Optimal Fiscal Policies in the Presence of Migration: A Dynamic Perspective

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Diplom-Volkswirtin Christiane Schuppert

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Contents

List of Figures

List of Tables

List of Symbols

Chapter 2

i	country index
t	time index
a	per capita asset holdings A
h	human capital
w	wage rate
r	interest rate
β	discount factor
c	consumption
$u(c)$	utility function
σ	intertemporal elasticity of substitution in consumption
y	per capita output Y
N	population size
$f(\cdot)$	per capita private production function $F(\cdot)$
$\Phi(\cdot)$	public production function
k	per capita capital supply K
	with $k^i = a^{ii} + \frac{A^{\bullet i}}{N^i} = a^{ii} + \sum_{j \neq i} \frac{A^{ji}}{N^i}$
$\mathcal{N}$	aggregate labor supply $h \cdot N$
g	per capita level of public good G

α	production elasticity of capital
γ	production elasticity of public input
η	congestion parameter
$\mathcal{G}$	effective public production input
τ_w	tax on wage income
τ_{rD}	tax on resident's capital income (domestic source)
τ_{rF}	tax on resident's capital income (foreign source)
τ_{rI}	tax on inbound investments
δ	tax credit on taxes already paid in other regions
τ_{rE}	effective tax rate on outbound investments
	with $\tau^i_{rE} = \tau^i_{rF} + (1 - \delta^i)\tau^j_{rI}$
λ	Lagrange multiplier
μ	Lagrange multiplier
ω	modified social welfare function (primal approach)
$\hat{c}$	growth rate of per capita consumption

Chapter 3

i	region index
t	time index
β	discount factor
$n = H, L$	skill-types
N^n	population size of skill type n
w^n	skill-specific wage rate
z^n	efficiency units supplied by n-type
Z	aggregate effective labor supply $Z = z^H N^H + z^L N^L$
$F(Z)$	production function
$R(Z)$	pure profit
c	consumption
e	parental investment in education
$u(c) + v(e)$	separable utility function $U(\cdot)$
$h(e)$	probability to become high-skilled
τ_w^n	skill-specific labor income tax (local level)
τ^n	skill-specific lump-sum tax (local level)
θ_e^n	skill-specific matching grant (federal level)
θ^n	skill-specific lump-sum tax (federal level)
λ	Lagrange multiplier
μ	Lagrange multiplier
κ	Lagrange multiplier
φ	Lagrange multiplier

Preface

This dissertation draws on research I undertook during the two years in which I held a scholarship of the Deutsche Forschungsgemeinschaft (DFG) at the Graduiertenkolleg "Allokationstheorie, Wirtschaftspolitik und kollektive Entscheidungen", and later while I was a teaching and research assistant at the chair of public finance at the University of Dortmund. The present thesis has strongly been influenced by and profited from discussions with professors and fellow students of the Graduiertenkolleg, as well as presentations at various national and international conferences. I am very grateful to all who supported my work in that way.

In particular, I would like to thank Wolfram Richter, who supervised my dissertation. Moreover, I would like to thank Heinz Holländer, Wolfgang Leininger, Michael Roos, Julia Angerhausen, and Frauke Eckermann, who all helped me to improve this thesis at the various stages of its development. Special thanks are given at the beginning of the respective chapters. Financial support by the Deutsche Forschungsgemeinschaft is gratefully acknowledged.

Christiane Schuppert

Chapter 1

Introduction

In view of the ongoing integration of the world economy, factor movements of both capital and labor have increased substantially. While capital mobility has been broadly discussed in the past, migration has only recently become an issue ranked high on the political agenda. Among the various dimensions of migration that include welfare-induced and illegal migration as well as asylum seekers and refugees, one aspect of migration is of special relevance for local tax policies: labor mobility. The observable increase in the mobility of workers confronts local governments with a mobile tax base that can easily evade unfavorable tax systems since it acts on a labor market that by far exceeds national boundaries. The scope of these factor markets might entail the entire world economy in case of highly-specialized labor, several independent national states such as the members of the European Union, or regions within a single federal country. In all of these circumstances, the increased mobility of labor raises the issue of whether and to what extent local governments lose the ability to tax their workforce.

So far, labor mobility has received relatively little attention in the economic literature on optimal fiscal policy compared to the vast body of research dealing with mobile capital.[1] One reason for this imbalance is the widespread conjecture of labor being relatively - if not totally - immobile. Yet, to acknowledge the actual relevance of migration, one has to relate the data on migration flows to the problem at hand: While international labor mobility might be limited in general, migration across relatively homogenous regions such as jurisdictions of a federation like the United States or across member states of the European Union is presumably much higher. To motivate the focus on labor mobility in the present thesis, the following Section 1.1 provides a brief assessment of the empirical relevance of migration for decentralized policy making.

While the magnitude of migration is empirically disputed, modeling labor mobility is also highly relevant from a theoretical perspective. This is due to the fact that labor and capital do not simply represent alternative production factors with identical characteristics. Rather, labor displays some crucially different features possibly altering the results of theoretical models with capital mobility: While capital flows directly affect a region's tax base, movements of labor impact the tax base not only directly, but also indirectly as the owner of the capital stock changes her place of residence. The sending country might thereby entirely lose it's scope to levy taxes on these assets.

Moreover, a comprehensive analysis of the impact of factor mobility on fiscal policy has to take into account the dynamic dimension of factor movements: While most recent work discusses the implications of mobility of a given stock of capital or labor, these stocks have been accumulated over time. This implies that in a dynamic framework, fiscal policy does not only affect

[1] See Wildasin (2006).

the allocation of a factor in space, but additionally the incentives to accumulate the factor endowment over time. The present research contributes to the literature by considering two different dynamic setups, each capable of analyzing both the spatial allocation as well as the evolution of stocks over time. To introduce the problem, Section 1.2 provides an overview on dynamic studies of fiscal competition incorporating the evolution of mobile factors over time, a topic which has only been recognized recently in the literature, and briefly outlines the structure of this thesis.

1.1 On the Relevance of Labor Mobility

To start the empirical assessment of the relevance of labor mobility, consider movements of labor between independent national states that are rather heterogeneous with respect to migration barriers such as language, culture or administrative systems. Figure (1.1) depicts the inflows of foreign nationals as a percentage of the total population for selected OECD countries in 2004. With an average of only 0.46%, mobility rates for movers from abroad are rather low and, hence, seem to support the popular conjecture of migration being of minor importance for policy making. Yet, this data has to be viewed with caution as international migration is still heavily restricted. Observed mobility rates thus most likely underestimate the potential for migration, as they mainly reflect rigid policy barriers that prohibit free factor movements.

