis has been introduced into the economics literature by Oniki [1973]. The idea is to make use of the Peano Theorem in the derivation of a variational differential equation system that needs to be solved in order to get the comparative dynamics of the system. Wildasin's [2003] analysis is an example of this approach. His model is a fortunate example as one can derive a closed-from solution for the variational equations. In cases where this is not possible, a graphical solution is an alternative. Of course graphical solutions are feasible for models with only one state variable. An advantage in comparison to the linearization approach is that the results are not limited to the effects of a (infinitesimal small) change of a parameter on the optimal solutions in the neighborhood of the steady state and is not only applicable to control problems that are of the infinite-horizon type and autonomous.

A third approach, which resembles the application of duality theory in comparative statics, has been put forward by Caputo [1990b]. This approach shares the advantages of the second approach of applying the Peano Theorem but has the advantage to be useful even when there is more than one state variable. Caputo [2003], moreover, claims that only the third approach is able to analyze closed-loop solutions of optimal control problems.[5]

The next subsection will present an application of the second approach. The question that will be discussed is how a small variation of a parameter (here: the tax rate τ) affects the optimal solution of the control problem from the last section, namely the optimal investment plan of a firm that is subject to taxation. The approach chosen allows to calculate the effects on the entire time paths of the state and costate variables.[6]

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[3] Note that (2.5) is not linear.

[4] Another approach is to rely for comparative dynamic analysis on the Laplace transforms of the endogenous variables, see Judd [1982]. Central for this approach is the discussion of border conditions. A generalization is found in Barelli / de Abreu Pessôa [2005] .

[5] The same author has also published a textbook in optimal control problems and their analysis that highlights the application of duality-theory to comparative dynamics, see Caputo [2005].

[6] It will turn out that the effect of an increase in the tax rate on the time path of the capital stock will be

2.3.1 Step 1: differentiation

In the framework of the model addressed in this note, comparative dynamic analysis means to discuss the effect of a parameter-variation (here: $d\tau$) on the system of differential equations (2.5). The solution $\{k(t,\tau),\lambda(t,\tau)\}$ of this system – the time path from $k = k_0$ towards the steady state – depends on time t, on the two boundary conditions (2.5c), and on the parameter τ. Denote this solution by

$$\{k(t,\tau),\lambda(t,\tau)\}\ . \tag{2.7}$$

Note that there is no initial condition for λ. Instead, a transversality condition is used to ensure that the optimal solution of the firm's maximisation problem is on the saddle-path.

Once the solution (2.7) is found, one can substitute back into the system (2.5):

$$\dot{k}(t,\tau) = \left(\frac{\lambda(t,\tau)-1}{b}-\delta\right)k(t,\tau) \tag{2.8a}$$

$$\dot{\lambda}(t,\tau) = -f'(k(t,\tau))+\tau+\lambda(t,\tau)\,(r+\delta)+\frac{(\lambda(t,\tau)-1)^2}{2b} \tag{2.8b}$$

$$k(0) = k_0 > 0 \text{ is given;}\quad \lim_{t\to\infty}\left(\lambda(t,\tau)e^{-rt}k(t)\right)=0\ . \tag{2.8c}$$

The Peano Theorem states that the solution of (2.8), i.e. $\left\{\frac{dk(t)}{d\tau},\frac{d\lambda(t)}{d\tau}\right\}$, satifies a system of variational equations as it is shown below:

$$\dot{\left(\frac{dk(t)}{d\tau}\right)} = \left(\frac{\lambda(t,\tau)-1}{b}-\delta\right)\frac{dk(t)}{d\tau}+\left(\frac{k(t,\tau)}{b}\right)\frac{d\lambda(t)}{d\tau}+0 \tag{2.9a}$$

$$\dot{\left(\frac{d\lambda(t)}{d\tau}\right)} = -f''(k(t,\tau))\frac{dk(t)}{d\tau}+\left(r+\delta+\frac{(\lambda(t,\tau)-1)}{b}\right)\frac{d\lambda(t)}{d\tau}+1 \tag{2.9b}$$

$$\frac{dk(0)}{d\tau} = 0,\ \lim_{t\to\infty}\frac{d\lambda(t)}{d\tau}=0\ . \tag{2.9c}$$

For a detailed statement of the Peano Theorem see Oniki [1973, p. 273]. Note first that the endogenous variables in (2.9), $\frac{dk(t)}{d\tau}$ and $\frac{d\lambda(t)}{d\tau}$, depend on time. They are the variables I am interested in: how does the time path of the state variable k and of the co-state variable λ change when the parameter τ changes.

The system of variational equations, (2.9), is to be evaluated at the initial solution (2.7), the one that depends on the initial parameter value τ. It is now ready to be solved for $\frac{dk(t)}{d\tau}$ and $\frac{d\lambda(t)}{d\tau}$.

Remark 1 (boundary conditions): The Peano theorem also states the initial conditions of the system of variational equations. In this application it is assumed that the change of the tax-rate does not change the initial value of the state variable $k_0 = k(0)$ as it is historically given. Nor does it change the initial time itself – time starts in $t = 0$ regardless of a possible perpetuation of the parameter.[7] This said, the first of the two conditions in (2.9c) is a direct application of the Peano Theorem as stated in Oniki [1973, eq. (26)].
The second condition in (2.8c) is an end-point condition. Assume that $\lim_{t\to\infty} k(t) > 0$.

negative for all future periods. See Huggett [2003] for conditions that ensure the monotonicity of comparative dynamic statements.

[7] The Peano Theorem also deals with situations in which the initial value or the initial time, or both, depend on the parameter.

Given that the Inada Conditions hold, a situation where capital approaches zero cannot be an optimal investment plan. This means that the discounted shadow price of capital must approach zero. The end-point condition in (2.8c) is equivalent to $\lim_{t\to\infty}\lambda(t) = 0$. Note also that it is possible to transform any endpoint condition into a condition on the initial value of the co-state variable. In a phase diagram, the endpoint condition in (2.8c) makes sure that for any initial value of the state variable, the corresponding value of the co-state variable is such that the system converges to a steady state. Hence, there always exists a corresponding initial condition for an endpoint condition as in (2.8c).
The second condition in (2.9c) is the variational-equations endpoint condition corresponding to $\lim_{t\to\infty}\lambda(t) = 0$. If there was a condition $\lambda_0 = \lambda(0)$ in (2.8c), the Peano Theorem would state that $\frac{d\lambda(0)}{d\tau} = 0$. The second condition shown in (2.9c) is the corresponding endpoint-condition.[8]

Remark 2 (solvability of the variational system): System (2.9) cannot be solved analytically as the entries in the Jacobian are not constants. This problem will be tackled in the next step. Note that is is a system with time-varying constants. One way to deal with this situation is to use phase diagrams, as there are only two equations. This is done in Caputo [1990a] and in Oniki [1973]. To allow for an analytical solution, the next step is necessary – and this is the approach taken by Boadway [1979] and also in Wildasin [2003].

2.3.2 Step 2: it is a transition between steady states

The problem with system (2.9) is that the entries in the Jacobian are not constant as they contain the original solutions (2.7) which are generally not constant over time. This would be different if I had chosen to substitute the initial system by its linearized version. But the drawback of a linearization is that the investigation of the dynamic system is then limited to a small neighborhood of the steady state. To avoid this limitation, the idea in Boadway [1979], Wildasin [2003] is to make a strong assumption, discussed in detail in the following, that has the advantage that (2.9) turns out to be a system with constant coefficients.

There is one special case where the original solution $\{k(t,\tau),\lambda(t,\tau)\}$ is time independent: if the system initially has been in a steady state. This is the case if the initial value k_0 for k in (2.5) happens to be a steady state value, labeled $k_{SS}(\tau)$ and the corresponding value of the shadow price of capital is $\lambda_{SS}(\tau)$. Then the solution (2.7) – the solution prior to a change in the parameter – can be written as

$$\{k(t,\tau) = k_{SS}(\tau) = \text{constant}, \quad \lambda(t,\tau) = \lambda_{SS}(\tau) = \text{constant}\}.$$

The system of variational equations then is:

$$\left(\frac{d\dot{k(t,\tau)}}{d\tau}\right) = 0\frac{dk(t)}{d\tau} + \left(\frac{k_{SS}(\tau)}{b}\right)\frac{d\lambda(t)}{d\tau} \tag{2.10a}$$

$$\left(\frac{d\dot{\lambda_{SS}(\tau)}}{d\tau}\right) = -f''(k_{SS}(\tau))\frac{dk(t)}{d\tau} + (r+2\delta)\frac{d\lambda(t)}{d\tau} + 1 \tag{2.10b}$$

$$\frac{dk_{t=0}}{d\tau} = 0, \quad \lim_{t\to\infty}\frac{d\lambda(t)}{d\tau} = 0\,. \tag{2.10c}$$

[8] Here I follow Caputo [1990a, footnote 3] who claims that the uniqueness of the solution (2.7) implies that the terminal boundary condition can always be rewritten as an initial condition and that therefore the Peano Theorem applies. There is no need for an initial condition for λ or $\frac{d\lambda}{d\tau}$. The terminal condition in Wildasin [2003, p. 2586] has the same effect.

This system is now ready to be solved *analytically* for $\frac{dk(t)}{d\tau}$ and $\frac{d\lambda(t)}{d\tau}$.

2.3.3 Step 3: solving

It is relatively straightforward to verify the solution found in Wildasin [2003]: The Jacobi-Matrix of coefficients is, given the form of the adjustment cost function,

$$\begin{bmatrix} 0 & k_{SS}/b \\ -f''(k_{SS}) & r+2\delta \end{bmatrix} .$$

The corresponding eigenvalues are real and distinct, one of them being negative and one positive:

$$\begin{bmatrix} \rho_1 = \frac{br+2\,b\delta+\sqrt{b(br^2+4\,br\delta+4\,b\delta^2-4\,f''(k_{SS})\,k_{SS})}}{2b} > 0 \\ \rho_2 = \frac{br+2\,b\delta-\sqrt{b(br^2+4\,br\delta+4\,b\delta^2-4\,f''(k_{SS})\,k_{SS})}}{2b} < 0 \end{bmatrix} .$$

The long-term solution (particular solution) is found from (2.10) and is

$$\lim_{t\to\infty} \frac{d\lambda_t}{d\tau} = 0 \tag{2.11a}$$

$$\lim_{t\to\infty} \frac{dK_t}{d\tau} = \frac{1}{f''(k_{SS}(\tau))} . \tag{2.11b}$$

(2.11c)

The general solution then is

$$\frac{dk(t)}{d\tau} = a_1 e^{\rho_1 t} + a_2 e^{\rho_2 t} + \frac{1}{f''(k_{SS}(\tau))} \tag{2.12a}$$

$$\frac{d\lambda(t)}{d\tau} = a_1 e^{\rho_1 t} + a_2 e^{\rho_2 t} . \tag{2.12b}$$

The remaining constants a_1, a_2 can be calculated from the boundary conditions (2.10c) and the result for the comparative-dynamic impact of a change in τ on $k(t)$ is

$$\frac{dk(t)}{d\tau} = \frac{1}{f''(k_{SS}(\tau))}\left(1 - e^{\rho_2 t}\right) . \tag{2.13}$$

Note that this approach to comparative dynamics calculates the impact of a change in the parameter τ for the entire path of the state and costate variable. (2.13) is not limited to the neighborhood of the initial steady state as there is no linear approximation involved. The result holds globally, see [Caputo 1990a, p. 224].

Linearization of 2.5 and a differentiation of the linearized system would have taken us to the same result.[9] But the drawback would have been that (2.13) would be valid only in the neighborhood of the steady state. Outside this neighborhood, the marginal effect of the change of the tax rate on the evolution of the capital stock and on the optimal investment policy would be unknown. The assumption of an initial steady state allows to calculate a global solution.

[9] The algebraic calculations would have been almost the same. The system of diffential equations in $dk(t)/d\tau$ and $d\lambda(t)/d\tau$ would be linear and with constant coefficients. A linearization means that a non-linear saddle path is approximated by a linear saddle-path. The assumption of an initial steady state means that the initial conditions is a special case where the saddle path is irrelevant as there is no evolution of the state variable and the co-state variable to the equilibrium point.

Proposition 1 (local/global) *Result* (2.13) *holds globally if the dynamic system of investment and capital accumulation* (2.5) *has been in a steady state at time* $t = 0$ *(the point in time when the tax-rate change occurs). Otherwise, it is limited to the neighborhood of the steady state.*

This does of course not mean that the closed-form solution for the time path of the capital stock is found. As in a comparative static exercise, (2.13) is an approximation of the reaction to a infinitesimal small change of the parameter. The actual change needs not to be small. And even if it was small[10] – or turned out to be smallonce the optimal tax rate is found – there would remain an approximation error.

It is shown in the next section how the comparative dynamic result derived above is used for the determination of the optimal tax rate by a local tax authority.

2.4 Optimal taxation

A well known result from many static models of tax competition is the following property:

$$\frac{dk}{d\tau} = \frac{1}{f''(k)} \ .$$

In words: an increase of the tax rate on capital by a small (marginal) amount induces an outflow of capital. This leads to a tax-base externality, see Wilson [1999]. Equation (2.13) above is the dynamic version of that result: In the long run, the marginal reaction of the capital stock will be the same as in a standard static setup. But it will take some time.

In the model discussed here, the strength of the tax-base externality depends on time. Initially, there is no capital flight at all and the local capital stock is a perfectly inelastic tax base. But as time goes on, firms subject to taxation reallocate capital and the tax-base externality becomes stronger. Local governments need to take that into account when they calculate optimal local tax policy. The time profile for the tax base externality matters when the marginal response is used in the first-order condition for the calculation of the optimal tax rate. Equation (8) in Wildasin [2003] is

$$\frac{dY}{d\tau} = \int_0^\infty \left(\underbrace{-k_{SS} f''(k_{SS}) \frac{dk(t)}{d\tau}}_{a)} + \underbrace{\tau \frac{dk(t)}{d\tau} + k_{SS}}_{b)} \right) e^{-rt} dt \ . \tag{2.14}$$

The government seeks to find the tax rate that maximizes the life-time wealth,

$$Y = \int_0^\infty \left(f(k(t) - k(t) f'(k(t) + \tau k(t)) \right) e^{-rt} \ \ ,$$

of worker households.[11] The overall effect of a marginal change in the tax rate on life-time income consists of two effects. Labeled with a) in (2.14), there is the effect of a marginal

[10] As will be seen in the next section, in the model discussed here, the tax rate a local government chooses depends on the initial capital stock. That in turn – as I have assumed that the initial situation is a steady state – depends on the initial, historically given tax rate in a way that is described in (2.6). One could of course imagine a situation where initial taxation is very high and hence the tax rate change on top of the historically given one is small. But it is not small in general.

[11] I assumed here for simplicity that the capital stock is owned by foreigners only, hence $\theta = 0$ in Wildasin's notation. A worker households income then consists of wages and redistribution.

change in the tax rate on wage-income and, labeled with b), the effect it has on revenue from capital taxation as this is redistributed to worker households.[12]

The optimal tax rate chosen by a tax authority, given the initial steady state, is found by equating (2.14) to zero and is [13]

$$\tilde{\tau} = \frac{rk_{SS}f''(k_{SS})}{\rho_2} > 0 \, . \tag{2.15}$$

Note that the tax rate corresponding with the initial steady state is labeled τ and the optimal tax rate chosen by the local government, given the initial circumstances, is labeled $\tilde{\tau}$. If $\tau \neq \tilde{\tau}$, there will be a transition away from the initial steady state.

The essential point in Wildasin [2003] is that the optimal tax rate is positive. Note that the effect b) is an approximation. A change in the tax rate means that there will be a tax rate effect (given the current tax base, revenue increases when the tax rate increases) and the tax base effect (for a given rate, revenues become smaller as the tax base shrinks). Wildasin's result can be stated also like this:

Proposition 2 (Wildasin) *The optimal tax rate described in* (2.15) *is always positive. It can be greater or smaller than the initial tax rate. Accordingly, there can be an inflow or an outflow of capital from time* $t = 0$ *on.*

Proposition 2 follows directly from (2.15) and from the fact that the initial value for the local capital stock, k_{SS}, that depends on the initial tax rate τ, can be arbitrarily chosen.

Another important point for the interpretation of (2.15) is to note that it depends on the initial situation (in particular on the initial capital stock and therefore also on the initial tax rate τ), both directly and because of the dependence of the negative Eigenvalue ρ_2 on the initial capital stock. The tax rate that is chosen is not independent from history. The decision characterized in the present model is a one-shot decision, with full commitment, to set a constant capital tax rate. (2.15) is an open-loop strategy. The fact that it is not history independent is important if one considers the closed-loop strategy where the tax authority can decide again about the optimal tax rate in all subsequent periods. In general, a tax authority that has the possibility to revise its decision in the future will find that the capital stock is lower than initially and hence will choose another tax rate.

Proposition 3 (time consistency) *The optimal tax policy described in* (2.15) *is not time consistent.*

[12] Here I use the same approximation as Wildasin does, namely that $\frac{d(\tau K(t))}{d\tau} = \tau \frac{dk(t)}{d\tau} + k_{SS}$. The approximation error stems from the difference between K_{ss} and $k(t)$. As will be shown in a moment, the local government strictly sets positive tax rates if capital is less then perfectly mobile. Hence $K_{ss} > k(t)$. The effect of a change in the tax rate on redistribution, labeled with b) in (2.14), is hence overstated.

[13] Without the approximation error mentioned in the previous footnote, the optimal tax rate would be

$$\tilde{\tau} = \frac{rk_{SS}f''(k_{SS})}{\rho_2} + \frac{\epsilon f''(k_{SS})(\rho_2 - r)}{-\rho_2} \, ,$$

where $\epsilon = \int_0^\infty k(t) - k_{SS}e^{-rt}dt$. Wildasin's approximation assumes implicitely $\epsilon = 0$. The additional term as compared with (2.15) is a negative number. The property that $\tilde{\tau} > 0$ holds for the tax rate without the approximation if $k_{SS}r$ is not too small.

This result is mainly due to the very restrictive assumption of the tax rate being constant over time. An alternative would be to let local government choose a time path of tax rates. The restriction that tax rates are equal in all periods allows to apply the Peano Theorem as taxation in this case is similar to the choice of a parameter. But this comes at the cost of time inconsistency.

The result of positive tax rates in Wildasin [2003] can also be seen as a variant of a result known from the literature on optimal taxation. Without the restriction of a constant tax rate, optimal taxation of capital usually means to tax capital strongly initially, to choose lower tax rates in the subsequent periods and not to tax capital in the steady state. The restriction of a constant tax rate has the effect that is becomes optimal to choose some average of initially high taxes and lower taxes later on. See, for example, Chari / Kehoe [1998].

2.5 Summary

This note has discussed in detail the comparative dynamic analysis in Wildasin [2003]. The importance of the assumption that the economy of the jurisdiction in question is in a steady state initially has been stressed. It allows to derive a global solution for the comparative dynamics of capital taxation when capital owners can either invest in the local capital stock or in financial assets abroad. It has been argued that the optimal local policy in this model setting, where the tax rate is assumed to be constant over time, is not time-consistent.

Appendix: The time path of the local capital stock for a linearized version of the model

An alternative strategy to solve for the comparative-dynamic properties of the model would have been to linearize around the steady state of the dynamic system (2.5) – the first approach mentioned in 2.3 on page 8. Employing the Peano Theorem for the comparative dynamics exercise dicussed in this chapter has the advantage that the results are exact and there is no approximation involved. The disadvantage is that the time path of the capital stock is unknown.

Let's consider the following scenario: The economy is initially in a steady state $\{K_{SS}(\tau), \lambda_{SS}(\tau)\}$ corresponding with an initial tax rate τ. The government then sets a tax rate $\tilde{\tau} > \tau$. What is the time path of the local capital stock, from $k_{SS}(\tau)$ to the new steady state, labeled $\tilde{k}_{SS}(\tilde{\tau})$? To derive a closed solution for $k(t)$, there is then the possibility to use numerical methods given explicit values for all parameters. An alternative is to use a linearization technique. This appendix provides the linear approximation for the time path of $k(t)$, given its initial value and the optimal tax rate τ. A textbook exposition of the linearization of a growth model of the Ramsey-type can be found, for example, in Barro / Sala-i-Martin [1995, ch. 2] or Blanchard / Fischer [1989, ch. 2]. Other approaches to derive analytically a closed-form solution of the Ramsey model are based on special assumptions about the structure of the model, see Smith [2006] and references therein.

The negative, stable root of the dynamic system (2.5) has already been calculated as ρ_2. The dynamics of the local capital stock around its new steady state $\tilde{k}_{SS}$ are then given by

$$k(t) = \tilde{k}_{SS} + \left(k_{SS} - \tilde{k}_{SS}\right) e^{\rho_2 t} \quad , \tag{2.A1}$$

where $\tilde{k}_{SS}$ is given implicitly by

$$\begin{aligned} \tilde{\tau} + (\delta b + 1)(r + \delta) + \frac{\delta^2 b}{2} &= f'(\tilde{k}_{SS}) \\ \Leftrightarrow \frac{r k_{SS} f''(k_{SS})}{\rho_2} + (\delta b + 1)(r + \delta) + \frac{\delta^2 b}{2} &= f'(\tilde{k}_{SS}) \end{aligned} \tag{2.A2}$$

Once a functional form for the production function $f(k)$ is given, the time path of the local capital stock could be calculated as a function of the initial capital stock r, k_{SS}, $\rho_2(b, r, \delta, k_{SS})$, δ, b.

Note that this would also allow to calculate the time path of revenue, $\tilde{\tau}k(t)$. However, this would not necessarily allow a better approximation of $d(\tau k(t))/d\tau$ than the one used above,

$$\frac{d(\tau K(t))}{d\tau} = \tau \frac{dk(t)}{d\tau} + k_{SS} \quad ,$$

to derive (2.15).

Chapter 3

Dynamic tax competition and public-sector modernisation

This chapter is based on Becker [2005].

3.1 Introduction

Competition for mobile resources can lead to an inefficiently low provision of public goods and can therefore be harmful for the wellbeing of nations. This is the major lesson to be drawn from the tax-competition literature surveyed by Wilson [1999]. However, there are circumstances under which the underprovision result does not hold. For example, if the public sector's activities involve the waste of ressources - caused by rent-seeking politicians or by an inefficiently operating bureaucracy - tax competition can be beneficial as it promotes public-sector modernisation. See, for example, Edwards / Keen [1996], Rauscher [2000] and Keen / Kotsogiannis [2003] for models in which the public sector is seen as such a Leviathan that needs to be tamed.

This paper takes a different look at the efficiency of the public sector. Improvements in public-sector efficiency are modelled as reducing its reliance on tax revenue for the provision of public services. In the model presented below, there is no wasteful behavior of the public bureaucracy that needs to be repelled. The public sector's main task in this model is to provide a redistributive transfer to households. But this is not as simple as raising tax revenue and giving it away to a group of the society that has been selected by the political process. Instead, I model redistribution as a production process where current revenue is only one input. The efficiency of the public sector's production technology depends on the availability of "public-sector efficiency" that is modelled similar to an input. "Public-sector efficiency" is the result of past investment of the public sector and could be IT technology, knowledge or some other stock that is necessary to fulfill the task of providing a transfer to a target group. As public-sector efficiency is modelled as a stock, a local government has control over its evolution. It decides about the investment in the efficiency of the production process, given the revenue it raises.

When public-sector modernisation is seen as an investment activity as in this paper, higher capital mobility is not helpful to improve public-sector efficiency. When capital is mobile, firms are able to shift capital to other jurisdictions. This loss of the tax base is the major disadvantage of capital taxation in open economies. Of course, the severity of this negative effect depends on the degree of capital mobility. Capital mobility in this paper weakens the ability of local governments to raise tax revenue that is needed for beneficial tasks such as the provision of redistribution and public-sector modernisation. The exact meaning of this statement will be developed below.

The aim of the paper is not only to express some doubt concering the "Leviathan wisdom" [Keen / Kotsogiannis 2003] about the benefits of tax competition when the public sector has a "grabbing hand".[1] Another aim is to present the use of a particular dynamic modelling framework based on Wildasin [2003]. It allows the introduction of dynamics in an analytically solvable model of interjurisdictional competition. Furthermore it allows to characterise different degrees of capital mobility.[2] Both the accumulation of public-sector knowledge and the re-location of capital in response to a change in capital taxation are dynamic processes and therefore a dynamic framework seems to be appropriate.

Wildasin (2003) presents a dynamic version of the "canonical" tax-competition model and analyses the dynamic reaction of the local capital stock to a change in capital taxation. Whether the reaction of firms is immediate or not depends on the convexity of an adjustment-cost function that is common in macroeconomic models. Wildasin's dynamic model provides some support for static models of tax competition. The long-term effects in the dynamic model are similar to those known from static models. However, the decision whether to tax capital or not, and at which rate, differs under imperfect capital-mobility. When it takes time for capital to flee a jurisdiction, the trade-off between capital-taxation and the loss of tax base is altered. The adjustment speed in Wildasin [2003] can serve as a reasonable measure of the degree of capital mobility. This allows to consider not only the polar cases of autarky compared with perfect integration but also the more realistic intermediate cases.

Modelling public-sector modernisation as an dynamic investment problem as in this paper introduces another consideration a government needs to take into account when deciding about the optimal tax structure. Investing in the stock of efficiency means that future redistribution becomes more efficient. To discuss intertemporal considerations like this, it is necessary to use a dynamic model as it is presented in this paper.

The plan of the paper is as follows. Section 3.2 presents the setup of the model, including the dynamic approach to capital mobility and tax competition. Section 3.3 analyses the decision problem the government faces in this dynamic environment. The following result are derived: the optimal input mix in the production of redistribution, for the comparative dynamics of public-sector efficiency and of local capital, for the optimal tax rate given a certain degree of capital mobility, and for the relationship between capital mobility and public-sector efficiency. Section 3.4 provides some numerical examples and section 3.5 concludes the paper.

[1] There are a number of arguments both in favor and against the view that tax competition might be favourable for the efficiency of the public sector. In Wilson [2005], for example, the mobility of the tax base is unambiguously welfare-improving because the Leviathan in his model is identified as a bureaucracy that has an interest to strengthen the tax base when capital is more mobile. Cai / Treisman [2005] are more pessimistic as they argue that poorly endowed governments do not engage in tax competition at all as they anticipate that they are not able to attract capital. Hence, tax competition cannot be a discipline device for these governments. In Cai / Treisman [2004], competition between jurisdiction weakens the central government that could otherwise eliminate the disadvantages of interjurisdictional competition.

[2] There are surprisingly few models in the tax competition literature that deal with imperfect factor mobility, with Lee [1997] being one of the exceptions. Public-sector modernisation, growth and tax competition is also analysed in Rauscher [2005], albeit in an endogenous growth model and with an alternative modelling of imperfect capital mobility. He finds that the effect of increased capital mobility on growth and on the behaviour of a Leviathan is ambiguous.

3.2 The model

3.2.1 Households

Let us consider a federation with many small jurisdictions. A single jurisdiction cannot influence decisions in other jurisdictions. Each jurisdiction is inhabited by an immobile representative household that has no market power. The household's budget constraint is

$$C(t) = w(t) + G(t) + A(t)r - S(t), \tag{3.1}$$

where $C(t)$ is consumption of a numeraire good, $w(t)$ is the wage rate, $G(t)$ is a redistributive transfer via a consumption good provided by the government and t is an index of time. Labour is inelastically supplied in a perfectly competitive labour-market and the number of households is normalized to one. There is an international capital market where a stock of accumulated savings $A(t)$ earns a return of r, expressed in terms of the numéraire good. $A(t)$ is a stock of financial capital. All agents take the interest rate r as given and I assume that $r \geq 0$. Capital is supplied by an integrated world capital market consisting of the accumulated savings of all countries. The federation is a small country compared to the rest of the world. Therefore, $A(t)$ represents the part of the world capital stock that is held by domestic residents. To simplify the model, I assume that domestic households hold only shares of foreign firms and that local firms are exclusively owned by foreigners.[3] $S(t)$ represents current savings.

3.2.2 Government

The role of the government is to provide a redistributive transfer $G(t)$. This is more complex than simply to redistribute tax revenue from the foreign-owned firms to the worker-household: $G(t)$ is *produced* with a Cobb-Douglas-Technology

$$G(t) = R(t)^{\gamma} H(t)^{1-\gamma} \text{ with } 0 < \gamma < 1 \,, \tag{3.2}$$

where $H(t)$ is a stock of knowledge and $R(t)$ a flow of revenues devoted to the production of redistribution. Technology (3.2) plays a central role in this model. $G(t)$ is a lump-sum transfer to households and can also be labeled redistribution.[4] The level of $G(t)$ a government can provide does not only depend on the tax revenue $R(t)$ devoted to redistribution, but also on the stock of $H(t)$.

In an ideal world, a government that provides redistribution simply diverts revenue taken from one group of citizens to another group of citizens that has been defined as a target group. One Euro raised implies that there is one Euro that can be passed on to the target group. This would be a perfectly efficient redistribution technology. The idea behind technology (3.2) is that in reality, redistribution is a complex procedure that can be modelled as a production process. Redistribution involves flow inputs of labour, for example public servants that process applications for social assistance. And it also involves stock inputs, for example IT-technology or knowledge about good practices to provide redistribution according to a politically defined goal. A government that produces redistribution with a technology like (3.2) has - similar to

[3] Alternatively I could introduce foreign and domestic shares. I will discuss this and other assumptions in the conclusion.
[4] A referee pointed out that redistribution in this model is not across consumers but from foreign capital owners to local households.

a private firm that produces goods - to decide about an optimal input mix between stocks and flows. It needs to decide about an investment strategy, where investment is broadly defined and includes training of public servants or the establishment of rules and procedures in the bureaucracy.

$G(t)$ and labour income are perfect substitutes. One could see technology (3.2) also as a way to model situations where the public sector provides a private good that is a close substitute to private consumption. Examples are public education or public health care. They are rival in consumption and can also be provided privately. Another way to interpret (3.2) is to see it as the technology of tax collection. $H(t)$ would then be the effectiveness of the public sector to raise tax revenue.

Public-sector efficiency in this paper is measured by the level of $H(t)$. It can be interpreted as the knowledge of the public sector about efficient technologies to transform tax revenue into a transfer. Without any knowledge, i.e. $H(t) = 0$, the public sector is a black hole in which tax revenues vanish without any benefits for the citizens. A high level of $H(t)$ can be seen as an indicator of a very efficient public sector where at least the first units of tax revenue generate very high marginal benefits for the household. The development of $H(t)$ over time reflects the development of public-sector efficiency. I assume throughout the paper that parameters are such that the efficiency of the public sector is not above the efficiency frontier ($G \leqslant R$).[5]

Tax revenue is used to provide a redistributive transfer and to modernise the public sector. It is assumed that the government cannot tax the immobile factor labour, but imposes a source tax τ per unit on the local capital stock $k(t)$. To keep the model simple, public debt is ruled out[6] and therefore, the government's budget constraint is

$$\tau k(t) = R(t) + M(t) \ , \tag{3.3}$$

where $M(t)$ is the investment in public efficiency or the modernisation effort at time t. Current public expenditure is financed by current capital tax revenue. Public-sector efficiency develops according to

$$\dot{H}(t) = M(t) = \tau k(t) - R(t) \quad \text{with } H(0) = H_0 \geq 0 \text{ given} \ . \tag{3.4}$$

Initially, the public sector's efficiency is H_0. If $H_0 = 0$, modernisation, i.e. accumulation of $H(t)$, is a prerequisite for redistribution. It is assumed, again for the sake of simplicity, that the public sector does not forget technologies and procedures to transform tax revenue into redistribution it has previously known. Thus, there is no depreciation in (3.4).

[5] The usage of an input as a measure of efficiency is a bit unusual. Think of a general technology $G = f(R)$, where G is one output, R is an input. Productivity is then measured as G/R. A more productive production unit is also more efficient. In this paper, where R is tax revenue and G a transfer, the efficiency border is naturally given by $R = G$. Hence, the productivity of the public sector and its distance from the efficiency border are related in a simple way. The reason for efficiency differences is usually that different technologies are used. The idea behind (3.2) is that the state of technology behind the transformation of R into G is under the control of the public sector. The state of technology is $H^{1-\gamma}$ and modelled similar to an input. The assumption that parameters are such that the public does not produce above its efficiency frontier means that I assume that the level of H is always low enough to ensure that $G(t) < R(t)$. Efficiency is *not* defined as the best possible way to use R *and* H for the production of G.

[6] The assumption that the public sector has no access to the international capital market is meant to reflect borrowing constraints governments face. An example is the Europan Growth and Stability Pact or the common practice of states in the U.S. to impose constitutional bans on borrowing. I see the assumption of no access at all as a simple way to incorporate such restrictions into the model.

3.2.3 Private firms and the dynamics of taxation and capital accumulation

In the local jurisdiction there are many identical firms. The representative firm takes prices and decisions by the government as given. This firm produces with a constant-returns-to-scale production function $F(k(t), L)$. The decision to hire labour and capital is dominated by the aim to maximise the current value of future cash flows. Labour is normalised to one such that the production function can be written as $f(k(t))$. The wage rate is determined in a competitive labour market. It depends on the current capital stock only and is given by

$$w(t) = f(k(t)) - f'(k(t))k(t) \ . \tag{3.5}$$

The development of the local capital stock $k(t)$ depends on the investment rate $i(t)$ chosen by the representative firm. The local capital stock evolves according to

$$\dot{k}(t) = (i(t) - \delta)\, k(t) \ \text{ with } k(0) = k_0 \geq 0 \text{ given,} \tag{3.6}$$

where δ is the depreciation rate.

The alternative investment opportunity for the local firm is to invest in financial capital A which bears an interest at rate r. The interest rate is assumed to be exogenous to the jurisdiction. Hence, the objective of the firm is to maximize the present value of profits with r being the discount rate. The cash flow at time t is

$$\pi(t) = f(k(t)) - c\,(i(t))\, k(t) - \tau k(t) - i(t)k(t) - w(t) \ \ , \tag{3.7}$$

with $c(i)$ being an investment cost function. The objective of the firm is

$$\max\ \Pi = \int_0^\infty \pi(t)e^{-rt}dt \ \ , \tag{3.8}$$

subject to (3.6). Profits and therefore investment depend on the local tax rate on capital, τ, which is assumed to be constant. From a technical point of view, τ is a parameter in the firm's optimization problem. Another important determinant of the firm's decision about the local capital stock is the investment cost function $c(i)$. It is assumed to be convex and its curvature will turn out to be crucial for the speed of a firm's reaction to a variation in the capital tax rate. To simplify the notation, assume the following quadratic specification of investment costs:

$$c\,(i(t))\, k(t) = \frac{b}{2} i(t)^2 k(t), \tag{3.9}$$

where $c(0) = 0$, $c' = bi(t)$, $c'' = b$. Parameter b can be interpreted as a measure for the mobility of capital. The lower b, the cheaper it is to adjust the capital stock. The total costs of investing one unit of capital are $i(t)\,(1 + c\,(i(t))\, k(t)) = i(t)\left(1 + \frac{b}{2} i(t)^2 k(t)\right)$.

Employing the Maximum Principle, and making use of the functional form for the investment cost function, the process of capital accumulation of the firm can be described as follows:[7]

$$\dot{k}(t) = \left(\frac{\lambda(t) - 1}{b} - \delta\right) k(t) \tag{3.10a}$$

$$\dot{\lambda}(t) = -f'(k(t)) + \tau + \lambda(t)\,(r + \delta) + \frac{(\lambda - 1)^2}{2b} \tag{3.10b}$$

$$k(0) = k_0 > 0 \text{ is given; } \quad \lim_{t\to\infty} \left(\lambda(t)e^{-rt}k(t)\right) = 0 \ . \tag{3.10c}$$

[7] See Becker [2007] for a step-by-step derivation.

λ is the costate variable associated with capital. The first-order condition for investment, $\lambda(t) = 1 + c'(i(t))$, has been used to express investment as a function of λ and the investment cost parameter b. Investment is $i(t) = \frac{\lambda(t)-1}{b}$. The boundary conditions in (3.10c) are standard.

(3.10) is a system of ordinary differential equations. Its solution $\{k(t,\tau), \lambda(t,\tau)\}$ depends on the parameter τ. The additional argument τ will be omitted if this does not cause any confusion in the remainder of the paper. Given all parameters and the initial value of $k_0 = k(0)$, the local capital stock grows towards a steady state $\{K_{SS}(\tau), \lambda_{SS}(\tau)\}$, which is defined by

$$\delta b + 1 = \lambda_{SS} \tag{3.11a}$$

$$\tau + (\delta b + 1)(r + \delta) + \frac{\delta^2 b}{2} = f'(k_{SS}) \,. \tag{3.11b}$$

The setup of the private sector is very similar toWildasin [2003], where the focus is on the comparative-dynamic response of the local capital stock to taxation. A key insight of Wildasin [2003] is that when capital is modelled as a stock variable, the elastic reaction of the local capital stock to a change of the capital tax rate evolves over time. Wildasin finds that a convex investment cost function implies that the tax base capital is not perfectly elastic as it is assumed in most static models of tax competition. The scenario in Wildasin [2003] and also in this paper is the following: At time $t = 0$, the government sets a time-invariant tax rate τ which comes as a surprise to the private sector.[8] Furthermore, it is assumed that the government can commit itself to its policy announcements. Raising the capital tax rate drives capital out of the jurisdiction as local firms have an incentive to disinvest. When this adjustment of the local capital stock in response to capital taxation is immediate, the mobility of (physical) capital is perfect.[9] If capital is not perfectly mobile, firms face the following trade off: When the new tax rate is higher than initially, local capital is less profitable compared with the external rate of return r. Therefore, they find it profitable to de-accumulate until the net return of local capital equals the external rate of return. On the other hand, de-accumulation (a negative rate of investment) raises adjustment costs. If the investment-cost function is convex, quick adjustments of the capital stock are more expensive per unit than slow adjustments.

The immobility of capital is an important determinant of the optimal tax policy. Assume for simplicity that firms are owned only by foreigners. The inhabitants of the local jurisdiction are workers. The local government tries to raise tax revenue that it can then redistribute to workers. Tax revenue is a prerequisite for redistribution. Furthermore, in this model, tax revenue is also needed to improve the efficiency of the public sector. On the other hand, capital taxation implies a lower local capital stock, lower marginal productivity of labour and therefore lower wages. If the adjustment of the capital stock in response to capital taxation is not immediate, the benefits of taxation occur immediately but the disadvantages need time to take effect. In a dynamic model, this is an elegant way to model imperfect capital mobility.

Trading off the present values of benefits and costs can result in positive capital tax rates

[8] One could argue that real-world governments decide about a path of tax rates. While this might be true, a model with a time-invariant tax rate generates dynamics that can be analysed by making use of the Peano Theorem about the comparative dynamic response of a dynamic system to a variation of a parameter. This will be shown below.

[9] There are no constraints on the mobility of financial capital. The adjustment of the stock of financial capital is free of cost. See, for example, Persson / Tabellini [1992] or Gordon / Bovenberg [1996] for models where capital mobility costs are associated with the investment abroad. In the present model, investment is either local (in physical capital k) or it is investment in the federation-wide market for financial capital.

even if non-distorting lump-sum taxes are available, as has been shown in Wildasin [2003]. The reason is that the tax burden is shifted away from worker-households and towards foreign owners of the capital stock temporarily. While the economy adjusts, the government extracts quasi-rents from foreign capital owner.

A key result in Wildasin [2003, eqs. (5), (6)] that will be derived for the specific functional forms in this paper later on, is

$$\frac{dk(t)}{d\tau} = \frac{1}{f''(k)} \left(1 - e^{\rho_2 t}\right) , \tag{3.12}$$

with $\rho_2 < 0$ representing the speed of adjustment.[10]

This is the comparative-dynamic response of the local capital stock to a change in the capital tax rate τ. When time goes to infinity, the response of the local capital stock to a change in the tax rate is the inverse of the second derivative of the production function with respect to capital, a result that is familiar from static models of tax competition. See, for example, Zodrow / Mieszkowski [1986, eq. 5]. For $0 < t < \infty$, the comparative-dynamic response to a change in the tax rate is less, depending on the magnitude of ρ_2. For the derivation of (3.12), it has been assumed that the starting value for capital, k_0 happens to be a steady state value. The need for this assumption will be explained later on, but let us introduce some notation: Initially, the capital stock has a value of k_0 that is a steady state. There might be an historically given tax rate on capital τ such that the initial steady state can be denoted by $\{k_{SS}(\tau), \lambda_{SS}(\tau)\}$, where λ is the costate variable associated with capital. The local government decides in time $t = 0$ about a new tax rate on capital. The new tax rate will be denoted by $\tilde{\tau}$. If $\tilde{\tau} \neq \tau$, the local capital stock will adjust from the initial steady state to another one, denoted by $\left\{\tilde{k}_{SS}(\tilde{\tau}), \tilde{\lambda}_{SS}(\tilde{\tau})\right\}$.

Further on, the parameter b in the adjustment cost function is used as a measure for capital mobility as it measures the speed with which the response of the local capital stock to a change in the tax rate becomes effective. More convex investment cost functions imply higher values of b and values of ρ_2 that are smaller (shown in detail later on). The investment cost function can be seen as a punishment of quick adjustments. High investment or de-investment implies higher than proportional investment costs and therefore it is profitable to adjust the capital stock only gradually, in a process that takes time. A more pronounced punishment is represented by a greater value of b and a value of ρ_2 that is smaller. If $\rho_2 \to 0$, capital is immobile. If $\rho_2 \to -\infty$, capital is perfectly mobile. When adjustment costs per unit of investment are strongly convex, firms are reluctant to adjust the local capital stock immediately as this would imply very high adjustment costs.[11]

The structure of the model in this paper is such that the comparative dynamics of the local capital stock are similar to (3.12). The speed of capital-stock adjustment will be crucial

[10] At time $t = 0$, $\frac{dk(t)}{d\tau} = 0$. For $t \to \infty$, $\frac{dk(t)}{d\tau} = \frac{1}{f''(k)}$. The absolute value of ρ_2 determines the speed of the transition of $\frac{dk(t)}{d\tau}$ from 0 to $\frac{1}{f''(k)}$.

[11] A potential problem with Wildasin's approach is that this adjustment cost function can be applied to closed economies as well. One might argue that adjustment costs should therefore not be used as a microfoundation for imperfect capital mobility that instead could to be caused by barriers to cross-border capital flows, see for example Persson / Tabellini [1992] or Lejour / Verbon [1997]. In this paper, it is assumed that it is costless to borrow and invest in the international capital market. Nevertheless, capital is not perfectly mobile in the sense that the process of capital flight is time-consuming.
Another possibility is to model the investment decision of the firm with investment in a second capital stock abroad as the alternative investment opportunity. Investment abroad then can be associated with a cost function similar to an adjustment cost function but representing the cost of overcoming barriers to capital. The resulting response of a firm would be very similar to the one illustrated in Figure 3.1.

for the results in this paper, where the government uses the revenue of capital taxation for redistribution and for public-sector modernisation. The solid line in Figure 3.1 shows the adjustment of the local capital stock in response to a change in the tax rate on capital from τ to $\tilde{\tau}$ with $\tau < \tilde{\tau}$ and a convex investment cost function ($b > 0$).

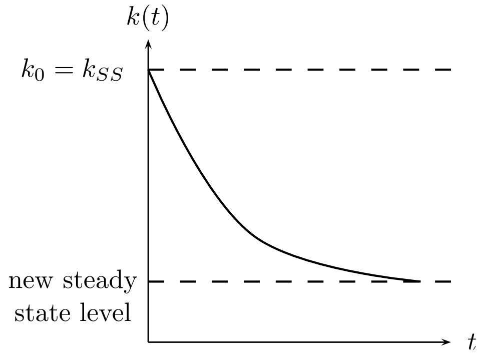


Figure 3.1: Comparative-dynamic response of the capital stock for $\tau < \tilde{\tau}$ and $b > 0$

A local government solves the problem of optimally exploiting (foreign) capital owners. Capital owners can defend themselves against exploitation because they can adjust the local capital stock. This in turn needs to be considered by a local government as the wage rate of its inhabitants depends on the capital stock. The other decision the local government needs to make is how to split the revenue extracted from foreigners between modernisation and redistribution.

Local governments are engaged in tax competition as they have to consider that the tax base capital depends on their decisions. Raising the tax on local capital triggers an outflow of capital. Many model of tax competition deal with the Nash equilibrium in a federation where tax rates are too low a long as the positive externality of capital outflows is not corrected. In this model, the local jurisdiction is assumed to be small such that the federation-wide interest rate does not depend on the decisions of the local government. Hence, there is no externality by definition. Nevertheless, local jurisdictions have an incentive to set tax rates that attract capital, a scenario that is commonly seen as one of tax competition.

This completes the setup of the model.

3.3 The intensity of tax competition and public-sector modernisation

3.3.1 The problem

The government's policy instruments are τ, $M(t)$ and $R(t)$. It needs to take the technology (3.2), the budget constraint (3.3) and the equation of motion for public-sector efficiency (3.4) and the evolution of the local capital stock into account. The objective is to maximise the lifetime income of the jurisdiction's citizens. The optimisation problem therefore is

$$\max_{\tau, R(t)} \int_0^\infty \left(w(t) + R(t)^\gamma H(t)^{1-\gamma} \right) e^{-rt} dt \; , \tag{3.13}$$

subject to (3.4) and (3.10a)-(3.10c). The present value of the household's income from saving over time, $\int_0^\infty (A(t)r - S(t))\, e^{-rt} dt$, is not part of the objective function. The world interest rate serves as discount factor, as households can borrow and lend on the international capital market. The government controls the supply of redistribution and (indirectly, via the capital stock) also the wage rate. Whatever the paths of $w(t)$ and $G(t)$ are, households will adjust their savings to maximise their lifetime utility of consumption. In this model, the government has no interest to intervene in the intertemporal consumption decision but maximises the income that is distributed over time to the household. Using this objective function instead of the discounted lifetime utility from consumption will simplify the algebra considerably and has the additional advantage that the government's decisions do not rely on the knowledge of the household's utility function.

The assumption that the income from assets and the saving decision of households is not part of the objective function may sound a bit unusual. In many growth models, it is the discounted utility of households that is maximised. In a model with an externally given interest rate, the best possible lifetime utility from consumption is achieved with the highest possible lifetime income. The path of consumption is irrelevant. A benevolent government has no reason to influence the time path of consumption as it has no influence on the external interest rate by assumption. A benevolent government tries to achieve the highest possible lifetime-income for its citizens and it can do so by maximising the lifetime-income from redistribution and work as it is assumed in (3.13). In a model without a fixed interest rate, this would be different. A government could try manipulate the time path of interest rate and investment activity in order to achieve a higher life-time utility, for example if saving and investment generates external effects not taken into account by households. This is not possible in this model where any investment project is evaluated against the alternative investment in assets bearing a fixed interest rate determined on the world market.