While mobility at the international level is rather low, this result does not necessarily carry over to internal migration rates between regions of a single federal state such as the United States, Canada or Germany. As jurisdictions of federations are typically rather homogenous with respect to major obsta-

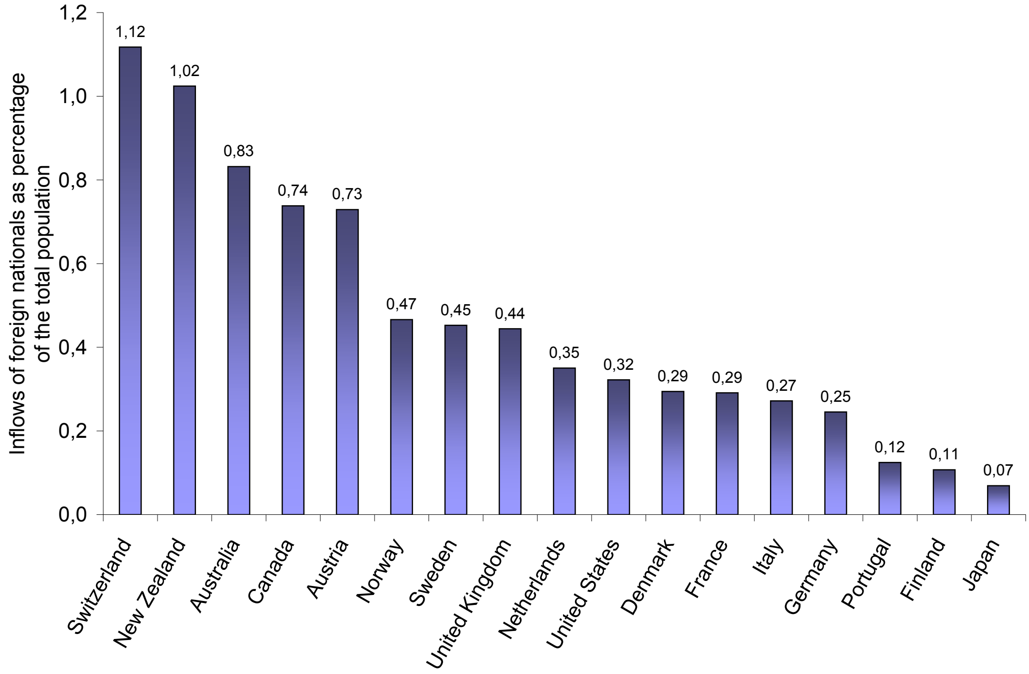

Figure 1.1: Inflows of foreign nationals as a percentage of the total population, selected OECD countries, 2004
Source: OECD (2006), Chart I.1.

cles of migration, one would expect to observe high levels of interregional mobility. This view is confirmed by data on internal geographical mobility rates for the United States, covering the period 2001 to 2005. Table (1.1) reports the annual number of national migrants in relation to the aggregate population of the U.S., distinguishing between movements within the same county and to a different county within the same state or to a different state. While an average of 13.6 percent of the total U.S. population changed their residence in the relevant years, more than one third of these moved to another county. Interestingly, mobility rates for movements across counties within the same state and across states are nearly identical, supporting the conjecture that barriers to migration between federal regions are relatively low.

Mobility period	Different residence in the United States				
	Total	Same county	Different county		
			Total	Same state	Different state
2004-2005	13,2	7,9	5,3	2,7	2,6
2003-2004	13,3	7,9	5,3	2,8	2,6
2002-2003	13,7	8,3	5,4	2,7	2,7
2001-2002	14,2	8,5	5,7	2,9	2,8

Table 1.1: Annual U.S. mobility rates by type of movement, 2001-2005
Source: U.S. Census Bureau,
http://www.census.gov/population/socdemo/migration/tab-a-1.pdf.

While the data on the United States displays a high internal mobility of workers, data on mobility rates at the international level seem to indicate that labor is significantly less mobile across national states, including the member states of the European Union. Still, it is reasonable to expect an increase in migration flows in the years to come, at least with respect to internal migration in highly integrated regions such as the European Union where several political initiatives aim at increasing mobility. These include e.g. the ongoing Bologna process that aims at enhancing mobility by improving the recognition of academic degrees and qualifications, and the proposal for the advancement of the portability of supplementary pension rights. Moreover, comparing mobility rates of the working age population across different geographical units in the European Union in 2005 suggests that there is a high potential for promoting migration: According to the European European Comission (2006), mobility rates between European regions surpassed annual mobility rates between EU member states on average by a factor of ten to thirteen, contingent on the regional classification system used.

Furthermore, it becomes obvious that migration displays an important phenomenon for policy making if one compares the population growth that is due to immigration with the natural rate of increase. Figure (1.2) decomposes the total population growth of the fifteen EU member states of 1995 into the rate of natural increase and the net migration rate.[2] It can easily be revealed that immigration as a component of total population growth in the EU has outranged natural population growth since the late 1980's.

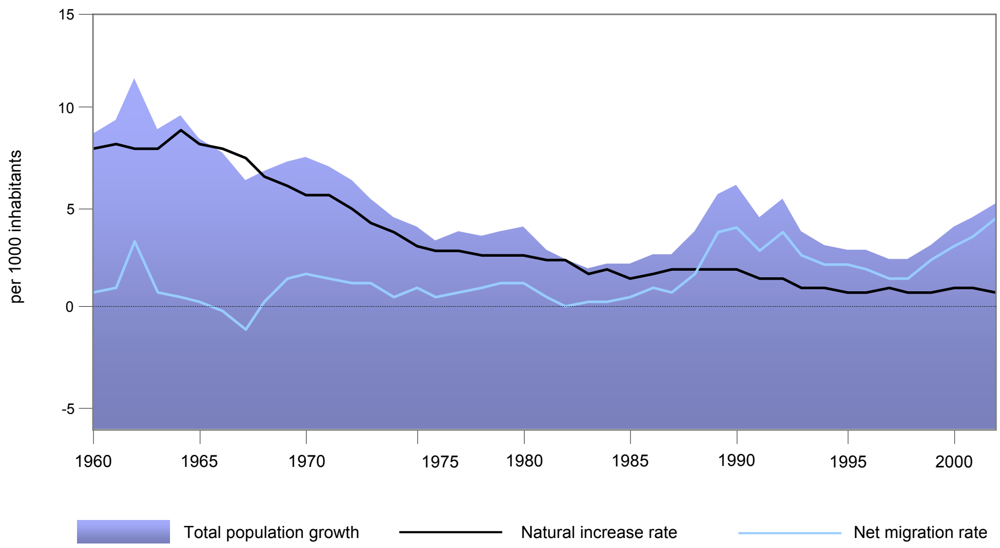

Figure 1.2: Components of total population growth in the fifteen EU member states of 1995, 1960 - 2002, measured per 1000 inhabitants at beginning of the year
Source: OECD (2004), Figure I.8

Moreover, as many obstacles to migration such as language and informational barriers are less relevant for highly qualified labor, a further increase in labor mobility is likely in view of the large and rising fraction of well

[2] The data covers the period 1960-2002. However, Portugal has been excluded from 2001 on and Greece from 2000 on.

educated workers.[3] This view of an enhanced mobility of skilled workers is supported by data on the share of highly qualified labor among immigrants. Figure (1.3) depicts the fraction of immigrants in the fifteen EU member

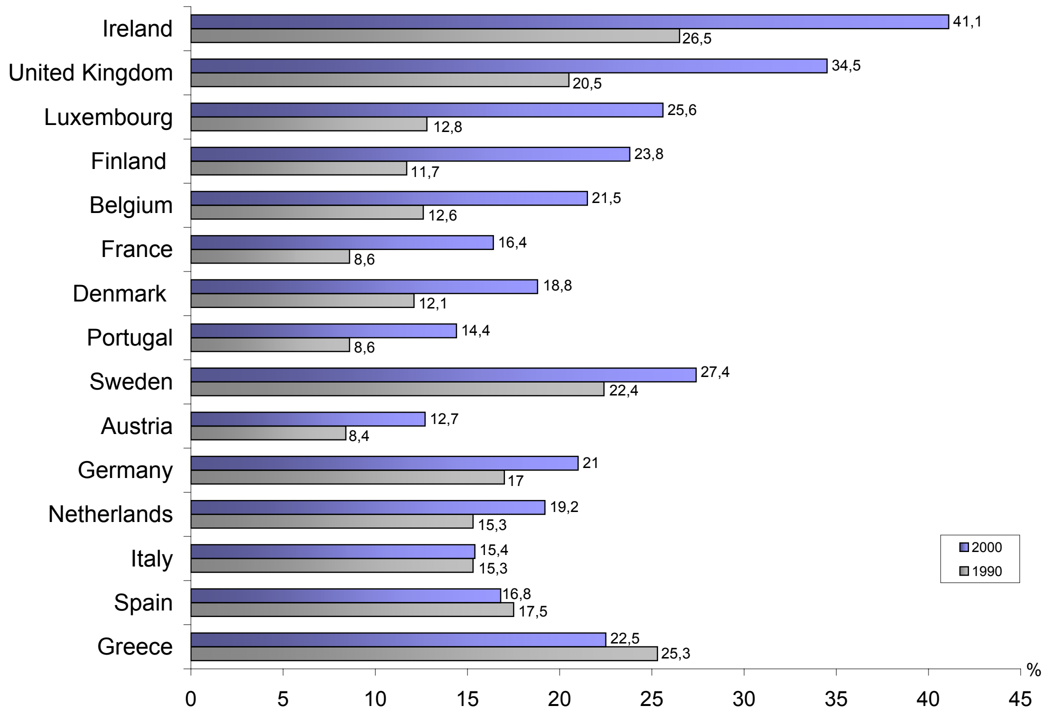

Figure 1.3: Proportion of tertiary among immigrants, 1990 and 2000
Source: Author's depiction based on Docquier and Marfouk (2006), Table 5.5.B.

states of 1995 with tertiary education for the years 1990 and 2000 and reveals a pronounced rise in the share of qualified immigrants for nearly all members states. Composing the average over all displayed EU countries, the proportion of working-age immigrants with at least tertiary education rose by 6.4 percentage points, nearly three times of the increase in the share of the world labor force with tertiary education of 2.2 percentage points only.[4]

[3] Between 1990 and 2000, the share of the OECD labor force with tertiary education has increased from 21.9 to 27.6 percent (Docquier and Marfouk, 2006).
[4] These calculations are based on data provided by Docquier and Marfouk (2006).

Still, given the data presented one might assess the mobility of labor as relatively low. However, one has to bear in mind that the data displayed is based on actual factor movements. Besides the obvious underestimation due to illegal migration, the threat of mobility can hardly be evaluated on the grounds of observed migration rates: The relatively low mobility of labor might represent an equilibrium phenomenon that reflects the fact that currently incentives to change the place of residence are low or even absent (Andersson and Konrad, 2006). Yet, changing economic environments e.g. as a result of a shift in fiscal policy, might result in large factor movements if the potential for migration is high. Hence, even though observed migration seems to be of negligible size and the true threat of migration is hard to assess, labor mobility is most likely an important policy constraint that should be kept in mind when designing optimal policies, at least at the regional level.

1.2 Towards a Dynamic Perspective

Based on the increasing importance of international factor movements for fiscal policies, a vast body of economic research has dealt with this phenomenon. With respect to local public finance, the literature can be traced back to two separate strands of argumentation: According to Tiebout (1956), fiscal competition among independent jurisdictions can be viewed as welfare improving since local public good provision can be tailored to better match the preferences of mobile residents than centralization. More precisely, community developers, aiming at maximizing the value of land, attract mobile labor by providing a certain mix of public goods and local head taxes. Since a single small region cannot alter the utility level mobile households' receive outside of the respective community, competition of land developers results in marginal-cost pricing: Local taxes can be interpreted as user fees for public good provision, and households efficiently sort themselves into the community that best serves the preferred public good level.

Quite differently, Wilson (1986) and Zodrow and Mieszkowski (1986) perceive tax competition for mobile capital as inefficient as it results in underprovision of public goods. Restricting the available local tax instruments to a source tax on mobile capital, provision of local public goods that benefits immobile households necessarily leads to capital outflows. At the same time, this induces an increase in tax revenue for neighboring regions where the tax base rises. Since this positive externality is disregarded by a single regions, local jurisdictions set both the tax rate as well as the public good at an inefficiently low level.

Later contributions to these opposing strands of literature recognize both a welfare enhancing effect of capital tax competition as well as possible inefficiencies in Tiebout-type models. A detailed survey over the various arguments and approaches can be found in Oates (1999), Wilson (1999) as well as Wilson and Wildasin (2004). Most of this research still resorts to static analyses; dynamic aspects and implications of fiscal competition are often ignored. Yet, while analyzing implications of tax competition for a fixed stock of physical or human capital points at important issues, it neglects the impact on incentives to accumulate the relevant factor over time: Fiscal policy does not only affect the geographical allocation of factors, but additionally determines the evolution of the factor endowment in time.

The literature on time-inconsistent fiscal policies has first recognized the relevance of accumulation of mobile factors over time: While standard tax competition models emphasize the arising inefficiencies, this literature detects welfare improving aspects of competition. Kehoe (1989) uses a two-period model with two countries in which households decide on the amount of savings before tax rates have been set. Since the government cannot commit to it's announced fiscal policy, savings will be inefficiently low in anticipation of excessive future taxation in the home country. Introducing the possibility of capital flight, Kehoe (1989) shows that competition for mobile capital serves as a commitment device for low source-based capital income taxes. Andersson and Konrad (2003a,b) as well as Thum and Uebelmesser (2003) build on this result focusing on different aspects of education policy in setups where mobile human capital is excessively taxed once accumulated. Bucovetsky and Smart (2006) study the efficiency of revenue equalization schemes when capital is elastically supplied. Introducing a hold-up problem of excessive capital taxation at the federal level, they confirm the view that delegating the power to tax capital to regional governments competing for the mobile factor can solve the commitment problem and improve welfare.