The assumption of an externally given and fixed interest rate is critical in this model. Note that with a utility function that implies consumption smoothing additional transfers to households will be used for both current consumption and savings. There is an additional supply of savings in the international capital market. The assumption of small jurisdictions means that the governments' decision to manipulate households income will not change supply and demand conditions in the international capital market substantially and that the market clearing interest rate is unchanged. The model is solved from the perspective of a single jurisdiction, given external conditions on the world capital market. I do not solve for the equilibrium of a system of identical jurisdictions. If jurisdictions were symmetric, all jurisdictions would set the same tax rate simultaneously, implying that the relative attractiveness of jurisdictions would not change and *ex post*, capital would not flee the country when the tax rate is raised. In a symmetric model, this would imply that the market-clearing interest rate would be lowered by the simultaneous decision to change capital taxation. The assumption that jurisdictions are small means that the decision of the individual government have no influence on the demand and supply conditions in the international capital market, neither ex ante nor ex post.[12]

[12] The endogeneity of the interest rate is considered, for example, by Makris [2005]. He considers whether decentralised decision making implies too low or too high capital tax rates and what the coordinated tax rate should be. Another paper where the interest rate effect of tax competition between indentical jurisdictions is considered is Becker / Rauscher [2007a].

3.3.2 Public-sector efficiency, the dynamics of the local capital stock and optimal taxation

The current-value Hamiltonian $\mathcal{H}$ for the government's decision problem is

$$\mathcal{H} = w(t) + R(t)^{\gamma} H(t)^{1-\gamma} + \mu(t)\left(\tau k(t) - R(t)\right). \tag{3.14}$$

Hestenes' Theorem[13] states that the following conditions hold for an optimal policy $\{\tau, R(t)\}$:

$$\frac{\partial \mathcal{H}}{\partial R(t)} = \gamma R(t)^{\gamma-1} H(t)^{1-\gamma} - \mu(t) = 0\ , \tag{3.15a}$$

$$\dot{\mu(t)} = \mu(t) r - \frac{\partial \mathcal{H}}{\partial H(t)} = \mu(t) r - (1-\gamma)\left(\frac{R(t)}{H(t)}\right)^{\gamma}\ , \tag{3.15b}$$

$$\frac{d}{d\tau}\int_0^{\infty} w(t) e^{-rt} dt = \tag{3.15c}$$

$$-\frac{d}{d\tau}\int_0^{\infty}\Big(R(t)^{\gamma} H(t)^{1-\gamma} + \mu(t)\left(\tau k(t) - R(t)\right)\Big) e^{-rt} dt\ ,$$

$$H(0) = H_0 > 0 \text{ is given;} \quad \lim_{t\to\infty}\Big(\mu(t) e^{-rt} H(t)\Big) = 0\ , \tag{3.15d}$$

together with (3.10) and (3.4).

Before the determination of the optimal tax rate from (3.15c), I solve for the dynamics of the model for a given tax rate τ. It is necessary to find closed-form solutions for the comparative-dynamic response of the state variables to a change of the tax rate before the integrals in (3.15c) can be calculated. Hence, the next step is to analyse the dynamic system that is described by (3.15a), (3.15b) and (3.15d).

From (3.15a), it follows that

$$R(t) = \left(\frac{\mu(t)}{\gamma}\right)^{\frac{1}{\gamma-1}} H(t). \tag{3.16}$$

This is the optimal flow of revenues devoted to the production of $G(t)$. Using (3.16) in (3.4) and (3.15b) results in the following non-linear and non-homogeneous system of differential equations:

$$\dot{H(t)} = -\left(\frac{\mu(t)}{\gamma}\right)^{\frac{1}{\gamma-1}} H(t) + \tau k(t)\ , \tag{3.17a}$$

$$\dot{\mu(t)} = r\mu(t) - (1-\gamma)\left(\frac{\mu(t)}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}\ , \tag{3.17b}$$

where $k(t)$ is given by (3.10). Equation (3.17b) is can be reduced to the linear form and therefore easily solved.[14] Applying the appropriate border condition $\lim_{t\to\infty}\left(\mu(t) e^{-rt} H(t)\right) = 0$ reveals[15] that $\mu(t)$ is a constant:

$$\mu(t) = \gamma\left(\tfrac{1-\gamma}{r\gamma}\right)^{1-\gamma}\ . \tag{3.18}$$

[13] As τ is time-invariant, it is not a control-variable in the maximisation of (3.14) but a "control parameter". For this kind of policy variables, Hestenes' Theorem applies, see Takayama [1985, ch. 8.C]. For the same reason, the equations of motion for $k(t)$ and $\lambda(t)$ (3.10) are not incorporated in the Hamiltonian. They are constraints for the local government's optimization problem, but for any given parameter value of τ, the expression $\tau k(t)$ could in principle be substituted by the solution of (3.10) that is independent of the choice of the control variable $R(t)$.

[14] (3.17b) is an Bernoulli Equation, see Chiang [1984, p. 491]. Thanks to an anonymous referee for pointing this out.

[15] See the appendix on page 40 for the details.

Together with (3.16), this yields

Proposition 4 (constant optimal input mix) *The optimal mix $R(t)/H(t)$ for the provision of the publicly provided consumption good $G(t)$ is*

$$\frac{R(t)}{H(t)} = \frac{r\gamma}{1-\gamma} \ . \tag{3.19}$$

and constant over time. There are no transitional dynamics for the input mix.

It is a standard result that for a given price, the input mix is constant (linear exapnsion path). In this model, the relative price of the inputs R and H is also constant, both in a steady state and in a transition phase. The local government always chooses some optimal input mix that reflects a trade-off between the future and the presence. A high return of households' savings in the international capital market makes investment in future benefits, i.e. in public-sector efficiency, relatively unattractive. This implies a relatively low level of $H(t)$ in the optimal input mix. A high output elasticity of current tax revenue $R(t)$ has a similar effect.

Using (3.18) in (3.17a) simplifies the equation of motion for public-sector efficiency a lot:

$$\dot{H(t)} = -\frac{r\gamma}{1-\gamma}H(t) + \tau k(t) \ . \tag{3.17a'}$$

The remaining problem is that the path for $k(t)$ is unknown. Hence, the dynamic system that describes the evolution of public-sector efficiency consist of three differential equations for $H(t)$, $k(t)$ and the costate variable for capital, $\lambda(t)$. It has non-constant coefficients. There exists a steady state for this system consisting of (3.17a'), (3.10a) and (3.10b) when time goes to infinity. One possible solution method would be to linearise around this steady state. The disadvantage of this approach would be that the solution would be valid only locally, in the neighbourhood of the steady state. To avoid this limitation and to achieve results that are global, the method used in Boadway [1979], and also in Wildasin [2003], is employed. The idea of this method can be described as follows: Assume that the system is initially in a steady state. The system of "variational equations" which is derived by differentiation of the system of equations (3.17) with respect to the policy parameter τ then has *constant* coefficients. It is then possible to solve the resulting system and to calculate the response of the state variable $H(t)$ to a variation of the policy parameter τ.[16]

The system of variational equations that needs to be solved is

$$\begin{bmatrix} \frac{d\dot{k(t)}}{d\tau} \\ \frac{d\dot{\lambda(t)}}{d\tau} \\ \frac{d\dot{H(t)}}{d\tau} \end{bmatrix} = \begin{bmatrix} \frac{\lambda(t,\tau)-1}{b} - \delta & \frac{k(t,\tau)}{b} & 0 \\ -f''(k(t,\tau)) & r+\delta+\frac{\lambda(t,\tau)-1}{b} & 0 \\ \tau & 0 & \frac{-r\gamma}{1-\gamma} \end{bmatrix} \begin{bmatrix} \frac{dk(t)}{d\tau} \\ \frac{d\lambda(t)}{d\tau} \\ \frac{dH(t)}{d\tau} \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \\ k(t,\tau) \end{bmatrix} . \tag{3.20}$$

To see the effect of a change in capital taxation on the efficiency $H(t)$ of the public sector and on the local capital stock $k(t)$, system (3.20) has to be solved for $dH(t)/d\tau$ and $dk(t)/d\tau$. Note that I do not try to find a closed-form solution for $H(t)$ or $k(t)$.

[16] This method employs the Peano-Theorem from the theory of differential equations that deals with the behaviour of a system of differential equations when a parameter – here the time-invariant tax rate – is changed, see for a textbook discussion Caputo [2005, ch.11]. The assumption of an initial steady state is necessary to achieve the property of constant coefficients in the system of differential equations that describe the evolution of the state and costate variables in response to the change of a parameter. Becker [2007] contains a more detailed discussion of the Peano-Theorem in the comparative-dynamic analysis of fiscal competition models.

The next step to transform (3.20) in a dynamic system that can be solved with standard methods is to make use of the assumption that the system has been initially in a steady state. (3.20) describes how the dynamic system $\{k(t,\tau), \lambda(t,\tau), H(t,\tau)\}$ for a given parameter value τ reacts to a variation of the parameter.In this case to a change of τ to $\tilde{\tau}$. The remaining problem is that the coefficients of the dynamic system are not constant in general and the closed-form solution for $k(t,\tau)$, $\lambda(t,\tau)$ and $H(t,\tau)$ that corresponds to the initial value of the parameter τ is unknown. This is where the assumption of an initial steady state is useful. If the initial situation happens to be steady state, then $\{k(t,\tau), \lambda(t,\tau), H(t,\tau)\}$ is constant by assumption.

Assumption 1 (initial steady state) *The capital stock $k(t)$, its costate variable $\lambda(t)$ and public-sector efficiency $H(t)$ are in a steady state in time $t = 0$. Their initial steady state values are denoted as k_{SS}, λ_{SS} and H_{SS}, respectively.*

Assumption 1 together with equation (3.11) allows to rewrite (3.20) as:

$$\begin{bmatrix} \frac{d\dot{k}(t)}{d\tau} \\ \frac{d\dot{\lambda}(t)}{d\tau} \\ \frac{d\dot{H}(t)}{d\tau} \end{bmatrix} = \begin{bmatrix} 0 & \frac{k_{SS}(\tau)}{b} & 0 \\ -f''(k_{SS}(\tau)) & r+2\delta & 0 \\ \tau & 0 & \frac{-r\gamma}{1-\gamma} \end{bmatrix} \begin{bmatrix} \frac{dk(t)}{d\tau} \\ \frac{d\lambda(t)}{d\tau} \\ \frac{dH(t)}{d\tau} \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \\ k_{SS}(\tau) \end{bmatrix}. \tag{3.21}$$

(3.21) is a dynamic system with constant coefficients that can be solved with standard methods. Note that $\frac{d\dot{k}(t)}{d\tau}$ and $\frac{d\dot{\lambda}(t)}{d\tau}$ are independent from $\frac{dH(t)}{d\tau}$ due to the structure of the model where the representative firm is connected with the local government only through the parameter τ.

By setting $\frac{d\dot{k}(t)}{d\tau} = \frac{d\dot{\lambda}(t)}{d\tau} = \frac{d\dot{H}(t)}{d\tau} = 0$, one can find the long-term solution of (3.21):

Proposition 5 (long-term effect) *In the long run ($\lim_{t\to\infty}$), the effects of a change of the capital tax rate on the local capital stock $k(t)$, its co-state variable and on public-sector efficiency H are:*

$$\lim_{t\to\infty} \frac{dk(t)}{d\tau} = \frac{1}{f''(k_{SS})} , \tag{3.22a}$$

$$\lim_{t\to\infty} \frac{d\lambda(t)}{d\tau} = 0 , \tag{3.22b}$$

$$\lim_{t\to\infty} \frac{dH(t)}{d\tau} = \frac{1-\gamma}{r\gamma}\left(\tau\frac{1}{f''(k_{SS})} + k_{SS}\right) . \tag{3.22c}$$

(3.22a) is well known from static models of tax competition, see, for example, Zodrow / Mieszkowski [1986, eq. 5]. It states that the tax base capital shrinks when the tax rate is raised. (3.22b) stems from the fact that the steady state of the co-state variable for capital is $\delta b+1$ and therefore independent of τ, see equation (3.11a). (3.22c) states that the loss or gain of revenue that results by a change in the capital tax rate has a stronger effect on public-sector efficiency the more important the role of the stock-variable $H(t)$ is for redistribution.[17]

The long-term effects of a change in the capital tax rate on public-sector efficiency depends only on parameters of the production technology for redistribution, on the initial tax rate

[17] The long-term effect on revenues is calculated as $\lim_{t\to\infty} \frac{d(\tau k)}{d\tau} = \lim_{t\to\infty} \tau \frac{dk(t)}{d\tau} + k(t)$. This can be seen as an approximation.

τ, and the corresponding initial capital stock k_{SS}. Investment in public-sector efficiency is costly from the perspective of the household as it is foregone current income through redistribution. The investment opportunity alternative to public-sector modernisation from the households point of view is to save and earn a return r. Higher rates of interest in the international capital market therefore let a government choose a lower stock of capital in the long run. Furthermore, a high output-elasticity of $H(t)$ in the public production technology (3.2) makes investment in public-sector efficiency attractive and vice versa. Once the steady state level of public-sector efficiency is reached, tax revenue is entirely used as a flow input in the production of redistribution.

The eigenvalues corresponding to the Jacobi matrix of coefficients in (3.21) are

$$\begin{bmatrix} \rho_1 = \frac{br+2\,b\delta+\sqrt{b(br^2+4\,br\delta+4\,b\delta^2-4\,f''(k_{SS})\,k_{SS})}}{2b} > 0 \\ \rho_2 = \frac{br+2\,b\delta-\sqrt{b(br^2+4\,br\delta+4\,b\delta^2-4\,f''(k_{SS})\,k_{SS})}}{2b} < 0 \\ \rho_3 = \frac{-r\gamma}{1-\gamma} < 0 \end{bmatrix}. \tag{3.23}$$

There are two negative eigenvalues and one positive eigenvalue and the system therefore has the property of saddle-point stability. Applying the appropriate border conditions[18] yields

Proposition 6 (comparative dynamics) *1. The comparative-dynamic response of the local capital stock k and public-sector efficiency H is*

$$\frac{dk(t)}{d\tau} = \frac{1}{f''(k_{SS}(\tau))}\left(1-e^{\rho_2 t}\right) < 0\;\forall\, t>0\,, \tag{3.24a}$$

$$\frac{dH(t)}{d\tau} = \frac{1-\gamma}{r\gamma}\left(\tau\frac{1}{f''(k_{SS})}+k_{SS}\right)\left(1-e^{\rho_3 t}\right)\,. \tag{3.24b}$$

2. *The sign of $\frac{dH(t)}{d\tau}$ depends on the initial tax rate τ and technological parameters: If $\tau\frac{1}{f''(k_{SS})}+k_{SS}>0$ (i.e. if the initial tax rate τ is low enough), then $\frac{dH(t)}{d\tau}>0\;\forall\, t>0$ and vice versa. In the former case, raising the tax rate implies higher public-sector efficiency $H(t)\;\forall\, t>0$.*

3. *The initial tax rate τ, the initial capital stock k_{SS} and the initial level of public-sector efficiency H_{SS} are not independent from each other as it has been assumed that the economy is in a steady state initially (Assumption 1). The initial tax rate determines the initial steady state of capital (equation* (3.11b)*). The initial value of public-sector efficiency, H_{SS}, is then implicitely given by the initial revenue τk_{SS} and by setting $\dot{H}(t)=0$ in* (3.17a').

(3.24a) replicates the result for the comparative-dynamic response of the local capital stock to a change in the tax rate that has already been introduced in equation (3.12) on page 23. Note that ρ_2, ρ_3 do not contain endogenous variables. The speed of adjustment of $k(t)$ and $H(t)$ depends on parameters and initial values only, see (3.23). Capital mobility, measured by b, has no direct influence on the comparative dynamics of public-sector efficiency as long as the initial capital stock k_{SS} is held constant. But – as will be shown below – it has an impact on the optimal tax rate that is chosen by local governments.

[18] The border conditions are $\frac{dk(0)}{d\tau}=0$, $\lim_{t\to\infty}\frac{d\lambda(t)}{d\tau}=0$ and $\frac{dH(0)}{d\tau}=0$. See Oniki [1973] and Becker [2007] for a more detailed discussion about border conditions when applying the Peano-Theorem.

The capital tax rate chosen by the local government can in principle be both positive or negative, depending on how the local government decides in the trade-off between raising capital tax revenue for modernisation and redistribution versus dispelling capital and reducing labour productivity. I will discuss the necessary conditions for a positive tax rate in more detail below.

The tax rate τ in this model is time-invariant. Technically spoken, the government sets a parameter to find the maximum of the objective function. Using the results from Proposition 6 in (3.15c), the optimal tax rate when capital is imperfectly mobile ($0 < |\rho_2| < \infty$ or $b > 0$) can be calculated as

$$\tilde{\tau} = \frac{k_{SS}\, f''(k_{SS})\, \left(\rho_2 r(-\rho_3)^{-\gamma} + (2-\gamma(3-\gamma))\,(r-\rho_2)\right)}{\left(\rho_2(2-\gamma) - r(1-\gamma)\right)(1-\gamma)} \ . \tag{3.25}$$

See the appendix for the derivation of (3.25). The tax rate is labeled $\tilde{\tau}$ to make clear that this the optimal tax rate. The tax rate that is historically given is labeled τ (without a tilde). Interestingly, the tax rate $\tilde{\tau}$ does not depend on the initial value of public-sector efficiency H_0. A local government with a low level of public-sector efficiency does not set a higher tax rate than other governments. The initial capital stock $K_0 = k_{SS}$ is crucial for the question whether capital should be taxed (further).

The optimal tax rate τ depends on the size of the integrals in (3.15c). If the time needed for the transition from the initial to the new steady state changes, the size of those integrals representing the welfare effects of taxation changes and, accordingly, the optimal tax rate.

The government in this model can tax capital in order to provide redistribution to households. In addition to the trade-off between capital flight and redistribution, it has to take into account that the amount of redistribution depends on its modernisation effort. Hence the complicated role of the technical parameter γ in the tax rate formula.

The optimal tax rate is positive if the following assumption is met:

Assumption 2 *The parameter space is restricted to values that fulfill the following condition:*

$$-\, r\rho_3^{-\gamma} + \gamma(\gamma-3) + 2 > 0 \ . \tag{3.26}$$

Figure 3.2 illustrates it for the range $0 < \gamma < 1 <$. *Interest rates below the solid line ensure that the assumption is met.*

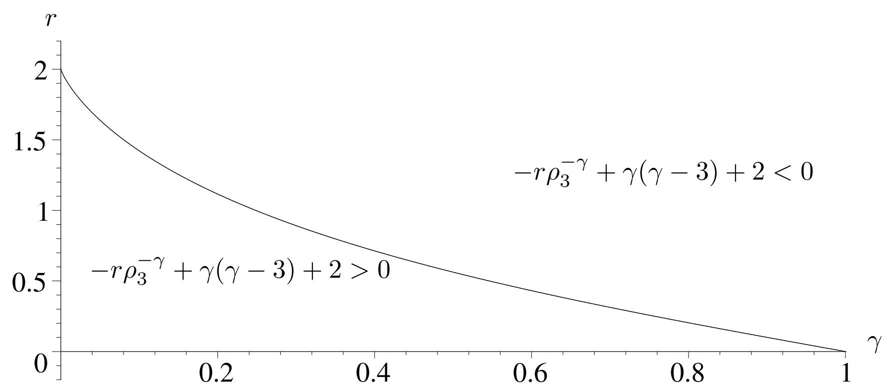


Figure 3.2: Condition (3.26) in the $\{r, \gamma\}$-Space.

I assume in the remainder of the paper that parameters fulfil Assumption 2. It is a sufficient but not a necessary condition to ensure positive tax rates. If it fails, positive tax rates are still possible if capital is not very mobile.

Note that

$$\lim_{\gamma \to 1} \tilde{\tau} = \frac{k_{SS} f''(k_{SS}) r}{\rho_2} > 0 \,. \tag{3.27}$$

With γ approaching 1, the relevance of the capital good $H(t)$ for the production of the capital good vanishes. The tax rate established in (3.27) is identical to the tax rate in Wildasin [2003, eq. (9)]. In Wildasin's paper, the government redistributes tax revenue directly to households. The tax rate (3.25) in comparison to the one in (3.27) reflects the additional considerations because of the need to accumulate knowledge in the public sector.

Even in the presence of perfect capital mobility ($b \to 0$ or $\rho_2 \to -\infty$), there is an incentive to tax capital:

$$\lim_{\rho_2 \to -\infty} \tilde{\tau} = \frac{-k_{SS} f''(k_{SS}) \left(-r(-\rho_3)^{-\gamma} + \gamma(\gamma - 3) + 2\right)}{2 - 3\gamma + \gamma^2} \,. \tag{3.28}$$

A condition for the tax rate being positive in the special case of $\lim_{\rho_2 \to -\infty}$ is again given by (3.26). The government does not only have to consider the trade-off between the immediate benefits of redistribution versus lower wages later on. In addition, taxation allows to invest in public-sector modernisation and to achieve a higher level of redistribution in the economy. The possibility to use tax revenue to generate benefits that accrue in all following moments of time is another motivation to tax capital even if capital flight is possible immediately. It is this additional incentive which lets the optimal tax rate be positive even in the presence of perfect capital mobility.

Higher capital mobility leads governments to choose lower tax rates. This can be seen by differentiation of (3.25) with respect to b while holding the initial capital stock k_{SS} constant:

$$\begin{aligned} \frac{d\tilde{\tau}}{db}_{|k_{SS} \text{ constant}} &= \frac{d\tilde{\tau}}{d\rho_2}_{|k_{SS} \text{ constant}} \frac{d\rho_2}{db} \\ &= \frac{r\left(2 - \gamma + r\left(-\rho_3\right)^{-\gamma}\right)\left(k_{SS} f''(k_{SS})\right)^2}{b\left(-r + 2\,\rho_2 + r\gamma - \gamma\,\rho_2\right)^2 \sqrt{b\left(br^2 + 4\,br\delta + 4\,b\delta^2 - 4\,f''(k_{SS})k_{SS}\right)}} > 0 \end{aligned}$$

Lower values of b imply smaller values of ρ_2 such that $d\rho_2 < 0$ – as long as the initial capital stock is not altered by the change in b.[19] The result in (3.29) is straightforward: higher capital mobility makes it easier (less costly) for foreign capital owners to flee jurisdictions that try to redistribute from foreigners to local households. The capital stock, labour productivity and wages shrink faster. Shrinking wages are the main reason for local governments to be reluctant to use capital taxation for the purpose of providing a transfer to households.

The optimal tax rate τ is always positive as long as Assumption 2 holds. But it is not necessarily greater than the initial tax rate. Consider two extreme situations. If the initial tax rate τ equals zero, the initial capital stock is relatively high, the tax rate $\tilde{\tau}$ is greater than the initial tax rate and there will be an outflow of capital from time $t = 0$ on. If the initial tax rate is almost a confiscatory rate, the initial steady state value for the local capital

[19] The statement that increasing capital mobility (lower values of b) implies lower a tax rate is only valid if the initial capital stock is the same. The initial capital stock depends on b itself, see (3.11b). Holding k_{SS} constant while b varies can be achieved by a variation of the initial tax rate τ.

stock is close to zero and the tax rate $\tilde{\tau}$ is below the initial tax rate. In this situation, there will be an inflow of capital. The initial situation is historically given. Both cases – $\tilde{\tau} > \tau$ with an outflow of capital and $\tilde{\tau} < \tau$ with an inflow – are possible. The local government – as long as capital mobility is imperfect ($\rho_2 > -\infty$) – doesn't always have an interest to extract rents from foreign capital owners. In situations where the historically given capital stock is very low, the opportunity costs of loosing even more capital due to a higher tax rate than initially are too high.

The dependence of the optimal tax rate on the historically given capital stock has an important consequence: The decision about capital taxation in time $t = 0$ that is characterized in the present model is a one-shot decision, with full commitment, to set a constant capital tax rate. It has been assumed that capital-owners do not anticipate the decision. (3.25) is an open-loop strategy. The fact that it is not history independent is important if one considers the closed-loop strategy where the tax authority can decide again about the optimal tax rate in all subsequent periods. In general, a tax authority that has the possibility to revise its decision in the future will find that the capital stock is lower than initially and hence will choose another tax rate. (3.25) is therefore not time-consistent.

Proposition 7 summarizes the results on the optimal tax rate on capital:

Proposition 7 (optimal capital taxation) *The optimal tax rate $\tilde{\tau}$ in* (3.25) *has the following properties:*

1. *It is positive if Assumption 2 if fulfilled.*
2. *If Assumption 2 is not fulfilled, values of ρ_2 that are close enough to zero (high enough values of b) ensure a positive tax rate.*
3. *Even in the presence of perfect capital mobility ($b \to 0$ or $\rho_2 \to -\infty$), $\tilde{\tau}$ is positive as long as Assumption 2 holds.*
4. *$\tilde{\tau}$ and capital mobility are negatively related: higher capital mobility leads governments to choose lower tax rates, given that the initial value of the local capital stock is the same.*
5. *$\tilde{\tau}$ can be greater or smaller than the initial tax rate τ. If the initial tax rate τ is small enough, $\tilde{\tau} > \tau$ and there will be an outflow of capital.*
6. *τ is not time-consistent.*[20]

3.3.3 Capital mobility, optimal taxation and public-sector modernisation

Does increased mobility of capital enhance public-sector modernisation? Is tax competition conducive to an efficient public sector? This is the central question in this paper. Proposition 7 states that higher capital mobility lets local governments choose lower tax rates. There is no direct effect of capital mobility on the accumulation of public-sector efficiency. The decision about the taxation of capital and the decision about the use of the resulting revenue are separate decisions. It follows from Proposition 6 that the direction of the change of the path of public-sector efficiency caused by a change in the tax rate on capital depends on the long-term consequences of that tax rate change on revenue. The second part of Proposition 6 already states that the path of public-sector efficiency is below the initial path if the tax

[20] Note that 5. and 6. apply also to the model in Wildasin [2003].

rate, $\tilde{\tau}$, is smaller than the old, τ, and if revenue shrinks because of that change in capital taxation. It is therefore necessary to know under which circumstances the local government lowers the capital tax rate and whether this is revenue enhancing or not.

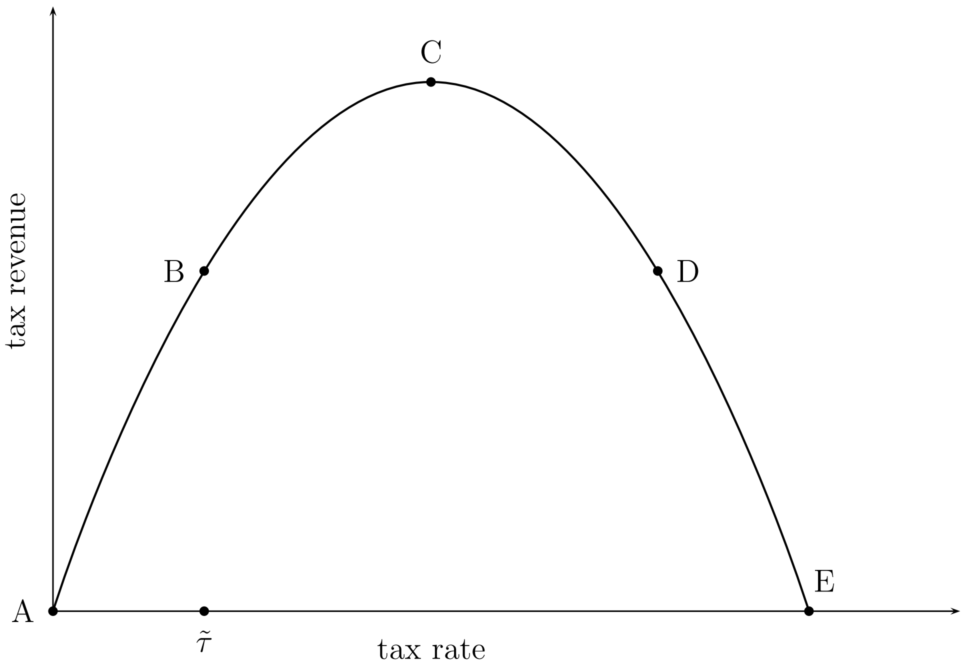


Figure 3.3: Stylized Laffer-curve

Figure 3.3 shows a stylized Laffer curve.[21] If the tax rate is zero (point A), the local government doesn't raise any revenue. If the tax rate is confiscatory[22], there is no capital accumulation in the economy and the revenue is again zero (point E). There is a revenue-maximising tax rate corresponding to the peak of that stylized Laffer curve (point C). The local government in this model does not choose the revenue-maximising tax rate. Revenue is beneficial for worker-households as it can be used for redistribution both directly or indirectly through public-sector modernisation. But raising the tax rate comes at the cost of lower wages. In equation (3.15c), if the left hand side would be zero, the local government would choose the revenue-maximising tax rate. But in this model, the optimal tax rate is always somewhere below, for example at point B in Figure 3.3. The position of point B depends on the degree of capital mobility. The more mobile capital is, the more rapid is the adjustment of the capital stock and the more important is the wage effect on life-time income that is caused by a change in capital taxation. In Wildasin [2003], the optimal tax rate is zero when capital is perfectly mobile. In this model, point B is always somewhere to the right of the origin.

The revenue consequences of the tax rate chosen in time $t = 0$ can be categorized depending on the initial position of the local government on the Laffer Curve. Take point B as the optimal position on the Laffer curve. If the initial tax rate is greater than the one corresponding to B, the local government decides to lower it, $\tilde{\tau} < \tau$, and there is an inflow of capital during the adjustment to the new steady state. The revenue-consequences of this change of the capital

[21] The exact shape of the Laffer curve depends on the functional form of the private production function $f(k)$. The Laffer curve is single-peaked, for example, if the production function is $f(k) = k^{\alpha}$ with $\alpha < 1$.
[22] As capital taxation is not a taxation of capital income in this model, the tax rate has no natural upper bound at 100 %. A confiscatory rate is the tax rate for which capital accumulation is not profitable in the long run. This is the case for $\tau \to \infty$.

tax rate can be either negative (for a initial position somewhere between B and D) or positive (for a initial position somewhere between D and E). If the initial tax rate is below the one corresponding with B, the local government decides to raise it, $\tilde{\tau} > \tau$ and there is an outflow of capital and revenue rises (initial position somewhere between A and B). This leads to:

Proposition 8 (capital mobility and public-sector modernisation)
Whether capital mobility enhances public-sector modernisation or not, for $t \to \infty$, depends on the initial position of the local government on a Laffer curve like the one in Figure 3.3. The local government will always choose a capital tax rate $\tilde{\tau}$ that is below the revenue-maximising rate. Group local governments according to their initial tax policy as follows:

- *(low-tax) Local governments with an initial tax rate below $\tilde{\tau}$ choose a higher tax rate on capital and face an outflow of capital. Revenue for $t \to \infty$ rises. Public-sector efficiency is higher than initially.*
- *(high-tax) Local governments with an initial tax rate that is higher than $\tilde{\tau}$ and less revenue than that corresponding with $\tilde{\tau}$ face an inflow of capital and an increase of revenue in the long run. Public-sector efficiency is higher than initially.*
- *(intermediate-tax) Local governments with an initial tax rate that is higher than $\tilde{\tau}$ and higher revenue than that corresponding with $\tilde{\tau}$ face an inflow of capital and less revenue in the long run. Public-sector efficiency is lower than initially.*

Higher capital mobility lets a local government choose a lower tax rate $\tilde{\tau}$. The range of tax rates that correspond with being a low-tax government is smaller when capital mobility is higher. In this sense, higher capital mobility causes lower public-sector efficiency. Whether this statement is true for a specific local government depends on its initial position on the Laffer-curve.

Whether increased mobility of capital enhances public-sector modernisation or not depends on the ability of local governments to increase revenue that is then used to support local households either through the modernisation of the public sector or by direct redistribution. But their problem is not simply to choose the revenue-maximising tax rate on a Laffer curve: To maximise the life-time income of households, they have to consider the time path of revenues and of the local capital stock as well.

The model in this paper is such that the relationship between public-sector efficiency and capital mobility narrows down to the question whether revenue shrinks or increases when the local government raises capital taxes. It is only necessary to know the long-term consequences on revenue, as can be seen from equation (3.24b) in Proposition 6. The revenue plotted in Figure 3.3 as a Laffer curve is the revenue in a steady state. The impact of capital mobility on the efficiency of the public sector depends on the existence of a Laffer effect. In a situation where increased capital mobility lets local governments choose lower tax rate, is this revenue enhancing or not?[23] However, whether a local government raises its capital taxes or not

[23] It is of course difficult to decide in which part of the Laffer curve for the taxation of capital a specific country or jurisdiction is. See Blinder [1981] for an example of an “guesstimation” of such a question. In general, it can be said that it is more likely to be on the wrong side of the Laffer curve if the activity taxed can be substituted by other activities easily. In the case of capital taxation, the integration of capital markets make the substitution of real investment in the local capital stock by investment in financial assets easier. In this model, this is captured by the fact that point B in Figure 3.3 moves to the left when capital mobility is increased.

depends on the initial situation: The higher the initial tax rate is, the more likely it is that a local government sets a lower tax rate than initially.[24]

Mankiw / Weinzierl [2006] show for a closed economy and several variants of the neoclassical growth model that tax cuts can be partly self-financing, depending on the assumptions about parameters. The main difference in this paper compared to Mankiw / Weinzierl [2006] is that the adjustment path of the local capital stock is not determined by local conditions only. In this paper, the adjustment path of the local capital stock depends on the externally interest rate r and on the intensity of tax competition ρ_2. In the long run, the local capital stock is determined by the equilibrium condition 3.11 and does not depend on local capital taxation as in Mankiw / Weinzierl [2006]. To what extent a tax cut is partly self-financing in the long run through its positive effect on the local capital stock can then be found out by a simple back-of-the-envelope calculation, once a functional form for the production function and the initial values for the capital tax rate are known. According to Proposition 8, it is also sufficient to associate initial tax rates with one of the three groups to make a qualitative statement.[25]

Market integration in the form of higher capital mobility hampers public-sector modernisation. The reason is that higher capital mobility implies that a smaller range of initial positions on the Laffer curve correspond to increased revenues and higher public-sector efficiency in the long run. The intuition for this result is that public-sector modernisation is modelled as an investment activity that needs to be funded by tax revenues. Higher capital mobility discourages taxation and tax revenues that are needed to pursue public-sector modernisation.

Before the results are summarized in the conclusion, the next section presents several numerical examples to illustrate the model.

3.4 A numerical example

This section provides a numerical example to illustrate the results derived so far.[26] In this numerical example, with given parameters and functional forms, it is possible to find a closed-form solution for the path of the local capital stock and to provide plots of tax rates, revenue and public-sector efficiency.

Throughout the section, I assume $f(k) = k^{0.3}$, $r = 0.1$ and $\delta = 0.1$. Assumption 2 is fulfilled. This allows to calculate the initial capital stock that corresponds to a tax rate τ or $\tilde{\tau}$ (equation (3.11b)), if necessary. From equation (3.25), it is possible to calculate the tax rate $\tilde{\tau}$ that corresponds to some initial τ.

[24] In many static models of tax competition, capital tax rates of a closed economy is compared against those of an open economy. In a standard tax competition model where capital taxation gives rise to a positive externality, comparing those polar cases leads to the clear result that capital tax rates too low in the presence of tax competition. In this model, I do not compare those polar cases. Parameter b ranges from perfect capital mobility ($b = 0$) to a closed economy ($b \to \infty$) and covers all intermediate cases. In this model, the sign of $d\tilde{\tau}/db$ is non-ambiguous. But whether a local government raises its tax rate in capital or lowers it depends on the characteristics of an initial steady state.

[25] Agell / Persson [2001] analyse Laffer effects in a simple AK model of endogenous growth. The key message of their paper is that in a dynamic context, it is very important to have a proper definition of what they call a dynamic Laffer effect. Note that in the preceding analysis, where growth is not endogenous and the central question is whether capital mobility has an influence on the level of public-sector efficiency, I am not looking for a dynamic Laffer effect. It is only necessary to know the revenue effect of a tax variation in the long run.

[26] I have used Maple 9.5 for Mac OS X to derive the plots in this section. The workfile is available on request.

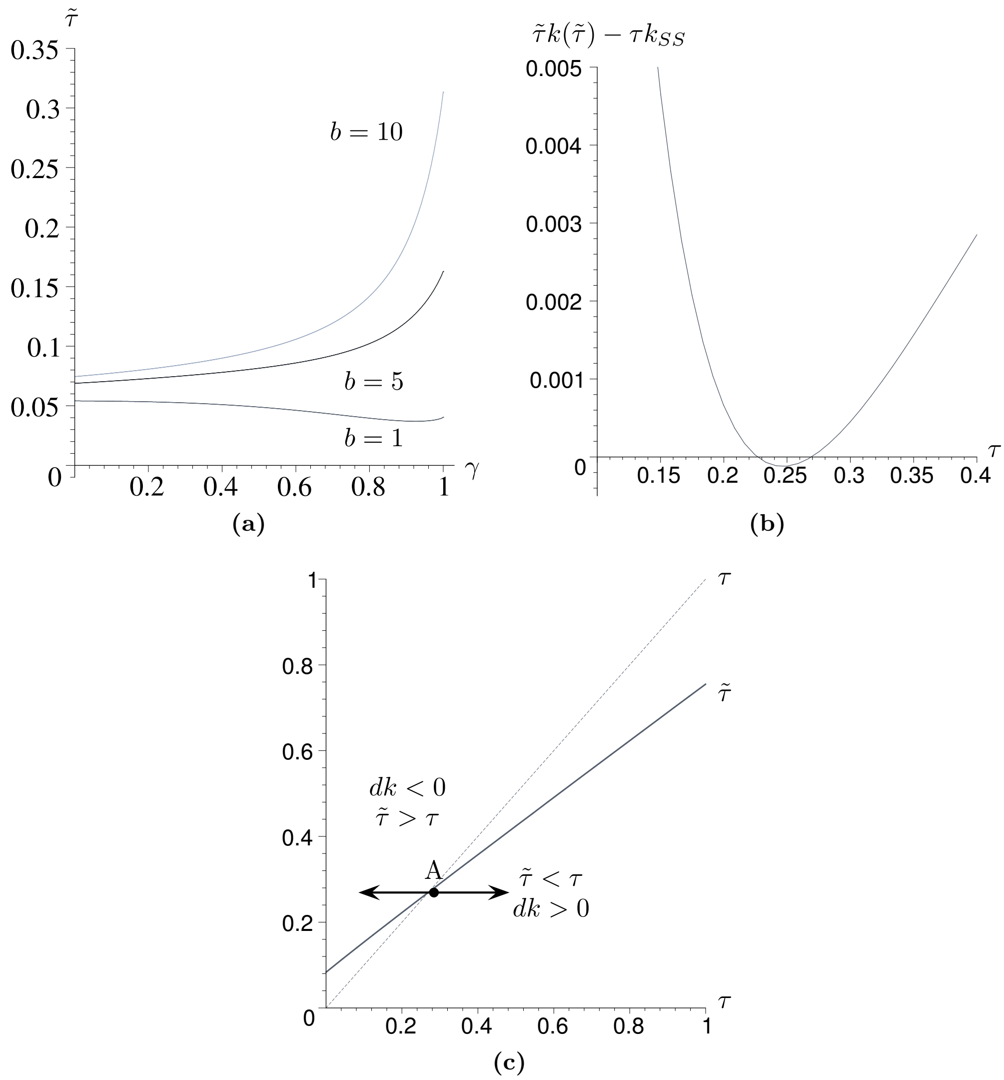


Figure 3.4: Numerical example (tax rate, revenue) (a) Tax rate (3.25) for different values of the capital mobility parameter b and an initial capital stock $k_{SS} = 10$. (b) Difference between the revenue in the initial and the new situation $b = 1$). (c) New tax rate $\tilde{\tau}$ as a function of the initial tax rate τ ($b = 1$)

Figure 3.4a shows the optimal tax rate for all possible values of γ and different values of b. The initial capital stock is assumed to be $k_{SS} = 10$. Note that fixing the initial capital stock k_{SS} ensures that higher values of b correspond with values of ρ_2 that are closer to zero. Higher values of b correspond with less capital mobility. The initial tax rate differs in the three cases illustrated in Figure 3.4a such that equation (3.11b) holds. In Figure 3.4a, higher capital mobility (lower values of b) implies lower tax rates. See Proposition 7.

Figure 3.4b plots the difference between the revenue raised in the initial steady state and the steady state that corresponds to the new tax rate that is chosen in time $t = 0$. Parameter b is set to 1. The initial situation is characterised by a tax rate between zero and 0.4. The initial capital stock then varies according to (3.11b). For small and high values of the initial tax rate, there is a clear revenue gain. These are tax rate of local governments in either the "low-tax" or the "high-tax" group in Proposition 8. The negative values are the revenue losses of local governments in the "intermediate-tax" group.

Figure 3.4c compares the initial tax rate $0 < \tau < 1$ with the new tax rate chosen, $\tilde{\tau}$. Again, Parameter b is set to 1 and the initial capital stock varies. It can be seen that $\tilde{\tau} > \tau$ for small values of the tax rate. This implies a shrinking capital stock. There is a crucial initial tax rate where this changes and the local government sets a tax rate the triggers a capital inflow from time $t = 0$ on.

Figure 3.5 illustrates the evolution of tax revenue and public-sector efficiency for different values of the capital-mobility parameter b when the initial capital stock is set to $k_{SS} = 1$ in all three scenarios. The initial tax rate is different in the three scenarios shown. Figure 3.5a shows the path of tax revenue. In all three scenarios, the new tax rate $\tilde{\tau}$ is lower than the initial tax rate. Revenue is higher than initially but then shrinks with the capital stock - see table 3.1 for the numbers. The initial values of public-sector efficiency differs. In all three cases, public-sector efficiency rises over time (Figure 3.5b).

b	τ	τk_{SS}	H_{SS}	$\tilde{\tau}$
$b = 1.0$	0.08	0.08	6.75	0.22
$b = 0.5$	0.09	0.09	7.88	0.21
$b = 0.1$	0.10	0.10	8.78	0.20

Table 3.1: Values of some key parameters and variables used for figure 3.5. All numbers rounded to two digits.

In Figure 3.6, the initial value of public-sector efficiency is set to zero. The initial tax rate is zero as well. The initial capital stock differs and shrinks as the new tax rate $\tilde{\tau}$ is positive. Revenue shrinks over time (Figure 3.6a) but is greater than initially. The higher capital mobility is (the lower b), the faster is the modernisation of the public sector (Figure 3.6b).

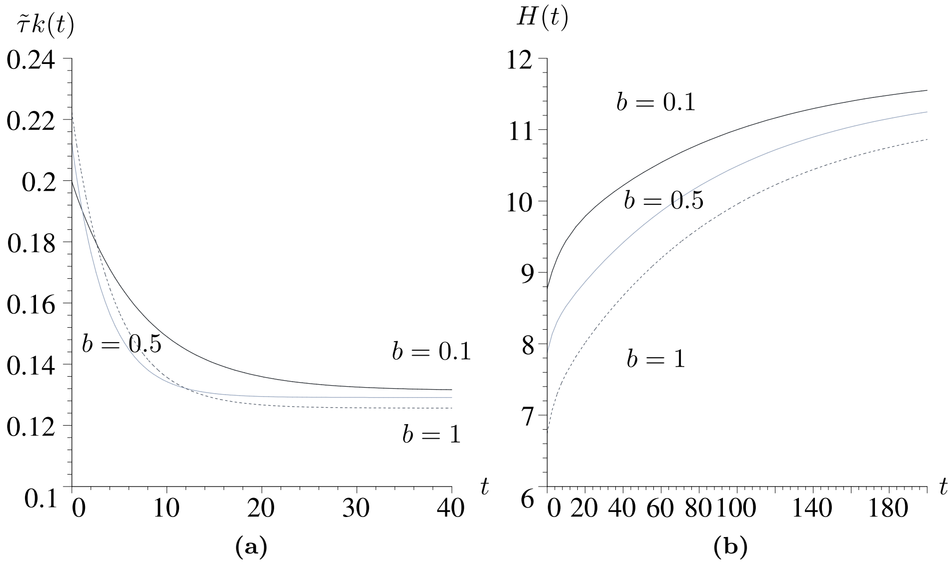


Figure 3.5: Revenue and public-sector efficiency for different values of the capital mobility parameter b and a common initial capital stock. (a) Revenue $\tilde{\tau}k(t)$ (b) Public-sector efficiency $H(t)$

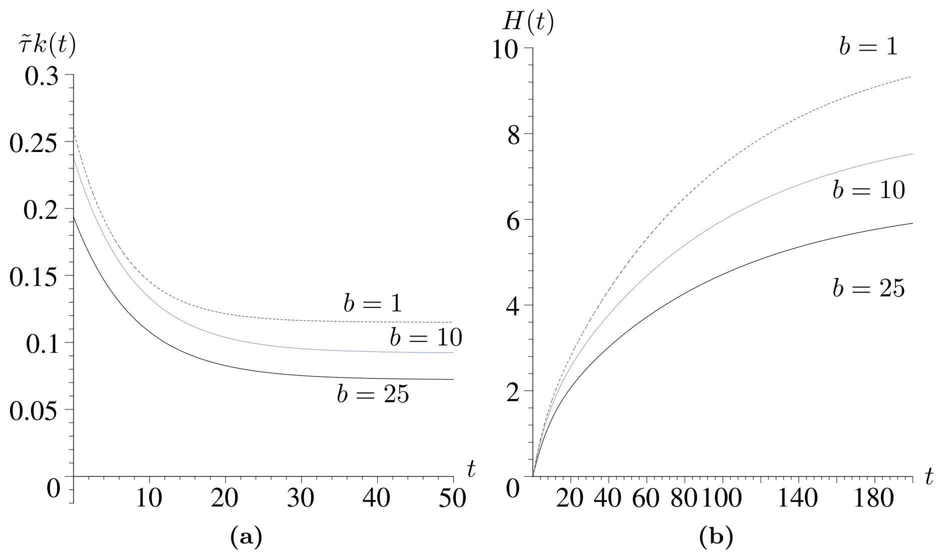


Figure 3.6: Revenue and public-sector efficiency for different values of the capital mobility parameter b and a common initial value of public-sector efficiency. (a) Revenue $\tilde{\tau}k(t)$ (b) Public-sector efficiency $H(t)$

3.5 Concluding Remarks

This paper tries to answer the question whether the competitive pressure induced by capital tax competition enhance the efficiency of the public sector. Public-sector efficiency is modelled as a stock variable and public-sector modernisation is seen as an investment activity that is financed by tax revenues. The model in this paper assumes that the jurisdiction under consideration is in an initial steady state. The main result is that the presence of tax competition hampers public-sector modernisation.

Public-sector efficiency depends on revenue that is either invested in modernisation or used directly as a flow input in the production of redistribution. Higher capital mobility implies lower tax rates. Whether this is revenue- and efficiency-enhancing or not depends on the situation the local jurisdiction is initially. But a smaller range of initial tax rates is compatible with a revenue-gain when capital mobility is higher.

A key assumption of the model is that private agents are caught by surprise by the government's decision to tax capital and that it can commit itself to this policy announcement. This is not very realistic. As long as the capital stock in the jurisdiction has some positive level, there is an incentive to deviate from the announcement in time $t = 0$. Rational investors would foresee that the announcement of a tax policy in time $t = 0$ is not time-consistent. With rational expectations, a credible policy announcement must not depend on initial conditions as in this model, see Taylor [2000, sect. 2.1]. One could see this as a major disadvantage of the model presented above. Still, it is a dynamic model as it describes local jurisdictions as growing economies. Furthermore, transitional dynamics matter: the speed of adjustment of the local capital stock to the new steady state is crucial for optimal policy of the local government. But the model is not dynamic in the sense that forward-looking decisions like investment in a capital stock and forward-looking tax-policy without commitment is analysed simultaneously, as it is done, for example, in Hassler et al. [2005]. A model of tax competition between growing jurisdictions where local governments cannot commitment themselves to their policy announcements is missing in the literature.

Another simplifying assumption is that households do not own parts of the local capital stock. Optimal policy is therefore the optimal exploitation of foreigners in the favour of local households. Households do not suffer from the fact that the net return of local capital is lower than the world interest rate during the transition phase after an surprising rise in capital taxation. The only reason not to expropriate foreign capital owners is that wages depends on the availability of capital. This is not a very realistic setup. If the local capital stock is partly owned by local households, the incentives for the local governments are different. The greater the share of local ownership is, the lower is the tax rate, revenues and public-sector efficiency in the long run. But as long as a part of the local capital stock is owned by foreigners, the local government tries to optimally exploit them. An alternative ad-hoc modelling strategy would be to introduce a parameter that represents the share of the local capital stock that is owned by foreign households. The higher the share of domestic ownership, the lower the optimal tax rate would be. This is done in Wildasin [2003]. As the qualitative results do not change, I abandoned domestic ownership of the capital stock altogether. It might be interesting to think about the endogenous evolution of the ownership structure of the local capital stock in a tax competition model, but this is beyond the scope of this paper.

The assumption of foreign ownership of the capital stock could have abandoned alltogether with a different structure of the model: Assume that there are two types of households in the economy. Worker households without access to the international capital market and capitalists that own capital. In this alternative model, assume further that the local government does not care about the welfare of capitalists as they do not vote. They express their will in the political process only by deciding where to invest in physical capital. In a model like this, the problem of the local government would be to optimally exploit capitalists regardless of their place of residence. Redistribution would be from "footloose" capitalists to local worker-households. The only group with access to the international capital market were firms or capital-owners. This alternative model would lead to similar results than those derived above.[27]

Public services benefit only households in this model. But of course the public sector provides also infrastructure and other public inputs that enter the private sector's production function. In a dynamic context, public inputs can be a potential source of sustained growth. Becker / Rauscher [2007a] analyse a growth model with a balanced growth path. Imperfect capital mobility is modelled in a way similar to this paper. They analyse a symmetric equilibrium of tax-competing jurisdictions, but without an application to public-sector modernisation. Whereas in Becker / Rauscher [2007a] public inputs are a flow variable, Futagami et al. [1993] analyse a model in which a public capital stock serves as an input in private production. Extending their analysis by a tax competition scenario and a public sector that can operate at various levels of efficiency seems to be interesting. It might be necessary to use numerical methods to tackle such a model, though.

The major lesson that can be drawn from this paper is that interjurisdictional tax competition might not be useful for the goal of an efficient public sector. Efficiency in this paper is the ability of the public sector to transform tax revenue into a transfer. A more efficient sector is one with a higher level of a accumulated knowledge or some other stock that improves the productivity of this transformation. If public-sector efficiency is plagued by egoistic politicians or lazy bureaucrats that waste resources, tax competition among jurisdictions might serve as a disciplining device. But when low efficiency is caused by underinvestment, as in this paper, competition and efficiency are no complements.

Appendix

Equation (3.17b) as a Bernouilli-Equation

A Bernoulli-Equation is a non-linear differential equation that can be reduced to a linear form. Following Chiang [1984, p. 491], assume that the equation in question is

$$\dot{y(t)} + Ry(t) = Ty^m.$$

Define $z = y^{1-m}$. The equation can then be written

$$\dot{z(t)} = (m-1)\,Ry(t) + T.$$

The general solution of this transformed equation is $z(t) = \frac{T}{R(m-1)} + e^{R(m-1)t}C_1$, where C_1 is an arbitrary constant. Substitution of z then leads to

$$y(t) = \left(\frac{T}{R} + e^{R(m-1)t}C_1\right)^{\frac{1}{1-m}}.$$

[27] A referee pointed out that there are indeed examples of taxes on foreign owned firms. For example, Argentina forced foreign firm to convert assets at the pre-devaluation rate in 2002. Since governments are sovereign these firms had difficulties in claiming their losses back even if the Argentine government broke international treaties.

Applying this formula to (3.17b) with $m = \frac{\gamma}{\gamma-1}$, $T = -(1-\gamma)\gamma^{\frac{\gamma}{1-\gamma}}$ and $R = -r$ then gives as the general solution:

$$\mu(t) = \left(\frac{1-\gamma}{r}\gamma^{\frac{\gamma}{1-\gamma}} + e^{\frac{r}{1-\gamma}t}C_1\right)^{1-\gamma}.$$

Together with the appropriate border- condition, this leads to the following equation to determine C_1:

$$\lim_{t->\infty}\left(\left(\frac{1-\gamma}{r}\gamma^{\frac{\gamma}{1-\gamma}} + e^{\frac{r}{1-\gamma}t}C_1\right)^{\frac{1}{1-m}}\right)H(t) = 0$$

because of $\frac{r}{1-\gamma} > 0$, C_1 is equal to 0 and (3.18) follows.

Calculation of the tax rate

Start with equation (3.15c):

$$\frac{d}{d\tau}\int_0^\infty w(t)e^{-rt}dt = -\frac{d}{d\tau}\int_0^\infty \Big(R(t)^\gamma H(t)^{1-\gamma} + \mu(t)\left(\tau k(t) - R(t)\right)\Big)e^{-rt}dt$$

The wage rate $w(t)$ depends on the current capital stock $k(t)$ but not on the tax rate τ directly. The impact of taxation on the wage rate therefore is

$$\frac{dw(t)}{d\tau} = \frac{dw(t)}{dk(t)}\frac{dk(t)}{d\tau} = -f''(k_{SS})k_{SS}\frac{dk(t)}{d\tau} = -k_{SS}\left(1 - e^{\rho_2 t}\right).$$

The LHS of (3.15c) then can be written

$$-k_{SS}\int_0^\infty \left(1 - e^{\rho_2 t}\right)e^{-rt}dt = -k_{SS}\int_0^\infty e^{-rt}dt - k_{SS}\int_0^\infty -e^{(\rho_2 - r)t}dt.$$

Calculation of these integrals[28] then gives for the LHS of (3.15c):

$$-k_{SS}\left(\frac{1}{r} - \frac{1}{(r-\rho_2)}\right)\Big) = \frac{k_{SS}\rho_2}{r(r-\rho_2)}.$$

Substitution of (3.16), (3.18) and rearranging then gives

$$\begin{aligned}\frac{k_{SS}\rho_2}{r(r-\rho_2)} &= -\frac{d}{d\tau}\int_0^\infty \left(\gamma r\left(\frac{1-\gamma}{r\gamma}\right)^{1-\gamma}H(t) + \gamma\left(\frac{1-\gamma}{r\gamma}\right)^{1-\gamma}\tau k(t)\right)e^{-rt}dt \\ &= -\gamma\left(\frac{1-\gamma}{r\gamma}\right)^{1-\gamma}\int_0^\infty \left(r\frac{dH(t)}{d\tau} + \frac{d\left(\tau k(t)\right)}{d\tau}\right)e^{-rt}dt\end{aligned}$$

Note first that

$$\int_0^\infty r\frac{dH(t)}{d\tau}e^{-rt} = \frac{1-\gamma}{r\gamma}\left(\frac{\tau}{f''(k_{SS})} + k_{SS}\right)\frac{-\rho_3}{r-\rho_3}.$$

Furthermore,

$$\frac{d(\tau k(t))}{d\tau} = \tau\frac{dk(t)}{d\tau} + k_{SS}.$$

This allows to calculate that

$$\int_0^\infty \left(\left(\tau\frac{dk(t)}{d\tau} + k_{SS}\right)\right)e^{-rt}dt =$$

[28] Note that $\int_0^\infty e^{-xt}dt, x > 0 \leftrightarrow \frac{1}{-x}e^{-xt}\Big]_0^\infty = 0 - \frac{1}{-x}e^0 = \frac{1}{x}$.

$$\left(\frac{k_{SS}}{r} + \frac{\tau}{f''(k_S)} \frac{-\rho_2}{r(r-\rho_2)}\right).$$

Collecting terms, the following remains. It needs to be solved for τ:

$$\frac{\rho_2 k_{SS}}{r\,(r-\rho_2)} =$$
$$-\gamma \left(\frac{1-\gamma}{r\gamma}\right)^{1-\gamma} \left(\frac{1-\gamma}{r\gamma} \left(\frac{\tau}{f''(k_{SS})} + k_{SS}\right) \frac{-\rho_3}{r-\rho_3} + \frac{k_{SS}}{r} + \frac{\tau}{f''(k_S)} \frac{-\rho_2}{r(r-\rho_2)}\right)$$

This results in:

$$\tau = \frac{k_{SS}\, f''(k_{SS}) \left(\rho_2 r \left(-\frac{-1+\gamma}{r\gamma}\right)^{\gamma} + 2\,r - 3\,r\gamma - 2\,\rho_2 + 3\,\gamma\,\rho_2 + \gamma^2 r - \gamma^2 \rho_2\right)}{(r - 2\,\rho_2 - r\gamma + \gamma\,\rho_2)\,(-1+\gamma)}$$

With $\left(-\frac{-1+\gamma}{r\gamma}\right)^{\gamma} = \left(\frac{1-\gamma}{r\gamma}\right)^{\gamma} = (-\rho_3)^{-\gamma}$:

$$\tau = \frac{\overbrace{k_{SS}\, f''(k_{SS})}^{<0} \left(\overbrace{\rho_2 r(-\rho_3)^{-\gamma} + 2\,r - 3\,r\gamma - 2\,\rho_2 + 3\,\gamma\,\rho_2 + \gamma^2 r - \gamma^2 \rho_2}^{???}\right)}{\underbrace{(\rho_2(2-\gamma) - r(1-\gamma))\,(1-\gamma)}_{<0}}$$

From this, the optimal tax rate (3.25) follows as

$$\tau = \frac{k_{SS}\, f''(k_{SS})\ (\rho_2 r(-\rho_3)^{-\gamma} + (2-\gamma(3-\gamma))\,(r-\rho_2))}{(\rho_2(2-\gamma) - r(1-\gamma))\,(1-\gamma)}\ .$$

Condition for τ being positive

The condition for τ being positive is:

$$\rho_2 r \left(\frac{1-\gamma}{r\gamma}\right)^{\gamma} + (2-\gamma(3-\gamma))\,(r-\rho_2) < 0$$

or, with assumption 2, as $(2-\gamma(3-\gamma)) > 0$ for $0 < \gamma < 1$:

$$\rho_2 < \frac{(2-\gamma(3-\gamma))\,r}{r(-\rho_3)^{-\gamma} + 2 - \gamma(3-\gamma)}\ .$$

which is always fulfilled for $0 < \gamma < 1$ and positive interest rates.

Calculation of (3.29)

This has been done with Maple 9.5 for Mac OS X:

$$\frac{d\tau}{d\rho_2} = -\left(-\gamma + r\left(-\frac{-1+\gamma}{r\gamma}\right)^{\gamma} + 2\right) r k_{SS}\, f''(k_{SS})\,(-r + 2\,\rho_2 + r\gamma - \gamma\,\rho_2)^{-2}$$

(3.29) follows after some simplifications.

Concavity check

The necessary conditions for optimal policy $\{\tau, R(t)\}$ discussed in the main text can be shown to be sufficient for an optimal policy when some concavity-conditions are met. See Takayama [1985, Theorem 8.C.5].

What needs to be checked is whether the functions $w(t) + R(t)^{\gamma} H(t)^{1-\gamma}$ and $\tau k(t) - R(t)$ are concave in $R(t)$ and $H(t)$. For the first of these, the quadratic form is

$$\begin{bmatrix} -\frac{(1-\gamma)}{\gamma} R(t)^{\gamma} H(t)^{-\gamma-1} & \gamma(1-\gamma) R(t)^{\gamma-1} H(t)^{-\gamma} \\ \gamma(1-\gamma) R(t)^{\gamma-1} H(t)^{-\gamma} & \gamma(\gamma-1) R(t)^{\gamma-2} H(t)^{1-\gamma} \end{bmatrix}.$$

For the second, the quadratic form is $\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}$, as it is independent of $H(t)$ and linear in $R(t)$. Both of them are negative-semidefinite and therefore, the sufficiency conditions are met.

Chapter 4

Fiscal competition in space and time: an endogenous-growth approach

This chapter is a slightly updated version of joint work with Michael Rauscher. Previous versions of the corresponding paper are Becker / Rauscher [2007a,b].

4.1 The issue

Fiscal federalism and competition have been important issues in public economics in the past two decades. Static models have shown that there is a tendency towards underprovision of public-sector services emerging from fiscal externalities when the tax base is mobile and the use of non-distorting taxes is restricted. See Wilson [1999] for an overview. This paper attempts to extend this literature to an economic-growth context. In particular, we attempt to answer two questions. Does increased competition for a mobile tax base lead to lower tax rates? And does it enhance economic growth?

The model we use to address these questions is an endogenous-growth version of Wildasin's (2003) steady-state gowth model. Wildasin models tax competition in space (i.e. across jurisdictions) and in time (i.e. across periods) by introducing a convex investment cost function known from the economic-growth literature, e.g. Hayashi [1982] and Blanchard / Fischer [1989, ch. 2.4], into a tax-competition model. Such an investment cost function does not only penalise the relocation of capital from one jurisdiction to another but also makes it more costly to relocate capital quickly than slowly. Thus, a jump in the capital stock as a response to a change in tax rates is not feasible. As regards economic growth, Wildasin's model is traditional in that it assumes decreasing returns to scale in the augmentable factor such that the growth path in the long run approaches a static equilibrium in which economic growth has come to an end. Although such a model provides valuable insights into the impact of tax competition on the growth dynamics along the transition path towards the equilibrium, the concept of a static long-run equilibrium is not satisfying. We extend the Wildasin's model to an endogenous-growth framework. Regarding the results of the analysis, this is not an innocent change of some minor model assumptions but it produces qualitatively different outcomes. We show that, in contrast to Wildasin, the impact of capital mobility on the tax base is ambiguous: depending on the parameters of the model, more mobility may induce higher tax rates. In addition, it is seen that tax-competition growth equilibria do not always exist, in particular if the investment cost is extremely high. Thirdly, we are able to show that, surprisingly, the tax rate may go to zero even if the mobility of the tax base is limited. Our final result is more conventional: more competition for a mobile tax base is good for economic growth.

Besides Wildasin, (2003), the literature on tax competition and growth is still small. Other papers on growth and tax competition include Lejour / Verbon [1997], Razin / Yuen [1999], Rauscher [2005], Brueckner [2006], and Hatfield [2006]. Lejour / Verbon [1997] look at a two-country model of economic growth. Besides the conventional fiscal externality leading to too-low taxes they identify a growth externality going into the opposite direction. Low taxes in one country increase the growth rate in the rest of the world. If this effect dominates the standard fiscal externality due to competition for a mobile tax base, uncoordinated taxes will be too high. This contrasts the finding of the standard static tax-competition models that taxes tend to be too low. Their result depends on the ad-hoc assumption of a taste for investing abroad on the side of investors that balances mobility costs. This preference for diversity makes sure that there is cross-border investment in their two-country model of fiscal competition. Köthenbürger / Lockwood [2007] argue that risk-diversification in the presence of technological shocks leads to similar results. Investors are diversified in their portfolio as they wish to avoid a too high variance of investment returns. Razin / Yuen [1999] look at a more general model that also includes human-capital accumulation and endogenous population growth. They come to the conclusion that optimum taxes should be residence-based, capital taxes should be abolished along a balanced growth path, and taxes will be shifted from the mobile to the immobile factor of production if the source principle is applied in a world of tax-competing jurisdictions. Their results extend those derived by Judd [1985] and are in accordance with the standard economic intuition. The underlying assumption is that the government's set of tax instruments is large enough such that distortion-free taxation becomes feasible. Rauscher [2005] uses an ad-hoc model of limited interjurisdictional capital mobility and comes to the conclusion that the effects of increased mobility are ambiguous. A central parameter in this context is the elasticity of intertemporal substitution, which does not only affect the magnitude of the economic growth rate, but also the signs of the comparative static effects. Similar results will be derived below, albeit with a micro-founded, non ad-hoc, model of limited tax-base mobility.[1]

Closely related to our paper is Hatfield [2006]. He addresses the question whether countries that are organised as federations grow faster than centralised countries and looks at the polar cases of either perfect integration or decentralisation. The findings are that decentralised governments choose growth-maximising tax rates, but a centralised government does not. The reason is that the central government is not forced by capital tax competition to offer the most attractive investment environment in order to attract capital. Instead, it balances initial consumption and long-term growth.

The slightly broader issue whether decentralisation – that is a prerequisite for tax competition to occur – and growth is an active are of research. Feld et al. [2008] provide an almost up-to-date review of the literature, together with a meta-analysis of the empirical results that can be found in the literature. They include heterogeneous demands for public goods that might be easier to meet in a decentralised economy, and the implications on saving,

[1] Brueckner [2006] looks at another possible link between fiscal federalism and growth, namely the idea that local governments are better able to tailor their services to the needs of local people. In his model, old and young people are segregated into different jurisdictions. With decentralisation, regionally differentiated supplies of public services are possible whereas centralisation is assumed to result in uniform provision of public goods. The incentives to save (to consume when old) are then lower with centralisation and hence decentralisation leads to higher growth rates.

capital accumulation, and growth. Second, tax competition in a decentralised economy could restrict Leviathan governments. If the behaviour of such governments is assumed to be growth-depressing, tax competition is growth-enhancing. Third, if agglomeration economies and knowledge spillovers play a significant role for growth, decentralised economies might have the advantage that they can organise themselves in a core-periphery structure known from the literature on economic geography, see Baldwin / Krugman [2004], Borck / Pfluger [2006]. And fourth, policy innovation might be easier to achieve if a country can use its decentralised structure as a "laboratory" to experiment with different policies, see Kollman et al. [2000], Strumpf [2002], Kotsogiannis / Schwager [2004]. The theoretical literature does not unambiguously predict a positive or negative relationship between decentralisation and growth. Hence, empirical studies might provide guidance which of the aforementioned channels – or others not yet identified in the theoretical literature – are the most important ones. However, as the review and the meta-regression analysis[2] contained in Feld et al. [2008] shows, the diversity of results in the theoretical literature is matched by similar diversity in the empirical literature. Overall, Feld et al. [2008] find only "mild support" for a positive link between decentralisation and growth. An interesting result that will be picked up in the conclusions is that this link seems to be different in developed and developing countries.

Unlike some of the aforementioned papers, we will not deal with the issue of centralisation versus decentralisation. We rather concentrate on the questions of whether deeper integration within a federation, modelled by declining investment costs, enhances economic growth and whether it reduces competitive tax rates. As in most other models of tax competition, we look at a federation consisting of a large number of very small jurisdictions that have no power to affect economic variables determined on the federal level. In our analysis, the only variable determined on the federal level will be the interest rate determining the remuneration of capital. Given this interest rate, governments choose their policies, consisting of a bundle of taxes and the provision of public goods. The set of policy instruments at hand is restricted insofar as capital owners cannot be taxed lump-sum. Therefore, distorting taxes become desirable. Our modifications of Wildasin's (2003) model are the following ones. To get long-term endogenous growth, we assume constant returns to scale with respect to the augmentable factor(s). The simplest way of doing this would be a simple Rebelo-type (1991) AK model. The problem with this model, however, is that factor rewards exceed output if, realistically, a second private factor, e.g. labour, is assumed to exist. We do make this assumption and in order to avoid problems with excessive factor rewards, we model technology such that the marginal productivity of private capital is diminishing. To make long-run growth possible nevertheless, we introduce a third factor of production which is augmentable and does not earn a factor income. This input is a flow of services provided by the government and financed through taxes like in Barro [1990].[3] Besides this input, the government, like in Wildasin [2003], provides a public consumption good which in our model for simplicity is assumed to be a perfect substitute for private consumption and is consumed by workers only. Two types of taxes are used: a source-based capital-income tax and a lump-sum tax on labour. The existence of the lump-sum tax results in an optimal provision of the public input. Underprovision like in Zodrow / Mieszkowski [1986] is excluded. With undistorted provision of public inputs, however, the only variable affected by the distortion arisingfrom the mobility of capital as a tax base is the public consumption good – like in Wildasin's paper.

[2] A meta-regression analysis is an empirical method that attempts to combine the results of empirical studies and to check whether they justify that some effect holds "on average". See Stanley [2001].

[3] Mainly because the public input is not modelled as a stock variable, there are no transitional dynamics for the evolution of output and physical capital. Models of public policy and growth that address the importance of modelling public capital as a stock variable include Futagami et al. [1993] and Turnovsky [1997].

Another related paper is Turnovsky [1996], who introduced convex investment costs into the Barro [1990] model. While our modelling of endogenous growth is close to Turnovsky [1996], we extend the model by considering the implications of tax competition for the choice of public policy as in Wildasin [2003] and by an endogenous determination of the equilibrium interest rate. A simplification we employ is to assume that workers do not save and that capital owners do not vote. This helps us to avoid some algebraic complications arising in other two-stages optimisation models in which less restrictive assumptions are made.[4]

The model is solved as follows. In the first step of the analysis, economic agents in the private sector maximise their utility given the interest rate and the economic policies announced by the government. In the next step, governments decide about policies taking as given the interest rate and the first-order conditions of the private sector. Finally, the interest rate itself is determined. The next section of this paper will present the assumptions of the model regarding production technology and the frictions that limit the mobility of capital. Sections 3 and 4 will look at the behaviour of the private sector and of the government, respectively. Section 5 closes the model by determining the interest rate and derives the central result by investigating the impact of capital mobility on the long-run economic-growth path. Section 6 summarises.

4.2 Definition of variables and characterisation of technology

Let us consider a federation consisting of a continuum of infinitely small identical jurisdictions, also labelled 'regions', on the unit interval. There is perfect competition in all markets and single jurisdictions do not have any market power vis-à-vis the rest of the federation. The private sector takes prices and policies announced by regional governments as given. Regional governments take variables determined on the federal level as given. As is always the case in models of tax competition, there is a distinction between ex ante objectives and ex post outcomes of actions taken to achieve the objectives. Ex ante, jurisdictions may be willing to use policy instruments to affect the allocation of mobile tax bases. Ex post, however, it turns out that all jurisdictions have acted in the same way and that the interjurisdictional allocation of the tax base is unaffected despite the efforts taken in the first place.

There are three types of agents in this model: workers, governments, and entrepreneurs, who also own the physical and financial capital in the economy. In order to save on notation, we do not distinguish between entrepreneurs and capital owners but assume that there is a homogenous group of capitalist producers.

- Workers are immobile across jurisdictions and inelastically supply one unit of labour per person in the perfectly competitive labour market of their home region at the current wage rate, which they take as exogenously given. Workers do not save and, thus, do not own physical capital or other assets.
- Governments charge taxes and provide a productive input. They are benevolent and maximise the utility of immobile residents. This includes the possibility of income redistribution.

[4] Optimising governments use the private-sector first-order conditions as constraints. This implies that second-order derivatives show up in the governments' first-order conditions. See Rauscher [2005], for an example. In models with benevolent governments and redistributive taxation, these terms cancel out if workers do not save.

- Capitalist producers own capital, hire labour, produce, save, and consume the unsaved share of their incomes. Saving yields an interest rate, which is determined on the federal capital market and which they take as exogenously given. If they want to transform their financial assets and invest in a particular jurisdiction, they face installation costs. If they want do withdraw physical capital, they have to bear de-installation costs. With these costs, federal financial assets and local physical capital are imperfectly malleable and, thus, capital is imperfectly mobile.

As all jurisdictions are identical, let us consider a representative jurisdiction. There are three factors of production: capital, labour, and a publicly provided input, denoted $K(t)$, $L(t)$, and $G(t)$, respectively, where t denotes time. For the sake of a simpler notation, the time argument will be omitted when this does not generate ambiguities. Output, $Q(t)$, is produced by means of the three factors where marginal productivities are positive and declining. Moreover, we assume that the production function, $\Phi(.,.,.)$, is linearly homogenous in (K, G) and in (K, L). An example is the Cobb-Douglas function

$$Q = \Phi(K, G, L) = K^{1-\alpha} G^{\alpha} L^{\alpha} \tag{4.1}$$

with $0 < \alpha < 1$. The size of the labour force is normalised to one. Each worker inelastically supplies one unit of labour, i.e. $L = 1$. Thus, (4.1) can be rewritten

$$Q = F(K, G) \equiv \Phi(K, G, 1) \quad , \tag{4.1a}$$

where $F(...)$ is a neoclassical constant-returns-to-scale production function measuring output per employee. A worker's income is the wage rate, $w(t)$, which is determined on the regional labour market. Moreover, let us introduce a production function in intensity terms,

$$f(g) \equiv F(1, g) \quad \text{where} \quad g \equiv G/K \quad , \tag{4.1b}$$

with $f'(g) > 0$ and $f''(g) < 0$, primes denoting derivatives of univariate functions. Regarding the marginal productivities we have

$$\begin{aligned} \Phi_K &= F_K = f - gf' \quad , & (4.2a)\\ \Phi_G &= F_G = f' \quad , & (4.2b)\\ \Phi_L &= F - KF_K = Kgf' \quad , & (4.2c) \end{aligned}$$

where subscripts denote partial derivatives and arguments of functions have been omitted for convenience.

Regarding the other two factors of production, we assume:

- Capital. $K(t)$ is the quantity of a composite capital good consisting of physical capital, human capital, and knowledge capital. Initially, each jurisdiction is endowed with $K(0) = K_0$. Capital depreciates at a constant exogenous rate m. Let $I(t)$ be the rate of gross investment as a share of the capital stock. Then capital accumulation evolves according to

$$\dot{K} = (I - m) K \quad , \tag{4.3}$$

  a dot above a variable denoting its derivative with respect to time. Capital is mobile, albeit at a finite speed. As already mentioned, there is a capital market on the federal level, yielding an interest rate $r(t)$ which is exogenous to individual capital owners and to governments of individual jurisdictions, but endogenously determined by demand and supply on the federal level. Assets and physical capital are imperfectly malleable.

Transforming financial capital into physical capital and vice versa is costly. We follow Wildasin [2003] in the specification of the installation cost function. Installation costs are defined as

$$c(I)K \text{ with } c(0) = 0 \text{ and } c''(.) > 0 .$$

The installation cost per unit depends on the rate of investment as a share of capital, i.e. on the speed of gross accumulation. This function also covers the possibility of de-installation costs for $I < 0$. For the derivation of explicit results in the forthcoming sections of the paper we assume a quadratic shape of such that

$$c(I)K = \frac{b}{2} I^2 K , \tag{4.4}$$

i.e. $c'(I) = bI$ and $c''(I) = b$, where the constant positive parameter b measures the barriers to mobility. $b = 0$ represents perfect mobility and malleability. If b goes to infinity, capital becomes absolutely immobile. For the interpretation of some of the results to be derived in the following sections, it is useful to introduce the absolute rate of investment, J. Using $I = J/K$ in equation (4.4) yields

$$c(I)K = c\left(\frac{J}{K}\right) K = \frac{b}{2} \frac{J^2}{K} . \tag{4.4'}$$

- The public-sector input. The government provides a productive input at a rate $G(t)$. This may be interpreted as physical infrastructure such as roads and ports, but also institutional infrastructure including the legal framework in which economic transactions take place. For the sake of simplicity, we treat this good as a flow variable which is provided anew in each period. Interjurisdictional spill-overs are excluded. The provision of the public input is financed by taxes. There are two types of fiscal instruments, a source tax on capital, the tax rate being θ,[5] and a redistributive lump-sum transfer going to the immobile factor of production. This transfer is special case of a publicly supplied consumption good to be consumed by workers only. We assume that the government chooses a constant tax rate and allocates a constant share of the budget, $1 - s$, to redistribution. Thus

$$G = s\theta K , \tag{4.5}$$

where $s > 0$ ($s > 1$ implies lump-sum taxation of immobile residents). The underlying assumption that the budget is balanced in each period seems to be restictive, but real-world governments are indeed subject to within-period budget constraints. A prominent example is the European Growth and Stability Pact, which restricts the policy makers' discretion to borrow. Equation (4.5) is a possibility of introducing such a restriction in a simplified way. The equation can be rewritten:

$$g = s\theta . \tag{4.5'}$$

Equation (4.5') implies that g is constant and using this in (4.2a) and (4.2b) yields:

Lemma 1 *All first derivatives of the production function F(.,.) are constant over time.*

This concludes the exposition of the model.

[5] Other papers like Judd [1985, 1999] and Lejour / Verbon [1997] introduce taxes on capital income rather than on capital itself. But as long as taxation is linear, the two instruments are equivalent.

4.3 Saving, investment and production in the private sector

As workers in this model do nothing besides inelastically supplying labour, capitalist producers drive the dynamics of the economy. They decide about consumption and about investment in either the local capital stock K or in financial assets A. These decisions depend on the tax rates and the provision of public inputs set by the local government. Other important determinants are the interest rate in the federation-wide capital market and installation (and de-installation) costs for investment in the local capital stock.

Capitalists hire labour, they save, and they invest. Moreover, unlike workers, capital owners are mobile and can choose to live where they want. If they are not satisfied with their domicile, they can vote with their feet like in Tiebout [1956] and move to another jurisdiction that offers better conditions. In contrast to the Tiebout model, mobile capitalists in our model do not demand local public goods. Thus, they are not willing to pay taxes to contribute to such goods. They will settle in the jurisdictions that tax them at the lowest rates. Real-world examples are Monaco and the Swiss cantons Zug, Schwyz, and Nidwalden, which levy very low taxes and attract millionaires from other parts of the country and from the rest of the world.[6] In a competitive world with many identical jurisdictions, there is a race to the bottom such that capitalists ultimately do not pay any taxes anywhere. Hence, capital income can only be taxed at source. The perfect mobility of capitalists has another important implication for the model. Since capitalists vote with their feet, they are not interested in participating in the political process. They do not show up at the ballot box and, thus, their interests are not taken into account by the policy maker.

The representative capitalist producer has two sources of income. On the one hand, she retains the share of output not being paid as wages to workers. On the other hand she has an interest income from her stock of saved assets, $A(t)$. There is a perfect asset market in the federation such that all assets yield the same rate of interest, $r(t)$, to their bearers. There are two possibilities to spend the income. It can be consumed or it can be saved. Moreover, savings (assets) can be transformed into physical capital, however only at a cost, the cost function being defined by (4.4). The rate of accumulation of assets is output minus the wage payments going to workers minus tax payments minus consumption minus investment into physical capital minus costs of investing into physical capital plus interest income from assets accumulated in the past. In algebraic terms:

$$\dot{A} = \Phi(K, G, L) - wL - \theta K - C - IK - c(I)K + rA \quad . \tag{4.6}$$

Since all jurisdictions are identical, there will be no lending and borrowing ex post, i.e. $A = 0$. In particular, $A(0) = 0$. Ex ante, however, capitalists consider the possibility of borrowing and lending according to (4.6). Ponzi games are excluded, i.e. the present value of assets in the long run must be non-negative

$$\lim_{t \to \infty} e^{-rt} A \geq 0 \quad .$$

A representative capitalist producer maximises the present value of her utility. Utility is derived from consumption, $C(t)$, only and is of the constant-elasticity-of-substitution type with σ being the elasticity of intertemporal substitution. The discount rate, δ, is positive and

[6] According to a report in the "Neue Zürcher Zeitung" from September 23, 2005, 13 percent of the ca. 3300 citizens of the the village of Walchwil in Zug are millionaires, and other villages in Zug, Schwyz, and Nidwalden report similar, though slightly lower, percentages.

constant and the time horizon is infinite. Thus, the individual's objective is to maximise

$$\int_0^\infty e^{-\delta t}\, u(C)\, dt \quad \text{with} \quad u(C) = \frac{C^{1-\frac{1}{\sigma}} - 1}{1 - \frac{1}{\sigma}} \ ,$$

subject to (4.3), (4.6), the initial endowments, K_0 und A_0, the tax rate θ, and the public expenditure, $G(t)$, the latter two having been announced by the government. Note that an individual capitalist-producer does not take the government's budget constraint, 4.5, into account. The decision maker's control variables are $C(t)$ and $L(t)$. The corresponding Hamiltonian is

$$H = u(C) + \lambda\,(\Phi(K,G,L) - wL - \theta K - C - IK - c(I)K - rA) + \mu\,(I - m)\,K \ ,$$

where $\lambda(t)$ and $\mu(t)$ are the shadow prices, or co-state variables, of financial and physical capital, respectively. The canonical equations are

$$\dot{\lambda} = (\delta - r)\lambda \ , \tag{4.7a}$$
$$\dot{\mu} = (\delta + m - I)\mu - (\Phi_K - \theta - I - c)\lambda \ , \tag{4.7b}$$

where subscripts denote partial derivatives and Φ_K will be replaced F_K in the remainder of the investigation. See equation (4.2a). Complementary slackness at infinity requires

$$\lim_{t\to\infty} e^{-\delta t}\lambda A = 0 \ ,$$

$$\lim_{t\to\infty} e^{-\delta t}\mu K = 0 \ ,$$

and, hats above variables denoting growth rates and using (4.2) to substitute for $\hat{K}$, these conditions imply that

$$\hat{\lambda} + \hat{A} < \delta \quad \text{for} \quad t \to \infty \ , \tag{4.8a}$$
$$\hat{\mu} + I - m < \delta \quad \text{for} \quad t \to \infty \ , \tag{4.8b}$$

First-order conditions are

$$w = \Phi_L \ , \tag{4.9a}$$
$$u' = \lambda \ , \tag{4.9b}$$

and

$$\mu = (1 + c')\lambda \ . \tag{4.9c}$$

Condition (4.8a) is a standard labour-demand equation and from (4.9b) we can derive the standard Ramsey-type growth equation with $\hat{C}$ as the growth rate of consumption

$$\hat{C} = \sigma(r - \delta) \ . \tag{4.10}$$

Equation (4.9c) states that there is a wedge between the shadow prices of financial capital on the federation level and local physical capital. Plausibly, this wedge depends on the marginal cost of installation. From (4.9c), one can derive a condition that links the rates of returns in the two markets for capital. Taking time derivatives of the shadow prices, inserting (4.7a) and (4.7b), and using (4.9c) again to eliminate λ/μ, we have

$$\dot{I} = \frac{1}{c''}\left((1 + c')r - (F_K - m - \theta - c) - (I - m)c'\right) \ . \tag{4.11}$$

The condition for a steady state, i.e. for $\dot{I} = 0$, is

$$F_K - m - \theta - c + (I - m - r)c' = r \ . \tag{4.12}$$

This is a capital-market indifference condition. On the right-hand side, the interest rate indicates the opportunity cost of investing into physical capital in terms of foregone interest. The left-hand side measures the net benefit from investing into physical capital. The first term is the gross productivity from which the rate of depreciation and the tax rate are subtracted. Without mobility cost, this would constitute the net productivity of capital after taxes. With mobility cost, however, two additional terms emerge. The first one is c. As defined in this model (see equation 4.4), mobility costs are proportional to capital. Thus, additional capital raises installation costs, the marginal effect being just c. The final term on the left-hand side may be interpreted as an intertemporal benefit from a larger capital stock. If $I > m$, the capital stock grows and this implies lower future installation costs per unit of newly installed capital, J. See equation (4.4').This intertemporal cost-saving effect of investment is counterweighted by another intertemporal effect: Investing an additional unit of capital has the opportunity cost of not earning the interest r in the future. Hence a higher interest rate r lowers the (future) benefits of investing in real capital as the raise the opportunity costs of investment.

In the derivation of the optimal rate of investment, we follow Turnovsky [1996]. Using the quadratic shape of the investment cost function, (4.4), we can rewrite (4.11) such that

$$\dot{I} = \frac{1}{2}\left(-I^2 + 2\,(r+m)\,I - \frac{2}{b}\,(F_K - m - \theta - r)\right) \ . \tag{4.11'}$$

This is a quadratic differential equation that can be represented as a hump-shaped curve in

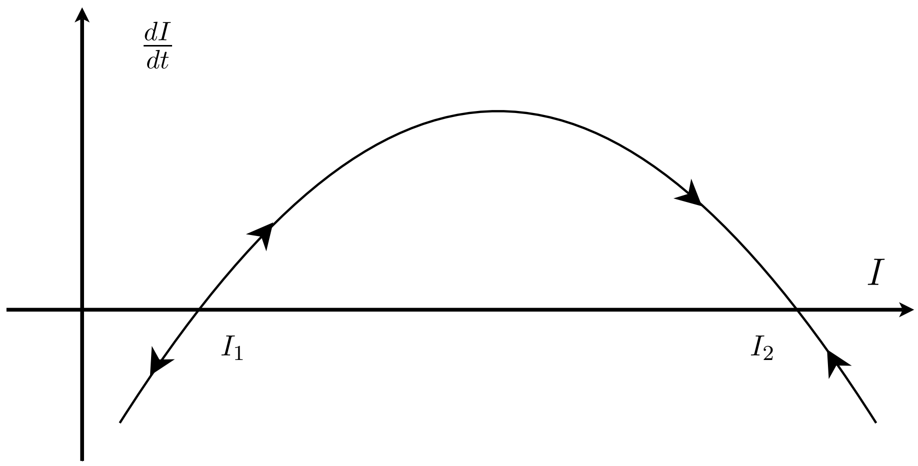


Figure 4.1: Investment dynamics

a phase diagram with a stable and an unstable equilibrium. See Figure 4.1. The condition for a steady state with $\dot{I} = 0$ is

$$I_{1,2} = r + m \pm \sqrt{(r+m)^2 - \frac{2}{b}(F_K - m - \theta - r)} \ , \tag{4.13}$$

where the smaller value, I_1, corresponds to the unstable equilibrium in Figure 4.1 and the larger one, I_2, to the stable equilibrium. An imaginary solution would imply a fluctuating path of capital accumulation. One can show that I_2 as well as an imaginary solution would violate the transversality condition.[7] Noting that I_1 is an instable solution of (4.11'), it follows that there are no transitional dynamics. This implies

Proposition 9 *The optimal rate of investment is constant along the optimal trajectory, with*

$$I_1 = r + m - \sqrt{(r+m)^2 - \frac{2}{b}(F_K - m - \theta - r)} \ . \tag{4.13'}$$

Constancy follows from Lemma 1, which states that F_K is constant over time. Condition (4.13') shows that the optimum rate of investment, as expected, is increasing in the marginal productivity of capital and decreasing in the depreciation rate, the interest rate, and the tax rate. The impact of the cost parameter b is ambiguous. It is negative if $I_1 > 0$ and positive if $I_1 < 0$. As deviations from zero in both directions are penalised by high installation and de-installation costs, this is also plausible.

Finally, to fully characterise the savings behaviour of the private sector, the initial level of consumption needs to be determined. Using (4.1a), (4.9a), (4.2c), (4.3), (4.4), and (4.10) in (4.6) yields

$$\dot{A} = \left(F_K - \theta - I_1 - \frac{2}{b}I_1^2\right) K(0)e^{(I_1 - m)t} - C(0)e^{\sigma(r-\delta)t} + rA \ .$$

In an intertemporal steady-state equilibrium with identical jurisdictions, there is no lending and borrowing, i.e. $A = 0 = \dot{A}$ for all t. This implies equal growth rates of the capital stock and of consumption,

$$I_1 - m = \sigma\,(r - \delta) \ , \tag{4.14}$$

and the starting value of C is:

$$C(0) = \left(F_K - \theta - I_1 - \frac{2}{b}I_1^2\right) K(0) \ . \tag{4.15}$$

Equation (4.14) determines, together with (4.13'), the equilibrium interest rate as an implicit function of the parameters of the model and of the tax rate. Note that the assumption of identical jurisdictions is central to determine the equilibrium in the federation-wide capital market. Identical jurisdictions imply that agents cannot differ in the sense that one agent is a borrower and another is a lender. Equation (4.15) states that consumption is positively related to initial capital endowment and capital productivity and negatively related to the tax rate, the rate of investment, and the installation cost.

Note that our characterisation of the capital market equilibrium is similar to the one implicitly found in many static models of tax competition. While the ex-ante incentives for the local governments shape the optimal tax policy, there are no cross-border movements of capital, i.e. neither lending nor borrowing. If we would analyse a small open economy, its choice of fiscal policies would not have an impact on the capital market equilibrium. In a symmetric equilibrium, however, where all countries simultaneously and identically choose its fiscal policies, the fiscal externalities of each individual jurisdiction caused by this choice sum up to a significant effect on the capital equilibrium. Hence, it is the presence of the (standard) fiscal externality in a tax competition model that is responsible for the impact of a change in capital mobility on the equilibrium interest rate, analysed later on.

[7] Note that I is constant in the steady state. Thus (4.9c) implies $\hat{\mu} = \hat{\lambda}$. Using (4.7a), we then have $\hat{\mu} = \delta - r$. Using this in (4.8b) yields the condition $I < r + m$. This is violated by by I_2 and by any imaginary solution to (4.13) because its real part would be $r + m$.

Given this characterisation of private-sector behaviour, the next step is to analyse government policies that influence private saving and investment decisions. In the next section this is done for a small open economy. Afterwards, the equilibrium in which many tax-competing governments interact will be addressed.

4.4 Government behaviour and taxation for a given rate of interest

The government maximises the welfare of immobile residents. Immobile residents are workers. Their wage rate is $gf'K$ and their transfer income $(1-s)\,\theta K$. See equations (4.9a), (4.2c), and (4.5). The government takes the interest rate as exogenously given as the jurisdiction is small. In particular, it does not consider condition (4.14), which determines the equilibrium interest rate when, ex post, all governments have chosen the same tax policies. Let us assume that workers have the same preference parameters as the capitalists. Thus, the government's objective is to maximise

$$W^L = \frac{\sigma}{\sigma-1}\int_0^\infty \left([(gf' + (1-s)\theta)K_0 e^{(I_1-m)t}]^{1-\frac{1}{\sigma}} - 1\right) e^{(-\delta t)} dt \ . \tag{4.16}$$

The condition for the objective function, (4.16), to be finite is

$$\left(1 - \frac{1}{\sigma}\right)(I_1 - m) < \delta \ , \tag{4.17}$$

and it is assumed for the remainder of the investigation that the parameters of the model are such that the condition is satisfied. Maximising (4.16) with respect to the government's policy parameters, θ and s, yields

Proposition 10 *The optimal tax-and-expenditure policy of the government for a given interest rate is characterised by*

$$f' = 1 \ , \tag{4.18}$$

$$\theta = b(r + m - I_1)\left(\delta - \left(1 - \frac{1}{\sigma}\right)(I_1 - m)\right) > 0 \ , \tag{4.19}$$

where I_1 is determined by (4.13').

Equations (4.18) and (4.19) are derived in the appendix. Equation (4.18) states that the marginal productivity of government expenditure is unity. This is a standard result in tax-competition models with lump-sum tax instruments. See, e.g., Zodrow / Mieszkowski [1986, p. 363]. The underlying intuition to explain this result in our model is the following one. In a first step, capital is taxed and the tax revenue is added to labour income. Out of this gross income, workers pay a lump-sum tax that is used to finance the publicly provided good. Thus, the cost of producing one unit of G is exactly one unit of GDP. Since $f' = \Phi_G$ is the marginal productivity of G, $f' = 1$ is nothing else but the rule that the marginal productivity of a factor should equal the marginal cost of employing it.

Equation (4.19) determines the optimum tax rate. This tax rate is positive since $(r + m - I_1) > 0$ due to Proposition 1 (see also Footnote 7) and $(\delta - (1 - \frac{1}{\sigma})(I_1 - m)) > 0$ due to assumption (4.17).[8] For $b \to \infty$, θ goes to infinity.

[8] Note that Turnovsky [1996, p. 58] derived a zero-tax rate. The difference between his and our model is the possibility of non-distorting taxation of capital owners. In Turnovsky's model of a small open economy,

4.5 Government behaviour and taxation in the equilibrium

In the equilibrium, the interest rate is determined by equation (4.14). This implies that the transversality condition, (4.17), can be rewritten such that

$$(1-\sigma)r + \sigma\delta > 0 \ . \tag{4.20}$$

This is the transversality condition known from models of economic growth in small economies, where the interest rate is exogenous. If $\sigma > 1$, the interest rate must not be too large. Otherwise, the economic growth rate would be so large that the increase in utility flows would dominate the effect of discounting.[9] If $\sigma < 1$, the interest rate must not be too negative. Otherwise, the fast rate of economic decline would make the welfare integral go to minus infinity. In order to rule out a non-converging welfare integral, we make

Assumption 3 *The parameters of the model are such that condition* (4.20) *is satisfied.*

Using (4.14) in the tax-rate formula, (4.19) and determining the interest rate via 4.13', yields

Proposition 11 *In the tax-competition equilibrium, the tax rate and the interest rate are determined by*

$$\theta = b((1-\sigma)r + \sigma\delta)^2 \ , \tag{4.21}$$

and the interest rate is determined by

$$b = \frac{2(F_K - r - m)}{((1-\sigma)r + \sigma\delta)^2 + (r+m)^2} \ . \tag{4.22}$$

Equation (4.21) follows directly from (4.19) and (4.22) is obtained by using first (4.21) in (4.13') and then (4.14) to eliminate I_1. In what follows, the right-hand side of equation (4.22) will be referred to as the $b(r)$ function. From (4.21) we have

Corollary 1 *For $b > 0$, the equilibrium tax rate is positive. It goes to zero if $b \to 0$ or if $(1-\sigma)r + \sigma\delta \to 0$.*

That perfect capital mobility leads to zero taxation, is a standard result. A perfectly mobile tax base should not be taxed. The other case is more surprising. Even if $b > 0$, i.e. if the tax base is imperfectly mobile, taxation may not be warranted. The underlying intuition is that the transversality condition, (4.20) is violated if $(1-\sigma)r + \sigma\delta$ happens to be zero. In this case, the welfare integral would go to infinity. If a tax is introduced, however small it may be, the growth rate of the economy would be reduced and the welfare integral would become finite. Thus, in this limiting case the marginal welfare cost of taxation would be infinity and the tax rate should therefore be zero. If $(1-\sigma)r + \sigma\delta$ is slightly greater that zero, the tax rate is very small. Finally, note that $s \to \infty$ if $\theta \to 0$, i.e. the government relies on lump-sum taxation of immobile residents to finance the public input if the source tax on capital goes to zero.

non-distorting taxation via consumption taxes is feasible whereas in our model capitalist producers are footloose and their incomes can only be taxed at source.

[9] This becomes more obvious if the condition is rewritten such that $1 - 1/\sigma)r < \delta$, where the left-hand term is the growth rate of utility, which must not exceed the discount rate.