In contrast, assuming that commitment is feasible, several studies have analyzed the role of savings for capital taxation in the presence of mobile capital, but failed to detect an additional effect due to introducing a savings decision.[5] Although deviating from the purely static setup, these contributions reproduce the finding of static models that source taxes on mobile capital are inefficient. This can be explained by the fact that these studies consider small open economies: Since the net rate of return on capital investments is fixed by the world rate of return, the time dimension does not alter savings incentives nor the standard tax competition results - at least not as long as perfect mobility of capital is assumed. Similarly, the inefficiency of source taxes on

[5] The first study in this respect was Gordon (1986).

mobile capital has been replicated in infinitely-lived agent frameworks. As a consequence, contributions on optimal taxation in dynamic general equilibrium models mostly focus on the optimality of international tax principles from a global perspective, while aspects of fiscal federalism and public good provision are ignored.[6]

The importance of imperfect mobility as a result of adjustment costs has first been recognized by Wildasin and Wilson (1996) for the case of mobile labor. While initially perfectly mobile, old individuals develop some sort of attachment to their country of residency implying that moving at a later stage becomes costly. The resulting imperfect mobility involves economic rents that land-value maximizing governments will try to capture, thereby inducing inefficient migration of rationale young individuals.

However, the initial mobility might provide a mechanism to overcome the underlying commitment problem: Wilson (1996) considers a dynamic framework in which firms are initially perfectly mobile, but relocation becomes costly once a firm has entered a specific region. Anticipating the incentives of local residents to capture the rent income resulting from imperfect firm mobility, firms will only enter the region if they are compensated for the loss of economic rents, e.g. via initial subsidies financed by future tax revenue.[7] Similarly, Lee (1997) shows in a two-period model that initial tax competition is especially fierce if firms face relocation costs in the second period. At the same time, however, imperfect second period mobility reduces tax competition and leads to an overprovision of public goods.

[6] For an overview see Atkeson et al. (1999) and Chari and Kehoe (1999).

[7] Similarly, Janeba (2000) utilizes a setup in which firms have incentives to invest in excess capacities at home as well as abroad to escape high taxation once investments are sunk: Since the firm can serve the market producing abroad, a local government starts to compete for utilization of domestic capacity by lowering it's tax rate.

The study by Wildasin (2003) emphasizes that imperfect mobility resulting from some sort of adjustment costs increases the scope of taxation of mobile factors to redistribute income.[8] Recognizing that the adjustment of factors in space is time-consuming, a dynamic model is set up that is capable of analyzing adjustments in the stock of capital over a long time horizon. It is shown that while adjustment costs can increase tax rates in the short run, this is only a transitory effect: Converging to the new steady state, the level of capital will adjust gradually to the change in fiscal policy. This implies that imperfect mobility affects the speed of adjustment, but not the long-run equilibrium level of capital employed.

In addition to the research stressing time-consuming adjustments of factors in space, the importance of incentives to accumulate mobile factors in time has been exploited recently in a new strand of literature concentrating on the link between growth and decentralization. While these studies typically consider growth maximizing rather than efficiency enhancing public policies, they utilize important insights of the tax competition literature.[9] Brueckner (2006) develops an endogenous growth model with overlapping generations in which young and old individuals live in separate regions and differ with respect to their preferred level of public good provision. Starting from a centralized system with uniform provision, decentralization can better match the different demands of consumers. Naturally, with an increasing income over the life cycle, tastes for public good provision of the young are lower,

[8] A brief description of the model and it's implications can already be found in Wildasin (2000a).

[9] Lejour and Verbon (1997) develop an endogenous growth model focusing on welfare rather than growth effects of tax competition. While an increase in local taxes induces a positive tax-base externality due to capital outflow, it also generates a negative growth externality: Since higher tax rates depress incentives to save and invest, outbound investments decline, lowering the growth rate abroad. This implies that tax competition results in inefficiently high tax rates and overprovision of public goods.

implying a lower head tax under decentralization where public good provision can be tailored to meet demands. The reverse applies for the group of old individuals.

Given this framework, Brueckner (2006) argues that lower (higher) head taxes for young (old) consumers change the time path of the available net income, raising it when young, while reducing it when old. This change in the net income path might not only increase savings but also affect the time spend on schooling, implying that the impact on growth is ambiguous. Yet, one can show that the regime change ultimately promotes growth.[10] Similarly, decentralization might enhance growth via increased savings incentives if tax competition is a means to restrain excessive taxation of rent-seeking politicians.[11] Yet, Rauscher (2005, 2007) demonstrates in different variants of endogenous growth models with Leviathan governments that the growth effects of increased competition are ambiguous.

The present thesis contributes to this literature on dynamic aspects of fiscal federalism, considering two distinct frameworks capable of analyzing fiscal policies that affect both the interregional allocation as well as the evolution of mobile factors over time. The model developed in Chapter 2 builds on previous dynamic general equilibrium setups with perfectly mobile capital, but additionally allows for migration of households. Using this framework it is shown that introducing labor mobility affects optimal fiscal policies. More precisely, migration alters the international tax regime a small open economy chooses. As will be demonstrated below, the residence principle

[10] A stimulating effect on savings as a result of better preference matching as well as a positive impact on growth during the transition to the new steady state has already been derived by Brueckner (1999) in an exogenous growth model.

[11] The idea that fiscal competition in federalist systems can serve to restrain Leviathan governments is due to Brennan and Buchanan (1980).

of taxation is efficient in the absence of migration. When allowing for mobile labor, however, source-based taxation of capital income turns out to be optimal. This is due to the fact that migration responds to differences in consumption growth. Since the source principle guarantees that after-tax rates of return and, consequently, savings decisions are independent of the place of residence, it ensures the convergence of consumption growth rates. The residence principle, in contrast, is inefficient as after-tax rates of return typically differ across regions, leading to tax-induced migration flows.

Chapter 3 considers a different aspect of the evolution of factors in time: Parental investments in human capital accumulation of their children improve the educational success, thereby affecting the composition of the future workforce. The model developed incorporates this social mobility across skill-types as an additional, dynamic dimension of labor mobility. Contrary to previous studies that conjecture a reduced incentive of small regions to invest in education if high-skilled workers are perfectly mobile, it is shown that local jurisdictions continue to subsidize education efficiently once social mobility is introduced. Since the amount of immobile low-skilled labor is still determined by previous local investment in human capital, regional governments are forced to take inefficiencies in the educational process into account and correct private underinvestment, irrespective of assumptions concerning the mobility of high-skilled workers. The present research, therefore, reveals that modeling the evolution of mobile factors in time provides novel insights with respect to optimal fiscal policies in the presence of factor mobility. Consequently, the last chapter concludes suggesting that more is to be gained from exploring the dynamic aspects of fiscal competition further.