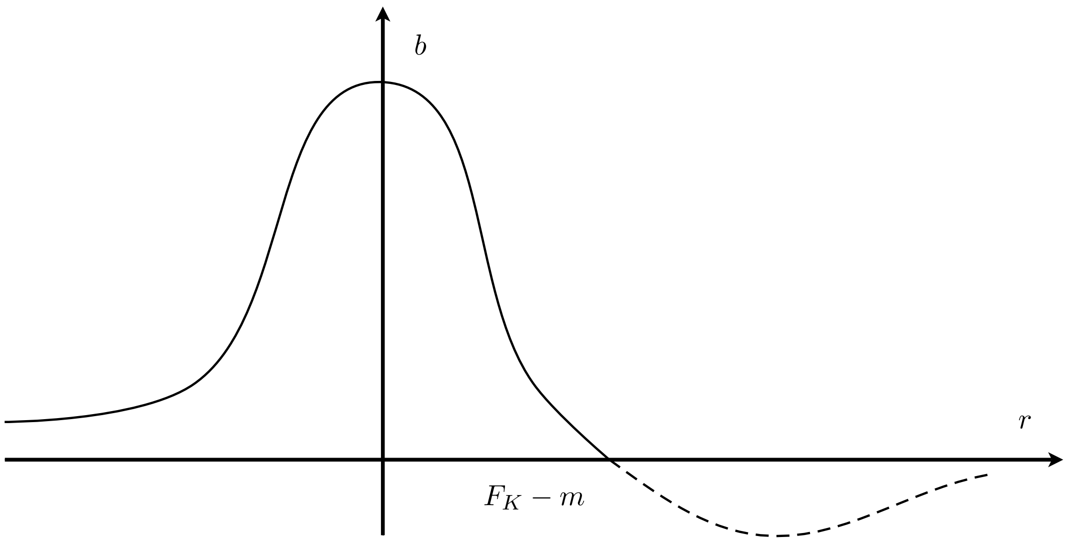


Figure 4.2: Equilibrium interest rate and capital mobility

Equation (4.22) determines the interest rate and, thus, the growth potential of the economy. The properties of the $b(r)$ function are explored in the appendix and they are depicted in Figure 4.2. The dashed part of the curve is irrelevant as b would be negative there. If $b = 0$, $r = F_K - m$, i.e. the interest rate equals the net marginal product of capital, which is a standard and straightforward result. If $b > 0$, $r < F_K - m$. The maximum of the curve is attained for

$$r^{maxb} = F_K - m - \sqrt{\frac{F_K^2 + ((1-\sigma)(F_K - m) + \sigma\delta)^2}{1 + (1-\sigma)^2}} \quad , \tag{4.23}$$

which follows from eq. (4.A7) in the appendix. For many realistic parameter constellations, (4.23) implies a negative interest rate, indicating negative growth and possibly dis-investment at the maximum feasible level of b. An interest rate exceeding the discount rate, leading to positive growth, is possible, but very unlikely. Note that

$$r^{\max b} = -m \quad \text{and} \quad b^{\max} = \infty \quad \text{for} \quad \sigma = \frac{m}{m+\delta} \quad .$$

For all other cases, the b^{max} is finite, implying that an equilibrium interest rate does not exist if b exceeds a certain threshold value. The reason is that for large values of b a small country's government would choose an extensively high tax rate. An individual government neglects the impact of its tax policy on the interest rate. If all countries do this, the asset market equilibrium collapses – unless one introduces an exogenous upper limit to taxation. Moreover, Figure 4.2 shows that for each $b > 0$, there are two values of r satisfying (4.23). However, the lower of the two values of r is irrelevant here. Assume that $b = 0$. In this case r should equal $F_K - m$ and not $-\infty$. Increasing b generates the decreasing segment of the curve. Hence, as the growth rate of the economy is determined by the interest rate via Ramsey's rule (equation (4.10), lowering capital mobility or increasing the degree of disintegration in the federation results in slower economic growth.

Before we proceed, we restrict the parameters of the model such that positive growth rates are possible:

Assumption 4 $F_K - m - \delta > 0$

F_K is determined via $f' = 1$ (equation (4.18)) and is constant. In the absence of installation costs, the growth rate would be $\sigma\,(F_K - m - \delta)$ like in Ramsey's (1928) model, the difference being that F_K does not decline along the accumulation path since we are in an endogenous-growth framework.

Given the properties of the $b(r)$ function, one can now determine the effects of changes in b on taxation. Differentiation of (4.22) yields

$$\frac{d\theta}{db} = ((1-\sigma)r + \sigma\delta)^2 + 2(1-\sigma)\,((1-\sigma)r + \sigma\delta)\left[\frac{db}{dr}\right]^{-1} , \tag{4.24}$$

where db/dr is the slope of the part of the function located to the right its maximum and it is negative. Equation (4.24) implies that the impact of b on θ is not necessarily positive. Let us distinguish the cases $\sigma > 1$ and $\sigma < 1$. In the limiting case $\sigma = 1$, matters are simple because $\theta = b\delta^2$ and the tax rate is linear in b.

Case A: $\sigma > 1$

From (4.24) it follows that the impact of b on the tax rate is positive as long as the transversality condition, (4.21), is satisfied. If $(1-\sigma)r + \sigma\delta = 0$, then $\theta = 0$ even if $b \neq 0$. Using $(1-\sigma)r + \sigma\delta = 0$ in (4.23), the corresponding value of b, b_0, turns out to be

$$b_0 = \frac{(1-\sigma)((1-\sigma)(F_K - m) + \sigma\delta)}{((1-\sigma)m + \sigma\delta)^2} , \tag{4.25}$$

which may be positive or negative depending on whether σ is larger or less than $\frac{F_K - m}{F_K - m - \delta}$, respectively. Figure 4.3 depicts $\theta(b)$ for the two cases. In the right-hand diagram, where σ is relatively small, matters are simple: the tax rate is increasing in b. If, however, σ is large the function is S shaped. As long as $b < b_0$, the transversality condition is not satisfied since the rate of economic growth is so large that the welfare integral does not converge in spite of discounting. This part of the curve is depicted as a dotted line. If $b > b_0$, the transversality condition is met and the tax rate is again monotonically increasing in b. $b = b_0$ is the limiting case referred to in Corollary 1. The tax rate goes to zero even though the tax base is imperfectly mobile.

Case B: $\sigma < 1$

From (4.24) it can be seen that the impact of b on the tax rate is ambiguous even if the transversality condition is satisfied. Like before, b_0 is given by equation (4.25). If Assumption 4 is fulfilled, $b_0 > 0$. For $\sigma \to m/(m+\delta)$, b_0 goes to infinity. In this case, using (4.23) in the tax-rate formula gives

$$\theta = \frac{2(F_K - m - r)}{1 + (1 + m/\delta)^2} \quad \text{if} \quad \sigma = \frac{m}{m+\delta} .$$

r ranges from $F_K - m$ for $b = 0$ to $-m$ for $b \to \infty$ and is monotonously decreasing in b. This implies that θ is monotonously increasing in b and goes to a value less than F_K for $b \to \infty$. Monoticity does not hold for the other cases in which σ is less or larger than this critical value. Let us distinguish these two sub-cases. The shapes of the curves are derived in the appendix and depicted in Figure 4.4.

Sub-case B1: $0 < \sigma < \frac{m}{m+\delta}$

The tax rate as a function of b is S shaped. Initially the tax rate is increasing in b . Above a certain threshold level of b , the curve bends back and the tax rate declines until it becomes

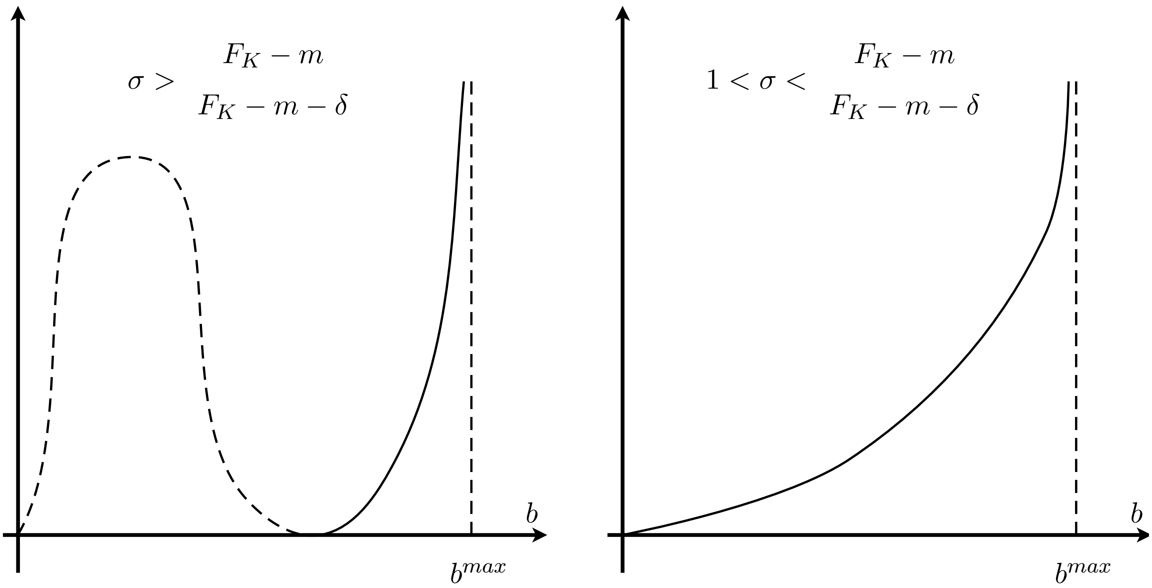


Figure 4.3: The tax rate as a function of b for $\sigma > 1$

zero at for the value of b at which the transversality condition starts to be violated. For values of b larger than b_0, the transversality condition continues to be violated until b attains its maximum level, b^{max}. Again the part, of the function along which the condition is not met, is illustrated by a dotted line. The underlying intuition for the S shape is rather straightforward. The initial increase in the tax rate is intuitive. As the tax rate increases, the interest rate declines and at eventually the growth rate becomes negative. With $\sigma < 1$, negative growth implies utility flows that are negative and become larger in absolute value. These losses in utility can be reduced by lower taxes. If, in the extreme, the transversality condition is close to be violated, an increase in the tax rate by a small amount would turn a finite negative welfare integral into an infinite one. Such taxes are avoided and this explains why the tax rate goes to zero as $(1-\sigma)r + \sigma\delta \to 0$.

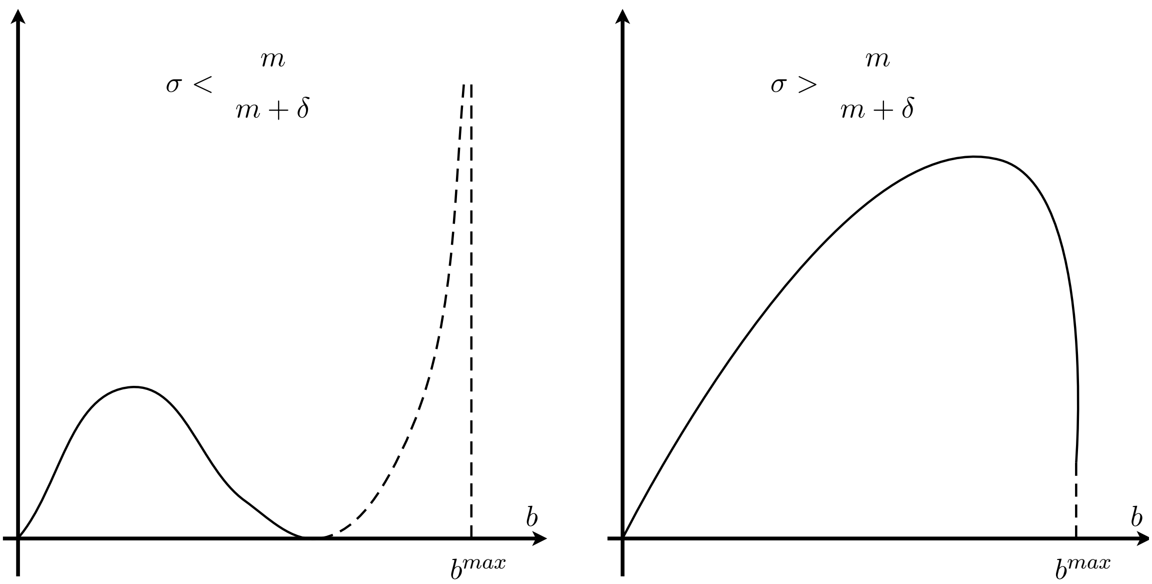


Figure 4.4: The tax rate as a function of b for $\sigma < 1$

Sub-case B2: $\frac{m}{m+\delta} < \sigma < 1$

In the appendix, it is shown that $\theta = 0$ is not possible for $b > 0$ and that the slope of the $\theta(b)$ function is positive for $b = 0$ and goes to $-\infty$ for $b \rightarrow b^{max}$. There is a segment of the curve along which the tax rate is decreasing in openness.

Summarising, we have the following results:

- If the elasticity of substitution exceeds 1, the tax rate is monotonically increasing in the cost parameter, b. For particularly large values of σ, the rate of taxation may go to zero although installation costs are still positive. The intuition behind this result is that welfare, i.e. the present value of future utility flows, is so large that small increases in the tax rate would lead to drastic welfare losses.
- If the elasticity of substitution is less than 1, the tax rate is a backward-bending function of b (with the notable exception of $\sigma = m/(m+\delta)$, where the tax rate is monotonously increasing in b. Decreasing taxes are possible for large values of b, for which the economic growth rate is likely to be negative. If $\sigma < 1$, the welfare integral is negative and with negative growth rates it becomes large in absolute value. Increases in b then lead to large welfare losses which can be offset by lower taxes. If σ is particularly small, the tax rate may even go to zero because the welfare integral goes to minus infinity at a certain threshold value of b. In this situation, small increases in the tax rate have dramatically negative consequences for welfare and the optimum tax rate, therefore, goes to zero.

4.6 Final Remarks

The paper has addressed tax competition in a general-equilibrium endogenous growth model. The starting point was Wildasin's (2003) model with quadratic installation costs. We are able to show that not all results carry over from the traditional-growth to the endogenous-growth framework. In particular, we established the following new results:

1. A tax-competition equilibrium does not always exist. If installation costs and capital depreciation are large and the rate of discount and the elasticity of intertemporal substitution are small, an equilibrium does not exist since the tax rate becomes very high and capitalists want to reduce their capital stock at a rate that is incompatible with the smooth consumption path implied by the low rate of discount and the small elasticity of intertemporal substitution. A way out of this the problem of non-existence would be the introduction of an exogenous upper limit to taxation.
2. Tax rates may go to zero even if installation costs are positive. This result is counter-intuitive at a first glance, but it can be explained by the fact that the present value of welfare may go to plus or minus infinity in an endogenous-growth framework. This implies that even small tax rates can induce dramatic welfare losses.
3. The impact of installation cost on the capital tax rate is ambiguous. Tax rates may be reduced when the mobility of the tax base is reduced. This result differs from the one derived by Wildasin [2003] for a growth model that approaches a no-growth steady state in the long run.

4. Many of the interesting results of this paper can be established only for variants of the model with an elasticity of substitution not equalling 1. This indicates that the assumption of logarithmic utility made in many papers on economic growth and taxation is by no means an innocent one. Since the empirical evidence suggests that σ is significantly smaller than one (see Hall [1988] and Guvenen [2006]), the assumption $\sigma = 1$ is hardly defendable on empirical grounds, too.

A result that is in line with what has been established by others, e.g. Hatfield [2006], is that increased factor mobility enhances economic growth. This result is challenged in the recent paper by Köthenbürger / Lockwood [2007], who, however, rely on stochastics and use a portfolio-diversification argument. In deterministic models, the general result seems to be that tax competition is pro-growth.

The elasticity of (intertemporal) substitution σ causes a lot of algebraic difficulties if it is not assumed to be equal to one. But its role in a model like the one presented above also offers a possible explanation why the link between capital mobility and growth is different in developed and developing countries. Rich and poor people seem to have different preferences for consumption smoothing, see Ogaki / Atkeson [1997]. In the light of our model, it is not surprising that countries that differ with respect to the crucial parameter σ behave differently when capital mobility changes.

A caveat we would like to mention is that our results have been derived by varying the costs of installing new or de-installing old capital. These costs definitely constitute a real-resources loss to the economy and no one should be surprised if the economy is worse off once these costs are increased. However, the economic growth rate is not affected by this resource loss. Assume that the installation cost is a pure distortion, which does not involve a direct resource loss. An example would be a payment made by an individual investor which, at the end of the day, is rebated lump-sum. The only effect this modification would have on the results of the model would be a change in the level of consumption in equation (4.15). The growth rate would remain unchanged.

As a possible agenda of future research, research could aim at looking for modifications of the model leading to a negative impact of tax competition on growth. Moreover, one could try to compare tax competition to a coordinated tax policy in the endogenous-growth framework. Given the algebraic complexities of our model, however, we conjecture that this will be possible only for specific assumptions about the parameters of the model, in particular a logarithmic utility function, which implies an elasticity of intertemporal substitution of unity.

Appendix

Derivation of (4.18)

Assuming that the integral in (4.16) is finite, the growth rate of the integrand must be negative. Then the integral can be rewritten:

$$W^L = \frac{[(gf' + (1-s)\theta)K_0]^{1-\frac{1}{\sigma}}}{(1-\frac{1}{\sigma})(\delta - (1-\frac{1}{\sigma})(I_1 - m))} - \frac{1}{\delta(1-\frac{1}{\sigma})} \quad .$$

Taking first derivatives with respect to s and θ and noting that $g = \sigma\theta$ (equation (4.5')), we have

$$\frac{[(gf' + (1-s)\theta)K_0]^{-\frac{1}{\sigma}} K_0\theta(gf'' + f' - 1)}{\delta - (1-\frac{1}{\sigma})(I_1 - m)} + \frac{[(gf' + (1-s)\theta)K_0]^{1-\frac{1}{\sigma}} \frac{\partial I_1}{\partial s}}{\left(\delta - (1-\frac{1}{\sigma})(I_1 - m)\right)^2} = 0 \quad , \tag{4.A1}$$

$$\frac{[(gf' + (1-s)\theta)K_0]^{-\frac{1}{\sigma}} K_0(s(gf'' + f' - 1) + 1)}{\delta - (1-\frac{1}{\sigma})(I_1 - m)} + \frac{[(gf' + (1-s)\theta)K_0]^{1-\frac{1}{\sigma}} \frac{\partial I_1}{\partial \theta}}{\left(\delta - (1-\frac{1}{\sigma})(I_1 - m)\right)^2} = 0 \quad . \tag{4.A2}$$

Combining (4.A1) and (4.A2) yields

$$\frac{\theta(gf'' + f' - 1)}{s(gf'' + f' - 1) + 1} = \frac{\partial I_1/\partial s}{\partial I_1/\partial \theta} \quad . \tag{4.A3}$$

To determine $\frac{\partial I_1}{\partial \theta}$ and $\frac{\partial I_1}{\partial s}$, substitute (4.2a) for F_K in (4.13') and note that $g = s\theta$ according to (4.5'). Then taking derivatives and re-substituting from (4.13') to eliminate the square-root term in the denominator yields

$$\frac{\partial I_1}{\partial s} = \frac{-\theta g f''}{b(r + m - I_1)} \tag{4.A4}$$

and

$$\frac{\partial I_1}{\partial \theta} = \frac{-sgf'' - 1}{b(r + m - I_1)} \quad . \tag{4.A5}$$

Using (4.A4) and (4.A5) in (4.A3) yields

$$\frac{\theta(gf'' + f' - 1)}{s(gf'' + f' - 1) + 1} = \frac{\theta g f''}{sgf''s + 1} \quad . \tag{4.A6}$$

Simple calculus then leads to $f' = 1$. Thus, condition (4.18) has been derived.

Derivation of (4.19)

Rearrranging terms in (4.A2) and using $f' = 1$ yields

$$(sgf'' + 1)\left(\delta - \left(1 - \frac{1}{\sigma}\right)(I_1 - m)\right) = -\left((gf' + (1-s)\theta)K_0\right)\frac{\partial I_1}{\partial \theta} \quad .$$

Use (4.A5) to subtitute for $\frac{\partial I_1}{\partial \theta}$. Noting that $sgf'' + 1$ cancels out, we have:

$$b\left(\delta - \left(1 - \frac{1}{\sigma}\right)(I_1 - m)\right) = \frac{g + (1-s)\theta}{r + m - I_1} \quad .$$

From $g = s\theta$, (4.19) then follows immediately.

Properties of (4.22)

From (4.22), we have

$$r = F_K - m \Leftrightarrow b = 0, r < F_K - m \Leftrightarrow b > 0 \ ,$$

$$r \to +\infty \Rightarrow b \to -0, r \to -\infty \Rightarrow b \to +0 \ .$$

Taking the derivative in (4.22), noting that $dI_1/dr = \sigma$ yields

$$\frac{db}{dr} = \frac{\left((1-\sigma)\, r + \sigma\delta\right)^2 + (r+m)^2 + 2\,(F_K - m - r)\,((1-\sigma)\,((1-\sigma)\, r + \sigma\delta) + r + m)}{-\frac{1}{2}\left(\left((1-\sigma)\, r + \sigma\delta\right)^2 + (r+m)^2\right)^2} \ . \tag{4.A7}$$

For $db/dr = 0$, we get a quadratic equation in r, which implies that $b(r)$ has two extrema, a maximum for $r < F_K - m$ and a minimum for $r > F_K - m$.

Properties of $\theta(b)$ **for** $\sigma < 1$ **(Case B)**

The general properties of $\theta(b)$ cannot be determined algebraically. E.g. it can be shown that $d\theta/db = 0$ is a highly complex polynomial of degree 3 which cannot be solved in general. Therefore, we restrict the investigation to particular values of b, namely 0, b_0, and b^{max}.

- Let $b = 0$. Then $\theta = 0$ and $d\theta/db > 0$.
- Let $b \to b^{max}$. If $(1-\sigma)r + \sigma\delta > 0$ (if the transversality condition is fullfilled) and $b \to b^{max}$, then $d\theta/db \to -\infty$. If $(1-\sigma)r + \sigma\delta < 0$, then $d\theta/db \to +\infty$.
- Let $b = b_0$. This is value of b for which $(1-\sigma)r + \sigma\delta = 0$. Using this in (4.A7) yields

  $$\frac{db}{dr} = \frac{-2(r+m)^2 - 4(F_K - m - r)(r+m)}{(r+m)^4} = \frac{-2(r+m)(2F_K - m - r)}{(r+m)^4} \ .$$

  Since $2F_K - m - r$ is always positive, this implies that $db/dr < 0$ if $r + m > 0$ and $db/dr > 0$ if $r + m < 0$. In the former case, we are on the decreasing segment of the $b(r)$ curve depicted in Figure 4.2, in the latter case on the increasing segment, which cannot be equilibrium. From $r + m > 0$ and $(1-\sigma)r + \sigma\delta = 0$, we have that $\sigma < m/(m+\delta)$. Thus, in order to have a zero-tax equilibrium at a positive level of installation cost, the elasticity of intertemporal substitution must be less than this critical value. For larger values of σ, such an equilibrium is not feasible.

Chapter 5

The efficiency of the public sector and the intensity of interjurisdictional competition – an empirical investigation

This chapter, or other versions of it, has not been made available to the public in written form before.

5.1 Introduction

The provision of public goods and services requires public expenditure that is, in the end, financed by tax revenue. It is hence natural that policymakers and their voters have an interest in using that money as efficient as possible. In many industrialised countries, public-sector efficiency is of high public interest as the ability and willingness to raise tax revenue is subject to constraints. Initiatives to cut public spending while maintaining the level of public goods and services that consumers and producers are used to can be found in many countries, both at the national and subnational level. Or, alternatively, there are demands that the output level is increased given the level of public expenditure. Both kinds of public-sector reform aim to increase public-sector efficiency. Accordingly, there is a need to measure, compare and explain differences in the performance and efficiency of governments internationally.

There is by now an immense number of studies in the literature that measure the efficiency of private firms like banks, insurance companies, electricity providers or farmers using non-parametric techniques to measure efficiency like data envelopment analysis (DEA). Also the efficiency of the public sector and publicly owned firms has been assessed using DEA-methods. Examples are studies about the efficiency of public transport systems, schools and universities, police forces and fire services, jails, libraries and other sub-units of the public sector. Gattoufi et al. [2004] provide a bibliography that covers the years 1951-2001. It lists over 1800 papers in the field of data envelopment analysis.[1]

[1] This bibliography is currently being updated to also cover in addition the years 2002 until 2007. Many thanks to Said Gattoufi for sharing his impressive database. It is planned for the not so far future to publish the bibliographic data on a website and to allow quick overviews of the literature according to different criteria like publication type, keywords and others.

Fewer studies attempt to evaluate the efficiency of the public sector of countries as a whole. This is of course due to enormous difficulties to define a set of indicators measuring inputs and outputs of the public sector that is treated as if it was a production unit. Regardless of all the difficulties, Afonso et al. [2005] made an attempt and evaluate the efficiency of the public sector for 23 industrialised countries.

The goal of this study is twofold: First, it tries to provide a robustness check for the results found in Afonso et al. [2005]. In order to do so, the inputs and outputs of the public sector are measured in this study in a similar way. Then efficiency measures ("scores") are calculated. I use two different samples that cover up to 74 countries and the years 1985, 1990, 1995 and 2000. Secondly, the efficiency scores are used in a regression analysis that tries to explain the pattern of public sector by the intensity of interjurisdictional competition. The idea is, as has been argued in chapter 3, that the competition between jurisdiction – in this case: countries – has an influence on the efficiency of the public sectors that uses tax revenue to provide public goods and services. In chapter 3 it has been argued that the competition for a mobile tax base can lead to less efficiency. The reason there is that the efficiency of the public sector is the result of past investment that is hurt by less tax revenue in the presence of capital mobility. But, from a theoretical point of view, it could also be the other way round: Tax competition can improve the efficiency of the public sector if inefficiencies are caused, for example, by a bureaucracy that does not act in the best interest of its citizens. Then tax competition can have a disciplining effect. Examples of the models with tax competition and "Leviathans" as governments include Edwards / Keen [1996], Rauscher [2000], Wilson [2005].[2] The theoretical literature as a whole does not come to a clear conclusion about the efficiency-consequences of tax competition or other forms of interjurisdictional competition. The results by and large depend on the a priori assumptions about the correct characterisation of the public sector, with the two extremes of assuming a benevolent vs a Leviathan government. Therefore this study tries to explore empirically the relationship between public-sector efficiency and the intensity of interjurisdictional competition.

The study is not only similar to Afonso et al. [2005], but also to other cross-country comparisons of public sector-efficiency. Using similar two-stage procedures as I do, Afonso / Aubyn [2006b, 2007] assess the efficiency of health care systems in OECD countries and find that factors like the GDP per capita or socio-economic variables like smoking habits or obesity are important factors explaining the efficiencies of health care. The same authors have also examined the efficiency of education system in the OECD, see Afonso / Aubyn [2006a], and find that the found inefficiencies are strongly related to GDP per capita and parents' educational attainment. Gupta / Verhoeven [2001] look at health care and education in Africa. Afonso et al. [2006] analyse public-sector efficiency of 24 nations from emerging markets in different regions and the European Union, including new members and future candidates. They find that public sector efficiency depends positively on the security of property rights, per capita GDP, the competence of civil servants, and the education level of people.

In terms of the sample that is considered, Angelopoulos et al. [2007] is close to this study. They consider 64 countries and four 5-year time periods 1980-2000 and calculate efficiency measures. As they are interested in the relationship of government size and growth, they incorporate these scores then in a growth regression. They present various growth regressions

[2] The Leviathan hypothesis in economics has nothing to do with notion of a Leviathan in mythology or in the bible, where it is a sea monster, identified in different passages with the whale and the crocodile (e.g., Job 41, Ps. 74:14), and with the Devil (after Isa. 27:1). The Leviathan in the economics literature has to do with the book by Thomas Hobbes, who argued that a strong government is necessary to avoid "war of all against all". In economics, a Leviathan is a government that is not legitimate and wastes resources.

that include the size of government and in addition an interaction term that involves both the size and the efficiency of the public sector. The size of government and the interaction term both have explanatory power. The authors conclusion is that “what matters to growth is not the size per se, but the size-efficiency mix” [Angelopoulos et al. 2007, p. 12].

This study is organised as follows: The next section describes the use of non-parametric methods like data envelopment analysis (DEA) for the evaluation of the efficiency of production processes. The next section explains how the input and output of the public sector is measured in this study and present the data on the performance of public sector, i.e. the output. Section 5.4 then presents the efficiency analysis that results in a set of efficiency scores in two different samples. The smaller one contains observations from 32 countries and one year and is analysed using a Free Disposable Hull (FDH) method. For the second sample (74 countries, four 4-year period 1985-2000), a data envelopment analysis (DEA) is carried out. Section 5.5 then uses the efficiency scores from the larger sample to explore the relationships between efficiency on the one hand and government size and intensity of interjurisdictional competition on the other.

5.2 A digression on non-parametric efficiency analysis

This section reviews the basic concepts of (non-parametric) efficiency analysis and provides an overview about recent research about methodological problems.

In order to measure the efficiency of a firm (or any other organization that converts inputs into outputs), it is necessary to determine a production frontier against which the efficiency of a firm can be evaluated.[3] Modern methods to measure efficiency against a “best practice frontier” can be seen as a refinement of ideas already presented in the 1950s, see Debreu [1951], Koopmans [1951], Farrell [1957]. Efficiency can be measured in output orientation (maximum attainable output given a level of inputs) or input orientation (minimum input to produce a given level of outputs).[4]

The alternative methods available for efficiency analysis of production processes differ in the way the efficiency frontier is inferred from data about inputs and outputs of a sample of firms. A major distinction is the one between parametric and non-parametric methods.[5]

Parametric efficiency analysis involves the econometric estimation of parametric functions. Whereas the estimation of a production function usually assumes a symmetric error term representing statistical noise, the idea of stochastic frontier analysis is to assume that the error term contains a one-sided component that is due to inefficiency.[6] The advantage of a frontier analysis is that it accounts for measurement errors and other reasons why an observed production process deviates from the production frontier. Furthermore, conventional

[3] This section draws on Coelli et al. [2005], a textbook on efficiency and productivity analysis. Where necessary, more specific references are given in the text.

[4] An alternative to input- or output oriented measurement is to measure efficiency “non-oriented”. This concept deals with possible reductions of inputs and possible expansion of output of inefficient production units at the same time, see Färe et al. [1985, 1994]. It is less popular than input- or output oriented models as it requires the solution of a non-linear program, see Johnson / Mcginnis [2006] and references therein.

[5] Note that the aim of this study is to evaluate the efficiency (or inefficiency) of the public sector. Hence it would be of no use to estimate production functions with the underlying assumption that all firms are efficient and deviations from the production function are due to random noise. For a clarification of concepts and terms, see the box on page 70.

[6] I keep the discussion of stochastic frontier analysis relatively short, as I do not use it. See Coelli et al. [2005, ch. 9, 10] for an introduction, and Kumbhakar / Lovell [2000].

statistical tests can be applied. But this advantage is limited since one has to specify the functional form of the production function and make an assumption about the distribution of the two-component error term. From a practical point of view, stochastic frontier analysis is relatively easy to accomplish once the necessary data is available. It is implemented in specialized packages like `FRONTIER` [Coelli 1996]. In `Stata`, `frontier` and `xtfrontier` (for panel data) are well established commands.

Non-parametric efficiency analysis does not require assumptions about the functional form of the production function. The idea is to calculate the production frontier as the envelope of the observed data using linear programming. Consider a data set of an input, x, and an output, y, for five firms as in Figure 5.1 where the triangles represent the observed data.

The production set consists of the set

$$\Psi = \{(x, y) \in \mathbb{R}^p_+ \times \mathbb{R}^q_+ | x \text{ can produce } y\}$$

with x,y representing vectors and p (q) being the number of inputs (outputs).[7] A standard assumption is free disposability. That means that for a given $(x, y) \in \Psi$, all (x', y') with $x' \geqslant x$ and $y' \leqslant y$ belong to the production set, where the inequalities between vectors are understood componentwise. If y consist of only one element, Ψ can also be characterised by a function $y = g(x)$ that is called the frontier function or production function. Free disposability implies that $g(x)$ is monotonously nondecreasing in inputs x. Figure 5.1 is a one-input-one-output example ($p = q = 1$). The functions represented by the solid, dashed and dotted lines are all examples of possible production frontiers.

Point A in Figure 5.1 represents an inefficient firm both in input orientation (it would be possible to produce the same level of outputs with less inputs) and output orientation (it would be possible to produce more of y given inputs), regardless of which production frontiers is used.

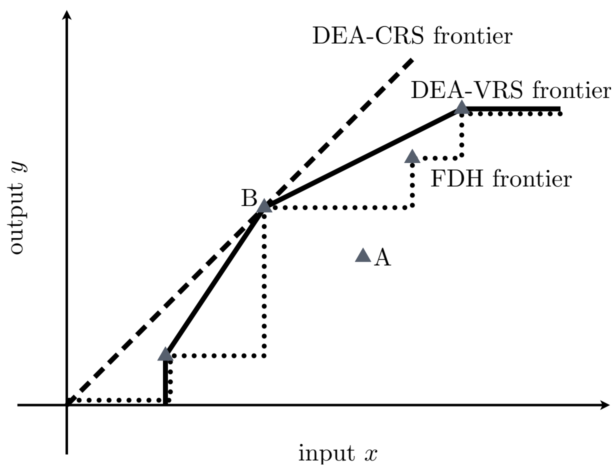


Figure 5.1: DEA and FDH production frontiers

The degree of inefficiency, i.e. the distance to the production frontier, depends on the production frontier that is used for the evaluation and on the orientation chosen, as long as constant returns to scale are not assumed.[8] As can be seen in Figure 5.1, returns to scale are an important property of the production set when it is used to determine the degree of efficiency. If the production set has constant returns to scale (CRS), only point B is on the efficiency border as the production function is a straight line. With variable returns to scale (VRS), the efficiency frontier envelops the data more tightly and more observations are on the efficiency frontier. Other possible assumptions are non-increasing returns to scale (NIRS) or non-decreasing returns to scale (NDRS).

Non-parametric efficiency analysis can being done either as DEA (Data Envelopment Analysis) or using the method of a FDH (Free Disposable Hull). DEA assumes convexity

[7] The notation and exposition follows Cízek et al. [2005, ch. 12].
[8] Cízek et al. [2005, sec. 12.1] define the distance of a point x, y relative to input and output isoquants. I skip this definition, as it is not essential for the understanding.

of the production set (a quasi-concave production function) and free disposability. DEA-methods can be further categorized with respect to to the assumption about returns to scale. The seminal paper is Charnes et al. [1978]. FDH assumes free disposability but a convex production set and has been suggested first by Deprins et al. [1984]. In terms of Figure 5.1, FDH means that the production frontier is defined as step function.

The aim of both DEA and FDH-analysis is to calculate so called efficiency scores (or efficiency degrees). The calculation is based on distance functions but can also stated as the solution to an linear programme. Consider a sample of three firms and a production process with one input, x, and one output y. Y is the 1×3 vector of observed outputs, X is the 1×3 vector of observed inputs. Then the calculation of an DEA efficiency score in input orientation, for firm k, with the assumption of constant returns to scale (DEA-CRS), means to solve a linear programme that can be stated as follows:

$$\min_{\{\theta_k,\lambda_1^k,\lambda_2^k,\lambda_3^k\}} \theta_k \qquad \text{subject to} \tag{5.1a}$$

$$\theta_k x_k - \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} \begin{pmatrix} \lambda_1^k & \lambda_2^k & \lambda_3^k \end{pmatrix} \geqslant 0 \tag{5.1b}$$

$$-y_k + \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} \begin{pmatrix} \lambda_1^k & \lambda_2^k & \lambda_3^k \end{pmatrix} \geqslant 0 \tag{5.1c}$$

$$\theta_k, \lambda_1^k, \lambda_2^k, \lambda_3^k \geqslant 0 \ , \tag{5.1d}$$

where k is index for the firm under consideration, θ_k is the input orientated efficiency score for firm k, $\lambda_1^k, \lambda_2^k, \lambda_3^k$ are weights.[9] Choosing weights in this linear program can be see as constructing a "hypothetical firm" that serves as the benchmark for firm k and produces on the production frontier. The condition in (5.1c) constraints the output of this hypothetical firm to be greater or equal to the output of firm k. Condition (5.1b) then states input of firm k, multiplied with the score θ_k, is smaller or equal to the input of the hypothetical firm. Condition (5.1d) contains non-negativity constraints. The program (5.1) needs to be solved for each firm k separately.

As shown, for example, in Tulkens [1993, pp. 187-190] other variants of DEA or FDH efficiency scores are similar linear programs. Accounting for additional restrictions on the production function means to add constraints on the weights λ. The linear program to calculate efficiency scores based on the FDH-step-function is derived by adding the constraints $\lambda_1^k + \lambda_2^k + \lambda_3^k = 1$ and $\lambda_1^k, \lambda_2^k, \lambda_3^k \in \{0, 1\}$, for example.

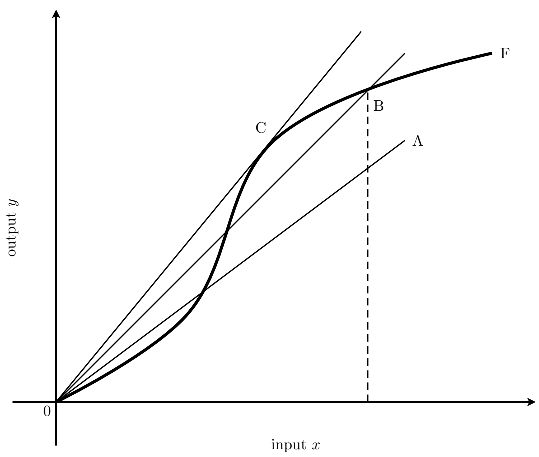
DEA- and FDH efficiency scores are bounded to be not greater than unity by construction. Their statistical properties (they are estimates of the production frontier) are an active area of research. It is an open question whether the numbers calculated can be seen as an accurate estimation of 'true" inefficiency. Grosskopf [1996] is an early survey, that focuses on the relevance statistical inference of DEA/FDH-methods for applied research.[10] Cherchye / Post

[9] The problem can easily extended to the case of more inputs and more outputs and a larger sample. The calculation of output orientated efficiency scores follows the same idea. See Coelli et al. [2005, p. 163] or any textbook on DEA analysis.

[10] Seiford [1996] describes the evolution of DEA-refinements since Charnes et al. [1978].
An issue that received a lot of attention in the literature but is not covered in this section is that of slacks. An input or output slack occurs in a DEA analysis because of the piecewise linearity of the efficiency frontier. Consider a production unit that has been identified as being inefficient. This inefficiency in input-orientation is then measured in comparison to the (piecewise-linear) efficiency frontier. It may happen that the implied

Definitions of a few key concepts in productivity and efficiency analysis

This box provides definitions of some concepts recurrently used in the analysis of efficiency and productivity of productions processes. This analysis is usually applied to private firms which convert inputs into outputs. But in principle, efficiency and productivity analysis can be applied to all organisations that use inputs in order to produce outputs.



Productivity is the ratio of outputs over inputs: $\frac{\text{outputs}}{\text{inputs}}$ or $\frac{y}{x}$. In the figure, the slope of the solid straight lines measure the productivity of the input-output combinations A, B and C. When there is more than a single input and/or a single output, it is necessary to aggregate inputs and/or outputs into an index in order to calculate the productivity ratio.

Total factor productivity is a measure of productivity that includes all factors of production (labour, capital, land,...). An example of *partial factor productivity* is, for example, labour productivity.

The *production frontier* is the maximum output attainable for a given given input. In the Figure, this is the solid line 0F that reflects the current state of technology of using input x to produce output y.

A firm that produces *technically efficiently* produces an output that is on the production frontier (points C and B in the Figure). A firm that is producing beneath the production frontier (like the one marked with point A), is producing inefficiently. Note that the productivities of firms C and B are different.

The *feasible production set* in the Figure consist of all combinations of x and y on and below the line 0F. An implicit assumption is that inputs and outputs are infinitely divisible.

A question that is separate from that of being efficient is whether a firm produces at its *optimal scale*. Obviously, whether there are economies of scale a firm can possibly exploit by choosing its optimal size depends on the underlying production technology. If the underlying technology is one that exhibits constant returns to scale, there is no optimal firm size and improvements of productivity can never be the result of choosing an optimal scale of production.

Technical change means a change in the state of the technology (over time), i.e. a shift of the production function 0F in the Figure.

The *possible sources of improvements in productivity* of a firm can be: a) higher efficiency by moving closer to the production frontier b) exploitation of scale economies (movement along the efficiency frontier) and c) technical change that improves the output for any given input (movement of the frontier).

Note that a profit-maximising firm that can employ several inputs to produce one (or more) outputs needs to solve the problem of an optimal input-mix. (And, additionally, that of an optimal output-mix, when there is more than one output.) This gives rise to the concept of *allocative efficiency*.

Based on Coelli et al. [2005, ch. 1]

[2003] discuss newer results in the literature. The discussion in the literature has several persistent topics:

noisy data, outliers The fact that DEA/FDH approaches are non-parametric means that all observed data points are considered to belong to the feasible production set. The frontier is a hull around the observed data, including possible outliers. Hence, it might be necessary to adjust DEA/FDH-estimates of efficiency frontiers for measurement error and other sources of randomness. For the detection of outliers, Wilson [1993] has suggested a detection method that is not based on OLS-residuals. Simar [2007] dicusses the problems of several ideas in the literature to account for noisy data and outliers. He also proposes a "stochastic DEA/FDH approach" that performs well both in simulated examples and with real data.

bias The DEA (and also FDH) estimator of the production frontier is "obviously biased" Gijbels et al. [1999, p. 221]". Consider the estimation of a production frontier, for example DEA-VRS in Figure 5.1. Add another observation that is above the estimated frontier. In a sample that includes this additional observation, the frontier needed to be adjusted upwards. Note that this problem is different from that of noisy data. It occurs even if the data on inputs and outputs could be considered to be without measurement or specification error. It is less severe the larger the sample is compared to the population. Coelli et al. [2005, p. 202] rightly stress that in the presence of statistical noise an additional bias with an undetermined direction is introduced that cannot be dealt with by bootstrapping-methods.

convergence / curse of dimensionality A very general property of an estimator is its consistency. It has been shown that both DEA and FDH-estimates of the efficiency border are consistent. But the rate of convergence can be small, where the rate of convergence depends negatively on the number of inputs and outputs used, see Banker [1993], Park et al. [2000], Kneip et al. [1998]. Especially for the FDH-method, the distribution of the estimates is known and hence in principle it is possible to infer from estimated efficiency scores to their true value and a confidence band. References can be found, for example, in Simar / Wilson [2000b]. But this knowledge about the distribution is limited to asymptotic properties. Most studies that can be found in the literature must be considered to deal with datasets of small sample size. The increasing number of published research on the statistical properties of DEA/FDH estimates in small samples is therefore highly relevant for applied research.

bias correction / bootstrapping One way to correct the bias in a small sample used for DEA/FDH estimation is to apply bootstrap procedures. [Simar / Wilson 2000b, p. 57] argue that this is the preferred method to correct the bias and calculate confidence intervals. The alternative would be to estimate the parameters of the distribution of FDH/DEA scores. This is problematic as additional noise is introduced. In the case of DEA, the asymptotic results are limited to the one-input one-output case. The procedures suggested in Simar / Wilson [1998, 2000a], Kneip et al. [2003] are implemented in the FEAR package [Wilson 2007, 2008a,b]. Unfortunately, the implementation is limited to the DEA-method. Moreover, in a recent paper co-authored by the same authors, a new bootstrapping procedure is suggested for the case of a

possibility of input reduction is understated, see Coelli et al. [2005, p. 164] for an illustration. However, the problem is solely due to the non-smoothness of the estimated efficiency frontier. The larger the sample used in a DEA analysis is, the better is the approximation of a smooth production surface by the piecewise-linear DEA-frontier and the less severe the issue of slacks. Coelli et al. [2005, p. 199] therefore consider the problem of slacks to be exaggerated. See also Ferrier / Lovell [1990].

DEA estimation under the assumption of variable returns to scale, see Kneip et al. [forthcoming]. It is based on new results about the distribution of the estimator in the case of an arbitrary number of inputs and outputs. This procedure has to my knowledge not yet been implemented in a software package. Overall, bootstrapping might be an alternative to methods based on estimation, especially in small samples. But to date, a common sense about a proper bootstrapping method to be applied in the various applications of DEA/FDH does not exist in the literature, especially as the literature about bootstrapping DEA/FDH-estimates is dominated by only two researchers. So far, also in terms of availability in software packages, bootstrapping is possible in the case of DEA with variable returns to scale. This is a possible cure for the bias caused by sampling variability. For FDH-analysis, Jeong / Simar [2006] suggest not to use bootstrapping for the bias correction, but a "smoothed" version of the FDH-estimator they claim to be unbiased. However, the problem that the DEA estimates suffer from statistical noise in the input- and output-data remains.

2-stage procedures, environmental variables A possibility to account for noise would be to use the efficiency scores as dependent variables in a regression that then allows naturally for an error term. Such a 2-stage procedure is an attempt not only to calculate efficiency score but furthermore to explain them, where statistical noise is one possible explanation.

In the DEA/FDH-literature, two-stage methods have been used to examine the impact of "environmental variables" on the performance of firms. For example, the production of vegetables depends on the general climate conditions. A general problem is whether the explanatory variables in the second-stage should be included in the DEA analysis in the first stage or not. An ad-hoc solution is to include in the first stage the variables that are "traditional inputs"under the control of the management of the firm. The variables that describe (relevant) characteristics of the environment a firm operates in are included in the second-stage, see [Coelli et al. 2005, p.194][11]. For the case in which the 2-stage procedure is meant to account for statistical noise of the input-output data, in addition to environmental (or "contextual") variables, the error term demands a certain specification known from the parametric estimation of production frontiers. Banker / Natarajan [2008] specify the error term "*as consisting of three distinct components: a linear function of multiple, possibly correlated, contextual variables; a one-sided inefficiency term; and a two-sided random noise term bounded above*" (p. 49). They also show that the resulting estimate is consistent. Note that the problem arising from a small bias is not addressed by this procedure. As efficiency scores are truncated, a truncated regression rather than an OLS procedure might be necessary.

There are many studies that use Tobit regressions to account for the upper bound of the efficiency scores. But the Tobit model, also known as "censored normal regression", is applicable only in situations where in principle, observations of the dependent variable are normally distributed, but observation beyond a limit value are not observed, for example because they are censored. In a Tobit model, there are observations where the value of the dependent variable is unknown (censored) but the corresponding value of the independent variable is available. A truncated regression should be used if both dependent and independent variables are missing from the data if they meet a certain criteria. In the case of DEA/FDH estimates, efficiency scores are truncated by construction, not because of censoring. Both observations for dependent and

[11] Introducing environmental variables could also be seen as relaxing the implicit assumption that firm share a common technology [Simar / Zelenyuk 2007].

independent variables are available. Hence the truncated regression model, not the Tobit model, correctly accounts for the upper bound of DEA/FDH estimates. See, for example Maddala [1992, ch. 8]. See also the appendix of Simar / Wilson [2007, pp. 58-59] for a discussion about the choice between Tobit and truncated regression in the context of DEA analysis and why truncated regressions are to be preferred over Tobit. An alternative would be to use log-transformed efficiency scores in the second-stage, see for example Banker / Johnston [1995], Puig-Junoy [1998].