Chapter 2

Optimal Capital Taxation

2.1 Motivation

Dating back to the seminal article of Chamley (1986), standard models of optimal capital income taxation in dynamic general equilibrium settings conclude that capital income should not be taxed in the steady state. Extensions to open economy setups with source- and residence-based taxation of internationally mobile capital arrive at a similar conclusion: While residence-based taxes on capital continue to be inefficient only in the long-run, source taxes on capital vanish in the presence of a perfectly elastic supply of capital on the world capital market - a standard result of the literature on local public finance in static models[1]. Therefore, this literature seems to indicate that adding a dynamic perspective by incorporating the accumulation of mobile factors in time does not provide further insights on the optimal taxation of

I would like to thank Ferdinand Fichtner, Wolfram Richter, Efraim Sadka, and Sabine Böckem for helpful comments and suggestions on earlier versions of this chapter.

[1] See e.g. Gordon (1986).

capital in open economies.

Nevertheless, important features are missing from these approaches. Firstly, models dealing with open economies regularly focus solely on the case of internationally mobile capital, while labor is assumed to be immobile. Though labor is clearly not perfectly mobile, the introductory chapter revealed that migration nevertheless is empirically significant and, consequently, of relevance for policy-making. Furthermore, labor mobility displays certain features that differ substantially from characteristics of mobile capital suggesting that results derived in the presence of capital mobility do not carry over to the case of migration: Since workers embody human capital and, moreover, take the assets they own with them when moving, migration flows are particularly important for fiscal policies, as they substantially influence the labor and, additionally, the capital tax base of an economy.

Secondly, a standard assumption of approaches to optimal taxation is that tax revenues are used to finance an exogenously given stream of government consumption. The analysis is, therefore, restricted to solving the so called Ramsey problem of financing public expenditures using distorting tax instruments. Public investment that is optimally chosen and increases domestic production or the utility of households is often neglected. Though the Ramsey problem is a good starting point to isolate the effects of distortive taxation from issues of public good provision, Turnovsky (1996) stresses the importance of examining the revenue and expenditure side jointly: A comprehensive analysis of fiscal policy cannot restrict itself to analyzing the influence of tax rates on private agents decisions. Rather, it has to take into account that private agents react to the way revenue is spend. Thus, the revenue and expenditure side are interconnected and should be considered in a single approach.[2] This is of special relevance in the presence of factor mobility since many publicly provided goods like infrastructure are subject to congestion. Hence, the chosen fiscal policy influences location decisions of mobile factors that in turn determine the productivity of the public good provided.

The present chapter extends standard approaches to optimal taxation in dynamic general equilibrium models by introducing labor mobility in addition to capital mobility. Deviating from the Ramsey problem, it incorporates productive public spending and emphasizes the relevance of rivalry in determining optimal fiscal policies.

[2] Based on this argument, Turnovsky (1996) develops an endogenous growth model with public good provision and studies how the degree of rivalry affects optimal tax rates.

2.2 Related Literature

This work is closely related to the literature on optimal taxation in dynamic general equilibrium models that was originated by Chamley (1986) and Judd (1985) and combines the theory of optimal taxation with exogenous growth models. Chamley analyzes an infinitely-lived agent framework in which a benevolent government chooses a specific fiscal policy in order to finance an exogenously given amount of public consumption. Since lump-sum taxation is excluded, the analysis aims at finding the fiscal policy that minimizes distortions and yields the second-best.[3] Chamley derives the result that in the long-run capital income taxes should optimally be zero.[4] This is due to the fact that any tax on savings is equivalent to an increasing tax on future consumption. Since consumption is constant along the balanced growth path, compensated demand elasticities of consumption at different points in time are identical once the steady state has been reached. Hence, according to the uniform taxation principle, present and future consumption should be taxed at a uniform rate implying that capital income taxes should be zero in the long-run.

Building on the work of Chamley (1986) and Judd (1985), the result of zero capital income taxes in the steady state has been extended in several directions.[5] Most relevant for the present study are extensions focusing on optimal taxation of capital income in open economies. Typically, these studies reproduce the zero tax result for small open economies facing perfectly

[3] This approach is due to Ramsey (1927) who first considered the optimal fiscal policy to finance a given amount of government spending relying on distortive tax instruments only.

[4] Judd (1985) derived the zero tax result in a heterogenous agent framework.

[5] Atkeson et al. (1999) and Chari and Kehoe (1999) provide an overview over several extensions of the Chamley result.

mobile capital. The intuition for zero capital taxes here is twofold. Firstly, the argumentation of the closed economy remains to be valid: With constant consumption levels in the steady state, compensated demand elasticities of consumption over time are identical. According to the uniform taxation principle, a residence-based capital income tax that taxes consumption at various dates differently is inefficient. Secondly, introducing international mobility of capital provides an additional argument in favor of zero capital income taxes that is independent of the steady state: Since the supply of capital is perfectly elastic, any source-based tax on the returns to capital is inefficient as it induces capital flight and, thereby, shifts the tax burden to the immobile factor labor.[6]

Since extending dynamic general equilibrium models to open economies does not impact the results on the optimal taxation of capital income, this literature proceeded discussing the optimal international tax regime: While Milesi-Ferretti and Roubini (1994) assume residence-based taxation and Correia (1996a) compares the residence and the source principle, Razin and Sadka (1995) introduce an explicit governmental choice between principles of international taxation showing that the residence principle is welfare maximizing. Razin and Yuen (1999) extend these approaches and establish the optimality of the residence principle in a multi-country model of endogenous population growth.

Although optimal taxation in open economies supports the Chamley-Judd result, several studies question it's robustness. For example, Erosa and Gervais (2001, 2002) and Garriga (2000) show that zero capital income taxes can only be replicated in overlapping generations models assuming the availability of

[6] This is a standard result of static open economy models with perfectly mobile capital (see e.g. Gordon (1986)).

age specific taxation. Other examples include the presence of imperfect competition (Judd, 1997), borrowing constraints that prevent insurance against idiosyncratic shocks (Aiyagari, 1995; Chamley, 2001), and time-inconsistent fiscal policies (Benhabib and Rustichini, 1997). Studies introducing labor market imperfections lead to ambiguous results. While Koskela and von Thadden (2003) derive a positive long-run tax on capital income under wage bargaining, Palokangas (2005) uses a slightly different setup to reproduce the zero tax result.

Moreover, allowing for public good provision provides a justification for positive capital income taxes. Corsetti and Roubini (1996) and Doménech and García (2002) consider a productive public input that is rival, but non-excludable and prove that the long-run capital income tax need not be zero: If congestion costs are induced by the factor capital, a capital income tax is efficient to establish the first-best allocation. In contrast, if capital does not impose any social costs, there is no reason for taxing this income source. Deriving a similar result, Jones et al. (1993) consider the case of productive government expenditure that enhances the effectiveness of investment. Yet, as Correia (1996b) notes, this is an example of a model in which not all factors can be taxed sufficiently. Introducing an untaxable factor like public investment imposes additional restrictions on the set of available tax instruments. In such a setting the Corlett-Hague rule applies according to which it is optimal to tax complementary factors like capital at higher rates.

The present chapter extends previous approaches to optimal capital income taxation in dynamic general equilibrium models with respect to two basic features: Firstly, in contrast to standard models of optimal taxation, labor as well as capital mobility is allowed for. Secondly, the expenditure side is explicitly taken into account. More precisely, productive public spending is incorporated, allowing for varying degrees of congestion induced by the internationally mobile factor labor.

The analysis reveals that introducing migration changes the optimal structure of international taxation: While a small open economy aims at establishing production efficiency by applying the residence principle of taxation in the absence of migration, consumption efficiency is welfare maximizing if labor mobility is allowed for. This implies that the source principle of taxation is efficient in the presence of migration. The optimality of source-based taxation can be explained by the fact that, in a dynamic framework, migration flows react to differences in consumption growth. Since the source principle ensures the convergence of consumption growth rates across countries, it avoids tax-driven migration flows and is, consequently, efficient in a setup where labor is internationally mobile.

The subsequent analysis proceeds in two steps: First, an open economy model with mobile capital and productive public spending is developed to reproduce the standard zero capital income tax result. In a second step, the model is extended to allow for perfect mobility of households and derive the optimal fiscal policy in the presence of mobile capital and labor. The last section summarizes the main results.

2.3 The Model

Suppose the world economy consists of many countries $i = 1, ..., m$, each deciding independently on local tax policy and public good provision. Every country behaves as a small open economy, taking foreign rates of return on capital and labor as well as fiscal policies as given. Initially, the countries are populated by a given number of identical households and have access to the same production technology. Any differences between countries are either due to differences in the size of the initial population, the tax policies adopted or the amount of the local public good provided.

At time $t = 0$ and prior to private agent decision making, the government of a particular country i decides on the path of tax rates and public good provision, anticipating the households' and firms' reaction to the announced sequence of fiscal policy. To rule out the issue of time inconsistency, it is assumed that the government has access to a commitment technology to guarantee that the chosen policy is indeed binding and will not be revised in future periods. Without such a commitment mechanism,[7] the government has an incentive to deviate from the optimal fiscal policy after private agents have made their decision, as this amounts to efficient lump-sum taxation.[8] Although factor mobility can in principle reintroduce the elasticity of the tax base forcing governments to stick to the announced path of policy,[9] the incentive to revise the fiscal policy persists in an open economy model with residence-based taxation as long as the labor force remains immobile.

[7] While access to a commitment technology might be unrealistic, binding fiscal policies could alternatively be enforced via reputational mechanisms (Chari and Kehoe, 1999).

[8] The problem of time-inconsistent policies has been pointed out by Kydland and Prescott (1977).

[9] Using a dynamic framework, Kehoe (1989) shows that competition among governments for mobile capital can serve as a commitment device for low tax rates.

To isolate the effects of migration on the optimal fiscal policy in the following analysis, two versions of the model are considered: a small open economy framework with perfectly mobile capital is used to reproduce the standard results of the literature in a setup with productive public good provision. Further insights into the optimal taxation of capital income and the role of congestion costs for optimal fiscal policies will be derived in an extension of this model that additionally allows for labor mobility.

2.3.1 Production

Firms in a particular country i produce a single aggregate good Y_t^i, that can be transformed at no cost into consumption c_t^i, asset holdings a_t^i, government debt b_t^i, and public spending G_t^i.[10] The aggregate production function consists of a private production function $F_t^i(\cdot)$ and a social production function $\Phi_t^i(\cdot)$,

$$Y_t^i = F(K_t^i, \mathcal{N}_t^i) \cdot \Phi(\mathcal{G}_t^i) = \left(K_t^i\right)^{\alpha} \left(\mathcal{N}_t^i\right)^{1-\alpha} \cdot \left(\mathcal{G}_t^i\right)^{\gamma}, \tag{2.1}$$

with $0 < \alpha + \gamma < 1$ and $\gamma \geq 0$. K_t^i denotes the capital input and $\mathcal{N}_t^i = h_t^i N_t^i$ the labor input, consisting of human capital provided, h_t^i, times the size of the labor force, N_t^i. Since investment of asset holdings can be spread across countries, locally employed capital comprises investments by residents, $a_t^{ii} N_t^i$, and capital inflows from abroad, $A_t^{\bullet i} = \sum_{j \neq i} A_t^{ji}$ with $A_t^{ji} = a_t^{ji} N_t^j$.[11] Notice that the distinction between residents' domestic capital investments, a_t^{ii}, and capital inflows from abroad, a_t^{ji}, is a prerequisite for modeling a general tax

[10] Throughout the analysis, upper-case letters denote aggregate variables, while lower-case letters refer to the respective variable per capita of the current population of the corresponding country. t is the time index and i indicates the country under consideration.

[11] The superscript ji indicates the flow of capital from country j to country i.

system comprising all variants of crediting.[12]

It is assumed that the government provides a local public input G_t^i that is rival but non-excludable and enters production via the function $\mathcal{G}_t^i$. The productivity of the public good is subject to congestion induced by either the capital input ($\frac{\partial \mathcal{G}_t^i}{\partial K_t^i} < 0$), or the aggregate labor supply ($\frac{\partial \mathcal{G}_t^i}{\partial \mathcal{N}_t^i} < 0$), or both.

Although the public good is subject to a congestion externality, it is important to note that a single firm perceives the effective public input $\mathcal{G}_t^i$ as exogenously given. This is due to the fact that the total factor supply, and accordingly the induced congestion costs, cannot be influenced by decisions of an individual firm. Rather, from the point of view of a single firm, the per capita production function is given by

$$y_t^i = f(k_t^i, h_t^i)\Phi_t^i(\mathcal{G}_t^i) = \left(k_t^i\right)^\alpha \left(h_t^i\right)^{1-\alpha} \left(\mathcal{G}_t^i\right)^\gamma . \tag{2.2}$$

With perfect competition among firms and profit maximization, production factors are paid their marginal products as perceived by private firms,

$$r_t^i = f_k^i \Phi(\mathcal{G}_t^i) = \alpha \frac{y_t^i}{k_t^i} \tag{2.3}$$

$$w_t^i = f_h^i \Phi(\mathcal{G}_t^i) = (1-\alpha) \frac{y_t^i}{h_t^i}, \tag{2.4}$$

where r_t^i denotes the rate of return on capital and w_t^i the wage rate.

Notice that in the present setup any market allocation will be inefficient as firms do not take into account the congestion costs arising at the aggregate level. The resulting wedge between the private and the social marginal rate of

[12] The available tax instruments will be discussed in detail below.

return can be eliminated using a Pigouvian tax on factor income. According to Turnovsky (1996),[13] the optimal income tax rate depends on the degree of congestion induced by the respective production factor,[14] implying that the optimal tax policy is contingent on the assumption as to which factor of production congests the public input to what extent.