Simar / Wilson [2007] criticise two-stage FDH/DEA-methods as being improper: "*A [...] serious problem in all of the two-stage studies that we have found arises from the fact that DEA efficiency estimates are serially correlated. Consequently, standard approaches to inference – used in all but two of the studies we have seen that employ the two-stage approach – are invalid.*" The serial correlation is related to the small-sample bias already discussed. Changing the position relative to the efficiency frontier of one observation is likely to have an influence on the estimated efficiency of other observations. Not surprisingly, Simar / Wilson [2007] propose a bootstrap method that has been used in Afonso / Aubyn [2006a,b].

inefficiency and perfect competition DEA/FDH methods aim to describe the inefficiency of some firms relative to an efficiency frontier. This means that markets somehow are not competitive as inefficient producers would be sorted out otherwise.[12] The deviations from optimal production are an interesting information by itself. Varian [1990] suggests to use those deviations as a measure for the goodness-of-fit. They can also be used to think about the reasons (market-failures) that allow inefficient firms to survive, an idea already contained in Farrell [1957].

Summing up, DEA/FDH-tools for productivity and efficiency analysis have been widely used for a long time. But only recently have the statistical foundations been subject to closer inspection. There is no free lunch. The advantage of DEA/FDH-methods being non-parametric comes at the cost that it is much more difficult to understand the statistical properties of estimates of the production frontier and individual scores of (in)efficiency. A DEA/FDH estimator that accounts for noise and is unbiased and allows to calculate confidence bands even in small samples is not (yet) available. For applied research this means the usual caveat applies that results based on DEA/FDH should be interpreted with caution.[13]

Another point is that recent techniques are not well implemented in standard Software packages. There is a wide variety of specialized tools for DEA- and, to a lesser extent, FDH-analysis. See Barr [2004] for a comparison. The tool chosen for this study is `FEAR` provided at no cost by Paul Wilson (2007, 2008a, 2008b) as it is well documented and implements some of the bootstrap methodologies mentioned above.[14]

In this study, both FDH- and DEA-methods are used. The next section presents the data that is used to measure inputs and outputs. Then an FDH-analysis of a sample of 32 countries will be presented and the results compared to those of Afonso et al. [2005]. DEA-methods,

[12] A possible explanation for inefficient firms to survive can be found in a model with heterogeneous firms, differentiated products and trade. See Melitz [2003] for a very influential model in which the exposure to trade is a key determinant for driving inefficient firms out of the market.

[13] There are also attempts to develop alternative nonparametric estimators of production frontiers. See, for example, Cazals et al. [2002], Martins-Filho / Yao [2007].

[14] `FEAR` is distributed as an package for `R`, an open-source statistical program that is widely used [R Development Core Team 2008]. However, the source code of `FEAR` is not open and it is not possible to adjust `FEAR` according to individual needs. Note that is straightforward to write a package for Stata that allows to calculate DEA/FDH-scores and efficiency frontiers. See Baum [2008, pp. 52-54].

including bootstrapping, are used in a larger sample of 74 countries and a time span of 15 years (1985, 1990, 1995, 2000) where sufficient data about inputs and outputs could be collected. In a last step, the DEA-scores of efficiency are used as the dependent variable in a regression that aims to explore the pattern of public-sector efficiency across the 74 countries in the sample.

5.3 Measuring output and input of public-sector production

Efficiency analysis of any production process is based on the measurement of inputs and outputs. In case of a firm that hires workers and rents capital and other inputs and sells its products in product markets, it is, in principle, possible to observe prices and quantities of inputs and outputs or cost and revenue. For the public sector, it is not straightforward to define what the output of the production process is. Furthermore it is difficult to measure prices and quantities, especially on the output side.

The three major problems of input and output measurement in the public sector are: prices, quantities, quality. The public sector typically provides non-market goods and services, hence prices are usually not observed. As far as information about prices is available, these prices are not the result of demand and supply on competitive markets but set by the public sector. Quantities are easier to observe, but data like the number of lectures given at universities is usually not available, in particular not for cross-country studies that include non-OECD countries. Furthermore, information about the quality of public services can usually be found in case studies of very specific sub-units of the public sector for only a few countries.[15] Given these difficulties especially on the output side, one has been willing to accept very crude measures of public sector production.

In this study, the public sector of a country is understood as a production unit that aims to provide good policy outcomes in several policy fields using tax revenue as an input. The performance of public policy is measured by variables that reflect whether a country's public sector is successful, for example, in providing health care. The measured success is then interpreted as an output measure. The inputs will be measured by public expenditure.

[15] Several statistical offices, responsible for the national accounts, explored whether quality-adjusted output measurement could be routinely done at least for some public sector activities like education. In Germany, the Federal Statistical Office (Statistisches Bundesamt) seems to be sceptical, see Mayer [2001] and Statistisches Bundesamt [2003]. For the revisions in the United Kingdom in the aftermath of the Atkinson Review [Atkinson 2005] , see UK Centre for the Measurement of Government Activity, Office for National Statistics [2005].
On the other hand, there are a number of projects in several countries and within the World Bank. A relatively recent development in this respects is the Worldwide Governance Indicators (WGI) project, see Kaufmann et al. [2008]. In version VII, the governance indicators cover a wide range of countries and the period 1996-1997, see their website www.govindicators.org for recent developments in this project.
Within the World Bank System, another rating is the Country Policy and Institutional Assessment (CPIA). It evaluates the quality of a country's policies and institutional arrangements in four clusters (economic management, structural policies, policies for social inclusion and equity and public sector management and institutions). They are prepared since the 1970s, but the first year for which the numbers are published is 2005. Furthermore, it does not cover developed countries in the world and the variation in the data is not very strong. They are used internally to allocate IDA-resources among eligible countries. Hence, it is likely that the numbers are not immune against the influence of lobbying and political negotiations. The IDA (International Development Association) is one of the lending channels of the World Bank, tailored to the poorest countries in the world.

5.3.1 Output measurement: public-sector performance

The five policy fields and the variables that measure how good a public sector performs (how much output it produces) considered in this study are listed below. Summary statistics and data sources can be found in the appendix. The internal names of variables are those that are typeset in a typewriter font.

administrative quality How good is the quality of the administration? I measure this aspect of public policy by several indices contained in the *Economic Freedom of the World* published by the Fraser Institute [Gwartney / Lawson 2007]. The variables used are: *Structure and security of property rights* (`efw_area2`), *Access to sound money* (`efw_area3`), *Regulation of credit, labor, and business* (`efw_area5`).

education The ability of the public sector to provide education is measured by its success to provide at least elementary education for every citizen (*percentage of no schooling in the total population, adults of age 25 or older*, `balee_lu`) and higher education for as many people as possible (*percentage of secondary school complete in the total population, adults of age 15 or older*, `balee_lsc15`). The data is taken from Barro / Lee [2001].

health care The output of the health care system is measured by *life expectancy at birth* (`life_exp`).

infrastructure One of the major activities of the public sector is to provide infrastructure. The variables used in this study to measure infrastructure are *Air transport, registered carrier departures world-wide* (`airtrans_rcdw_rel`) and *Telephone mainlines* (`tel_mainl`), both per 1 000 people.

economic stability & performance The performance of the public sector to stabilise the economy and to promote economic growth is measured by the following variables: The moving average of the annual inflation rate (`inf_gdpdefl_ma`), the coefficient of variation of inflation (`inf_var`), the moving average of real GDP per capita (`pwt_cgdp_ma`), the moving average of the growth rate of real GDP per capita (`pwt_grgdpch_ma`) and the coefficient of variation of the real GDP per capita (`gdp_var`). The data is taken from the Penn World Tables (PWT) and the World Development Indicators (WDI), see the appendix for further details.

It is obvious that the selected variables provide only a crude measure of the success of public sector activities. The selection has been carried out following several guidelines. As one of the goals of this study is to check the robustness of the results in Afonso et al. [2005], I tried to maintain important aspects of their approach to the measurement of public-sector performance and efficiency. Hence, the policy fields are roughly the same as in their paper. Secondly, I tried to use similar variables for the measurement of the outcomes of public policy in the different policy fields. On the other hand, an important goal was to include as many observations, i.e. countries and years, as possible in the analysis. The core of the paper by Afonso et al. [2005] is an an FDH-analysis with 23 countries for the year 2000. For the year 1990, an index for public-sector performance is calculated in addition. A potential problem with the analysis of Afonso et al. [2005] is that 23 observations are by far too few observations to overcome the curse of dimensionality problem mentioned above (see page 71). On the basis of these principles – comparability with Afonso et al. [2005] and as many observations as possible given the constraint of data availability – in mind, a panel data set containing all countries has been created, with observation from the 1950s until 2005. Then possible variables measuring the public sectors output and public expenditure have been selected, where missing values for each candidate variable reduce the panel to less years and countries. For example, the inclusion of the Gini index to measure the success of redistributive public policies makes the sample shrink considerably.[16] In order to keep the sample reasonably large, many variables that are possibly better indicators of public-sector performance had to be discarded.[17]

In order to permit a comparison of public-sector performance across the five policy fields mentioned above, I follow Afonso et al. [2005] and calculate "Public-Sector Performance (PSP) Indicators" for each field. These indicators are calculated by centering each variable around the mean of all observations and all years and then using a unweighted average of all variables per policy field as PSP-index. The average outcome per policy field then is measured with an index value of unity. The PSP-index for a country that performs better than the average is greater than one and vice versa. Finally, an overall PSP index is calculated as the mean of the sub-indices for each country and year. More formally, consider $i \in \{1, 2, ..., n\}$ countries, $j \in \{1, 2, ..., m\}$ policy areas, $y \in \{1985, ..., 2000\}$ years and $k \in \{1, 2, ..., l\}$ variables x_{ijyk} measuring the success of public policy in country i in area j and year y. Then the index measuring the success of country i in policy area j in year y is defined as

$$PSP_{jiy} = \frac{\sum_{k=1}^{l} \frac{x_{ijyk}}{\overline{x_{jk}}}}{l}, \tag{5.2}$$

where

$$\overline{x_{jk}} = \frac{\sum_{y=1985}^{2000} \sum_{i=1}^{n} x_{ijyk}}{4 \cdot n}$$

is the mean of variable x_{ijyk} over all countries and the four years in the sample. $\frac{x_{ijyk}}{\overline{x_{jk}}}$ stands for the k'th variable in policy area j, centered around the mean. The result is a panel dataset for n countries, over the year 1985 until 2000, with PSP-indices for the five policy areas and an PSP-index covering all policy areas, calculated as the average of PSP1-PSP5.[18] The numbers are reported below.[19] Note that this approach allows to compare the PSP score across countries and across time.

This approach of measuring the output of public sector activities has the advantage that it is possible to construct a large data set of output measures. But of course there are numerous problems. Obviously, policy targets in a field like education are more complex than simply increasing the number of degrees that an educational system produces. In health care, the aim is not only to increase the life expectancy. However, the choice of variables depends crucially on data availability. For this study, where the sample covers both developed and developing countries, variables were chosen in a way that provides enough potential variability for all countries in the sample. An implicit assumption is that the actual policy targets can be approximated by the variables chosen. Furthermore, the definition of the five policy

[16] UNU-WIDER [2008] is an very useful attempt to collect and consolidate national data on income distribution. However, for the purpose of this study, not enough observations are available.

[17] See, for example, Afonso / Aubyn [2006a] for a cross-country study about education provision and Afonso / Aubyn [2006b, 2007] for a similar study about national health care systems. Restricting a study to a specific public sector activity and to a subset of coutries (usually the OCED) improves data availability noticeable.

[18] Taking a simple average as an overall PSP-index ignores that different policy fields could be valued differently in different societies. This is ignored in the calculation of the overall PSP-index. It is therefore an output measure that is based on a common standard applied to all countries, where a low output in a particular country could simply reflect that the output is not valued a lot. See footnote 29.

[19] Where necessary, the variables have been recoded such that higher values reflect better outcomes. An example is the variable *percentage of no schooling in the total population*. See the appendix for details.

fields is somehow arbitrary. For example, internal and external security have been left out although they are classic issues the public sector takes care of. This is less problematic as long as it is possible to match the policy fields on the input side. As long as the purpose of the expenditure used for the input measurement matches the policy field, leaving parts of the activities of the public sector is possible. It must be kept in mind, however, that the measurement of public-sector performance and efficiency covers only the policy fields listed above. It could well be that a country that performs badly in all areas looked at in this study performs well in other areas.

5.3.2 Input measurement: public expenditure

The input side of the production process in the five policy areas is measured by public expenditure. Ideally, each PSP-index is matched with functional expenditure data that is spent with the purpose to improve public policy in the same area. The availability of national expenditure data, disaggregated by purpose of spending and consolidated to account for lower than national levels of government, is very limited. For this study, the time series from the IMF Government Finance Statistics, Historical Series (consolidated government[20]) [IMF 2006] and the Penn World Tables (PWT) [Heston et al. 2006] have been used .[21] The expenditure data used to match the PSP-indices in the several policy areas is:

expenditure policy area 1 - administrative quality Expenditure of the government on goods and services (`exp_imf_econ1_real`).[22]

expenditure policy area 2 - education Expenditure of the government on education affairs and services (`exp_imf_4_real`).

expenditure policy area 3 - health care Expenditure of the government on health affairs and services (`exp_imf_5_real`).

expenditure policy area 4 - infrastructure Capital expenditure of the government. This expenditure category is used as an approximation of public investment (`exp_imf_econIV_real`).

expenditure policy area 5 - economic stability & performance Total expenditure and lending minus repayments (`exp_imf_econI_real`). The amount of total spending can be seen as a proxy for the government activities to stabilise the economy and to promote economic growth.

expenditure overall public-sector performance The IMF-GFS historical expenditure data is very limited in coverage. Therefore, I use another measure of public expenditure that covers all policy areas 1-5 and is based on the Penn World Tables only (Real govern-

[20] The "consolidated government" expenditure data covers all national and subnational government layers.

[21] The *IMF-GFS historical* series is in local currency. For the purpose of this study, the data has been converted in expenditure measured in percent of GDP and then multiplied with the the real gross domestic product per capita from the PWT, measured om International Dollar in current prices (International Dollar in Current Prices) (`pwt_cgdp`). Note that this version of the real GDP is comparable across countries, but not over time, see Summers / Heston [1991, p. 347] for a discussion about the relative merits of using different variants of PWT GDP data. The appendix contains a few notes about the usage of *IMF-GFS historical* series.

[22] The appendix contains detailed definitions of the variables. Note that the *IMF-GFS historical* series contains both expenditure data that is categorised by function and by economic type. The expenditure data from the *IMF-GFS historical* series and from the Penn World Tables are not comparable, as they are compiled following different conventions (IMF [1986] vs. United Nations [2001]).

ment expenditure per capita, `exp_gov_pwt_pc_real`).[23] It covers final consumption expenditure as defined in the System of National accounts (SNA, see United Nations [2001]) and therefore excludes social transfers.[24] The SNA contains a broad and a narrow definition of government final consumption. The Penn World Tables are based on the broad definition that includes, for example, individual consumption goods and services like education and health care.[25]

For the efficiency analysis to be presented below, the moving averages (current year and the four preceding years) of the six expenditure variables have been used to account for business-cycle effects. The expenditure data has been converted to real expenditure in international dollars according to the conventions in the Penn World Tables. The usage of expenditure data as a proxy for input implicitly assumes that input prices are equal across countries. This is a strong assumption but the Penn World Tables try to account for that.

The real expenditure data used is measured in per capita terms. Afonso et al. [2005] use expenditure data measured in percent of GDP. But in a sample where the GDP differs substantially, this is not a valid approach. A poor country that devotes, say, 10 percent of GDP to some activity commands over less real resources than a rich country that spends 10 percent of GDP to the same activity.[26]

Obviously, the expenditure data available for this study on the one hand and the policy targets that are taken as a measure for the results of public spending on the other hand do not match perfectly. Although reasonable expenditure data is available for the policy areas of education and health care, rather crude expenditure categories need to be used for the other areas. This problem is prevalent in this study and also in Afonso et al. [2005]. The expenditure categories used in this study are roughly the same in their paper, with the exception that redistribution as a policy field is not looked at in this study. Accordingly, the measure for overall public expenditure does not contain social transfers as well.

For the efficiency analysis presented below, one has to keep in mind that surprising results can first of all be caused by measurement error and misspecification on the input or on the output side. It is difficult to argue whether the PSP-indices used in this study systematically overestimate or underestimate the "true performance". Also note that the preferences of citizens in the different countries are not taken into account. But even in a hypothetical country where citizens do not care much about the five policy areas that are under closer inspection in this study, there should be an interest that the public sector operates close to the efficiency border. However, when interpreting public-sector performance indices and

[23] It has been calculated as `pwt_rgdpl` · `pwt_kg`. As this variable is used for comparisons over time, the real GDP based on a Laspeyre-Index needs to be used [Summers / Heston 1991, p. 347].

[24] A warning might be appropriate. As the data from the Penn World Tables follows the conventions of the SNA, that by itself is somehow special in its treatment of government expenditure (broad vs. narrow definition), the numbers from the Penn World are substantially lower than those published frequently in the media or in studies that deal with smaller samples like the OECD countries. The numbers of the government share given in the Penn World Tables are substantially lower than those frequently seen, see IMF, Fiscal Affairs Department [1995] for an example. They exclude expenditure for social security. They include government military expenditures that are part of governmental capital formation. The treatment of the public sector in the System of National accounts [United Nations 2001] is rather complicated and sometimes confusing. A description of national accounting standards on an international level, such as Brümmerhoff [2007] for Germany, is missing.

[25] United Nations Economic and Social Council [2004] contains a useful discussion about the distinction of broad vs. narrow government consumption. The "serious defect" in applying the broad definition consistently mentioned in United Nations Economic and Social Council [2004, p. 6] has been corrected in the current version of the PWT.

[26] However, the results turned out to be roughly the same using expenditure data in percent of GDP.

efficiency scores, one should not confuse the utility derived from publicly provided goods and services, or the “happiness” of people, with the issue how well the public sector performs in terms of output.

5.3.3 Public-sector performance in two different samples

The subsequent analysis is done with two different samples. The first sample contains 32 countries in a cross section for the year 1990. These are the countries where expenditure data for all five policy areas is available. The second sample contains 74 countries and the years 1985, 1990, 1995 and 2000. A list of all countries together with their abbreviated names can be found in Table A8 in the appendix (page 99). The smaller sample is used in a FDH-analysis. I refer to it as the “FDH-sample” in the following. The results are then compared to those of Afonso et al. [2005]. The larger sample contains the input and output data for an DEA efficiency analysis that employs the bootstrap and two-stage estimation techniques discussed earlier (section 5.2). It is henceforth referred to as “DEA-sample”.

Public-sector performance results (FDH-sample)

Table 5.1 reports summary statistics for the output measurement for the smaller sample. All PSP-indices have a mean of unity (by construction). The variation of the sub-indices differs across the five policy areas, with the subindex for health care having a very low variability. This reflects that the health care index is composed of only one variable (life expectancy) that has a mean of seventy years and a standard deviation of seven years (See the codebook in the appendix, Table A9.). The detailed results for the Public-Sector Performance can be found in the appendix (Table A12)

Variable	Mean	Std. Dev.	Min.	Max.	N
PSP area 1: Administrative Quality	1.000	0.223	0.646	1.346	32
PSP area 2: Education	1.000	0.474	0.195	2.123	32
PSP area 3: Health	1.000	0.101	0.758	1.102	32
PSP area 4: Infrastructure	1.000	0.902	0.014	2.919	32
PSP area 5: econ. stability & performance	1.000	0.416	0.131	1.710	32
overall PSP	1.000	0.370	0.465	1.667	32

Table 5.1: Summary statistics for the PSP indices in the FDH-sample

Figure 5.2 plots the overall Public-Sector Performance Index (the average of PSP1-PSP5) as a function of the KOF Index of Globalisation, an index that measures the economic, political and cultural globalisation of a country [Dreher 2006, Dreher et al. 2008]. The plot seems to suggest that more globalized countries perform better in terms of public good and services provision. But this is of course not a statement about causal relationships. In the regression analysis presented below, globalisation will be used as a proxy for the intensity of interjurisdictional competition. The idea that interjurisdictional competition might have a positive impact on public-sector efficiency is then explored more carefully, see section 5.5.

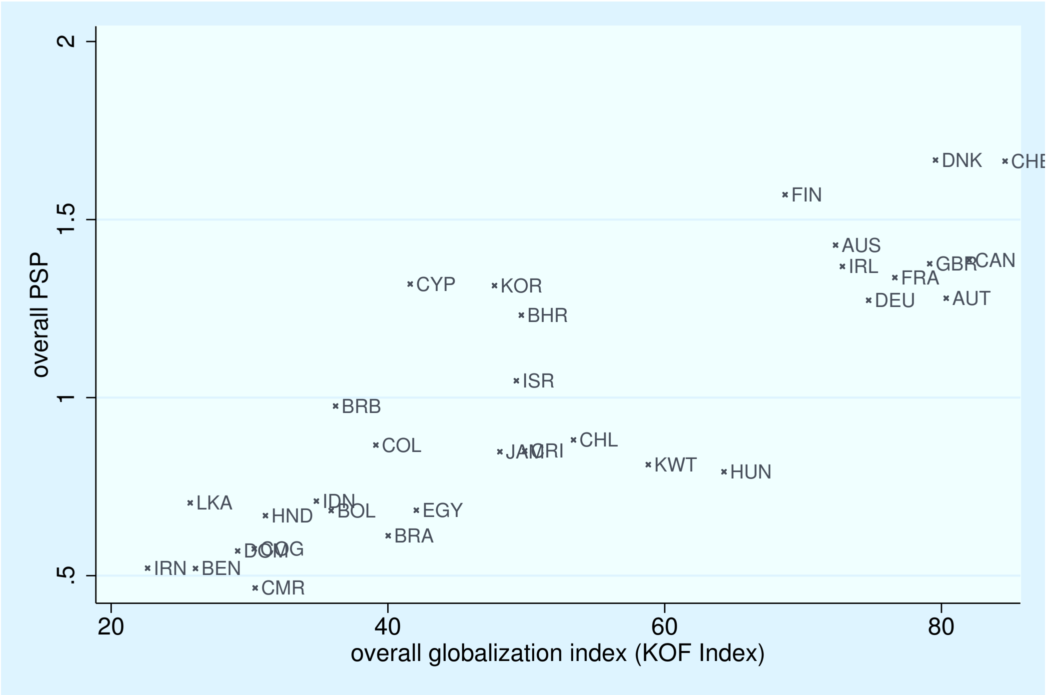


Figure 5.2: Public-sector performance and globalization (FDH-sample).

Public-sector performance Results (DEA-sample)

The performance indices have been calculated separately for the DEA-sample. This is necessary as the PSP-indices are relative measures that are sensible to sample selection. Table 5.2 reports summary statistics. The pattern of the standard deviation is similar to the one for the FDH-sample, suggesting that it is a result of the choice of variables, not one that is sample-dependent.

Variable	Mean	Std. Dev.	Min.	Max.	N
PSP area 1: Administrative Quality	1.000	0.241	0.328	1.514	296
PSP area 2: Education	1.000	0.530	0.077	2.688	296
PSP area 3: Health	1.000	0.142	0.575	1.196	296
PSP area 4: Infrastructure	1.000	1.101	0.007	5.833	296
PSP area 5: econ. stability & performance	1.000	0.581	-0.780	3.023	296
overall PSP	1.000	0.444	0.244	2.244	296

Table 5.2: Summary statistics for the PSP indices in the DEA-sample, 1985-2000

The DEA-sample contains four observation per country. The way the PSP-indizes are calculated implies that comparisons across time and across countries are possible. A country can be compared against itself in different years. A closer inspection of the full list of all results – see the appendix, Table A13 – reveals that the public-sector performance has improved for most countries over time, relative to the average performance over all countries and all years. This is mainly due to improvements in area 5 (economic stability and performance), see Figure A10 in the appendix.[27]

[27] All PSP-indices seem to have a trend, albeit this is difficult to judge with only four observations in the time dimension.

An overview about the geographical scope of the DEA-Sample is provided in Figure 5.3 showing a world map of Public-Sector Performance for the year 1990. The darker the colour of an area is, the better the performance of the public sector. Countries on the same continent tend to have similar values for public-sector performance. In Europe and North America, for example, most countries have PSP-indices in the upper quartile.

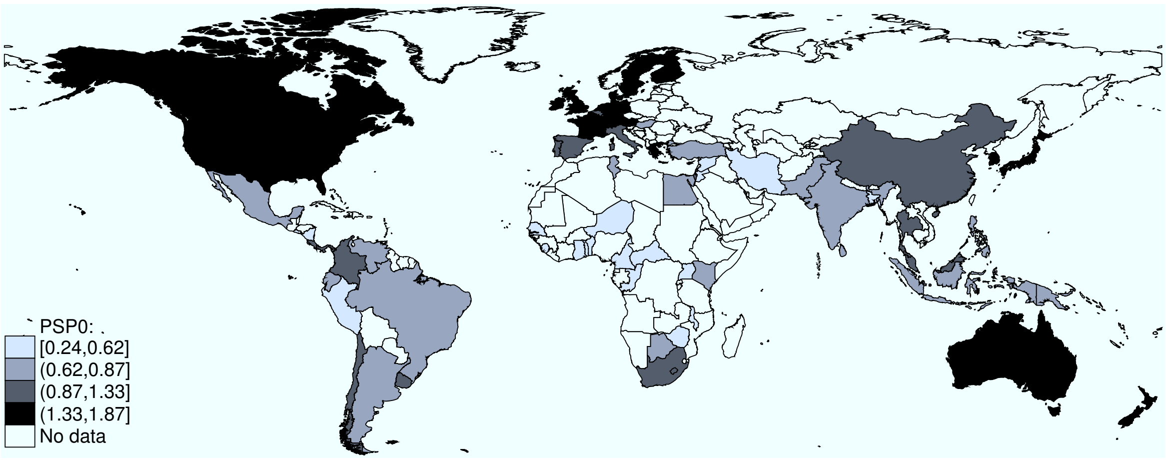


Figure 5.3: A world map (with blanks) of public-sector performance. (DEA-sample, 1990)

5.4 Efficiency analysis

A well performing public sector benefits the citizens of a country and supports production in the private sector. On the other hand, the inputs used in the public sector are lost for private consumption or as an input in private production. It is therefore important to include public expenditure in an evaluation of the public sector. This is done in the next step of the analysis, again separately for the two samples.

5.4.1 FDH-Analysis in the small sample

One goal of this study is to provide an robustness check for the results in Afonso et al. [2005]. In their paper, a sample of OECD countries is analysed using an FDH efficiency estimator. Their results suggest that countries that are small in terms of public expenditure use resources more efficiently than those with a bigger government. The robustness check will be done in a slightly larger sample, for a different year, with roughly the same policy fields. The technique is an FDH efficiency analysis in both studies.

I will calculate efficiency scores for each policy area separately. Figure 5.4 illustrates the FDH-method for the policy field 4 (education). Input is measured in real expenditure per capita, output by the PSP-index. The production frontier is constructed as a step function as shown in the figure. I calculate the efficiency score in output-orientation, meaning that the input is held constant. For example, the FDH-score for Cyprus (CYP) is calculated as quotient of the actual output of Cyprus divided by the output of its “peer”, Korea. Korea produces a higher output with less inputs.[28] As an overall efficiency score, I will use the average of the efficiency scores of the five policy fields (`fdh_av`).[29] The results are reported in Table 5.3.

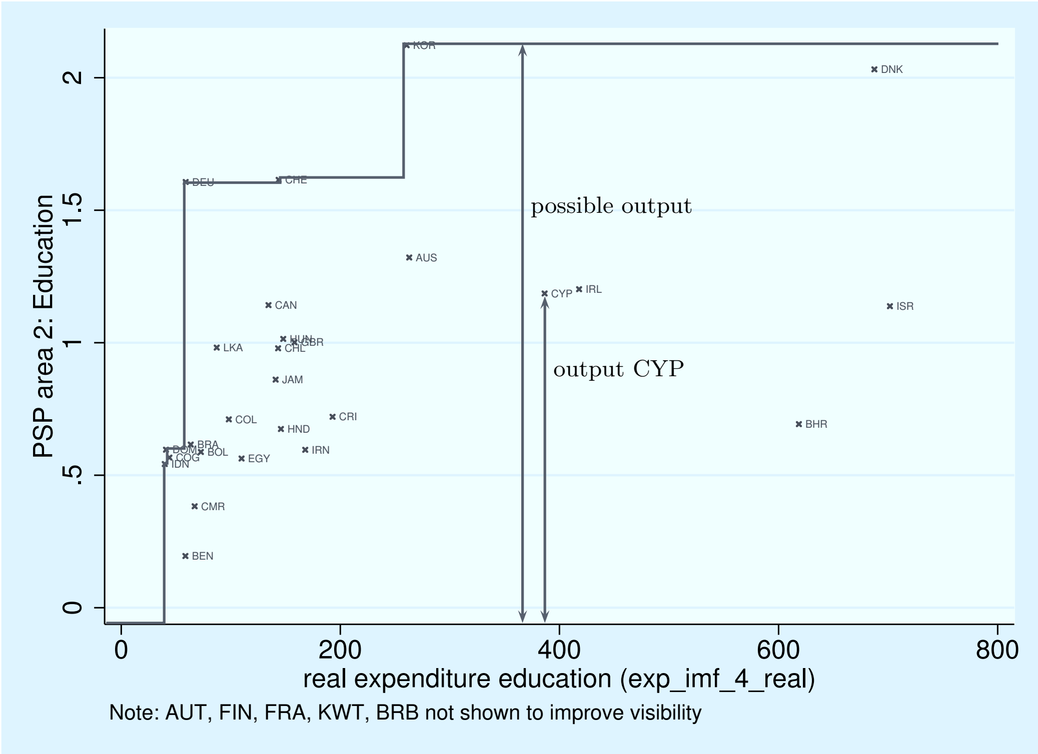


Figure 5.4: An illustration of the FDH-efficiency analysis

[28] Note that in the example, Cyprus could not only produce more output given its input. It could also reduce its input and still produce as much as Korea. This an example of a slack, see footnote 10.

[29] This means that all five policy areas receive an equal weight in the overall efficiency score. I also calculated an FDH-efficiency score that takes `PSP0` as an output measure and `exp_gov_pwt_pc_real` as an input measure. The results did not differ substantially, indicating that the weights attached to the different policy fields are not driving the results in the FDH-sample.
Another possibility – different from assuming equal weights as I have done — to attach weights that reflect the relative importance of the different policy areas would be to rely on survey, as has been done for a study about health care system by the World Health organisation. See Smith / Street [2005, p. 409] and references therein.

Table 5.3: Public-sector efficiency for the FDH-sample. The table shows the FDH-scores for the five subareas (fdh1-5) separately and the mean of fdh1-5 as fdh_av. The table is sorted by fdh_av.

country		**year**	**fdh1**	**fdh2**	**fdh3**	**fdh4**	**fdh5**	**fdh_av**
CHE	Switzerland	1990	0.97	1.00	1.00	1.00	0.87	0.97
DNK	Denmark	1990	0.96	0.96	1.00	1.00	0.82	0.95
CAN	Canada	1990	1.00	0.71	1.00	1.00	0.76	0.89
KOR	Korea. Rep.	1990	0.90	1.00	1.00	0.42	1.00	0.86
FIN	Finland	1990	0.95	0.91	0.97	0.87	0.60	0.86
IRL	Ireland	1990	1.00	0.57	0.96	1.00	0.74	0.85
GBR	United Kingdom	1990	0.93	0.62	0.98	0.63	1.00	0.83
AUS	Australia	1990	0.96	0.62	0.99	0.72	0.83	0.83
BOL	Bolivia	1990	0.79	0.37	0.89	1.00	1.00	0.81
DEU	Germany	1990	0.93	1.00	0.97	0.42	0.71	0.81
IDN	Indonesia	1990	1.00	1.00	0.94	0.04	1.00	0.80
FRA	France	1990	0.93	0.52	0.99	0.57	0.91	0.79
CYP	Cyprus	1990	0.77	0.56	1.00	0.60	0.97	0.78
AUT	Austria	1990	0.95	0.65	0.98	0.46	0.77	0.76
BHR	Bahrain	1990	0.85	0.33	0.93	0.68	0.83	0.72
CHL	Chile	1990	1.00	0.61	0.98	0.17	0.64	0.68
COL	Colombia	1990	0.74	0.44	0.96	0.19	1.00	0.67
BRA	Brazil	1990	0.64	0.38	0.89	1.00	0.32	0.65
CRI	Costa Rica	1990	1.00	0.45	0.98	0.23	0.56	0.64
COG	Congo. Rep.	1990	0.76	1.00	1.00	0.07	0.40	0.64
JAM	Jamaica	1990	0.77	0.53	0.96	0.33	0.53	0.62
BRB	Barbados	1990	0.77	0.44	0.96	0.28	0.65	0.62
DOM	Dominican Republic	1990	0.72	1.00	0.95	0.08	0.34	0.62
ISR	Israel	1990	0.49	0.54	0.99	0.43	0.64	0.62
BEN	Benin	1990	0.87	0.12	0.94	0.06	1.00	0.60
HND	Honduras	1990	0.89	0.42	1.00	0.10	0.56	0.59
LKA	Sri Lanka	1990	0.74	0.61	1.00	0.02	0.49	0.57
HUN	Hungary	1990	0.72	0.63	0.93	0.12	0.41	0.56
EGY	Egypt. Arab Rep.	1990	0.83	0.35	0.87	0.04	0.67	0.55
KWT	Kuwait	1990	0.52	0.47	0.97	0.24	0.35	0.51
CMR	Cameroon	1990	0.98	0.24	0.83	0.02	0.13	0.44
IRN	Iran. Islamic Rep.	1990	0.71	0.37	0.91	0.07	0.13	0.44

On average, Switzerland has the most efficient public sector, followed by Denmark. The countries that are ranked best according to the average efficiency measure can also be found on the production frontier in several policy fields (FDH-score of 1). An interesting result is that the ranking based on public-sector performance (PSP) is similar - countries that provide high levels of public goods and services tend to have relatively efficient public sectors. A high output level is not an indicator for inefficiency.

But what about the "small is beautiful" result of Afonso et al. [2005]? Figure 5.5 plots the efficiency score as a function of the government share of real GDP per capita (pwt_cg).[30] The goverment shares of the three most efficient countries according to the FDH-analysis – Switzerland, Canada and Denmark – cannot be characterised as being small. In the group of countries with an average FDH-score above 0.8, there are countries with a public sector of different size, most of them close to the median size. At least according to the results in this study, the association of the "smallness" of the public sector with its efficiency is not justified.

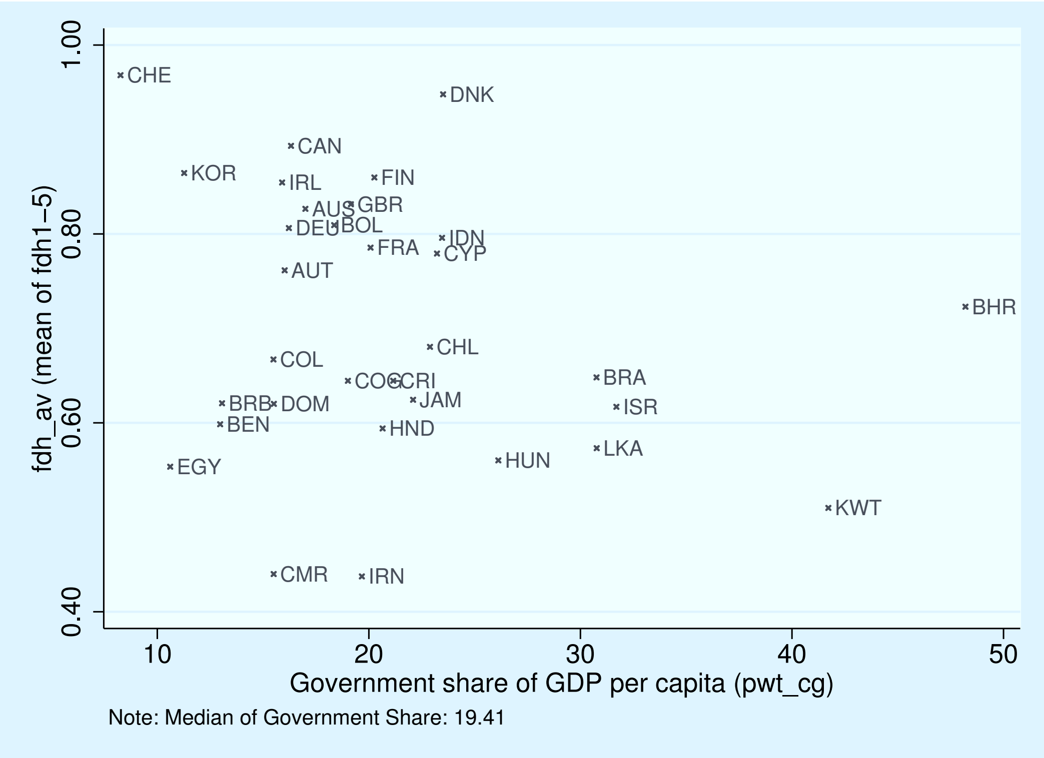


Figure 5.5: Efficiency of the public sector and government size. (FDH-sample)

According to Bjørnskov et al. [2007, p. 267], there are two polar views in the economics profession about the size of the public sector. According to the authors, the "neoclassical view" claims that "governments play unambiguously positive roles for individuals' quality of life, while the theory of public choice has been developed to understand why governments often choose excessive involvement in – and regulation of – the economy, thereby harming their citizens' quality of life." If the latter view is correct, it would be welfare-improving if the government is decreased. One would then expect that smaller governments are more efficient, as they interfere less in the economy and less real resources can be wasted by politicians.

[30] The government share of real GDP per capita in the Penn World Tables is calculated based on nominal expenditure taking the price level of government consumption into account. It could also be labelled "real government share". See Knowles [2001] and Dowrick [2005] for a review and a discussion of the PWT, including a warning that the government share of poor countries might be overstated due to the calculation based on international prices. However, the variable pwt_cg can be seen as representing the real resources devoted to government activities. Because of the Balassa-Samuelson effect, the nominal exchange rate is undervalued in terms of purchasing power for poor countries. The government consumption typically consists to a large extend of non-traded goods and services. Therefore, the government share in the PWT for poor countries is systematically higher than that found in national accounts.

Labelling the theory of public choice as being antagonistic to the neoclassical theory as in the quotation above is misleading. However, in the literature, there are the two mutually exclusive assumptions of benevolent governments and governments that are seen as the result of a political process and are not necessarily benevolent. The results in this study do not suggest that smaller governments are less wasteful. Hence, it does not provide support for the assumption of non-benevolent governments that should be disciplined, the smaller, the better.[31]

In the next section, the sample is increased and the method of efficiency analysis changed from FDH to DEA with bootstrapping. These efficiency scores will then be used in a regression to explore possible explanations for the diversity of efficiency-scores across countries empirically.

5.4.2 DEA-Analysis with bootstraping in the larger sample

It is possible to increase the sample from 32 to 74 countries by using the overall Performance index PSPO as the single output measure and the final consumption expenditure of the government as the single input measure.[32] The DEA approach assuming variable returns to scale is used to analyse efficiency in the larger sample.[33]

Variable	Mean	Std. Dev.	Min.	Max.	N
Year	1992.500	5.600	1985.000	2000.000	296
DEA score	0.622	0.164	0.145	1.000	296
bias	0.030	0.051	0.007	0.777	296
DEA score (bias corrected)	0.592	0.156	0.138	0.966	296

Table 5.4: Summary statistics for the DEA efficiency scores

Table 5.4 reports summary statistics for the DEA efficiency scores. The calculation of the DEA-scores follows a similar procedure than that for the calculation of the FDH-scores. The difference is that the efficiency frontier is not a step-function (see Figure 5.1 and the discussion in section 5.2). The output-orientation is maintained.

The bias-corrected DEA-score is the result of applying the bootstrapping procedure described in Simar / Wilson [2000a] and implemented in the software package FEAR, see the reference on page 73. DEA (and FDH) efficiency measurement is sensitive for the inclusion of individual observations. Each DEA efficiency score is relative to those of all other observations in the sample. In a nutshell, the bootstrapping procedure repeatedly draws subsamples from the 256 observations and corrects for the bias caused by the inclusion of an observation. A bias correction is calculated for each observation, additional to a confidence interval.

[31] Bjørnskov et al. [2007] claim that they contribute to the resolution of the question which of the two assumptions is more realistic. They find in a regression analysis that people in countries with a smaller government are happier.

[32] I checked in the smaller FDH-sample whether the better match of inputs and outputs that is possible in the smaller sample makes a big difference compared with the simpler approach used here. The results did not differ much. This can be seen as a robustness check whether abandoning detailed functional expenditure data has a big impact on the results.

[33] Variable returns to scale is assumed because for a production process like the one considered here, stronger assumptions like constant returns to scale cannot be justified by other empirical or theoretical studies. DEA with variable returns to scale fits the data almost as tightly as the FDH-approach.

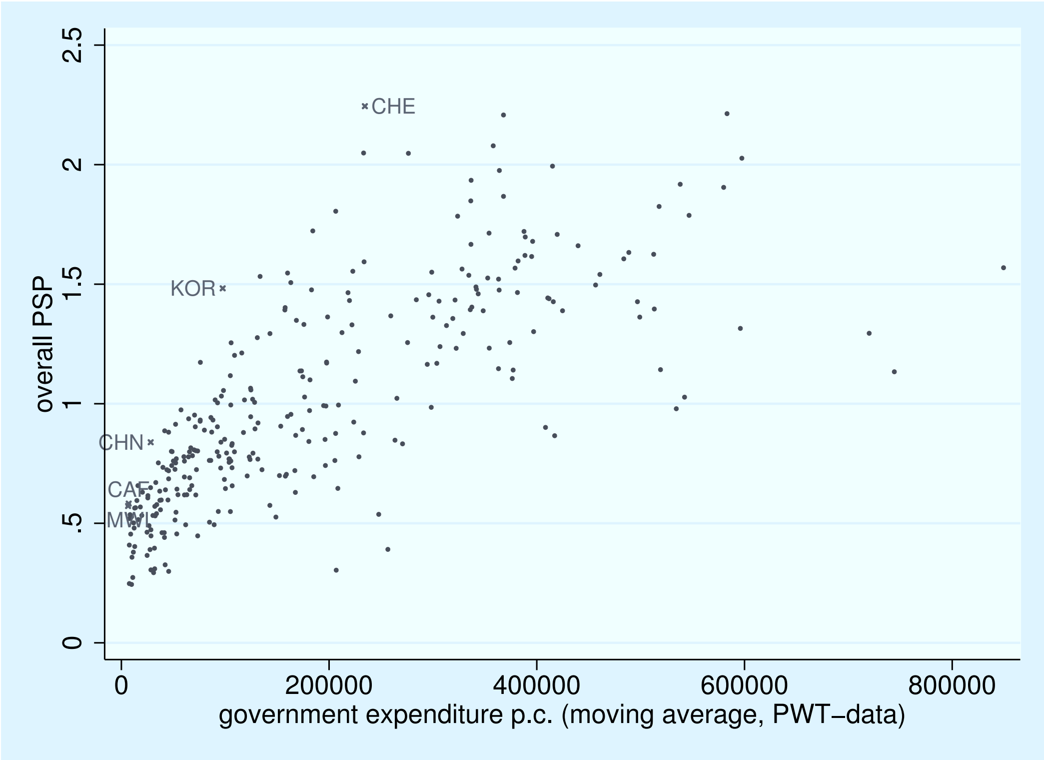


Figure 5.6: The efficiency frontier (DEA-sample, 1985-2000).

The list of all results can be found in the appendix (Table A14). Figure 5.6 plots the input and output data. The observations that define the efficiency frontier are labelled, i.e. those that receive an uncorrected DEA-score of unity. These are Malawi in the year 1985, the Central African Republic (2000), China (1985), Korea (1990) and Switzerland (2000). The bias correction is moderate on average due to the relatively large number of observations. For a few observations however, the bootstrapping procedure finds that their inclusion introduces a strong bias. Malawi in 1985, for example, is an observation where the estimated bias is particularly strong, followed by the Central African Republic in 2000. The intuition for the relatively large bias that is attributed to those two observations is the following. In a DEA analysis without bootstrapping, they are on the efficiency frontier, hence a lot of other DEA-scores are influenced by their inclusion. Taking them out of the sample has a big impact if there are not many other observation that can potentially play a similar role for the definition of the efficiency frontier. This is the case for Malawi in 1985 and the Central African Republic in 2000, but not for Switzerland in (2000).[34]

Figure 5.7 plots the bias-corrected efficiency scores as a function of the KOF globalization index. A simple linear regression seems to suggest that more globalized countries are more efficient, but the correspondence is not very strong. The next section explores this and other relationships in the data more carefully.

With respect to the "small is beautiful" result of Afonso et al. [2005], which has already been checked for its robustness in the FDH-sample, the result of the DEA analysis is similar. Figure 5.8 plots the bias-corrected efficiency scores as a function of the government share of real GDP per capita. Again, the government share of the countries with an efficiency

[34] Note that given the presence of four observations per year for each country in the sample, the bootstrapping procedure accounts for outliers in the sense that the data of a country varies a lot across time.

score close to one is diverse. However, the public sectors of a few countries with a very high goverment share operate far below the efficiency frontier.

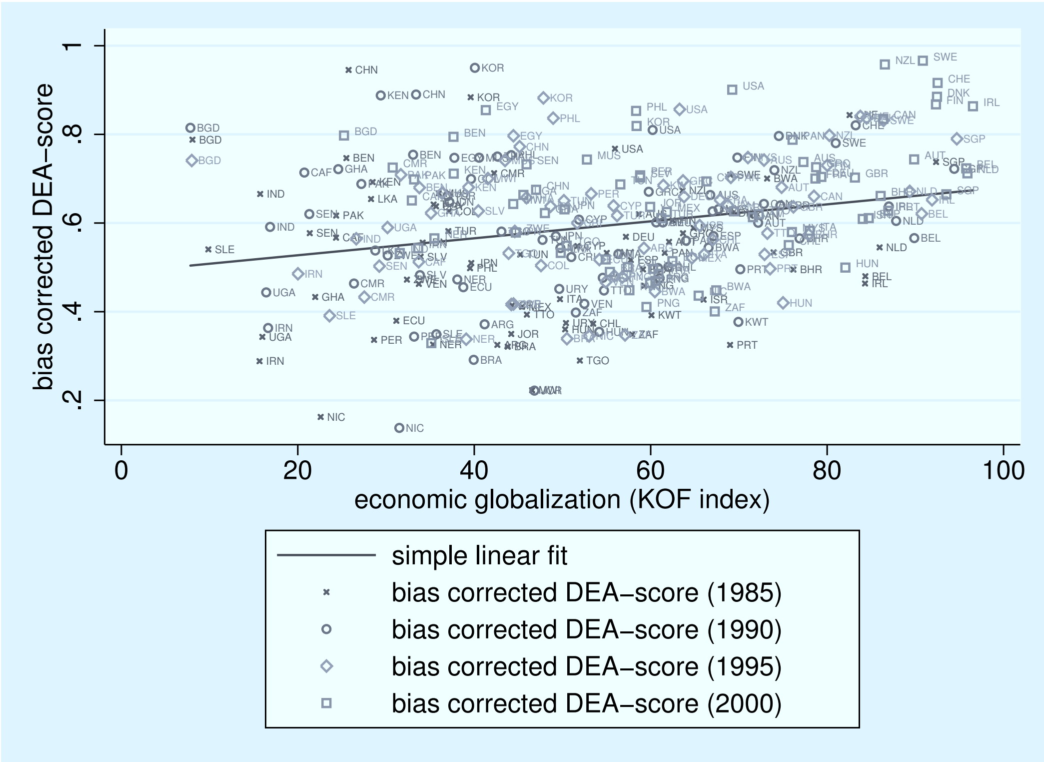


Figure 5.7: Public-sector efficiency and economic globalization (DEA-sample, 1985-2000).