The relevance of public-spending-related externalities for the optimal long-run capital income tax has also been studied by Corsetti and Roubini (1996) in a closed economy setup with physical as well as human capital accumulation. They consider the polar cases of rivalry induced by just one of the two production factors in a two-sector endogenous growth model. The optimal taxation analysis reveals that a long-run tax on capital income is only optimal if capital congests the public good. If the other production factor human capital exerts the external effect, the capital income tax will be zero. Their framework has been extended by Doménech and García (2002) who allow for simultaneous congestion by both production factors and reproduce the basic result of Corsetti and Roubini (1996): The optimal fiscal policy involves a positive capital income tax whenever the factor capital induces at least part of the congestion costs.

Since the present study focuses on the effects of migration on optimal long-run capital income taxation, positive capital income taxes that are driven by underlying assumptions on rivalry should be avoided. Therefore, the following analysis is restricted to the case of congestion induced by the ag-

[13] Turnovsky (1996) uses a dynamic model of a closed economy in which capital is the only production factor to study the impact of congestion on optimal policies for public consumption as well as production goods.

[14] In contrast, Glomm and Ravikumar (1994) show that the income tax rate is independent of the degree of rivalry. Yet, in their model the set of available tax instruments is restricted to uniform income taxes on capital and labor. Since both factors congest the public input to varying degrees, a uniform income tax rate can never fully internalize the externality, entailing that their analysis refers to a second-best problem.

gregate labor supply.[15] According to Corsetti and Roubini (1996) as well as Doménech and García (2002) such a setup should yield the optimality of a wage tax while the tax on capital income should be zero.

In the following, it is assumed that the productive public good G_t^i is subject to congestion induced by the production factor labor, that is $\frac{\partial \Phi_t^i(\cdot)}{\partial \mathcal{N}_t^i} \leq 0$. To allow for various degrees of congestion, the function $\mathcal{G}_t^i$ is defined as

$$\mathcal{G}_t^i = \frac{G_t^i}{(\mathcal{N}_t^i)^\eta} = \frac{G_t^i}{(h_t^i N_t^i)^\eta}. \tag{2.5}$$

The congestion parameter η with $0 \leq \eta \leq 1$ indicates the degree of rivalry of the public good and comprises the extreme cases of a pure public good ($\eta = 0$) and a publicly provided private good ($\eta = 1$). In case of $\gamma = 0$, government spending is purely consumptive and has no impact on production.

The aggregate social production function per capita can now be written as

$$y_t^i = f(k_t^i, h_t^i)\Phi_t^i(\mathcal{G}_t^i) = \left(k_t^i\right)^\alpha \left(h_t^i\right)^{1-\alpha-\eta\gamma} \left(\frac{G_t^i}{(N_t^i)^\eta}\right)^\gamma. \tag{2.6}$$

Notice that although the production factor labor reduces the productivity of the public input on the aggregate level, this negative externality is disregarded by a single firm. Consequently, the marginal product of labor exceeds the social rate of return,

$$w_t^i = f_h^i \cdot \Phi_t^i(\cdot) = (1-\alpha)\frac{y_t^i}{h_t^i} > (1-\alpha-\eta\gamma)\frac{y_t^i}{h_t^i} = f_h^i \cdot \Phi_t^i(\cdot) + f_t^i\,(\cdot)\,\Phi_h^i. \tag{2.7}$$

Expression (2.7) reveals that the wedge between the private and the social rate of return depends on the congestion costs $\eta\gamma y_t^i$. In contrast, Corsetti and

[15] Still, the present framework can easily be extended to allow for a more general specification of rivalry.

Roubini (1996) as well as Doménech and García (2002) argue that the wedge is induced by pure profits generated by the public good and appropriated by one of the production factors. Their intuition is derived from modeling a publicly provided private good ($\eta = 1$). Consequently, in their framework the congestion costs are equivalent to the pure profits of public good provision that might arise theoretically, γy_t^i. Still, as they assume linear homogeneity of private production, pure rents do not arise. Rather, as becomes apparent when introducing varying degrees of rivalry, the wedge between the private and social rate of return relates to the congestion externality.[16]

2.3.2 Government

The government of a single region i is benevolent in the sense that it maximizes the discounted lifetime utility of a representative resident. It has access to a set of distortive income taxes that it uses to finance public spending. To balance the budget, the government can issue one-period debt b_t^i domestically. Since in representative agent models equilibrium borrowing and lending only occurs between households and the government, one can assume without any loss of generality that bonds are tax-exempt. The return on bonds is denoted by r_{bt}^i.

The tax instruments available to generate revenue comprise taxes on wage income (τ_{wt}^i) as well as taxes on residents' capital income from domestic source (τ_{rDt}^i) and foreign source (τ_{rFt}^i). Furthermore, returns on inbound investments, that is non-residents' domestic source capital income, are taxed

[16] If public good provision generates factor rents that accrue to capital, positive source-based taxation of capital income is justified since this amounts to a fully efficient user charge for public good provision. As Kellermann (2006) points out, user fees on capital exceed the revenue requirements to finance the public input in the steady state, thereby entailing the possibility of redistributing income.

at the rate τ^i_{rIt}. Hence, double taxation of foreign source capital income can arise whenever both the residence and the source country levy taxes on capital returns. In order to alleviate the arising double taxation of foreign source income, the government can credit capital income taxes already paid in the foreign country at the rate δ^i_t. The effective tax residents of country i pay on foreign source capital income is $\tau^i_{rEt} = \tau^i_{rFt} + (1 - \delta^i_t)\tau^j_{rIt}$. This approach is capable of integrating the credit system, the exemption system, as well as the deduction system into a single framework.[17]

Under the crediting system, foreign source capital income is subject to domestic taxation. However, part of the taxes paid to the source country are credited against domestic tax liabilities. With full crediting ($\delta^i_t = 1$), double taxation is eliminated and the effective tax rate equals the domestic tax on capital income, $\tau^i_{rEt} = \tau^i_{rFt}$. With a crediting rate of $\delta^i_t = 0$, full double taxation persists and the effective tax rate on foreign source income becomes $\tau^i_{rEt} = \tau^i_{rFt} + \tau^j_{rIt}$. Since countries typically limit refunding to tax liabilities at home, the tax revenue collected from foreign capital income is non-negative ($\tau^i_{rFt} - \delta^i_t\tau^j_{rIt} \geq 0$). Therefore, the maximum credit rate equals $\delta^i_t = \frac{\tau^i_{rFt}}{\tau^j_{rIt}}$. In this case, the effective tax rate on foreign source income reduces to $\tau^i_{rEt} = \tau^j_{rIt}$, and the exemption system is realized under which foreign capital income is not subject to domestic taxation.