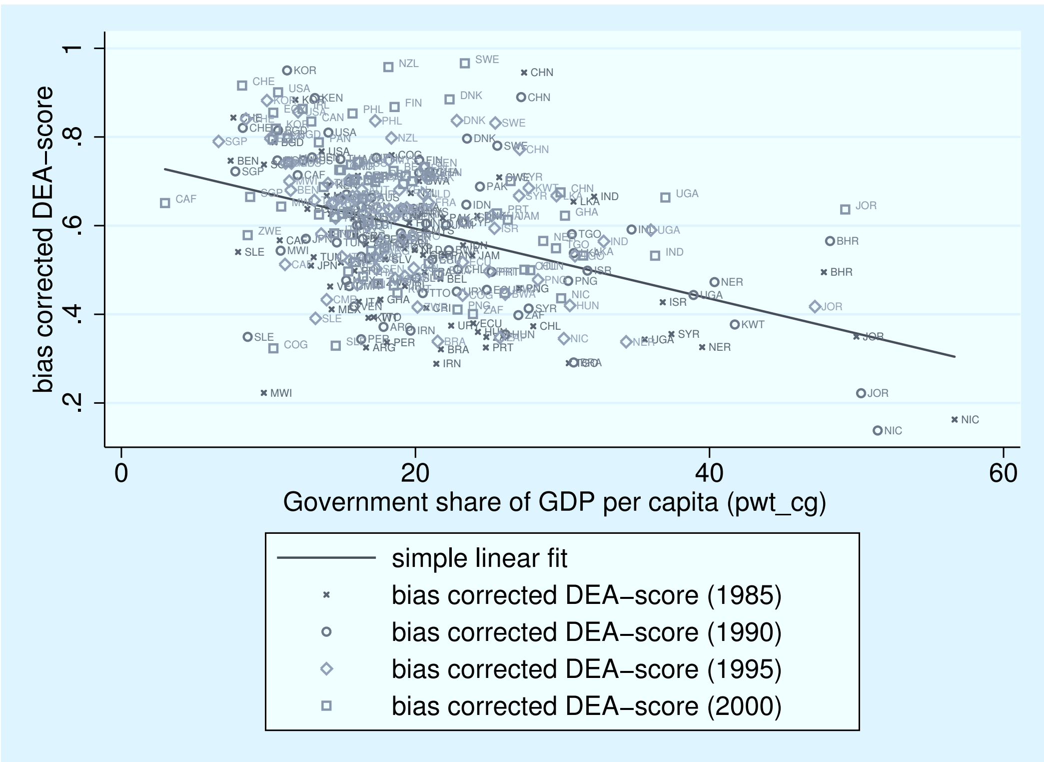


Figure 5.8: Public-sector efficiency and government share (DEA-sample, 1985-2000).

5.5 Public-sector efficiency and interjurisdictional competition – a second-stage estimation

In a DEA efficiency analysis, a second-stage estimation can be used to not only measure inefficiency of firms (or countries), as has been done in the last section, but to explain it, see section 5.2. The idea is that there might be circumstances that are not under control of decision-making units responsible for the organisation of the production process. In the context of this study, such circumstances are obvious. To build a railway line is much more difficult in a mountainous country (Switzerland, Nepal) than in a country with a relatively flat topography (Belgium, Netherlands).

In the theory of fiscal federalism, it has been argued that a possible determinant of public-sector efficiency is the intensity of interjurisdictional competition for a mobile tax base. From a theoretical point of view, the influence can go in both directions, depending on the set of assumptions used. For example, in chapter 3 (or in Becker [2005]), where the government is assumed to be a welfare maximiser and public-sector efficiency depends on past investment, tax competition harms efficiency. The opposite effect is also possible, see, for example, Edwards / Keen [1996], Rauscher [2000], Wilson [2005]. In a growth model, Rauscher [2005] finds that it depends on the elasticity of intertemporal substitution whether "taming of the Leviathan" occurs. The theoretical work on the issue of interjurisdictional competition as a determinant of public sector efficiency so far does not come to an unambiguous result. The goal of the estimation presented below is not to provide a test which of the two conflicting views is supported by the data. Given the data available, it is not possible to simulate a ceteris paribus experiment that controls for the assumptions usually taken in theoretic work about public-sector modernisation. But "letting the data speak" can give an idea about the importance and the sign of the intensity of interjurisdictional competition as an explanatory variable.[35]

As a measure for the intensity of public-sector modernisation, I use the *KOF index of globalization* [Dreher 2006, Dreher et al. 2008]. Ideally, one would like to measure factor mobility, i.e. the ease of relocating taxable production factors to another jurisdiction. This measure should not be based on, for example, actual cross-border flows of capital. The actual flows of capital do not necessarily reflect that even with zero flows, there could be a credible threat of moving capital out of a jurisdiction.[36] In theoretical models of capital-tax competition with perfect capital mobility and identical jurisdictions, there are not necessarily cross-border flows of capital in the (long-run) equilibrium. But this does not mean that capital does not flee the country in which capital tax rates are raised.[37] The KOF

[35] Oates [1985] tests whether the size of government is smaller in decentralised countries. The idea is that in decentralised countries, the intensity of interjurisdictional countries should be higher and therefore, the public sector should be smaller in decentralised countries if it is correctly described as a Leviathan that needs to be tamed. He doesn't find evidence for the Leviathan hypothesis and concludes that Perhaps, after all, Leviathan is a mythical beast" Oates [1985, 756]. See also Oates [1989] and Anderson / van den Berg [1998] for a recent test that does not find evidence for the Leviathan hypothesis.

[36] Hence, measures of capital mobility based on the correlation between domestic savings and investment [Feldstein / Horioka 1980] are not appropriate in this context. They should be seen as measures of *actual* capital mobility, not of *potential* capital mobility. Coakley et al. [1998] review the literature about the claim of Feldstein / Horioka [1980] that capital mobility is relatively small. See Hoffmann [2004], Caporale et al. [2005], Christopoulos [2007], Evans et al. [2008] for recent re-estimations of the Feldstein-Horioka regression.

[37] See, for example, Wilson [1986, p. 300], for a model where it is only the *potential* of capital movements that matters for local governments when choosing their policy. Of course there are many models where even in equilibrium, capital goods are traded. Davies [2003] is an example. But the essential point here is that the actual flows of capital are not a good measure of the intensity of capital tax competition.

data on globalisation contains sub-indices about economic, social and political globalisation. The economic globalisation index is compiled from data about actual flows but also about restrictions for trade and capital account transactions. I use the overall globalisation index (`kof_index`) as a proxy for the mobility of the tax base, which in turn is a measure for the intensity of interjurisdictional competition. The reasoning behind is that the political and social dimension of the index captures barriers to mobility like language and cultural differences or difficulties for foreign investors to adjust to another political system [Persson / Tabellini 1992, Gordon / Bovenberg 1996].

Other possible explanatory variables that have an impact on public sector efficiency are population density and two variables capturing attributes of the political system. Population density (`pwt_pop/landarea`, 1000 people per sq. km) is a proxy for the urbanisation of a country. Whether the urbanisation of a country offers cost-advantages or disadvantages is not clear per se. The degree of agglomeration has an influence on property prices and transport costs for example, but the overall effect on the efficiency of public goods and services production is ambiguous, see, for example Geys et al. [2007, p. 10]. A political variable considered is the Herfindahl-index of all political parties (`pn_herftot`). The reasoning behind the inclusion of this index is that a higher concentration of political parties implies less political competition and hence lower public-sector efficiency. While the KOF index of globalisation might be a proxy for the elasticity of mobile tax bases internationally, it does not capture whether there is competition within the country between different subnational jurisdictions. I therefore include a federalism index (`pn_Gerring`) as another political variable. The theoretical literature about fiscal federalism and public-sector efficiency can be interpreted as statements about competition between countries or between lower levels of government. The expected sign of the coefficient is therefore ambiguous, for the reasons discussed above.

I include time dummies in all regressions (`year1990`, `year1995`, `year2000`). The regression analysis is done as a pooled cross section, hence including 296 (74 countries and 4 years) observations of the dependent variable, the bias-corrected DEA efficiency score. The time dummies capture possible time trends in the pattern of efficiency scores.[38] Furthermore, dummies for the continent a country belongs to are included as possible explanatory variables. They allow to answer the question if the pattern of public-sector efficiency is similar to the geographic dispersion of countries, perhaps because they share a common culture and history.

Another characteristic of the data is that it contains several observations per country. This construction has the advantage that the number of observations is multiplied by four compared with a procedure that looks at every year separately. The disadvantage is that a country in different years is treated as if it was a different country. This ignores that it is very likely that a country that performs well in 1985 performs similar well in later years. It can be expected that the variance of the residual is not constant. I am therefore using robust standard errors. A simple correlation matrix (not reported) does not indicate any problems with multicollinearity. As has been argued above, see page 72, I am using a trunctated regression approach, where the upper limit of the dependent variable is set to one, the maximal possible efficiency score.

The selection of the estimated model follows a general-to-specific approach, where the main explanatory variable of interest is the index of economic globalisation. In the absence of an identification strategy, significance of globalisation – a proxy for the intensity of interjurisdictional competition - would allow the statement that a relationship between

[38] Note that four observations in time are not suitable to perform a time-series analysis. Hence a pooled regression has been chosen to increase the number of observations.

public-sector efficiency and interjurisdictional competition cannot be denied given the data I have. A statement about causality is not possible.

Equation (1) in Table 5.5 corresponds to the simple linear fit in Figure 5.7. Economic globalisation is a highly significant explanatory variable.[39] As for all other equations, the lower part of the table reports summary and diagnostic statistics. Under the heading "sigma (St.E. of Estimate)", the estimated standard error of the regression is reported. The lower the estimated value is, the better the fit of the regression. The log pseudo-likelihood can be used as relative measure to compare different models. A higher value indicates that the fit of the model is better. And, finally, I report the Wald Chi-Square statistic. It can be used to test the hypothesis that the coefficients for all variables in the model (except the constant) are equal to zero. This hypothesis can be rejected for all regressions with a probability value of 1% or less.

Equation (2) is the most general model estimated. It includes all variables that are possible explanatory variables. Globalisation remains a significant variable. Most of the time and regional dummies are significant. The goodness of fit of the model is improved compared to model (1). The time dummies and a few of the continent dummies are significant. For the political variables, I do not have observations for all countries. Hence, they are left out in model (3) and will be considered separately. In equation (3), the globalisation measure, the government share and population density are significant. Most regional and all time dummies are significant as well. Equation (3) in Table 5.5 indicates[40] that the pattern of inefficiency in the sample can be explained by

- Time. Efficiency is higher in later years. For example, observations from the year 2000 on average improved their efficiency score by roughly 0.09 percent.
- Continent. The continent dummies are in most regressions (reported and unreported) significant. The reference group consists of the pacific countries. This suggests that public-sector efficiency is partly driven by common characteristics of countries located on the same continent, such as climate conditions or a common history.
- Population density. Countries in the sample that are sparsely populated are less efficient. The population density variable is very stable in the several models I looked at.
- Percentage Government Share. Countries in which the government claims less real resources in percentage of GDP tend to have a more efficient public sector. The effect is very stable but of moderate size.

Table 5.6 reports the base regression (2) with all variables for easier reference, followed by three other equations that explore the political variables. Model (5) is an equation that includes the Herfindahl index of political fractionalisation and the unitary (inverse federalism) variable, together with the globalisation index and the government share. Population density has been left out as it is insignificant in model (2). From the two political variables, only the unitarism index is significant. This does not change if the continent dummies are left out, see equation (6). Globalisation, gains significance in this step, indicating that the pattern

[39] I use the term "significant" when p-values are 10% or less.

[40] Equation (3) can be seen as the "best" model. The selection of models has been done with having in mind Sala-I-Martin [1997] who argues in favour of running multiple regressions and looking out for variables that are good predictors "on average". The main variables of interest, the globalisation index and the percentage government share, are never dropped. Moving from model (1) to (2) and (3) shows that the inclusion of additional variables improves the goodness of fit. Dropping insignificant variables has not to be considered in model (3). Note that dropping a single continent dummy changes the reference group and is therefore not advisable.

	(1)	(2)	(3)
Variables:			
overall globalization index (KOF Index)	0.003***	0.001	0.002*
	(0.000)	(0.001)	(0.001)
Perce. Gov. Share (pwt_cg)		-0.008***	-0.007***
		(0.001)	(0.001)
Population Density		0.059	0.091*
		(0.052)	(0.048)
Herfindahl Index political fractionalisation		0.008	
		(0.049)	
Unitarism index (Gerring-Thacker)		0.011**	
		(0.005)	
Asia (dummy)		0.333	0.461**
		(0.240)	(0.213)
Australia (dummy)		0.412*	0.535**
		(0.244)	(0.222)
Caribbean (dummy)		0.245	0.373*
		(0.235)	(0.213)
Europe (dummy)		0.289	0.415*
		(0.235)	(0.212)
Latin America (dummy)		0.203	0.326
		(0.247)	(0.221)
North Africa (dummy)		0.318	0.470**
		(0.246)	(0.222)
North America (dummy)		0.402*	0.516**
		(0.243)	(0.222)
Sub Saharan Africa (dummy)		0.274	0.410*
		(0.246)	(0.221)
year1990		0.054***	0.049**
		(0.021)	(0.021)
year1995		0.072***	0.056***
		(0.023)	(0.021)
year2000		0.097***	0.080***
		(0.027)	(0.025)
Constant	0.447***	0.274	0.175
	(0.027)	(0.271)	(0.232)
sigma (St.E. of Estimate)	0.148***	0.112***	0.119***
	(0.006)	(0.005)	(0.006)
Observations	296	262	296
Pseudo Log-Likelihood	151.292	205.535	213.966
Wald Chi-Square	37.699	315.495	306.202

Notes: Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Truncated regressions, upper limit set to 1. Estimation with robust Standard-Errors.
Point estimates of coefficients and standard errors rounded to three digits.
For the time-dummies, the reference year is 1985.
For the continent dummies, Pacific is the reference category.

Table 5.5: Regression results with environmental variables (dependent variable: bias-corrected DEA-scores). Models (1)-(4)

of globalisation across continents is not uniformly distributed. Equation (7), finally, is a model without the Herfindahl Index. I could not find a significant association of political fractionalisation with efficiency in all models I tried. The unitary (inverse federalism) variable, however, seems to be a useful predictor of public-sector efficiency.[41]

The additional results from Table 5.6 are:

- Globalisation. The globalisation index is significant in model (3) that excludes political variables. In the models that include political variables, globalisation is not a very stable predictor. Overall, there is weak evidence that globalisation has a positive but small impact on public-sector efficiency.
- Unitarism (inverse federalism). Among the political variables I tried, the unitarism measure proved to be the only one with explanatory power. The public sector of more centralised countries seems to be more efficient.

An issue that has not been covered so far is privatisation of public sector activities. Imagine a government that decides to cut spending on, for example, health care to a very low level. The variable measuring output (life expectancy) cannot be expected to drop proportionally, as people will spend private income on health care. A similar argument applies to all policy areas covered. One could therefore expect that countries where the provision of many public services and goods is not paid for with government expenditure systematically are more efficient than others where privatisation is less important. To capture this effect, I calculated a "privatisation index" that relies on private versus public expenditure on health care and education, using data from the World Development indicators and the UNESCO. I did not find evidence that this index explains the pattern of measured inefficiency in my sample. A possible reason could be that the impact of privatisation is covered by other variables like the continent and time dummies. Or, more likely, that the index I calculated is not appropriate.

The regression analysis so far has dealt with the levels of efficiency scores. To investigate the dynamics of public-sector modernisation, Table 5.7 reports models where the dependent variable is the change of public-sector efficiency between 1985 and 2000. For the independent variables, I took the values from 1985. Regression (8) contains only the globalisation index, the government share and a constant. Countries that in 1985 were more globalised made more progress in terms of public-sector efficiency during the 15 years covered in the sample. The constant, representing a trend, is not significant. A regression that contains all possible explanatory variables, model (9), has a better goodness of fit. Model (10) is derived by subsequently leaving insignificant variables out of the model. Whereas for the levels of public-sector efficiency the continental dummies have a relatively high explanatory power, this is reversed when the change of public-sector efficiency is considered. I could not find a model specification where the continental dummies have explanatory power. The Unitarism-Index and the government share proved to be stable in the models I tried. Its sign indicates that more centralised countries are more successful in improving public-sector efficiency. This is in line with Kotsogiannis / Schwager [2006], who argue on theoretical grounds against the popular idea that more federalised countries have advantages in creating policy innovations.[42]

The time span covered in this study is too short to inspect dynamic properties of the measured efficiency-scores more closely, especially as public-sector modernisation presumably

[41] I also tried the democracy and human rights indices from Freedom House [2008] and several other variables describing the political system covered by Norris [2008], but could not find a model where these have explanatory power.

[42] See Inman / Rubinfeld [1997] for an overview of the literature about federalised countries as a "laboratory" for policy innovations and Kollman et al. [2000], Strumpf [2002].

	(2)	(5)	(6)	(7)
Variables:				
overall globalization index (KOF Index)	0.001	0.001	0.002***	0.001
	(0.001)	(0.001)	(0.000)	(0.001)
Perce. Gov. Share (pwt_cg)	-0.008***	-0.008***	-0.008***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)
Population Density	0.059			
	(0.052)			
Herfindahl Index political fractionalisation	0.008	0.007	0.018	
	(0.049)	(0.050)	(0.038)	
Unitarism index (Gerring-Thacker)	0.011**	0.011**	0.012*	0.011**
	(0.005)	(0.005)	(0.006)	(0.005)
Asia (dummy)	0.333	0.050		0.048
	(0.240)	(0.065)		(0.053)
Australia (dummy)	0.412*	0.121**		0.117**
	(0.244)	(0.056)		(0.049)
Caribbean (dummy)	0.245	-0.036		-0.038
	(0.235)	(0.056)		(0.052)
Europe (dummy)	0.289	0.007		0.003
	(0.235)	(0.052)		(0.041)
Latin America (dummy)	0.203	-0.088		-0.095*
	(0.247)	(0.062)		(0.049)
North Africa (dummy)	0.318	0.025		0.022
	(0.246)	(0.056)		(0.052)
North America (dummy)	0.402*	0.112*		0.108**
	(0.243)	(0.060)		(0.054)
Sub Saharan Africa (dummy)	0.274	-0.018		-0.027
	(0.246)	(0.064)		(0.057)
year1990	0.054***	0.057***	0.054**	0.053***
	(0.021)	(0.021)	(0.023)	(0.020)
year1995	0.072***	0.076***	0.070***	0.066***
	(0.023)	(0.022)	(0.022)	(0.022)
year2000	0.097***	0.103***	0.093***	0.092***
	(0.027)	(0.026)	(0.023)	(0.026)
Constant	0.274	0.577***	0.532***	0.598***
	(0.271)	(0.107)	(0.057)	(0.082)
sigma (St.E. of Estimate)	0.112***	0.112***	0.124***	0.114***
	(0.005)	(0.005)	(0.005)	(0.005)
Observations	262	262	262	275
Pseudo Log-Likelihood	205.535	204.708	178.393	209.962
Wald Chi-Square	315.495	321.038	142.305	342.882

Notes: Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Truncated regressions, upper limit set to 1. Estimation with robust Standard-Errors.
Point estimates of coefficients and standard errors rounded to three digits.
For the time-dummies, the reference year is 1985.
For the continent dummies, Pacific is the reference category.

Table 5.6: Regression results with environmental variables (dependent variable: bias-corrected DEA-scores). Models (2),(5)-(7)

must be thought of as a slow process. But it is an interesting result that the explanatory variables affect the levels and the change of public-sector efficiency differently. Whereas for the level of public sector efficiency, the continent dummies are important predictors, both in terms of significance and size, this is not true for the change, i.e. the modernisation of the public sector. This suggests that the issue of public-sector modernisation is one where the distinction of stocks and flows really matters.[43] A more thorough analysis of the dynamic properties of public-sector efficiency, based on a longer period of time, could investigate whether there is long-run equilibrium of public sector efficiency. The results in this study suggest that there is no tendency that countries with a less efficient public sector are improving faster. Hence, a convergence of public-sector efficiency cannot be expected.

[43] Note that this distinction is explicitly made in chapter 3.

	(8)	(9)	(10)
Variables:			
overall globalization index (1985, KOF)	0.003***	0.001	0.003***
	(0.001)	(0.002)	(0.001)
Perce. Gov. Share (pwt_cg)	0.004***	0.004*	0.004**
	(0.002)	(0.002)	(0.002)
Pop. Density		-0.034	-0.066***
		(0.029)	(0.013)
Herfindahl Index political fractionalisation		-0.088	
		(0.092)	
Unitarism index (Gerring-Thacker)		0.029***	0.024**
		(0.010)	(0.011)
Asia (dummy)		-0.047	
		(0.084)	
Australia (dummy)		0.130	
		(0.092)	
Caribbean (dummy)		0.111	
		(0.084)	
Europe (dummy)		0.077	
		(0.099)	
Latin America (dummy)		0.092	
		(0.077)	
North Africa (dummy)		0.144*	
		(0.078)	
North America (dummy)		0.133	
		(0.108)	
Constant	-0.082	-0.129	-0.185**
	(0.061)	(0.104)	(0.075)
sigma (St.E. of Estimate)	0.150***	0.133***	0.139***
	(0.017)	(0.020)	(0.018)
Observations	74	62	68
Pseudo Log-Likelihood	35.440	37.337	37.812
Wald Chi-Square	16.502	334.754	98.103

Notes: Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Truncated regressions, upper limit set to 1. Estimation with robust Standard-Errors.
Point estimates of coefficients and standard errors rounded to three digits.

Table 5.7: Regression results with environmental variables (dependent variable: change in bias-corrected DEA-score 1985-2000). Models (8)-(10).

5.6 Conclusions

This study explores empirically the efficiency of the public sector of a large set of countries. Furthermore, it uses a regression analysis to explain the pattern of public sector (in-)efficiency. The focus here is on the “small-is-beautiful”-result found in Afonso et al. [2005] and on globalisation as a proxy for the intensity of interjurisdictional competition between countries. The regression analysis shows that the level of public-sector efficiency can partly be explained by continent dummies, suggesting that common history and cultural background are important factors. Smaller governments in the sample systematically have more efficient public sectors, what can be seen as support of the “small-is-beatiful”-result. Furthermore, it cannot be said that smaller countries tend to be closer to the efficiency border. The bulk of countries that are close to the efficiency border achieve this with a public sector of medium size, compared to all countries in the sample. More globalised countries also tend to be more efficient, albeit the effect is, again, not very sizable. Hence this can be seen as only mild evidence that the intensity of interjurisdictional competition plays a crucial role in the determination of public sector efficiency. Furthermore, it could be shown that the more centralised countries in the sample are more efficient. The effect is again not very big. But overall, the efficiency scores calculated in this study do not show a pattern that would be consistent with the idea that public sector efficiency is better when the degree of interjurisdictional competition (either between countries, or, within countries, between local jurisdictions) is higher. Over time, public sector efficiency has improved on average in the full sample of 74 countries. While continent dummies played an important and sizable role in explaining the level of public sector efficiency, this is not true for the change between 1985 and 2000.

Even if the “small-is-beautiful”-effect could have been shown to be sizable and significant, it would not be clear whether the result was useful in terms of policy advice. One might be tempted to suggest that an inefficient public sector should be scaled down to improve efficiency. In the terminology of an DEA-analysis, the diagnosis would be that a public sector that is large and inefficient is not scale-efficient. But this study is not dealing with private firms, where an optimal firm size might exist. The size of the public sector cannot be optimised following standard optimisation rules that can be applied to private firms.[44] How much the public sector spends to produce public goods and services is a political decision. Still, given that a society somehow has decided to spend a particular amount of tax revenue for education, health care and other policy fields, it is an important information whether the achieved outcome is as high as possible, compared to the efficiency frontier.[45]

Stone [2002] formulates a harsh criticism of DEA and stochastic frontier analysis being applied to the efficiency of public services. Many of his recommendations apply to any empirical analysis, but his major point is that for the evaluation of public sector efficiency, one ideally would need to know how a society weights different goods and services. In this study, I chose to attach equal weights to policy fields − assuming that all policy fields are equally important in a social welfare function − and to all output measures − assuming that in the several policy fields, all societies weight the importance of a particular output similar. If efficiency scores for a particular country were to be criticised, the easiest defence would be to claim that the country, for example, defines its success in the area of health care not in terms of life expectancy at birth but tries to minimise the number of illnesses in a life span. It is not possible to account for this kind of criticism in a study like this that deals with a large variety of countries from all over the globe. Hence, the results for the countries should be interpreted with care. If a country is marked as a bad performer, or as inefficient, this is only a first indicator that the production of goods and services of the public sector is malfunctioning. See also Smith / Street [2005] for a discussion of the interplay of scientific studies of organisational efficiency and policy.

The best approach to gain an insight into the specifics of a particular country or a particular policy field seem to be studies that deal exclusively with the specific problems associated with, for example,

[44] Hence, statistical tests that try to infer the scale properties of a production process from the data in the context of an DEA- or FDH-analysis – see Banker [1996], Briec et al. [2000], Soleimani-damaneh et al. [2006] – are not used above. Instead, I assumed variable returns to scale to enclose the data as tightly as possible. Especially for a study like this one, where the production process under inspection is as complex as policy-making, the concept of returns to scale is in my view not applicable.

[45] In the sample used for this study, the governments with a relatively high government share of GDP could be asked why they do not perform as well as Switzerland in 2000, see Figure 5.6.

the educational system in Germany. The Atkinson Review [Atkinson 2005] surely provides more insight into the functioning of the public sector in Great Britain than any cross-country study of the type presented here can ever attain. But this does not mean that cross-country studies that compare the performance and efficiency of the public sector and are (necessarily) based on indicators chosen by the researcher are useless. They reveal common features and patterns in the operation of public sectors, for example in the case of this study, that globalisation seems to improve the efficiency of the input-usage of the public sector, but only mildly. An output-oriented efficiency measurement as it has been done in this study could be used to identify those countries that potentially can serve as a role model for others and that are similar in terms of the inputs that are used for the production of public goods and services. Overall, this study – and other that apply FDH- or DEA-methods to cross-country data – should be seen as an attempt to gain an oversight about the efficiency of public sectors that suggest where a more detailed analyis might be interesting.[46] It would be a crude misinterpretation to take the numbers presented here literally for the individual countries.[47] Even worse would be to base political decision solely on a study like this one.[48]

After having mentioned at several places the caveats of DEA-efficiency measurement in a cross-country context, a robustness check might be interesting. How well do the bias-corrected DEA efficiency scores show a similar picture than other attempts to evaluate the efficiency of the public sector? The Worldwide Governance Indicators (WGI) project, see Kaufmann et al. [2008], aggregates in its recent edition 340 variables from 35 different sources into common indicators. Figure 5.9 shows the relationship between their index for government effectiveness and the bias-corrected DEA efficiency scores for the year 2000. There is a positive correlation between both indices that seems to be strong enough to claim that the efficiency scores calculated in this study are surprisingly robust and reliable when compared with Kaufmann et al. [2008].

[46] That the specifics and details matter when it comes to policy advice is also acknowledged in the final report of the Commission on Growth and Development, see Commission on Growth and Development [2008] and Rodrik [2008].

[47] See Starck [2007] for an example of a politicians that could not resist. He argues that the public sector should not exceed the size of 35% and could still attain core objectives. This number is based on a rough calculation of a possible government share of a hypothetical country, that is a "best performer" and at the same time a "low spender" in each of several policy fields including education, infrastructure investment and redistribution. See also Heipertz [2007].

[48] In the words of one of the commentators to Stone [2002]: Reports that contain efficiency indices similar to those calculated in this study, should not "hide political values behind a technical smoke-screen" [Stone 2002, p. 423].

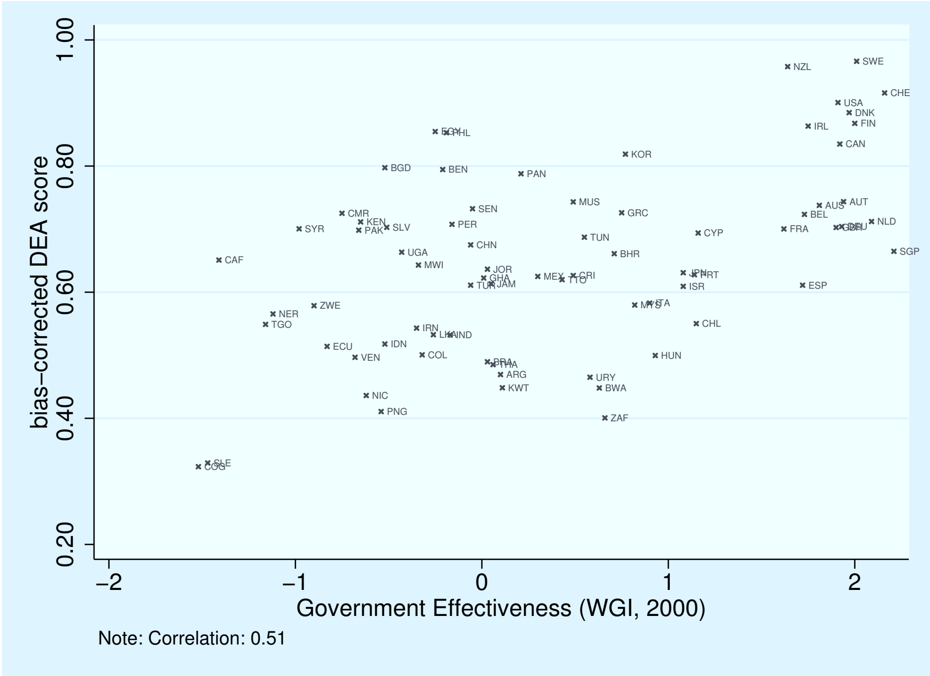


Figure 5.9: Bias-corrected DEA efficiency scores and the government effectiveness as rated in Kaufmann et al. [2008] for the year 2000.

I hope the study demonstrates that one way to proceed in further research about the relationship between public-sector efficiency is to apply DEA-methods. In particular, it seems to be reasonable and also possible to construct a panel-dataset that contains a broad range of countries and covers a longer time spam than the one used in this study.[49] For example, the international data on educational attainment by Barro / Lee [2001] covers the years 1960-2000. A longer time-span would allow to assess the dynamics of public-sector efficiency empirically.[50]

[49] Another reason to pin hopes on DEA- and, to a lesser extent, FDH-methods of efficiency analysis is that the methodology will be developed further in the near future, see the review of the recent literature in section 5.2 or the textbook by Cooper et al. [2007] that provides a comprehensive exposition of the state of the art in DEA.

[50] The approach could then be similar to the one in Büttner / Wildasin [2006]. They analyse the dynamics of fiscal adjustments in a large sample of municipalities in the United States.

Appendix

The dataset (as far as licensing issues can be resolved), the "do-files" for use with Stata (and R) are available on request. The do-files start with reading in the original data, to avoid unrecoverable mistakes that happen when data is edited "by hand" in a spreadsheet program. Hence, the documentation of the data-cleaning is also available on request. See also my website, www.wiwi.uni-rostock.de/~wsf8545/. It contains a few scripts and other "tricks" to use Stata and LaTeX efficiently.

List of countries

Table A8: List of countries in the dataset. The last column indicates whether a country is included in the FDH study or not.

countrycode	countryname	DEA/FDH?
ARG	Argentina	DEA
AUS	Australia	DEA FDH
AUT	Austria	DEA FDH
BEL	Belgium	DEA
BEN	Benin	DEA FDH
BGD	Bangladesh	DEA
BHR	Bahrain	DEA FDH
BOL	Bolivia	FDH
BRA	Brazil	DEA FDH
BRB	Barbados	FDH
BWA	Botswana	DEA
CAF	Central African Republic	DEA
CAN	Canada	DEA FDH
CHE	Switzerland	DEA FDH
CHL	Chile	DEA FDH
CHN	China	DEA
CMR	Cameroon	DEA FDH
COG	Congo. Rep.	DEA FDH
COL	Colombia	DEA FDH
CRI	Costa Rica	DEA FDH
CYP	Cyprus	DEA FDH
DEU	Germany	DEA FDH
DNK	Denmark	DEA FDH
DOM	Dominican Republic	FDH
ECU	Ecuador	DEA
EGY	Egypt. Arab Rep.	DEA FDH
ESP	Spain	DEA
FIN	Finland	DEA FDH
FRA	France	DEA FDH
GBR	United Kingdom	DEA FDH
GHA	Ghana	DEA
GRC	Greece	DEA
HND	Honduras	FDH
HUN	Hungary	DEA FDH
IDN	Indonesia	DEA FDH
IND	India	DEA
IRL	Ireland	DEA FDH
IRN	Iran. Islamic Rep.	DEA FDH
ISR	Israel	DEA FDH

(continued on next page)

Table A8: List of countries in the dataset – continued

countrycode	countryname	DEA/FDH?
ITA	Italy	DEA
JAM	Jamaica	DEA FDH
JOR	Jordan	DEA
JPN	Japan	DEA
KEN	Kenya	DEA
KOR	Korea. Rep.	DEA FDH
KWT	Kuwait	DEA FDH
LKA	Sri Lanka	DEA FDH
MEX	Mexico	DEA
MUS	Mauritius	DEA
MWI	Malawi	DEA
MYS	Malaysia	DEA
NER	Niger	DEA
NIC	Nicaragua	DEA
NLD	Netherlands	DEA
NZL	New Zealand	DEA
PAK	Pakistan	DEA
PAN	Panama	DEA
PER	Peru	DEA
PHL	Philippines	DEA
PNG	Papua New Guinea	DEA
PRT	Portugal	DEA
SEN	Senegal	DEA
SGP	Singapore	DEA
SLE	Sierra Leone	DEA
SLV	El Salvador	DEA
SWE	Sweden	DEA
SYR	Syrian Arab Republic	DEA
TGO	Togo	DEA
THA	Thailand	DEA
TTO	Trinidad and Tobago	DEA
TUN	Tunisia	DEA
TUR	Turkey	DEA
UGA	Uganda	DEA
URY	Uruguay	DEA
USA	United States	DEA
VEN	Venezuela. RB	DEA
ZAF	South Africa	DEA
ZWE	Zimbabwe	DEA

(end of table)

Codebooks and description of variables

Table A9: Codebook for the FDH-Analysis

Variable	obs	mean	sd	min	max	label
year	32	1990.0	0.0	1990.0	1990.0	Year
countrycode	32	.	.	.	.	Country Code
countryname	32	.	.	.	.	Country Name
country_id	32	58.8	30.1	13.0	115.0	ID number of country
airtrans_rcdw	32	114006.3	163737.9	500.0	670700.0	Air transport, registered carrier departures worldwide
airtrans_rcdw_rel	32	7.0	7.1	0.1	22.6	Air transport, registered carrier departures worldwide per 1000 people
balee_lsc15	32	14.3	11.0	1.7	44.7	percentage of secondary school complete in the total pop. (adults of age 15+)
balee_lu	32	20.8	22.6	0.0	78.5	percentage of no schooling in the total population (adults of age 25+)
efw_area2	32	5.7	2.0	2.2	8.3	Area 2: Legal Structure and Security of Property Rights (EFW Index)
efw_area3	32	7.0	2.4	0.0	9.7	Area 3: Access to Sound Money (EFW Index)
efw_area5	32	5.5	0.9	3.5	6.8	Area 5: Regulation of Credit, Labor, and Business (EFW Index)
exp_gov_pwt_pc_real	32	237651.9	194768.8	12875.0	766907.0	Real government expenditure per capita (PWT)
exp_gov_pwt_pc_real_ma	32	223149.5	176284.3	9828.4	720072.8	Moving Average of exp_gov_pwt_pc_real
exp_imf_4	32	0.1	0.1	0.0	0.5	Expenditure: Education affairs and services (in percent of GDP)
exp_imf_4_real	32	751.6	1761.4	39.7	8869.4	real expenditure (based on exp_imf_4)
exp_imf_4_real_ma	32	661.7	1572.3	34.9	8034.7	Moving Average of exp_imf_4_real
exp_imf_5	32	0.1	0.1	-0.0	0.7	Expenditure: Health affairs and services (in percent of GDP)
exp_imf_5_real	32	976.0	2531.1	-16.5	12324.4	real expenditure (based on exp_imf_5)
exp_imf_5_real_ma	32	842.4	2195.3	-10.2	10736.1	Moving Average of exp_imf_5_real

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Table A9: Codebook for the FDH-Analysis – continued

Variable	obs	mean	sd	min	max	label
exp_imf_econ1	32	0.2	0.2	0.0	1.3	Expenditure: Expenditure on goods and services (in percent of GDP)
exp_imf_econ1_real	32	2249.2	4650.1	100.5	24099.5	real expenditure (based on exp_imf_econ1)
exp_imf_econ1_real_ma	32	2012.3	4189.2	90.2	21765.3	Moving Average of exp_imf_econ1_real
exp_imf_econI	32	0.6	1.0	0.1	5.2	Expenditure: Total expenditure and lending minus repayments (II+V) (in percent o
exp_imf_econIV	32	0.1	0.1	0.0	0.4	Expenditure: Capital expenditure (in percent of GDP)
exp_imf_econIV_real	32	689.2	1524.4	39.7	8329.7	real expenditure (based on exp_imf_econIV)
exp_imf_econIV_real_ma	32	634.9	1359.9	34.6	7414.1	Moving Average of exp_imf_econIV_real
exp_imf_econI_real	32	8181.6	19049.3	301.9	98281.2	real expenditure (based on exp_imf_econI)
exp_imf_econI_real_ma	32	7293.5	16760.8	280.3	86365.6	Moving Average of exp_imf_econI_real
gdp_curr_LCU	32	1.5e+13	4.9e+13	1.2e+07	2.1e+14	GDP (current LCU)
gdp_var	32	0.1	0.0	0.0	0.2	stability of real GDP per capita (coefficient of variation)
health_exp_private	32	.	.	.	.	Health expenditure, private (% of GDP)
health_exp_public	32	.	.	.	.	Health expenditure, public (% of GDP)
health_priv	32	0.9	0.7	0.2	2.9	Reliance on private vs. public expenditure in health care (2000)
inf_gdpdefl	32	92.3	448.7	-1.0	2509.5	Inflation, GDP deflator (annual %)
inf_gdpdefl_ma	32	11.9	13.0	1.5	59.2	Inflation (moving average)
inf_var	32	1.2	2.7	0.1	14.8	stability of price level (coefficient of variation)
kof_index	32	51.8	19.8	22.6	84.6	overall globalization index (KOF Index)
kof_index_a	32	54.8	18.4	16.6	87.0	economic globalization (KOF index)
kof_index_ai	32	55.4	16.6	7.9	88.8	actual flows (KOF index)
kof_index_aii	32	51.4	22.9	17.6	85.2	restrictions (KOF index)

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Table A9: Codebook for the FDH-Analysis – continued

Variable	**obs**	**mean**	**sd**	**min**	**max**	**label**
kof_index_bii	32	51.4	25.0	7.3	90.7	information flows (KOF index)
landarea	32	1116968.1	2437883.2	430.0	9093510.0	Land area (sq. km)
life_exp	32	70.2	7.1	53.2	77.4	Life expectancy at birth, total (years)
pn_Gerring	32	3.8	1.5	1.0	5.0	Unitarism index (Gerring-Thacker)
pn_herftot	32	0.5	0.3	0.2	1.0	Herfindahl Index political fractionalisation
pwt_cg	32	20.8	8.5	8.3	48.2	Government Share of CGDP (percent in Current Prices)
pwt_cgdp	32	9594.7	6747.9	839.0	22772.1	Real Gross Domestic Product per Capita (Int-Dollar in Current Prices)
pwt_cgdp_ma	32	8587.3	6023.7	853.1	20284.1	Moving Average of pwt_cgdp
pwt_grgdpch	32	1.3	6.9	-26.8	11.1	growth rate of Real GDP per capita (Constant Prices: Chain series) (percent in 2
pwt_grgdpch_ma	32	1.9	2.9	-5.2	9.4	Moving Average of pwt_grgdpch
pwt_kg	32	20.4	8.0	8.1	44.6	Government Share of RGDPL (percent in 2000 Constant Prices)
pwt_pop	32	27688.7	43236.4	262.6	188005.4	Population (thousands)
pwt_rgdpch	32	11508.3	8065.9	1086.5	27515.3	Real GDP per capita (Constant Prices: Chain series) (IntD in 2000 Constant Price
region	32	.	.	.	.	Geographic Region
region_antarc	32	0.0	0.0	0.0	0.0	Antarctica dummy
region_asia	32	0.3	0.4	0.0	1.0	Asia dummy
region_aus	32	0.0	0.2	0.0	1.0	Australia dummy
region_carib	32	0.1	0.3	0.0	1.0	Caribbean dummy
region_europe	32	0.3	0.5	0.0	1.0	Europe dummy
region_latinam	32	0.2	0.4	0.0	1.0	Latin America dummy
region_northafr	32	0.0	0.2	0.0	1.0	North Africa dummy
region_northam	32	0.0	0.2	0.0	1.0	North America dummy
region_paci	32	0.0	0.0	0.0	0.0	Pacific dummy
region_subsahafr	32	0.1	0.3	0.0	1.0	Sub Saharan Africa dummy

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Table A9: Codebook for the FDH-Analysis – continued

Variable	obs	mean	sd	min	max	label
tel_mainl	32	220.6	207.6	2.8	587.4	Telephone mainlines (per 1,000 people)
wb_class_eap	32	0.1	0.2	0.0	1.0	East Asia + Pacific (World Bank Classification, April 2008)
wb_class_eca	32	0.0	0.0	0.0	0.0	Europe + Central Asia (World Bank Classification, April 2008)
wb_class_emu	32	0.2	0.4	0.0	1.0	Euro area (World Bank Classification, April 2008)
wb_class_hic	32	0.0	0.0	0.0	0.0	High income (World Bank Classification, April 2008)
wb_class_hpc	32	0.1	0.3	0.0	1.0	Heavily indebted poor countries (HIPC) (World Bank Classification, April 2008)
wb_class_lac	32	0.3	0.4	0.0	1.0	Latin America + Caribbean (World Bank Classification, April 2008)
wb_class_ldc	32	0.0	0.0	0.0	0.0	Least developed countries (UN classification)
wb_class_lic	32	0.0	0.2	0.0	1.0	Low income (World Bank Classification, April 2008)
wb_class_lmc	32	0.3	0.5	0.0	1.0	Lower middle income (World Bank Classification, April 2008)
wb_class_mna	32	0.1	0.2	0.0	1.0	Middle East + North Africa (World Bank Classification, April 2008)
wb_class_noc	32	0.2	0.4	0.0	1.0	High income: nonOECD (World Bank Classification, April 2008)
wb_class_oec	32	0.3	0.5	0.0	1.0	High income: OECD (World Bank Classification, April 2008)
wb_class_sas	32	0.0	0.2	0.0	1.0	South Asia (World Bank Classification, April 2008)
wb_class_ssa	32	0.1	0.3	0.0	1.0	Sub-Saharan Africa (World Bank Classification, April 2008)
wb_class_umc	32	0.2	0.4	0.0	1.0	Upper middle income (World Bank Classification, April 2008)
wgi_goveff	32	.	.	.	.	Government Effectiveness (WGI, 2000)

(end of table)

Table A10: Codebook for the DEA-Analysis. Years: 1985, 1990, 1995, 2000. Number of Countries: 74.

Variable	obs	mean	sd	min	max	label
year	296	1992.5	5.6	1985.0	2000.0	Year
countrycode	296	.	.	.	.	Country Code
countryname	296	.	.	.	.	Country Name
country_id	296	37.5	21.4	1.0	74.0	ID number of country
airtrans_rcdw	296	203974.1	850077.8	200.0	8820878.0	Air transport, registered carrier departures worldwide
airtrans_rcdw_rel	296	6.8	8.9	0.0	62.9	Air transport, registered carrier departures worldwide per 1000 people
balee_lsc15	296	11.1	9.2	0.2	44.9	percentage of secondary school complete in the total pop. (adults of age 15+)
balee_lu	296	26.4	24.3	0.0	90.6	percentage of no schooling in the total population (adults of age 25+)
efw_area2	296	5.8	1.9	2.0	9.6	Area 2: Legal Structure and Security of Property Rights (EFW Index)
efw_area3	296	7.0	2.4	0.0	9.8	Area 3: Access to Sound Money (EFW Index)
efw_area5	296	5.6	1.1	2.7	8.8	Area 5: Regulation of Credit, Labor, and Business (EFW Index)
exp_gov_pwt_pc_real	296	187186.2	159819.2	2806.9	766907.0	Real government expenditure per capita (PWT)
exp_gov_pwt_pc_real_ma	296	184224.5	159543.7	6450.8	849452.9	Moving Average of exp_gov_pwt_pc_real
gdp_curr_LCU	296	4.7e+14	7.3e+15	23.1	1.2e+17	GDP (current LCU)
gdp_var	296	0.1	0.0	0.0	0.3	stability of real GDP per capita (coefficient of variation)
health_exp_private	296	2.7	1.2	0.6	7.4	Health expenditure, private (% of GDP)
health_exp_public	296	3.5	2.0	0.5	8.2	Health expenditure, public (% of GDP)
health_priv	296	1.1	0.8	0.2	3.8	Reliance on private vs. public expenditure in health care (2000)
inf_gdpdefl	296	72.0	527.1	-7.0	6836.9	Inflation, GDP deflator (annual %)

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Table A10: Codebook for the DEA-Analysis – continued

Variable	**obs**	**mean**	**sd**	**min**	**max**	**label**
inf_gdpdefl_ma	296	12.2	15.6	1.5	59.2	Inflation (moving average)
inf_var	296	0.0	11.8	-140.7	20.3	stability of price level (coefficient of variation)
kof_index	296	51.2	19.3	12.3	93.6	overall globalization index (KOF Index)
kof_index_a	296	54.7	20.4	7.8	96.5	economic globalization (KOF index)
kof_index_ai	296	55.4	21.3	5.5	98.5	actual flows (KOF index)
kof_index_aii	296	53.6	23.5	9.1	97.1	restrictions (KOF index)
kof_index_bii	296	51.5	24.5	3.3	96.6	information flows (KOF index)
landarea	296	1009653.2	2172284.4	670.0	9326410.0	Land area (sq. km)
life_exp	296	67.8	9.6	39.0	81.1	Life expectancy at birth, total (years)
pn_Gerring	296	4.0	1.4	1.0	5.0	Unitarism index (Gerring-Thacker)
pn_herftot	296	0.5	0.3	0.0	1.0	Herfindahl Index political fractionalisation
pwt_cg	296	20.1	8.4	3.0	56.7	Government Share of CGDP (percent in Current Prices)
pwt_cgdp	296	8781.4	7801.5	531.7	34364.5	Real Gross Domestic Product per Capita (Int-Dollar in Current Prices)
pwt_cgdp_ma	296	8005.8	7083.2	503.4	31361.3	Moving Average of pwt_cgdp
pwt_grgdpch	296	2.0	4.8	-26.8	22.0	growth rate of Real GDP per capita (Constant Prices: Chain series) (percent in 2
pwt_grgdpch_ma	296	1.6	3.0	-7.6	13.8	Moving Average of pwt_grgdpch
pwt_kg	296	20.4	8.7	3.0	56.7	Government Share of RGDPL (percent in 2000 Constant Prices)
pwt_pop	296	58110.2	170124.9	424.0	1262474.3	Population (thousands)
pwt_rgdpch	296	9962.1	8437.2	680.0	34364.5	Real GDP per capita (Constant Prices: Chain series) (IntD in 2000 Constant Price
region	296	.	.	.	.	Geographic Region
region_antarc	296	0.0	0.0	0.0	0.0	Antarctica dummy
region_asia	296	0.3	0.4	0.0	1.0	Asia dummy

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Table A10: Codebook for the DEA-Analysis – continued

Variable	obs	mean	sd	min	max	label
region_aus	296	0.0	0.2	0.0	1.0	Australia dummy
region_carib	296	0.0	0.2	0.0	1.0	Caribbean dummy
region_europe	296	0.2	0.4	0.0	1.0	Europe dummy
region_latinam	296	0.2	0.4	0.0	1.0	Latin America dummy
region_northafr	296	0.0	0.2	0.0	1.0	North Africa dummy
region_northam	296	0.0	0.2	0.0	1.0	North America dummy
region_paci	296	0.0	0.1	0.0	1.0	Pacific dummy
region_subsahafr	296	0.2	0.4	0.0	1.0	Sub Saharan Africa dummy
tel_mainl	296	192.8	209.4	1.0	758.6	Telephone mainlines (per 1,000 people)
wb_class_eap	296	0.1	0.3	0.0	1.0	East Asia + Pacific (World Bank Classification, April 2008)
wb_class_eca	296	0.0	0.1	0.0	1.0	Europe + Central Asia (World Bank Classification, April 2008)
wb_class_emu	296	0.2	0.4	0.0	1.0	Euro area (World Bank Classification, April 2008)
wb_class_hic	296	0.0	0.0	0.0	0.0	High income (World Bank Classification, April 2008)
wb_class_hpc	296	0.2	0.4	0.0	1.0	Heavily indebted poor countries (HIPC) (World Bank Classification, April 2008)
wb_class_lac	296	0.2	0.4	0.0	1.0	Latin America + Caribbean (World Bank Classification, April 2008)
wb_class_ldc	296	0.0	0.0	0.0	0.0	Least developed countries (UN classification)
wb_class_lic	296	0.2	0.4	0.0	1.0	Low income (World Bank Classification, April 2008)
wb_class_lmc	296	0.2	0.4	0.0	1.0	Lower middle income (World Bank Classification, April 2008)
wb_class_mna	296	0.1	0.3	0.0	1.0	Middle East + North Africa (World Bank Classification, April 2008)
wb_class_noc	296	0.1	0.3	0.0	1.0	High income: nonOECD (World Bank Classification, April 2008)
wb_class_oec	296	0.3	0.4	0.0	1.0	High income: OECD (World Bank Classification, April 2008)

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Table A10: Codebook for the DEA-Analysis – continued

Variable	obs	mean	sd	min	max	label
wb_class_sas	296	0.1	0.2	0.0	1.0	South Asia (World Bank Classification, April 2008)
wb_class_ssa	296	0.2	0.4	0.0	1.0	Sub-Saharan Africa (World Bank Classification, April 2008)
wb_class_umc	296	0.2	0.4	0.0	1.0	Upper middle income (World Bank Classification, April 2008)
wgi_goveff	296	0.4	1.0	-1.5	2.2	Government Effectiveness (WGI, 2000)

(end of table)

Table A11: Description of variables

variable / label / source	description
year: Year *Source:* -	-
countrycode: Country Code *Source:* -	Countrycodes follow WDI [2007]
countryname: Country Name *Source:* -	The full names of countries follow WDI [2007].
country_id: ID number of country *Source:* -	-
airtrans_rcdw: Air transport, registered carrier departures worldwide *Source:* WDI [2007]	Registered carrier departures worldwide are domestic takeoffs and takeoffs abroad of air carriers registered in the country. Source: International Civil Aviation Organization, Civil Aviation Statistics of the World and ICAO staff estimates.
airtrans_rcdw_rel: Air transport, registered carrier departures worldwide per 1000 people *Source:* own calculations	calculated as airtrans_rcdw/pwt_pop
balee_lsc15: percentage of secondary school complete in the total pop. (adults of age 15+) *Source:* Barro / Lee [2001]	For a detailed description, see Barro / Lee [2001] and Barro / Lee [1993, 1996].
balee_lu: percentage of no schooling in the total population (adults of age 25+) *Source:* Barro / Lee [2001]	For a detailed description, see Barro / Lee [2001] and Barro / Lee [1993, 1996].
efw_area2: Area 2: Legal Structure and Security of Property Rights (EFW Index) *Source:* Gwartney / Lawson [2007]	EFW Index - Area 2: Legal Structure and Security of Property Rights. Computed from subindices efw_area2a - efw_area2g.
efw_area3: Area 3: Access to Sound Money (EFW Index) *Source:* Gwartney / Lawson [2007]	EFW Index - Area 3: Access to Sound Money. Computed from subindices efw_area3a - efw_area3d.

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Table A11: Description of variables – continued

variable / label / source	description
efw_area5: Area 5: Regulation of Credit, Labor, and Business (EFW Index) *Source:* Gwartney / Lawson [2007]	EFW Index - Area 5: Regulation of Credit, Labor, and Business. Computed from subindices efw_area5a - efw_area5c.
exp_gov_pwt_pc_real: Real government expenditure per capita (PWT) *Source:* own calculations, based on PWT data	Real government expenditure per capita (PWT) (Current Prices). Calculated as pwt_rgdpl · pwt_kg.
exp_gov_pwt_pc_real_ma: Moving Average of exp_gov_pwt_pc_real *Source:* own calculations	Moving Average of exp_gov_pwt_pc_real (Mean of current year and the four preceding years)
exp_imf_4: Expenditure: Education affairs and services (in percent of GDP) *Source:* IMF [2006]	Expenditure on education affairs and services (pre-primary and primary education affairs and services, secondary education affairs and services, tertiary education affairs and services, education services not definable by level, subsidiary services to education, education affairs and services not elsewhere classified). All Data has been converted from nominal expenditure in national currency to percentage of GDP using data on the nominal GDP from the World Development Indicators (gdp_curr_LCU). Zero values have been set to missing. The historical series uses the GFSM 1986 classification, see IMF [1986, p. 153-155].
exp_imf_4_real: real expenditure (based on exp_imf_4) *Source:* own calculations	Real expenditure per capita, based on exp_imf_4 (exp_imf_4 · pwt_cgdp)
exp_imf_4_real_ma: Moving Average of exp_imf_4_real *Source:* own calculations	Moving Average of exp_imf_4_real (Mean of current year and the four preceding years)
exp_imf_5: Expenditure: Health affairs and services (in percent of GDP) *Source:* IMF [2006]	Expenditure on health affairs and services (hospital affairs and services, clinics, and medical, dental, and paramedical practitioners, public health affairs and services, medicaments, prostheses, medical equipment, and appliances or other prescribed health-related products, applied research and experimental development related to the health and medical delivery system, health affairs and services not elsewhere classified). All Data has been converted from nominal expenditure in national currency to percentage of GDP using data on the nominal GDP from the World Development Indicators (gdp_curr_LCU). Zero values have been set to missing. The historical series uses the GFSM 1986 classification, see IMF [1986, p. 156-158].
exp_imf_5_real: real expenditure (based on exp_imf_5) *Source:* own calculations	Real expenditure per capita, based on exp_imf_5 (exp_imf_5 · pwt_cgdp)

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Table A11: Description of variables – continued

variable / label / source	description
exp_imf_5_real_ma: Moving Average of exp_imf_5_real *Source:* own calculations	Moving Average of exp_imf_5_real (Mean of current year and the four preceding years)
exp_imf_econ1: Expenditure: Expenditure on goods and services (in percent of GDP) *Source:* IMF [2006]	Expenditure on goods and services. This includes all government payments in exchange for goods and services, whether in the form of wages and salaries to employees, employer contributions to employee benefit schemes outside this level of government in compensation for employee services, or other purchases of goods and services. All Data has been converted from nominal expenditure in national currency to percentage of GDP using data on the nominal GDP from the World Development Indicators (gdp_curr_LCU). Zero values have been set to missing. The historical series uses the GFSM 1986 classification, see IMF [1986, p. 177].
exp_imf_econ1_real: real expenditure (based on exp_imf_econ1) *Source:* own calculations	Real expenditure per capita, based on exp_imf_econ1 (exp_imf_econ1 · pwt_cgdp)
exp_imf_econ1_real_ma: Moving Average of exp_imf_econ1_real *Source:* own calculations	Moving Average of exp_imf_econ1_real (Mean of current year and the four preceding years)
exp_imf_econI: Expenditure: Total expenditure and lending minus repayments (II+V) (in percent o *Source:* IMF [2006]	Total expenditure and lending minus repayments (total expenditure and capital expenditure). All Data has been converted from nominal expenditure in national currency to percentage of GDP using data on the nominal GDP from the World Development Indicators (gdp_curr_LCU). Zero values have been set to missing. The historical series uses the GFSM 1986 classification, see IMF [1986, p. 177].
exp_imf_econIV: Expenditure: Capital expenditure (in percent of GDP) *Source:* IMF [2006]	Capital expenditures. Capital expenditures are payments for the acquisition of fixed capital assets, strategic or emergency stocks, land, or intangible assets, or unrequited payments for the purpose of permitting the recipients to acquire such assets, compensating the recipients for damage or destruction of capital assets, or increasing the financial capital of the recipients. All Data has been converted from nominal expenditure in national currency to percentage of GDP using data on the nominal GDP from the World Development Indicators (gdp_curr_LCU). Zero values have been set to missing. The historical series uses the GFSM 1986 classification, see IMF [1986, p. 182].
exp_imf_econIV_real: real expenditure (based on exp_imf_econIV) *Source:* own calculations	Real expenditure per capita, based on exp_imf_econIV (exp_imf_econIV · pwt_cgdp)
exp_imf_econIV_real_ma: Moving Average of exp_imf_econIV_real *Source:* own calculations	Moving Average of exp_imf_econIV_real (Mean of current year and the four preceding years)

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Table A11: Description of variables – continued

variable / label / source	description
exp_imf_econI_real: real expenditure (based on exp_imf_econI) *Source:* own calculations	Real expenditure per capita, based on exp_imf_econI (exp_imf_econI · pwt_cgdp)
exp_imf_econI_real_ma: Moving Average of exp_imf_econI_real *Source:* own calculations	Moving Average of exp_imf_econI_real (Mean of current year and the four preceding years)
gdp_curr_LCU: GDP (current LCU) *Source:* WDI [2007]	GDP (current LCU). GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current local currency.
gdp_var: stability of real GDP per capita (coefficient of variation) *Source:* own calculations, Heston et al. [2006]	Own calculations, based on pwt_rgdpch. A coefficient of variation is calculated for the current year and two years in the past and in the future.
health_exp_private: Health expenditure, private (% of GDP) *Source:* WDI [2007]	Private health expenditure includes direct household (out-of-pocket) spending, private insurance, charitable donations, and direct service payments by private corporations. Source: World Health Organization, World Health Report and updates and from the OECD for its member countries, supplemented by World Bank poverty assessments and country and sector studies, and household surveys conducted by governments or by statistical or international organizations.
health_exp_public: Health expenditure, public (% of GDP) *Source:* WDI [2007]	Public health expenditure consists of recurrent and capital spending from government (central and local) budgets, external borrowings and grants (including donations from international agencies and nongovernmental organizations), and social (or compulsory) health insurance funds. Source: World Health Organization, World Health Report and updates and from the OECD for its member countries, supplemented by World Bank poverty assessments and country and sector studies.
health_priv: Reliance on private vs. public expenditure in health care (2000) *Source:* own calculations, WDI [2007]	Reliance on private vs. public expenditure in health care in the year 2000. Calculated as health_exp_private / health_exp_public. High values indicates that private health care spending is important. If health_priv is equal to one, health care expenditure is equally private and public.
inf_gdpdefl: Inflation, GDP deflator (annual %) *Source:* WDI [2007]	Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency. Source: World Bank national accounts data, and OECD National Accounts data files.

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Table A11: Description of variables – continued

variable / label / source	description
inf_gdpdefl_ma: Inflation (moving average) *Source:* own calculations, Heston et al. [2006].	Own calculations, based on inf_gdpdefl. Moving Average, current year and two years in the past and in the future. To account for hyperinflation, values higher than the 90% percentile (59.23400115966797) have been replaced by the the 90% percentile. On the lower end, the data has been truncated at the 10% percentile.
inf_var: stability of price level (coefficient of variation) *Source:* own calculations, Heston et al. [2006]	Own calculations, based on inf_gdpdefl. A coefficient of variation is calculated for the current year and two years in the past and in the future.
kof_index: overall globalization index (KOF Index) *Source:* Dreher [2006], Dreher et al. [2008]	Index of globalization, compiled from subindices of economic, social and political globalization. See Dreher [2006], Dreher et al. [2008] for the weights used and other details.
kof_index_a: economic globalization (KOF index) *Source:* Dreher [2006], Dreher et al. [2008]	Index of economic globalization, compiled from data on actual flows (trade, foreign direct investment, portfolio investment, Income Payments to Foreign Nationals) and restrictions (Hidden Import Barriers, Mean Tariff Rate, Taxes on International Trade, Capital Account Restrictions). See Dreher [2006], Dreher et al. [2008] for the weights used and other details.
kof_index_ai: actual flows (KOF index) *Source:* Dreher [2006], Dreher et al. [2008]	Index of economic globalization (actual flows), compiled from data on trade, foreign direct investment, portfolio investment, Income Payments to Foreign Nationals. See Dreher [2006], Dreher et al. [2008] for the weights used and other details.
kof_index_aii: restrictions (KOF index) *Source:* Dreher [2006], Dreher et al. [2008]	Index of economic globalization (restrictions), compiled from data on Hidden Import Barriers, Mean Tariff Rate, Taxes on International Trade, Capital Account Restrictions. See Dreher [2006], Dreher et al. [2008] for the weights used and other details.
kof_index_bii: information flows (KOF index) *Source:* Dreher [2006], Dreher et al. [2008]	Index of social globalization (information flows), compiled from data on Internet Users, Cable Television, Trade in Newspapers, Radios. See Dreher [2006], Dreher et al. [2008] for the weights used and other details.
landarea: Land area (sq. km) *Source:* WDI [2007]	Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes. Source: Food and Agriculture Organization, Production Yearbook and data files.
life_exp: Life expectancy at birth, total (years) *Source:*	Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life. Source: World Bank staff estimates from various sources including census reports, the United Nations Population Division's World Population Prospects, national statistical offices, household surveys conducted by national agencies, and Macro International.

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Table A11: Description of variables – continued

variable / label / source	description
pn_Gerring: Unitarism index (Gerring-Thacker) *Source:* Norris [2008]	Data taken from dataset that accompanies Norris [2008]. The actual data is from Gerring / Thacker [2004]. The index measures the degree of centralization on a scale of 1 to 5. Examples of very federalised countries with a value of 1 are Switzerland and Germany.
pn_herftot: Herfindahl Index political fractionalisation *Source:* Norris [2008]	Data taken from dataset that accompanies Norris [2008]. The actual data is from Beck et al. [2001]. pn_herftot is the sum of the squared seat shares of all parties. Equals NA (missing) if there is no parliament or if there are no parties in the legislature and blank if any government or opposition party seats are blank. Higher values indicate that the political concentration is less.
pwt_cg: Government Share of CGDP (percent in Current Prices) *Source:* Heston et al. [2006]	See Data Appendix and Technical Documentation of Heston et al. [2006].
pwt_cgdp: Real Gross Domestic Product per Capita (IntDollar in Current Prices) *Source:* Heston et al. [2006]	See Data Appendix and Technical Documentation of Heston et al. [2006].
pwt_cgdp_ma: Moving Average of pwt_cgdp *Source:* own calculations	Moving Average of pwt_cgdp (Mean of current year and the four preceding years)
pwt_grgdpch: growth rate of Real GDP per capita (Constant Prices: Chain series) (percent in 2 *Source:* Heston et al. [2006]	See Data Appendix and Technical Documentation of Heston et al. [2006].
pwt_grgdpch_ma: Moving Average of pwt_grgdpch *Source:* own calculations	Moving Average of pwt_grgdpch, current year and the four preceding years.
pwt_kg: Government Share of RGDPL (percent in 2000 Constant Prices) *Source:* Heston et al. [2006]	See Data Appendix and Technical Documentation of Heston et al. [2006].
pwt_pop: Population (thousands) *Source:* Heston et al. [2006]	See Data Appendix and Technical Documentation of Heston et al. [2006].
pwt_rgdpch: Real GDP per capita (Constant Prices: Chain series) (IntD in 2000 Constant Price *Source:* Heston et al. [2006]	See Data Appendix and Technical Documentation of Heston et al. [2006].
region: Geographic Region *Source:* Information from this variable has been converted into 0,1-variables region_XYZ.	International Potato Center [2002]
region_antarc: Antarctica dummy *Source:* International Potato Center [2002]	See `region`

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Table A11: Description of variables – continued

variable / label / source	description
region_asia: Asia dummy *Source:* International Potato Center [2002]	See region
region_aus: Australia dummy *Source:* International Potato Center [2002]	See region
region_carib: Caribbean dummy *Source:* International Potato Center [2002]	See region
region_europe: Europe dummy *Source:* International Potato Center [2002]	See region
region_latinam: Latin America dummy *Source:* International Potato Center [2002]	See region
region_northafr: North Africa dummy *Source:* International Potato Center [2002]	See region
region_northam: North America dummy *Source:* International Potato Center [2002]	See region
region_paci: Pacific dummy *Source:* International Potato Center [2002]	See region
region_subsahafr: Sub Saharan Africa dummy *Source:* International Potato Center [2002]	See region
tel_mainl: Telephone mainlines (per 1,000 people) *Source:* WDI [2007]	Telephone mainlines are fixed telephone lines connecting a subscriber to the telephone exchange equipment. Source: International Telecommunication Union, World Telecommunication Development Report and database, and World Bank estimates. Footnote: Please cite the International Telecommunication Union for third-party use of these data.
wb_class_eap: East Asia + Pacific (World Bank Classification, April 2008) *Source:* World Bank [2008]	East Asia + Pacific according to the World Bank Classification from April 2008.
wb_class_eca: Europe + Central Asia (World Bank Classification, April 2008) *Source:* World Bank [2008]	Europe + Central Asia according to the World Bank Classification from April 2008.
wb_class_emu: Euro area (World Bank Classification, April 2008) *Source:* World Bank [2008]	Euro area according to the World Bank Classification from April 2008.

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Table A11: Description of variables – continued

variable / label / source	description
wb__class__hic: High income (World Bank Classification, April 2008) *Source:* World Bank [2008]	High income according to the World Bank Classification from April 2008.
wb__class__hpc: Heavily indebted poor countries (HIPC) (World Bank Classification, April 2008) *Source:* World Bank [2008]	Heavily indebted poor countries (HIPC) according to the World Bank Classification from April 2008.
wb__class__lac: Latin America + Caribbean (World Bank Classification, April 2008) *Source:* World Bank [2008]	Latin America + Caribbean according to the World Bank Classification from April 2008.
wb__class__ldc: Least developed countries (UN classification) *Source:* World Bank [2008]	Least developed countries (UN classification) -
wb__class__lic: Low income (World Bank Classification, April 2008) *Source:* World Bank [2008]	Low income according to the World Bank Classification from April 2008.
wb__class__lmc: Lower middle income (World Bank Classification, April 2008) *Source:* World Bank [2008]	Lower middle income according to the World Bank Classification from April 2008.
wb__class__mna: Middle East + North Africa (World Bank Classification, April 2008) *Source:* World Bank [2008]	Middle East + North Africa according to the World Bank Classification from April 2008.
wb__class__noc: High income: nonOECD (World Bank Classification, April 2008) *Source:* World Bank [2008]	High income: nonOECD according to the World Bank Classification from April 2008.
wb__class__oec: High income: OECD (World Bank Classification, April 2008) *Source:* World Bank [2008]	High income: OECD according to the World Bank Classification from April 2008.
wb__class__sas: South Asia (World Bank Classification, April 2008) *Source:* World Bank [2008]	South Asia according to the World Bank Classification from April 2008.
wb__class__ssa: Sub-Saharan Africa (World Bank Classification, April 2008) *Source:* World Bank [2008]	Sub-Saharan Africa according to the World Bank Classification from April 2008.
wb__class__umc: Upper middle income (World Bank Classification, April 2008) *Source:* World Bank [2008]	Upper middle income according to the World Bank Classification from April 2008.
wgi__goveff: Government Effectiveness (WGI, 2000) *Source:* Kaufmann et al. [2008]	Government Effectiveness index in the year 2000 from the Worldwide Governance Indicators (WGI) project.

Public-sector performance in the FDH-sample

Table A12: Public-sector performance for the FDH-sample. Reported are the PSP-indices for the six subareas (PSP1-6) and overall (PSP0). The table is sorted by the ranking based on PSP0.

rank	country		year	PSP1	PSP2	PSP3	PSP4	PSP5	PSP0
1	DNK	Denmark	1990	1.29	2.03	1.07	2.54	1.40	1.67
2	CHE	Switzerland	1990	1.30	1.61	1.10	2.92	1.38	1.66
3	FIN	Finland	1990	1.28	1.93	1.07	2.55	1.03	1.57
4	AUS	Australia	1990	1.29	1.32	1.10	2.12	1.32	1.43
5	CAN	Canada	1990	1.35	1.14	1.10	2.14	1.20	1.39
6	GBR	United Kingdom	1990	1.25	1.00	1.08	1.84	1.71	1.38
7	IRL	Ireland	1990	1.15	1.20	1.06	2.25	1.17	1.37
8	FRA	France	1990	1.25	1.11	1.09	1.68	1.55	1.34
9	CYP	Cyprus	1990	1.03	1.19	1.09	1.76	1.53	1.32
10	KOR	Korea. Rep.	1990	0.95	2.12	1.01	0.90	1.58	1.31
11	AUT	Austria	1990	1.27	1.39	1.08	1.34	1.32	1.28
12	DEU	Germany	1990	1.25	1.61	1.07	1.22	1.22	1.27
13	BHR	Bahrain	1990	1.14	0.69	1.03	1.99	1.31	1.23
14	ISR	Israel	1990	0.66	1.14	1.09	1.26	1.09	1.05
15	BRB	Barbados	1990	1.04	0.93	1.06	0.83	1.02	0.98
16	CHL	Chile	1990	1.05	0.98	1.05	0.37	0.96	0.88
17	COL	Colombia	1990	0.74	0.71	0.97	0.41	1.49	0.87
18	CRI	Costa Rica	1990	1.11	0.72	1.08	0.50	0.84	0.85
19	JAM	Jamaica	1990	0.86	0.86	1.02	0.72	0.79	0.85
20	KWT	Kuwait	1990	0.71	1.00	1.07	0.69	0.60	0.81
21	HUN	Hungary	1990	0.97	1.01	0.99	0.35	0.64	0.79
22	IDN	Indonesia	1990	1.00	0.54	0.88	0.09	1.03	0.71
23	LKA	Sri Lanka	1990	0.75	0.98	1.01	0.05	0.73	0.70
24	EGY	Egypt. Arab Rep.	1990	0.88	0.56	0.89	0.09	1.00	0.68
25	BOL	Bolivia	1990	0.79	0.59	0.84	0.23	0.97	0.68
26	HND	Honduras	1990	0.89	0.67	0.94	0.30	0.54	0.67
27	BRA	Brazil	1990	0.65	0.62	0.95	0.34	0.51	0.61
28	COG	Congo. Rep.	1990	0.76	0.57	0.81	0.15	0.60	0.58
29	DOM	Dominican Republic	1990	0.73	0.60	0.97	0.20	0.36	0.57
30	IRN	Iran. Islamic Rep.	1990	0.75	0.60	0.92	0.14	0.19	0.52
31	BEN	Benin	1990	0.88	0.20	0.76	0.01	0.76	0.52
32	CMR	Cameroon	1990	0.98	0.38	0.78	0.05	0.13	0.47

Public-sector performance in the DEA-sample

Table A13: Public-sector performance for the DEA-sample. Reported are the PSP-indices for the six subareas (PSP1-6) and overall (PSP). The table is sorted by the ranking based on PSP0.

rank	country		year	PSP1	PSP2	PSP3	PSP4	PSP5	PSP0
1	CHE	Switzerland	2000	1.44	1.95	1.18	4.84	1.82	2.24
2	SWE	Sweden	2000	1.39	2.66	1.17	4.01	1.83	2.21
3	NZL	New Zealand	2000	1.45	1.20	1.16	5.83	1.39	2.21
4	USA	United States	2000	1.48	1.57	1.14	4.04	2.16	2.08
5	CHE	Switzerland	1995	1.40	1.95	1.16	3.65	2.09	2.05
6	IRL	Ireland	2000	1.38	1.42	1.13	4.05	2.26	2.05
7	DNK	Denmark	2000	1.44	2.38	1.13	3.36	1.83	2.03
8	FIN	Finland	2000	1.42	2.21	1.14	3.48	1.72	1.99
9	USA	United States	1995	1.46	1.66	1.12	3.64	2.00	1.98
10	CAN	Canada	2000	1.44	1.23	1.17	4.05	1.78	1.93
11	DNK	Denmark	1995	1.44	2.40	1.11	3.01	1.64	1.92
12	SWE	Sweden	1995	1.35	2.69	1.16	3.18	1.15	1.90
13	USA	United States	1990	1.34	1.66	1.11	3.38	1.85	1.87
14	NZL	New Zealand	1995	1.51	1.21	1.13	3.77	1.62	1.85
15	DNK	Denmark	1990	1.28	2.49	1.10	2.76	1.49	1.83
16	CHE	Switzerland	1990	1.29	1.96	1.14	3.15	1.49	1.81
17	SWE	Sweden	1990	1.18	1.73	1.14	3.55	1.34	1.79
18	USA	United States	1985	1.32	2.17	1.10	2.94	1.40	1.78
19	CHE	Switzerland	1985	1.28	2.17	1.13	2.61	1.43	1.72
20	FIN	Finland	1990	1.27	2.36	1.10	2.76	1.12	1.72
21	AUS	Australia	1995	1.40	1.51	1.15	2.89	1.62	1.71
22	AUT	Austria	2000	1.38	1.62	1.15	2.55	1.85	1.71
23	AUS	Australia	2000	1.42	1.45	1.17	2.87	1.57	1.70
24	FIN	Finland	1995	1.41	2.29	1.13	2.82	0.74	1.68
25	NZL	New Zealand	1990	1.22	1.21	1.11	3.86	0.94	1.67
26	BEL	Belgium	2000	1.35	1.11	1.14	2.88	1.82	1.66
27	NLD	Netherlands	2000	1.46	1.25	1.15	2.67	1.63	1.63
28	SWE	Sweden	1985	1.13	1.90	1.13	2.95	1.01	1.63
29	DEU	Germany	2000	1.34	1.70	1.15	2.24	1.66	1.62
30	GBR	United Kingdom	2000	1.46	1.16	1.15	2.62	1.70	1.62
31	FRA	France	2000	1.33	1.32	1.16	2.50	1.72	1.61
32	CYP	Cyprus	2000	1.05	1.52	1.15	2.86	1.41	1.60
33	IRL	Ireland	1995	1.44	1.42	1.12	2.65	1.34	1.59
34	KWT	Kuwait	1995	1.09	1.25	1.12	1.36	3.02	1.57
35	AUT	Austria	1995	1.31	1.63	1.13	2.23	1.53	1.57
36	NZL	New Zealand	1985	1.08	1.31	1.09	3.20	1.14	1.56
37	SGP	Singapore	2000	1.37	1.04	1.15	2.51	1.70	1.55

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Table A13: Public-sector performance for the DEA-sample – continued

rank	country		year	PSP1	PSP2	PSP3	PSP4	PSP5	PSP0
38	BHR	Bahrain	2000	1.17	1.02	1.10	3.12	1.34	1.55
39	KOR	Korea. Rep.	2000	1.06	2.49	1.12	1.78	1.29	1.55
40	NLD	Netherlands	1995	1.40	1.26	1.14	2.32	1.58	1.54
41	AUS	Australia	1990	1.28	1.57	1.14	2.29	1.41	1.54
42	KOR	Korea. Rep.	1995	0.99	2.55	1.08	1.38	1.66	1.53
43	CAN	Canada	1995	1.43	1.28	1.15	2.26	1.51	1.53
44	DEU	Germany	1995	1.34	1.75	1.13	1.81	1.58	1.52
45	SGP	Singapore	1995	1.41	1.03	1.13	2.14	1.83	1.51
46	FRA	France	1995	1.26	1.31	1.15	2.06	1.71	1.50
47	CAN	Canada	1990	1.33	1.34	1.14	2.34	1.29	1.49
48	KOR	Korea. Rep.	1990	0.94	2.62	1.05	1.01	1.79	1.48
49	CYP	Cyprus	1995	1.03	1.46	1.14	2.47	1.29	1.48
50	GRC	Greece	2000	1.09	1.84	1.15	2.07	1.23	1.48
51	GBR	United Kingdom	1990	1.23	1.16	1.12	2.01	1.86	1.48
52	GBR	United Kingdom	1995	1.46	1.15	1.13	2.23	1.36	1.47
53	IRL	Ireland	1990	1.14	1.42	1.10	2.38	1.28	1.46
54	JPN	Japan	2000	1.32	1.30	1.20	1.64	1.84	1.46
55	AUS	Australia	1985	1.29	1.57	1.12	2.13	1.17	1.46
56	PRT	Portugal	2000	1.27	0.97	1.13	1.90	1.95	1.44
57	FRA	France	1990	1.24	1.30	1.13	1.85	1.67	1.44
58	CYP	Cyprus	1990	1.02	1.40	1.13	1.92	1.71	1.43
59	CAN	Canada	1985	1.28	1.37	1.13	2.24	1.15	1.43
60	TTO	Trinidad and Tobago	2000	1.20	1.11	1.02	2.33	1.50	1.43
61	ESP	Spain	2000	1.29	1.16	1.16	1.98	1.56	1.43
62	BEL	Belgium	1995	1.26	1.13	1.13	2.22	1.39	1.43
63	DNK	Denmark	1985	1.09	1.49	1.10	2.37	1.08	1.43
64	FIN	Finland	1985	1.17	1.47	1.09	2.21	1.08	1.40
65	MYS	Malaysia	1995	1.21	1.13	1.05	1.09	2.52	1.40
66	ISR	Israel	2000	1.20	1.31	1.16	1.93	1.38	1.40
67	DEU	Germany	1990	1.24	1.94	1.11	1.36	1.32	1.39
68	MUS	Mauritius	2000	1.22	1.95	1.06	1.37	1.37	1.39
69	NLD	Netherlands	1990	1.26	1.28	1.13	1.77	1.50	1.39
70	AUT	Austria	1990	1.26	1.65	1.11	1.48	1.43	1.39
71	JPN	Japan	1990	1.28	1.30	1.16	1.43	1.67	1.37
72	JOR	Jordan	2000	1.24	0.93	1.04	0.58	3.02	1.36
73	ISR	Israel	1995	1.05	1.33	1.14	1.76	1.53	1.36
74	JPN	Japan	1995	1.31	1.31	1.17	1.60	1.42	1.36
75	ITA	Italy	2000	1.22	1.13	1.17	1.70	1.56	1.36
76	GRC	Greece	1995	1.02	1.83	1.14	1.87	0.88	1.35
77	GRC	Greece	1990	1.00	1.79	1.13	1.58	1.16	1.33

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Table A13: Public-sector performance for the DEA-sample – continued

rank	country		year	PSP1	PSP2	PSP3	PSP4	PSP5	PSP0
78	ESP	Spain	1990	1.03	1.15	1.13	1.30	2.04	1.33
79	DEU	Germany	1985	1.20	2.10	1.09	1.05	1.19	1.33
80	BHR	Bahrain	1995	1.17	0.93	1.09	2.34	1.05	1.32
81	BEL	Belgium	1990	1.26	1.16	1.12	1.51	1.46	1.30
82	TTO	Trinidad and Tobago	1995	1.09	1.08	1.03	2.29	1.00	1.30
83	BHR	Bahrain	1990	1.13	0.81	1.06	2.09	1.38	1.29
84	AUT	Austria	1985	1.18	1.67	1.09	1.30	1.23	1.29
85	SGP	Singapore	1990	1.23	0.93	1.10	1.64	1.57	1.29
86	MUS	Mauritius	1995	1.24	1.89	1.04	0.92	1.29	1.28
87	NLD	Netherlands	1985	1.25	1.24	1.13	1.54	1.12	1.26
88	ESP	Spain	1995	1.24	1.16	1.15	1.57	1.16	1.26
89	PAN	Panama	2000	1.14	1.51	1.10	1.03	1.49	1.25
90	ITA	Italy	1990	1.20	1.13	1.13	1.32	1.42	1.24
91	GBR	United Kingdom	1985	1.20	1.11	1.10	1.59	1.16	1.23
92	ITA	Italy	1995	1.12	1.13	1.15	1.49	1.27	1.23
93	JPN	Japan	1985	1.21	1.27	1.15	1.23	1.24	1.22
94	SGP	Singapore	1985	1.18	0.94	1.08	1.60	1.27	1.21
95	MUS	Mauritius	1990	1.02	1.82	1.02	0.71	1.44	1.20
96	CHL	Chile	2000	1.23	1.15	1.13	0.98	1.38	1.17
97	KOR	Korea. Rep.	1985	0.88	1.63	1.01	0.50	1.84	1.17
98	CYP	Cyprus	1985	0.88	1.33	1.12	1.34	1.18	1.17
99	HUN	Hungary	2000	1.16	1.26	1.05	1.20	1.19	1.17
100	PRT	Portugal	1990	0.99	0.89	1.09	0.95	1.90	1.16
101	PRT	Portugal	1995	1.24	0.94	1.11	1.46	0.99	1.15
102	ISR	Israel	1990	0.65	1.35	1.13	1.38	1.20	1.14
103	FRA	France	1985	1.07	1.09	1.11	1.43	1.01	1.14
104	GRC	Greece	1985	0.91	1.20	1.11	1.38	1.09	1.14
105	MYS	Malaysia	2000	1.09	1.19	1.07	1.09	1.24	1.14
106	BHR	Bahrain	1985	1.15	0.81	1.04	2.25	0.42	1.13
107	PAN	Panama	1995	1.17	1.52	1.08	0.75	1.06	1.12
108	CHL	Chile	1995	1.23	1.14	1.11	0.73	1.36	1.11
109	BEL	Belgium	1985	1.23	1.14	1.11	1.12	0.93	1.11
110	ARG	Argentina	1995	1.02	1.10	1.07	0.66	1.64	1.10
111	IRL	Ireland	1985	1.07	1.29	1.08	1.19	0.84	1.09
112	MYS	Malaysia	1990	1.19	1.04	1.04	0.78	1.28	1.06
113	CRI	Costa Rica	2000	1.17	0.81	1.15	1.07	1.09	1.06
114	CHN	China	2000	0.96	1.20	1.04	0.33	1.74	1.06
115	MUS	Mauritius	1985	1.10	1.26	1.00	0.56	1.24	1.03
116	ESP	Spain	1985	1.00	1.23	1.12	0.98	0.82	1.03
117	KWT	Kuwait	2000	1.09	1.27	1.13	1.20	0.44	1.03
118	ITA	Italy	1985	0.98	1.12	1.11	1.02	0.88	1.02

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Table A13: Public-sector performance for the DEA-sample – continued

rank	country		year	PSP1	PSP2	PSP3	PSP4	PSP5	PSP0
119	CRI	Costa Rica	1995	1.11	0.82	1.13	0.94	1.08	1.02
120	TUN	Tunisia	2000	1.04	0.85	1.07	0.41	1.71	1.02
121	JAM	Jamaica	2000	1.09	1.04	1.05	0.95	0.95	1.02
122	MYS	Malaysia	1985	1.15	0.93	1.02	0.60	1.33	1.01
123	LKA	Sri Lanka	1995	0.95	1.20	1.07	0.07	1.74	1.00
124	MEX	Mexico	2000	0.90	1.31	1.09	0.54	1.13	0.99
125	TTO	Trinidad and Tobago	1990	1.00	1.05	1.03	1.67	0.23	0.99
126	ARG	Argentina	2000	1.17	1.10	1.09	0.88	0.72	0.99
127	URY	Uruguay	2000	1.10	1.03	1.10	0.97	0.76	0.99
128	HUN	Hungary	1995	1.09	1.23	1.03	0.69	0.88	0.98
129	ISR	Israel	1985	0.65	1.40	1.11	1.13	0.61	0.98
130	PHL	Philippines	2000	1.08	1.65	1.03	0.15	0.97	0.97
131	URY	Uruguay	1995	0.89	1.03	1.08	0.71	1.15	0.97
132	COL	Colombia	2000	0.83	0.90	1.05	0.82	1.19	0.96
133	THA	Thailand	1990	1.08	0.65	0.99	0.15	1.88	0.95
134	CHL	Chile	1990	1.04	1.14	1.09	0.39	1.07	0.95
135	PAN	Panama	1990	1.06	1.52	1.07	0.40	0.68	0.95
136	THA	Thailand	1995	1.12	0.71	1.00	0.26	1.62	0.94
137	CHN	China	1995	0.85	1.15	1.02	0.11	1.55	0.94
138	SLV	El Salvador	2000	1.09	0.52	1.03	0.70	1.31	0.93
139	JAM	Jamaica	1995	0.95	1.01	1.06	0.79	0.86	0.93
140	COL	Colombia	1990	0.74	0.81	1.01	0.44	1.63	0.93
141	TTO	Trinidad and Tobago	1985	0.96	0.96	1.02	1.69	-0.02	0.92
142	PAN	Panama	1985	1.07	1.09	1.05	0.43	0.95	0.92
143	PHL	Philippines	1995	1.08	1.59	1.00	0.12	0.78	0.91
144	BRA	Brazil	2000	0.95	0.74	1.04	0.72	1.08	0.91
145	JAM	Jamaica	1990	0.85	0.98	1.05	0.75	0.89	0.90
146	PER	Peru	2000	1.04	1.09	1.02	0.25	1.12	0.90
147	KWT	Kuwait	1985	1.07	1.21	1.08	0.94	0.21	0.90
148	CRI	Costa Rica	1990	1.10	0.81	1.12	0.54	0.91	0.89
149	URY	Uruguay	1990	0.90	1.01	1.07	0.46	1.01	0.89
150	TUN	Tunisia	1995	1.00	0.75	1.05	0.27	1.37	0.89
151	CHN	China	1990	0.84	1.09	1.02	0.03	1.46	0.89
152	TUR	Turkey	2000	0.82	0.73	1.04	0.84	0.99	0.88
153	EGY	Egypt. Arab Rep.	2000	1.10	0.84	1.01	0.26	1.19	0.88
154	LKA	Sri Lanka	2000	0.92	1.24	1.09	0.12	1.03	0.88
155	HUN	Hungary	1985	0.92	1.14	1.02	0.30	1.01	0.88
156	ZAF	South Africa	1990	0.78	0.63	0.91	0.41	1.64	0.88
157	BWA	Botswana	2000	1.24	0.86	0.72	0.51	1.01	0.87
158	KWT	Kuwait	1990	0.70	1.21	1.11	0.75	0.57	0.87

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Table A13: Public-sector performance for the DEA-sample – continued

rank	country		year	PSP1	PSP2	PSP3	PSP4	PSP5	PSP0
159	IRN	Iran. Islamic Rep.	2000	0.94	0.97	1.02	0.48	0.85	0.85
160	ZAF	South Africa	2000	1.16	0.73	0.72	0.48	1.17	0.85
161	HUN	Hungary	1990	0.95	1.18	1.02	0.38	0.70	0.85
162	JOR	Jordan	1995	1.05	0.87	1.02	0.49	0.78	0.84
163	BWA	Botswana	1990	0.98	0.63	0.93	0.37	1.28	0.84
164	CHN	China	1985	0.86	0.89	1.01	0.01	1.42	0.84
165	MEX	Mexico	1995	0.93	1.26	1.07	0.43	0.48	0.83
166	JOR	Jordan	1985	0.95	0.62	0.96	0.57	1.06	0.83
167	ECU	Ecuador	1995	0.89	0.87	1.05	0.30	1.02	0.83
168	TUR	Turkey	1990	0.72	0.66	0.97	0.37	1.35	0.82
169	IDN	Indonesia	1995	0.94	0.73	0.94	0.14	1.28	0.81
170	SLV	El Salvador	1995	1.07	0.51	1.01	0.39	1.03	0.80
171	TUR	Turkey	1995	0.79	0.73	1.00	0.64	0.85	0.80
172	COG	Congo. Rep.	1985	0.80	0.62	0.84	0.25	1.50	0.80
173	PHL	Philippines	1990	0.70	1.17	0.97	0.11	1.05	0.80
174	JAM	Jamaica	1985	0.72	0.92	1.05	0.94	0.36	0.80
175	VEN	Venezuela. RB	2000	0.79	1.05	1.08	0.70	0.37	0.80
176	LKA	Sri Lanka	1985	0.87	1.14	1.03	0.04	0.91	0.80
177	COL	Colombia	1995	0.74	0.86	1.03	0.65	0.69	0.79
178	VEN	Venezuela. RB	1995	0.55	1.12	1.06	0.56	0.67	0.79
179	COL	Colombia	1985	0.81	0.81	1.00	0.45	0.85	0.78
180	ECU	Ecuador	2000	0.67	0.89	1.08	0.36	0.90	0.78
181	PER	Peru	1995	0.90	1.07	1.00	0.23	0.68	0.78
182	PRT	Portugal	1985	0.90	0.75	1.08	0.59	0.57	0.78
183	THA	Thailand	1985	1.02	0.66	0.97	0.10	1.14	0.78
184	VEN	Venezuela. RB	1985	1.02	0.93	1.03	0.60	0.31	0.78
185	BWA	Botswana	1985	1.02	0.42	0.92	0.25	1.23	0.77
186	THA	Thailand	2000	1.03	0.75	1.01	0.36	0.71	0.77
187	IRN	Iran. Islamic Rep.	1995	0.72	0.84	0.99	0.28	1.01	0.77
188	BWA	Botswana	1995	1.11	0.75	0.83	0.29	0.86	0.77
189	ECU	Ecuador	1990	0.75	0.85	1.02	0.32	0.90	0.77
190	LKA	Sri Lanka	1990	0.74	1.16	1.05	0.05	0.81	0.76
191	IND	India	2000	1.02	0.67	0.93	0.10	1.10	0.76
192	ZAF	South Africa	1995	1.06	0.74	0.86	0.40	0.76	0.76
193	PAK	Pakistan	1995	0.95	0.87	0.90	0.09	1.01	0.76
194	PNG	Papua New Guinea	1995	0.94	0.34	0.83	0.48	1.22	0.76
195	IDN	Indonesia	1990	1.00	0.64	0.91	0.10	1.16	0.76
196	MEX	Mexico	1990	0.87	1.21	1.05	0.32	0.33	0.75
197	EGY	Egypt. Arab Rep.	1995	0.96	0.76	0.97	0.16	0.92	0.75

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Table A13: Public-sector performance for the DEA-sample – continued

rank	country		year	PSP1	PSP2	PSP3	PSP4	PSP5	PSP0
198	PAK	Pakistan	1990	0.84	0.92	0.87	0.06	1.06	0.75
199	ZAF	South Africa	1985	0.86	0.68	0.88	0.33	0.96	0.74
200	SYR	Syrian Arab Republic	2000	0.76	0.79	1.07	0.32	0.77	0.74
201	EGY	Egypt. Arab Rep.	1990	0.87	0.67	0.92	0.10	1.11	0.73
202	PNG	Papua New Guinea	1985	1.03	0.21	0.79	1.19	0.44	0.73
203	PNG	Papua New Guinea	1990	1.06	0.29	0.81	1.21	0.28	0.73
204	SYR	Syrian Arab Republic	1995	0.76	0.74	1.04	0.21	0.87	0.73
205	TUN	Tunisia	1990	0.86	0.65	1.04	0.21	0.86	0.72
206	CRI	Costa Rica	1985	0.94	0.82	1.10	0.44	0.32	0.72
207	CMR	Cameroon	1985	0.95	0.38	0.80	0.07	1.43	0.72
208	CHL	Chile	1985	0.96	1.12	1.06	0.27	0.19	0.72
209	PAK	Pakistan	2000	0.88	0.83	0.93	0.09	0.87	0.72
210	URY	Uruguay	1985	0.86	1.04	1.06	0.45	0.12	0.70
211	ECU	Ecuador	1985	0.84	0.84	0.98	0.29	0.55	0.70
212	VEN	Venezuela. RB	1990	0.81	0.76	1.05	0.51	0.37	0.70
213	ARG	Argentina	1990	0.72	1.09	1.06	0.49	0.12	0.70
214	BRA	Brazil	1995	0.64	0.70	1.01	0.42	0.71	0.69
215	IND	India	1990	0.88	0.53	0.87	0.03	1.16	0.69
216	IND	India	1995	0.96	0.60	0.91	0.05	0.94	0.69
217	IND	India	1985	0.93	0.47	0.83	0.02	1.17	0.69
218	NIC	Nicaragua	2000	1.01	0.60	1.03	0.09	0.69	0.68
219	CMR	Cameroon	2000	0.86	0.52	0.75	0.04	1.17	0.67
220	TUN	Tunisia	1985	0.80	0.55	0.96	0.20	0.77	0.66
221	KEN	Kenya	1990	0.96	0.40	0.88	0.06	0.99	0.66
222	MEX	Mexico	1985	0.71	0.76	1.02	0.32	0.48	0.66
223	SEN	Senegal	2000	0.87	0.34	0.90	0.07	1.06	0.65
224	BRA	Brazil	1990	0.64	0.69	0.98	0.36	0.56	0.65
225	PNG	Papua New Guinea	2000	0.93	0.38	0.84	0.44	0.63	0.65
226	TUR	Turkey	1985	0.75	0.59	0.94	0.16	0.78	0.64
227	SLV	El Salvador	1985	0.70	0.49	0.90	0.20	0.92	0.64
228	EGY	Egypt. Arab Rep.	1985	1.02	0.59	0.86	0.09	0.65	0.64
229	UGA	Uganda	2000	1.04	0.42	0.69	0.01	1.02	0.63
230	BGD	Bangladesh	2000	0.86	0.48	0.90	0.01	0.90	0.63
231	ARG	Argentina	1985	0.65	0.99	1.04	0.47	-0.01	0.63
232	IDN	Indonesia	1985	0.94	0.68	0.86	0.09	0.53	0.62
233	IDN	Indonesia	2000	0.76	0.81	0.97	0.14	0.41	0.62

(continued on next page)

Table A13: Public-sector performance for the DEA-sample – continued

rank	country		year	PSP1	PSP2	PSP3	PSP4	PSP5	PSP0
234	ZWE	Zimbabwe	1990	0.78	0.58	0.90	0.10	0.73	0.62
235	SLV	El Salvador	1990	0.66	0.50	0.97	0.22	0.74	0.62
236	GHA	Ghana	1990	0.81	0.42	0.84	0.07	0.94	0.62
237	KEN	Kenya	2000	1.02	0.50	0.77	0.09	0.65	0.61
238	COG	Congo. Rep.	1990	0.75	0.67	0.84	0.15	0.58	0.60
239	PAK	Pakistan	1985	0.86	0.34	0.85	0.05	0.90	0.60
240	GHA	Ghana	2000	0.88	0.48	0.86	0.05	0.71	0.60
241	BGD	Bangladesh	1990	0.78	0.44	0.81	0.01	0.94	0.60
242	CAF	Central African Republic	2000	0.82	0.35	0.65	0.04	1.06	0.58
243	SEN	Senegal	1990	0.83	0.32	0.85	0.05	0.85	0.58
244	BRA	Brazil	1985	0.58	0.57	0.95	0.32	0.45	0.57
245	MWI	Malawi	1985	0.87	0.40	0.69	0.07	0.84	0.57
246	GHA	Ghana	1995	0.86	0.46	0.86	0.02	0.66	0.57
247	BGD	Bangladesh	1995	0.89	0.46	0.86	0.01	0.62	0.57
248	BGD	Bangladesh	1985	0.74	0.40	0.76	0.01	0.90	0.57
249	BEN	Benin	2000	0.86	0.29	0.80	0.04	0.83	0.56
250	ZWE	Zimbabwe	2000	0.74	0.63	0.63	0.13	0.65	0.56
251	IRN	Iran. Islamic Rep.	1990	0.75	0.71	0.96	0.16	0.18	0.55
252	NIC	Nicaragua	1995	0.87	0.54	1.00	0.07	0.27	0.55
253	PHL	Philippines	1985	0.71	1.03	0.93	0.10	-0.04	0.55
254	TGO	Togo	1990	0.86	0.32	0.85	0.02	0.66	0.54
255	JOR	Jordan	1990	0.88	0.78	1.00	0.52	-0.48	0.54
256	BEN	Benin	1985	0.82	0.15	0.76	0.05	0.91	0.54
257	KEN	Kenya	1995	0.87	0.46	0.83	0.06	0.44	0.53
258	UGA	Uganda	1995	0.77	0.41	0.68	0.01	0.79	0.53
259	SEN	Senegal	1985	0.82	0.32	0.80	0.08	0.63	0.53
260	BEN	Benin	1990	0.87	0.22	0.78	0.02	0.74	0.53
261	IRN	Iran. Islamic Rep.	1985	0.72	0.60	0.91	0.11	0.29	0.53
262	MWI	Malawi	1995	0.66	0.37	0.71	0.04	0.81	0.52
263	KEN	Kenya	1985	1.00	0.33	0.87	0.06	0.32	0.52
264	ZWE	Zimbabwe	1985	0.80	0.49	0.91	0.11	0.26	0.51
265	SYR	Syrian Arab Republic	1985	0.63	0.55	0.97	0.14	0.23	0.50
266	CAF	Central African Republic	1990	0.85	0.30	0.73	0.10	0.51	0.50
267	PER	Peru	1985	0.33	0.99	0.93	0.16	0.06	0.49
268	ZWE	Zimbabwe	1995	0.86	0.59	0.77	0.10	0.14	0.49
269	NER	Niger	2000	0.92	0.13	0.79	0.02	0.59	0.49

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Table A13: Public-sector performance for the DEA-sample – continued

rank	country		year	PSP1	PSP2	PSP3	PSP4	PSP5	PSP0
270	BEN	Benin	1995	0.78	0.26	0.80	0.03	0.53	0.48
271	TGO	Togo	1995	0.78	0.37	0.86	0.03	0.32	0.47
272	TGO	Togo	2000	0.78	0.40	0.85	0.04	0.24	0.46
273	CMR	Cameroon	1990	0.98	0.43	0.81	0.05	0.04	0.46
274	NER	Niger	1990	0.90	0.09	0.69	0.01	0.62	0.46
275	SYR	Syrian Arab Republic	1990	0.60	0.68	1.01	0.17	-0.18	0.46
276	MWI	Malawi	2000	0.76	0.38	0.68	0.04	0.42	0.45
277	PER	Peru	1990	0.45	0.91	0.97	0.14	-0.23	0.45
278	SEN	Senegal	1995	0.72	0.33	0.88	0.06	0.26	0.45
279	COG	Congo. Rep.	1995	0.71	0.64	0.80	0.20	-0.15	0.44
280	MWI	Malawi	1990	0.81	0.37	0.72	0.04	0.12	0.41
281	CAF	Central African Republic	1985	0.67	0.19	0.73	0.13	0.29	0.40
282	CMR	Cameroon	1995	0.83	0.48	0.78	0.03	-0.14	0.40
283	NIC	Nicaragua	1985	0.34	0.44	0.90	0.08	0.19	0.39
284	UGA	Uganda	1990	0.42	0.43	0.74	0.01	0.35	0.39
285	SLE	Sierra Leone	1985	0.58	0.15	0.58	0.07	0.52	0.38
286	GHA	Ghana	1985	0.52	0.39	0.81	0.04	0.07	0.37
287	CAF	Central African Republic	1995	0.75	0.32	0.70	0.04	-0.02	0.36
288	NER	Niger	1985	0.83	0.08	0.65	0.02	0.06	0.33
289	NER	Niger	1995	0.73	0.12	0.74	0.01	-0.05	0.31
290	UGA	Uganda	1985	0.44	0.27	0.75	0.01	0.05	0.31
291	NIC	Nicaragua	1990	0.40	0.47	0.95	0.11	-0.41	0.30
292	TGO	Togo	1985	0.85	0.26	0.83	0.04	-0.49	0.30
293	COG	Congo. Rep.	2000	0.63	0.66	0.78	0.18	-0.78	0.29
294	SLE	Sierra Leone	1995	0.63	0.20	0.58	0.01	-0.06	0.27
295	SLE	Sierra Leone	2000	0.80	0.24	0.60	0.01	-0.41	0.25
296	SLE	Sierra Leone	1990	0.58	0.17	0.58	0.02	-0.12	0.24

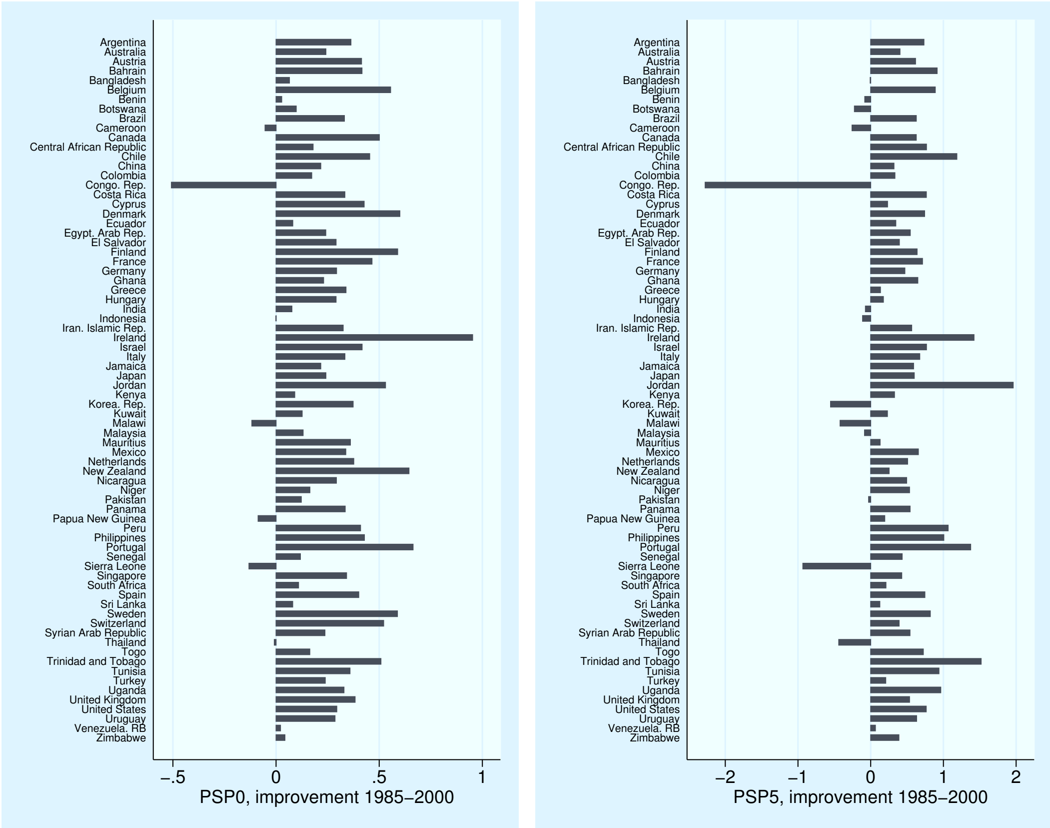

Figure A10: Change of public-sector performance 1985-2000. Left: Overall PSP. Right: PSP5, economic stability and performance.

Public-sector efficiency in the DEA-sample

Table A14: Public-sector efficiency for the DEA-sample. (Bias, 95% confidence interval, uncorrected DEA-score, corrected DEA-score)

country		**year**	**bias**	**lower bound CI**	**upper bound CI**	**DEA-score**	**DEA-score (corrected)**
SWE	Sweden	2000	0.02	0.93	0.99	0.99	0.97
NZL	New Zealand	2000	0.03	0.92	0.98	0.98	0.96
KOR	Korea. Rep.	1990	0.05	0.91	0.99	1.00	0.95
CHN	China	1985	0.05	0.90	0.99	1.00	0.95

(continued on next page)

Table A14: Public-sector efficiency for the DEA-sample – continued

country		year	bias	lower bound CI	upper bound CI	DEA-score	DEA-score (corrected)
CHE	Switzerland	2000	0.08	0.88	0.99	1.00	0.92
USA	United States	2000	0.03	0.86	0.93	0.93	0.90
CHN	China	1990	0.03	0.85	0.92	0.92	0.89
KEN	Kenya	1990	0.06	0.83	0.94	0.95	0.89
DNK	Denmark	2000	0.02	0.85	0.90	0.90	0.88
KOR	Korea. Rep.	1985	0.03	0.85	0.91	0.91	0.88
KOR	Korea. Rep.	1995	0.03	0.85	0.91	0.91	0.88
FIN	Finland	2000	0.02	0.83	0.89	0.89	0.87
IRL	Ireland	2000	0.05	0.82	0.91	0.91	0.86
USA	United States	1995	0.02	0.82	0.88	0.88	0.86
EGY	Egypt. Arab Rep.	2000	0.03	0.82	0.88	0.88	0.85
PHL	Philippines	2000	0.02	0.82	0.87	0.88	0.85
CHE	Switzerland	1985	0.03	0.80	0.87	0.88	0.84
CHE	Switzerland	1995	0.08	0.80	0.91	0.92	0.84
DNK	Denmark	1995	0.02	0.80	0.85	0.85	0.84
PHL	Philippines	1995	0.02	0.81	0.86	0.86	0.84
CAN	Canada	2000	0.03	0.80	0.86	0.86	0.83
SWE	Sweden	1995	0.02	0.80	0.85	0.85	0.83
CHE	Switzerland	1990	0.04	0.78	0.86	0.86	0.82
KOR	Korea. Rep.	2000	0.03	0.78	0.84	0.85	0.82
BGD	Bangladesh	1990	0.06	0.76	0.87	0.88	0.81
USA	United States	1990	0.02	0.77	0.83	0.83	0.81
NZL	New Zealand	1995	0.03	0.76	0.82	0.82	0.80
BGD	Bangladesh	2000	0.05	0.75	0.84	0.85	0.80
EGY	Egypt. Arab Rep.	1995	0.03	0.76	0.83	0.83	0.80
DNK	Denmark	1990	0.02	0.76	0.81	0.81	0.80
BEN	Benin	2000	0.07	0.73	0.86	0.86	0.79
SGP	Singapore	1995	0.03	0.75	0.81	0.82	0.79
BGD	Bangladesh	1985	0.07	0.73	0.85	0.85	0.79
PAN	Panama	2000	0.03	0.76	0.82	0.82	0.79
SWE	Sweden	1990	0.02	0.75	0.80	0.80	0.78
CHN	China	1995	0.02	0.74	0.79	0.80	0.77
USA	United States	1985	0.03	0.73	0.79	0.80	0.77
COG	Congo. Rep.	1985	0.02	0.73	0.78	0.78	0.76
BEN	Benin	1990	0.10	0.69	0.85	0.86	0.75
PHL	Philippines	1990	0.02	0.72	0.77	0.78	0.75

(continued on next page)

Table A14: Public-sector efficiency for the DEA-sample – continued

country		year	bias	lower bound CI	upper bound CI	DEA-score	DEA-score (corrected)
THA	Thailand	1990	0.02	0.72	0.77	0.77	0.75
MYS	Malaysia	1995	0.02	0.72	0.77	0.77	0.75
FIN	Finland	1990	0.02	0.72	0.77	0.77	0.75
MUS	Mauritius	1990	0.03	0.72	0.77	0.78	0.75
EGY	Egypt. Arab Rep.	1990	0.03	0.72	0.77	0.77	0.75
BEN	Benin	1985	0.15	0.69	0.89	0.90	0.75
AUT	Austria	2000	0.02	0.71	0.76	0.76	0.74
MUS	Mauritius	2000	0.02	0.71	0.76	0.77	0.74
AUS	Australia	1995	0.02	0.71	0.76	0.76	0.74
MUS	Mauritius	1995	0.02	0.71	0.76	0.76	0.74
BGD	Bangladesh	1995	0.05	0.69	0.78	0.79	0.74
SGP	Singapore	1985	0.03	0.71	0.76	0.76	0.74
AUS	Australia	2000	0.02	0.71	0.76	0.76	0.74
SEN	Senegal	2000	0.04	0.70	0.77	0.77	0.73
FIN	Finland	1995	0.02	0.70	0.75	0.75	0.73
GRC	Greece	2000	0.03	0.69	0.75	0.75	0.73
CMR	Cameroon	2000	0.03	0.69	0.75	0.76	0.73
BEL	Belgium	2000	0.02	0.69	0.74	0.74	0.72
SGP	Singapore	1990	0.02	0.69	0.74	0.75	0.72
GHA	Ghana	1990	0.04	0.68	0.76	0.76	0.72
NZL	New Zealand	1990	0.02	0.69	0.74	0.74	0.72
CAF	Central African Republic	1990	0.07	0.65	0.78	0.78	0.71
CMR	Cameroon	1985	0.02	0.68	0.73	0.74	0.71
NLD	Netherlands	2000	0.02	0.68	0.73	0.73	0.71
KEN	Kenya	2000	0.04	0.68	0.75	0.75	0.71
SWE	Sweden	1985	0.01	0.68	0.72	0.72	0.71
PAK	Pakistan	1995	0.02	0.68	0.73	0.73	0.71
PER	Peru	2000	0.02	0.68	0.73	0.73	0.71
DEU	Germany	2000	0.02	0.67	0.72	0.72	0.70
PAN	Panama	1995	0.03	0.67	0.73	0.73	0.70
SLV	El Salvador	2000	0.02	0.67	0.72	0.73	0.70
GBR	United Kingdom	2000	0.02	0.67	0.72	0.72	0.70
SYR	Syrian Arab Republic	2000	0.02	0.67	0.72	0.72	0.70
BWA	Botswana	1985	0.02	0.67	0.72	0.72	0.70

(continued on next page)

Table A14: Public-sector efficiency for the DEA-sample – continued

country		year	bias	lower bound CI	upper bound CI	DEA-score	DEA-score (corrected)
MWI	Malawi	1995	0.18	0.65	0.87	0.88	0.70
FRA	France	2000	0.02	0.67	0.72	0.72	0.70
COL	Colombia	1990	0.02	0.67	0.72	0.72	0.70
PAK	Pakistan	2000	0.02	0.67	0.72	0.72	0.70
GRC	Greece	1995	0.02	0.66	0.72	0.72	0.70
CYP	Cyprus	2000	0.02	0.66	0.71	0.71	0.69
KEN	Kenya	1985	0.05	0.64	0.74	0.74	0.69
PAK	Pakistan	1990	0.02	0.66	0.71	0.71	0.69
TUN	Tunisia	2000	0.03	0.66	0.71	0.72	0.69
KWT	Kuwait	1995	0.01	0.66	0.70	0.70	0.68
KEN	Kenya	1995	0.04	0.64	0.72	0.72	0.68
AUT	Austria	1995	0.02	0.65	0.70	0.70	0.68
BEN	Benin	1995	0.06	0.62	0.74	0.74	0.68
CHN	China	2000	0.03	0.65	0.70	0.71	0.68
NZL	New Zealand	1985	0.02	0.64	0.70	0.70	0.67
NLD	Netherlands	1995	0.01	0.64	0.69	0.69	0.67
GRC	Greece	1990	0.02	0.64	0.69	0.69	0.67
LKA	Sri Lanka	1995	0.03	0.64	0.69	0.70	0.67
SYR	Syrian Arab Republic	1995	0.02	0.64	0.68	0.69	0.67
MUS	Mauritius	1985	0.03	0.64	0.70	0.70	0.67
PER	Peru	1995	0.02	0.64	0.68	0.69	0.67
IND	India	1985	0.02	0.64	0.68	0.69	0.67
SGP	Singapore	2000	0.05	0.63	0.71	0.71	0.66
UGA	Uganda	2000	0.03	0.64	0.69	0.69	0.66
AUS	Australia	1990	0.02	0.63	0.68	0.68	0.66
TUR	Turkey	1990	0.02	0.63	0.68	0.68	0.66
BHR	Bahrain	2000	0.03	0.63	0.69	0.69	0.66
CAN	Canada	1995	0.02	0.63	0.68	0.68	0.66
DEU	Germany	1995	0.02	0.63	0.68	0.68	0.66
THA	Thailand	1995	0.03	0.63	0.68	0.68	0.66
LKA	Sri Lanka	1985	0.02	0.63	0.67	0.67	0.65
IRL	Ireland	1995	0.06	0.62	0.70	0.71	0.65
FRA	France	1995	0.01	0.63	0.67	0.67	0.65
CAF	Central African Republic	2000	0.35	0.69	0.98	1.00	0.65

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Table A14: Public-sector efficiency for the DEA-sample – continued

country		year	bias	lower bound CI	upper bound CI	DEA-score	DEA-score (corrected)
TUN	Tunisia	1995	0.02	0.62	0.67	0.67	0.65
IDN	Indonesia	1990	0.02	0.62	0.66	0.67	0.65
CAN	Canada	1990	0.02	0.61	0.66	0.66	0.64
MWI	Malawi	2000	0.11	0.59	0.74	0.75	0.64
THA	Thailand	1985	0.02	0.62	0.66	0.66	0.64
JAM	Jamaica	1995	0.03	0.61	0.66	0.67	0.64
GBR	United Kingdom	1990	0.02	0.61	0.66	0.66	0.64
CYP	Cyprus	1995	0.02	0.61	0.66	0.66	0.64
IDN	Indonesia	1995	0.02	0.61	0.66	0.66	0.64
EGY	Egypt. Arab Rep.	1985	0.02	0.61	0.66	0.66	0.64
IRL	Ireland	1990	0.04	0.60	0.68	0.68	0.64
GBR	United Kingdom	1995	0.02	0.61	0.65	0.65	0.64
JOR	Jordan	2000	0.03	0.60	0.66	0.67	0.64
MYS	Malaysia	1990	0.02	0.61	0.65	0.65	0.63
JPN	Japan	2000	0.02	0.60	0.65	0.65	0.63
PRT	Portugal	2000	0.01	0.60	0.64	0.64	0.63
SLV	El Salvador	1995	0.02	0.60	0.65	0.65	0.63
COL	Colombia	1985	0.02	0.60	0.64	0.65	0.63
FRA	France	1990	0.01	0.60	0.64	0.64	0.63
CRI	Costa Rica	2000	0.02	0.60	0.65	0.65	0.63
MEX	Mexico	2000	0.03	0.60	0.65	0.65	0.62
GHA	Ghana	2000	0.02	0.60	0.64	0.65	0.62
GHA	Ghana	1995	0.03	0.59	0.65	0.65	0.62
DNK	Denmark	1985	0.01	0.60	0.64	0.64	0.62
BEL	Belgium	1995	0.01	0.60	0.64	0.64	0.62
SEN	Senegal	1990	0.03	0.59	0.64	0.65	0.62
AUS	Australia	1985	0.03	0.59	0.65	0.65	0.62
TTO	Trinidad and Tobago	2000	0.04	0.59	0.66	0.66	0.62
TUR	Turkey	1995	0.02	0.59	0.63	0.64	0.62
PAK	Pakistan	1985	0.02	0.59	0.64	0.64	0.62
CAN	Canada	1985	0.02	0.59	0.64	0.64	0.62
JAM	Jamaica	2000	0.02	0.59	0.63	0.64	0.61
TUR	Turkey	2000	0.03	0.59	0.63	0.64	0.61
ESP	Spain	2000	0.03	0.58	0.64	0.64	0.61
ISR	Israel	2000	0.01	0.58	0.62	0.62	0.61
CYP	Cyprus	1990	0.03	0.58	0.64	0.64	0.61

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Table A14: Public-sector efficiency for the DEA-sample – continued

country		**year**	**bias**	**lower bound CI**	**upper bound CI**	**DEA-score**	**DEA-score (corrected)**
FIN	Finland	1985	0.02	0.58	0.62	0.63	0.61
NLD	Netherlands	1990	0.01	0.58	0.62	0.62	0.60
JAM	Jamaica	1990	0.03	0.58	0.63	0.63	0.60
DEU	Germany	1990	0.02	0.57	0.62	0.62	0.60
AUT	Austria	1990	0.02	0.57	0.62	0.62	0.60
CRI	Costa Rica	1995	0.02	0.58	0.62	0.62	0.60
ISR	Israel	1995	0.01	0.57	0.61	0.61	0.59
IND	India	1990	0.02	0.57	0.61	0.61	0.59
UGA	Uganda	1995	0.03	0.56	0.62	0.62	0.59
MYS	Malaysia	1985	0.02	0.57	0.61	0.61	0.59
COG	Congo. Rep.	1990	0.02	0.56	0.60	0.60	0.58
ITA	Italy	2000	0.02	0.56	0.60	0.60	0.58
TUR	Turkey	1985	0.02	0.56	0.60	0.60	0.58
JPN	Japan	1995	0.03	0.55	0.60	0.61	0.58
TGO	Togo	1990	0.03	0.56	0.60	0.61	0.58
MYS	Malaysia	2000	0.02	0.55	0.60	0.60	0.58
ZWE	Zimbabwe	2000	0.02	0.55	0.60	0.60	0.58
SEN	Senegal	1985	0.03	0.55	0.60	0.60	0.58
TTO	Trinidad and Tobago	1995	0.03	0.55	0.61	0.61	0.58
GRC	Greece	1985	0.02	0.55	0.59	0.60	0.58
BHR	Bahrain	1995	0.01	0.55	0.59	0.59	0.57
ESP	Spain	1990	0.04	0.54	0.61	0.61	0.57
JPN	Japan	1990	0.04	0.54	0.61	0.61	0.57
DEU	Germany	1985	0.02	0.54	0.59	0.59	0.57
CAF	Central African Republic	1985	0.05	0.52	0.61	0.62	0.57
BEL	Belgium	1990	0.01	0.54	0.58	0.58	0.57
NER	Niger	2000	0.03	0.54	0.59	0.60	0.57
BHR	Bahrain	1990	0.01	0.54	0.58	0.58	0.57
IND	India	1995	0.02	0.54	0.58	0.58	0.56
CHL	Chile	1995	0.02	0.54	0.58	0.58	0.56
TUN	Tunisia	1990	0.02	0.54	0.58	0.58	0.56
PAN	Panama	1990	0.02	0.54	0.58	0.58	0.56
AUT	Austria	1985	0.02	0.53	0.58	0.58	0.56
IDN	Indonesia	1985	0.02	0.54	0.57	0.57	0.56
CHL	Chile	2000	0.03	0.52	0.57	0.58	0.55

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Table A14: Public-sector efficiency for the DEA-sample – continued

country		year	bias	lower bound CI	upper bound CI	DEA-score	DEA-score (corrected)
TGO	Togo	2000	0.03	0.52	0.58	0.58	0.55
CYP	Cyprus	1985	0.03	0.52	0.57	0.57	0.55
NLD	Netherlands	1985	0.01	0.52	0.56	0.56	0.55
BWA	Botswana	1990	0.03	0.52	0.57	0.57	0.54
MWI	Malawi	1990	0.15	0.51	0.68	0.69	0.54
ARG	Argentina	1995	0.02	0.52	0.56	0.56	0.54
IRN	Iran. Islamic Rep.	2000	0.03	0.52	0.57	0.57	0.54
SLE	Sierra Leone	1985	0.05	0.50	0.59	0.60	0.54
LKA	Sri Lanka	1990	0.02	0.52	0.56	0.56	0.54
GBR	United Kingdom	1985	0.02	0.51	0.55	0.55	0.53
PAN	Panama	1985	0.02	0.51	0.55	0.55	0.53
LKA	Sri Lanka	2000	0.02	0.51	0.55	0.55	0.53
JAM	Jamaica	1985	0.02	0.51	0.55	0.56	0.53
IND	India	2000	0.02	0.51	0.55	0.55	0.53
TGO	Togo	1995	0.03	0.51	0.56	0.56	0.53
ITA	Italy	1990	0.02	0.51	0.55	0.55	0.53
ITA	Italy	1995	0.02	0.51	0.55	0.55	0.53
ESP	Spain	1995	0.03	0.50	0.56	0.56	0.53
TUN	Tunisia	1985	0.02	0.51	0.54	0.55	0.53
ZWE	Zimbabwe	1990	0.02	0.51	0.54	0.54	0.53
SLV	El Salvador	1985	0.02	0.50	0.54	0.54	0.52
CRI	Costa Rica	1990	0.02	0.50	0.54	0.54	0.52
MEX	Mexico	1995	0.02	0.50	0.54	0.54	0.52
IDN	Indonesia	2000	0.02	0.50	0.53	0.53	0.52
ECU	Ecuador	1995	0.02	0.50	0.54	0.54	0.52
ESP	Spain	1985	0.02	0.49	0.53	0.54	0.52
ECU	Ecuador	2000	0.02	0.49	0.54	0.54	0.51
CAF	Central African Republic	1995	0.06	0.47	0.57	0.58	0.51
JPN	Japan	1985	0.04	0.49	0.55	0.55	0.51
COL	Colombia	1995	0.02	0.48	0.53	0.53	0.50
SEN	Senegal	1995	0.03	0.48	0.53	0.53	0.50
CHL	Chile	1990	0.02	0.48	0.52	0.52	0.50
COL	Colombia	2000	0.02	0.48	0.52	0.52	0.50
HUN	Hungary	2000	0.02	0.48	0.52	0.52	0.50
ISR	Israel	1990	0.01	0.48	0.51	0.51	0.50

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Table A14: Public-sector efficiency for the DEA-sample – continued

country		year	bias	lower bound CI	upper bound CI	DEA-score	DEA-score (corrected)
PHL	Philippines	1985	0.01	0.48	0.51	0.51	0.50
PRT	Portugal	1995	0.01	0.48	0.51	0.51	0.50
VEN	Venezuela. RB	2000	0.02	0.48	0.51	0.52	0.50
PRT	Portugal	1990	0.02	0.47	0.52	0.52	0.50
FRA	France	1985	0.01	0.47	0.51	0.51	0.50
BHR	Bahrain	1985	0.01	0.48	0.50	0.51	0.50
BRA	Brazil	2000	0.02	0.47	0.50	0.51	0.49
IRN	Iran. Islamic Rep.	1995	0.02	0.47	0.50	0.51	0.49
THA	Thailand	2000	0.02	0.47	0.50	0.51	0.49
SLV	El Salvador	1990	0.02	0.46	0.50	0.50	0.48
URY	Uruguay	1995	0.02	0.46	0.50	0.50	0.48
BEL	Belgium	1985	0.01	0.46	0.49	0.49	0.48
PNG	Papua New Guinea	1995	0.02	0.46	0.50	0.50	0.48
MEX	Mexico	1990	0.02	0.46	0.50	0.50	0.48
PNG	Papua New Guinea	1990	0.02	0.46	0.50	0.50	0.48
NER	Niger	1990	0.02	0.45	0.49	0.49	0.47
ZWE	Zimbabwe	1985	0.01	0.45	0.48	0.49	0.47
ARG	Argentina	2000	0.02	0.44	0.49	0.49	0.47
VEN	Venezuela. RB	1995	0.02	0.45	0.48	0.48	0.47
URY	Uruguay	2000	0.02	0.44	0.49	0.49	0.47
IRL	Ireland	1985	0.04	0.44	0.50	0.50	0.46
CMR	Cameroon	1990	0.02	0.45	0.48	0.48	0.46
VEN	Venezuela. RB	1985	0.02	0.44	0.48	0.48	0.46
PNG	Papua New Guinea	1985	0.02	0.44	0.48	0.48	0.46
ECU	Ecuador	1990	0.02	0.44	0.47	0.47	0.46
URY	Uruguay	1990	0.02	0.43	0.47	0.47	0.45
KWT	Kuwait	2000	0.01	0.43	0.46	0.46	0.45
BWA	Botswana	2000	0.01	0.43	0.46	0.46	0.45
TTO	Trinidad and Tobago	1990	0.03	0.42	0.47	0.47	0.45
BWA	Botswana	1995	0.01	0.43	0.46	0.46	0.45
UGA	Uganda	1990	0.03	0.42	0.47	0.47	0.44
COG	Congo. Rep.	1995	0.02	0.43	0.46	0.46	0.44
NIC	Nicaragua	2000	0.02	0.42	0.46	0.46	0.44
GHA	Ghana	1985	0.03	0.41	0.45	0.46	0.43
CMR	Cameroon	1995	0.02	0.41	0.45	0.45	0.43
ITA	Italy	1985	0.03	0.41	0.45	0.46	0.43

(continued on next page)

Table A14: Public-sector efficiency for the DEA-sample – continued

country		year	bias	lower bound CI	upper bound CI	DEA-score	DEA-score (corrected)
ISR	Israel	1985	0.01	0.41	0.44	0.44	0.43
HUN	Hungary	1995	0.02	0.40	0.44	0.44	0.42
VEN	Venezuela. RB	1990	0.01	0.40	0.43	0.43	0.42
JOR	Jordan	1995	0.02	0.40	0.43	0.43	0.42
ZWE	Zimbabwe	1995	0.01	0.40	0.43	0.43	0.42
CRI	Costa Rica	1985	0.01	0.40	0.43	0.43	0.41
SYR	Syrian Arab Republic	1990	0.01	0.40	0.42	0.43	0.41
MEX	Mexico	1985	0.02	0.39	0.43	0.43	0.41
PNG	Papua New Guinea	2000	0.02	0.39	0.43	0.43	0.41
ZAF	South Africa	2000	0.02	0.38	0.42	0.42	0.40
ZAF	South Africa	1990	0.02	0.38	0.42	0.42	0.40
TTO	Trinidad and Tobago	1985	0.03	0.37	0.42	0.42	0.39
KWT	Kuwait	1985	0.01	0.38	0.40	0.40	0.39
SLE	Sierra Leone	1995	0.04	0.36	0.43	0.43	0.39
ECU	Ecuador	1985	0.01	0.36	0.39	0.39	0.38
KWT	Kuwait	1990	0.01	0.36	0.39	0.39	0.38
URY	Uruguay	1985	0.01	0.36	0.39	0.39	0.37
CHL	Chile	1985	0.01	0.36	0.38	0.39	0.37
ARG	Argentina	1990	0.01	0.36	0.38	0.38	0.37
IRN	Iran. Islamic Rep.	1990	0.02	0.35	0.38	0.38	0.36
HUN	Hungary	1985	0.03	0.34	0.39	0.39	0.36
SYR	Syrian Arab Republic	1985	0.01	0.34	0.37	0.37	0.36
HUN	Hungary	1990	0.02	0.34	0.38	0.38	0.35
JOR	Jordan	1985	0.02	0.33	0.37	0.37	0.35
SLE	Sierra Leone	1990	0.05	0.32	0.39	0.40	0.35
ZAF	South Africa	1985	0.02	0.33	0.36	0.36	0.35
ZAF	South Africa	1995	0.02	0.33	0.36	0.37	0.35
NIC	Nicaragua	1995	0.01	0.33	0.36	0.36	0.35
PER	Peru	1990	0.01	0.33	0.35	0.36	0.34
UGA	Uganda	1985	0.02	0.33	0.36	0.36	0.34
BRA	Brazil	1995	0.01	0.32	0.35	0.35	0.34
NER	Niger	1995	0.02	0.32	0.35	0.35	0.34
PER	Peru	1985	0.01	0.32	0.35	0.35	0.34
SLE	Sierra Leone	2000	0.09	0.31	0.41	0.42	0.33

(continued on next page)

Table A14: Public-sector efficiency for the DEA-sample – continued

country		**year**	**bias**	**lower bound CI**	**upper bound CI**	**DEA-score**	**DEA-score (corrected)**
NER	Niger	1985	0.01	0.31	0.34	0.34	0.33
ARG	Argentina	1985	0.01	0.31	0.33	0.34	0.33
PRT	Portugal	1985	0.03	0.31	0.35	0.35	0.33
COG	Congo. Rep.	2000	0.02	0.31	0.34	0.34	0.32
BRA	Brazil	1985	0.01	0.31	0.33	0.33	0.32
BRA	Brazil	1990	0.02	0.28	0.31	0.31	0.29
TGO	Togo	1985	0.01	0.28	0.30	0.30	0.29
IRN	Iran. Islamic Rep.	1985	0.01	0.28	0.30	0.30	0.29
MWI	Malawi	1985	0.78	0.59	0.96	1.00	0.22
JOR	Jordan	1990	0.02	0.21	0.24	0.24	0.22
NIC	Nicaragua	1985	0.01	0.16	0.17	0.17	0.16
NIC	Nicaragua	1990	0.01	0.13	0.14	0.15	0.14

Chapter 6

Summary and outlook

Summary

This dissertation consists of four chapters dealing with selected topics in the field of fiscal competition and public-sector modernisation. The detailed results and the summary can be found in the respective chapters. This summary describes the most important contributions of this dissertation.

Chapter 2 introduces a particular method ("comparative dynamics") to analyse a dynamic model of fiscal competition. This method was used by Wildasin [2003] and earlier by Boadway [1979]. Fiscal competition is modelled as tax competition for mobile capital. In many tax competition models, tax competition is associated with a negative "fiscal externality", see Wilson [1999, p. 272]. If a country tries to attract capital by lowering its capital tax rate, it triggers an outflow of capital in other regions. Ceteris paribus, this makes their tax base and revenues smaller [Wildasin 1989]. In a static model of tax competition, when undistorting taxes are available, this implies zero taxation of capital. Chapter 2 shows the implications of this externality for capital taxation in a traditional growth model where the economy converges to a stationary steady state and adjustment costs for the installation and de-installation of capital are a convex function of investment. While this is already contained in Wildasin [2003], chapter 2 is more elaborate on the technical details, including the necessary assumptions. Of particular importance is the assumption that the economy of a local jurisdiction can be described as one that is in a steady state initially, then the local government sets an optimal tax rate and the economy converges to a new steady state.

Chapter 2 tries to be as clear as possible about methodological issues. Furthermore it introduces the modelling of imperfect competition that is used in the subsequent chapters 3 and 4. The convexity of the adjustment cost function is shown to provide a measure for the mobility of capital. The more convex the adjustment cost function is, the more expensive is the relocation of capital. It is hence optimal from the point of view of the capital owner to avoid sudden jumps in the capital stock and to adjust the capital stock only gradually, in a process that takes time. Note that the fiscal competition literature usually compares the polar cases of perfect capital mobility in a decentralised federation with a centralised (closed) economy. An exception is Lee [1997]. But his results are mainly driven by his assumption that there are only two periods. The concept of adjustment costs in a growing economy allows to model imperfect capital mobility that is measured by a parameter. To improve the exposition, a functional form for the adjustment costs is assumed and the algebra is shown in a step-by-step fashion. In addition, the time-inconsistency of the optimal tax rate in Wildasin [2003] is highlighted.

Chapter 3 applies the methodology of comparative dynamics to the issue of public-sector modernisation. The economic content of the model is that the issue of public-sector efficiency is not linked to the assumption of a wasteful government as it is usually done in the literature. In this model, the efficiency of the public sector is the result of past investment. It is, hence, modelled as a stock variable that plays a crucial role in the public sector's production technology. The application in chapter 3 considers a specific task of the public sector: the redistribution between two groups in the society. On the one hand, there are capital owners. The government tries to optimally exploit them in favour of the other group in the society, worker households. Doing so, it faces the trade-off that capital taxation is a prerequisite for transfers to households. On the other hand, capital taxation depresses the accumulation of capital and this eventually depresses the wages of workers. Furthermore, the government faces a trade-off whether it should invest the tax revenue in its own production process (benefiting future worker households) or use it directly as a transfer. Public-sector efficiency is the result of past investment of the public sector and could be IT technology, knowledge or some other stock that is necessary to fulfill the task of providing a transfer to a target group. An example of one of the tasks that can be done more or less efficiently is to identify whether the transfer receivers qualify for the payment, given the rules governing the transfer program.

The title of chapter 3 contains the notion of "tax competition". The literature usually solves for the Nash equilibrium in a system of jurisdictions. But still, the individual jurisdiction behaves in a fashion that is usually associated with tax competition. Raising the tax rate triggers an outflow of capital that benefits other jurisdictions. The optimal tax rate is the lower, the more mobile capital is. This is the standard externality around which many tax competition models are built, albeit the model framework is somehow different. In chapter 3, the negative relationship between capital mobility and capital tax rates may cause a less efficient public sector. But, due to the aforementioned assumption of an initial steady state, the efficiency consequences of a variation of capital mobility depend on the description of the economy in this initial steady state. See section 3.3.3 for the details. Subtleties acknowledged, chapter 3 shows that the intensity of interjurisdictional competition, measured by capital mobility, and public-sector efficiency are possibly negatively related.

While chapters 2 and 3 analyse a traditional growth model, chapter 4 contains a model of endogenous growth. The idea of this paper is to use an relatively easy model of endogenous growth to model tax competition in a federation where capital is imperfectly mobile. The growth framework is the same as in Barro [1990], where sustained growth is based on the provision of a flow of public services. This flow enters a production function with constant returns to scale in capital and public services. The assumption that public service is a flow, not a stock, simplifies the model substantially, as it has a balanced growth path and no transitional dynamics.[1] The core of chapter 4 is the modelling of the capital market in a federation where the taxation of capital is decentralised. As the federation is assumed to consist of identical jurisdictions, the capital market equilibrium can be characterised by the interest rate that ensures that no agent with access to the capital market has an incentive to act as a borrower or a lender. In equilibrium, symmetry in the model ensures that there is no interjurisdictional lending and borrowing. Based on this insight, the implications of a variation of capital mobility on the market clearing interest rate are shown. In the growth

[1] Introducing additional stock variables in a growth model complicates them to a large extend as the resulting dynamic systems get more and more complex. An example is Futagami et al. [1993] that differs from Barro [1990] only in the assumption that the public sector provides a stock of public capital.

framework used, there is a simple relationship between the market clearing interest rate and the equilibrium growth rate of the federation and its local jurisdictions.

One finding in chapter 4 is that capital mobility is beneficial for growth. Other findings are that a linear relationship between capital mobility and taxation is a special case and in general, the relationship is non-monotonous. Perfect capital mobility implies zero capital taxation. But zero taxation is also a possibility with imperfect capital mobility. Increasing the parameter measuring the mobility of capital sometimes implies higher tax rates, but the opposite is also possible. The crucial parameter in this respect is the elasticity of intertemporal substitution, i.e. the taste for consumption smoothing. The tax policy of the local government takes into account its implications on the consumption path of households. The somehow unconventional results in chapter 4 are mainly due to this complication that only occurs in an explicitly dynamic model that does not fix the elasticity of intertemporal substitution to unity (log-utility). Furthermore, chapter 4 shows that an equilibrium with a balanced growth path does not exist if capital mobility falls below a certain threshold. Hence, a minimum level of capital mobility is a prerequisite for the economy modelled in chapter 4 to exist.

Chapters 2 to 4 are theoretic contributions. In chapter 5, public-sector efficiency is explored empirically. It provides a robustness check for a closely related paper by Afonso et al. [2005], with which it shares the general concept on how to measure the inputs and outputs of the public sector. Also similar to Afonso et al. [2005] it uses non-parametric methods to construct efficiency-scores for the public sector of countries relative to an estimated efficiency border. But, after a discussion of methodological issues and recent developments in the field of non-parametric efficiency measurement, it applies a more advanced method to calculate those efficiency scores. Other differences include a slightly different choice of variables in the input and output measurement and that the sample is larger both cross-sectional (up to 74 countries) and in time (four 5-year periods 1985-2000). Additional value is added insofar as the efficiency scores are used in a regression analysis that tries to explain the pattern of public sector by the intensity of interjurisdictional competition. The idea is, as has been argued in chapter 3, that the competition between jurisdiction – in this case: countries – has an influence on the efficiency of the public sectors that use tax revenue to provide public goods and services. The regression analysis is also used to check the robustness of the major result of Afonso et al. [2005]. According to their study, countries with a small government in terms of government expenditure in relation to the GDP tend to be more efficient.

The results in chapter 5 suggest that the pattern of public-sector inefficiency can be explained by continent dummies, with the implication that common cultural background and common shared history shapes the public sector to a considerable extent. Both government size and the intensity of interjurisdictional competition (measured by a globalisation index as a proxy) are shown to have explanatory power, but the size of the estimated coefficients is not very strong. Still, smaller and more globalised countries do better in terms of public-sector efficiency in the sample I have considered. A somehow surprising result is that more centralised countries are also shown to be more efficient. In chapter 5, I argue that the numbers produced by the analysis should not be taken literally and also that political decisions are better based on a careful consideration of all the details that can hardly be considered in a large panel of countries. Still, the efficiency measures I calculate are not very different from an index that is based on surveys, the perception of country analysts and commercial risk rating agencies [Kaufmann et al. 2008].

Outlook

As maybe all dissertations, this one does not only provide answers but also leads to new questions and items on the research agenda. Some of those are already described in the conclusions of chapters 2-5.

For the empirical investigation of the nexus between interjurisdictional competition and public-sector efficiency, the most pressing issue is whether studies like the one presented in chapter 5 are robust. One obvious way to check robustness is replication, see the footnotes in de Haan [2007]. Another way is to find other, probably better, solutions for the measurement problem. The measurement of the inputs and outputs of the public sector will always be imperfect, but still, I think that it is possible to construct datasets that are a reasonable basis for studies similar to the one contained in chapter 5. Future studies in the same fashion need to keep pace with the methodological developments in parametric and non-parametric efficiency measurement, see section 5.2. One task in this respect is a very practical one: new methods need to be implemented in statistical packages in such a way that the research community is able to check for coding errors and in a transparent way.

Theoretical work could proceed in many directions, some of them are mentioned in the conclusions of earlier chapters. An issue of particular importance seems to understand better why the link between decentralisation and tax competition on the one hand and growth and public-sector efficiency on the other is different between developed and developing countries, see Acemoglu et al. [2004] for a review of the literature about institutions and growth.

Maybe the most challenging direction for future research – not mentioned earlier – is to proceed further in the direction of a truly dynamic theory of tax competition. The dynamics in the models presented in the theoretical chapters above are, of course, not “untrue”. The models are dynamic as they are growth models, where the economy is described by differential equations. But in some important respect, they do not model tax competition dynamically as all models assume that governments can commit themselves credibly to the tax policy they announce. In the game-theoretic language, governments (and all other agents) pursue open-loop strategies.[2] To simplify matters even more, this strategy has been assumed to be time-invariant. This is not meant as a dismissal of modelling of tax competition in dynamic growth models that is an area of active research in public finance. For example, it allows to model imperfect capital mobility consistently, as has been argued repeatedly above. But the issue of dynamics could be taken even more seriously in models that also consider closed-loop strategies.[3] This implies to abandon the assumption of the availability of a commitment technology and would hence be a step towards more realism. Instead of the deterministic theory of optimal control, differential games then need to be considered.

Why should it be interesting to model tax competition as a differential game? In a standard tax competition model, governments face, ex ante, an incentive to relax capital taxation in order to attract the mobile tax base capital. Ex post, however, capital does not move if all jurisdictions are assumed to be equal. All governments face the same incentives, behave identically and therefore the relative attractiveness of the jurisdictions is unchanged. In a dynamic model with adjustment cost as they were used in the preceding chapters, capital flight is a time-consuming process. Hence, governments have a possibility to learn about the

[2] An open-loop strategy in a dynamic system depends on time t and on the initial conditions of a dynamic system. See Feichtinger / Hartl [1986, ch. A.7] and for an introduction into the theory of differential games Dockner et al. [2000].

[3] Closed-loop strategies depend on time t, on the initial conditions of a dynamic system, and, in addition, on the current state of the dynamic system.

environment they operate in and adjust their expectations about the elasticity of the tax base accordingly. One would expect that the equilibrium of (closed-loop) strategies is one where tax rates are higher than in a model that assumes open-loop strategies.

Once a basic tax-competition game in closed-loop strategies is well understood, a next step could be to analyse the role of infrastructure investment in such a game. An important characteristic of infrastructure capital in this context is that its adjustment might be more difficult and time consuming than changing the capital tax rate. What does this mean for the equilibrium strategies? Is the competition for mobile resources more intense when public capital is considered to be one of the instruments to attract capital? Are there possibilities to use public capital as a commitment device?

The answers to these and other open questions cannot be found in this thesis. But, hopefully, they will be given in not so far future, in papers that yet need to be written.

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If available for a reference, the DOI-number (DOI = Digital Object Identifier) is listed. Digital Object Identifiers are similar to ISBN-numbers for books. They are stable over time and provide in the case of academic journals a way to link to the publisher-website associated with a published paper. The link between a doi and a website is provided by http://dx.doi.org/. If you are reading the pdf-Version of this document, the doi-entries are clickable.

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