If the government applies the deduction method, domestic taxes are levied on the net return of foreign investment after source taxes have been subtracted from the tax base. Therefore, the effective rate of return to capital investments abroad becomes $(1 - \tau^i_{rEt})r^j_t = (1 - \tau^i_{rFt})(1 - \tau^j_{rIt})r^j_t$. Put dif-

[17] While previous research by Frenkel et al. (1991) as well as Razin and Sadka (1995) consider effective tax rates, Razin and Yuen (1999) explicitly integrate the crediting rate into the analysis.

ferently, the effective tax rate comprises the source taxes paid abroad and the domestic capital taxes paid on the net returns of foreign investment, $\tau^i_{rEt} = \tau^j_{rIt} + \tau^i_{rFt}(1 - \tau^j_{rIt})$. Rewriting the effective tax rate under the deduction system to $\tau^i_{rEt} = \tau^i_{rFt} + (1 - \tau^i_{rFt})\tau^j_{rIt}$ reveals that the deduction system is a special case of crediting with $\delta^i_t = \tau^i_{rFt}$.

Table 2.1 summarizes the different ways to alleviate double taxation, displaying the corresponding crediting rate as well as the effective tax rate.

	Credit rate ($0 \leq \delta^i_t \leq \frac{\tau^i_{rFt}}{\tau^j_{rIt}}$)	Effective tax rate
Crediting	$0 < \delta^i_t < \tau^i_{rFt}/\tau^j_{rIt}$	$\tau^i_{rEt} = \tau^i_{rFt} + (1 - \delta^i_t)\tau^j_{rIt}$
– no crediting:	$\delta^i_t = 0$	$\tau^i_{rEt} = \tau^i_{rFt} + \tau^j_{rIt}$
– unlimited ∼:	$\delta^i_t = 1$ for $\tau^i_{rFt} \geq \tau^j_{rIt}$	$\tau^i_{rEt} = \tau^i_{rFt}$
Exemption	$\delta^i_t\tau^j_{rIt} = \tau^i_{rFt}$ for $\tau^i_{rFt} \leq \tau^j_{rIt}$	$\tau^i_{rEt} = \tau^j_{rIt}$
Deduction	$\delta^i_t = \tau^i_{rFt}$	$\tau^i_{rEt} = \tau^i_{rFt} + (1 - \tau^i_{rFt})\tau^j_{rIt}$

Table 2.1: Methods to tax foreign source income

The different methods of taxation can be used to model different international tax regimes like the pure residence principle, the pure source principle, or any combination of the two. If $\tau^i_{rDt} = \tau^i_{rFt}$ and $\tau^i_{rIt} = 0$ in all countries, pure residence-based capital income taxation is implemented, entailing that all residents' capital income is taxed at a uniform rate. As a result, the effective tax rate on foreign source capital income equals $\tau^i_{rEt} = \tau^i_{rFt}$, and the pre-tax rates of return to capital are equalized across countries. This implies that investment decisions are based on marginal productivities, leading to an efficient allocation of investment across countries (production efficiency). At the same time, however, the saving decision will be distorted when the after-tax rates of return to capital and, thus, the prices of future consumption vary across countries. Therefore, consumers' intertemporal marginal rates of substitution differ, and the allocation of savings is inefficient (consumption inefficiency).

If $\tau^i_{rDt} = \tau^i_{rIt}$ and $\tau^i_{rFt} = \delta^i = 0$ or $\tau^i_{rFt} = \delta^i \tau^j_{rIt}$ in all countries, a pure source-based capital income tax system is realized. This entails that, from the point of view of investors residing in different countries, after-tax rates of return of a particular investment are leveled out. Consequently, the allocation of savings is efficient (consumption efficiency), while the allocation of investment is distorted (production inefficiency). In this case, the effective tax rate on foreign source capital income reduces to $\tau^i_{rEt} = \tau^j_{rIt}$.

Given the tax system discussed above, the period t budget constraint in per capita terms can be written as

$$g^i_t = b^i_{t+1} - (1 + r^i_{bt})b^i_t + T^i_t, \tag{2.8}$$

where T^i_t captures the tax revenue generated using labor and capital income taxes,

$$T^i_t = \tau^i_{wt} w^i_t h^i_t + \tau^i_{rDt} r^i_t a^{ii}_t + \sum_{j \neq i} \left(\tau^i_{rFt} - \delta^i_t \tau^j_{rIt}\right) r^j_t a^{ij}_t + \tau^i_{rIt} r^i_t \frac{A^{\bullet i}_t}{N^i_t}. \tag{2.9}$$

Note that, since initial asset holdings, bonds and human capital are inelastically supplied, the government can tax these endowments without any efficiency loss. To avoid the exclusive use of such lump-sum taxation and keep the problem interesting, all tax rates in period $t = 0$ are exogenously fixed.[18]

[18] Obviously, lump-sum taxation can only be eliminated assuming vanishing tax rates. Still, it suffices to restrict the tax rates by introducing some upper bound preventing that the entire budget is financed using non-distorting tax instruments.

Furthermore, consumption taxes are not allowed for.

2.3.3 Household Behavior

Households maximize their discounted lifetime utility resulting from consumption,

$$\sum_{t=0}^{\infty} \beta^t u(c_t^i), \tag{2.10}$$

where $0 < \beta < 1$ is a discount factor and c_t^i denotes current consumption in period t. The utility function is assumed to be strictly concave with $u_{ct}^i > 0, u_{cct}^i < 0$ and fulfills the Inada conditions, $\lim_{c \to 0} u_{ct}^i = \infty$ and $\lim_{c \to \infty} u_{ct}^i = 0$. An isoelastic utility function satisfies the above conditions and is commonly used in the literature,

$$u(c_t^i) = \frac{(c_t^i)^{1-\sigma} - 1}{1 - \sigma}, \tag{2.11}$$

where σ is the inverse of the intertemporal elasticity of substitution in consumption.

Households can smooth consumption over time by accumulating physical capital a_t^i, holding government bonds b_t^i, and investing in human capital h_t^i. The endowments with assets a_0^i, government bonds b_0^i as well as human capital h_0^i are given and identical for all households, irrespective of the initial country of residence.

While government bonds are issued domestically and human capital can only be employed in the residence country, physical capital investments can be split between countries. Therefore, households earn capital income from investment at home a_t^{ii} and abroad a_t^{ij}, with total asset holdings $a_t^i = a_t^{ii} +$

$\sum_{j \neq i} a_t^{ij}$. Pre-tax wage income can be summarized as $w_t^i h_t^i$ and pre-tax capital income from various sources as $r_t^i a_t^{ii} + \sum_{j \neq i} r_t^j a_t^{ij}$. The entire net income

$$(1 - \tau_{wt}^i) w_t^i h_t^i + (1 - \tau_{rDt}^i) r_t^i a_t^{ii} + \sum_{j \neq i} (1 - \tau_{rEt}^i) r_t^j a_t^{ij} + r_{bt}^i b_t^i \tag{2.12}$$

is spent on current consumption c_t^i, savings in form of assets $a_{t+1}^i - a_t^i$ or government bonds $b_{t+1}^i - b_t^i$, and human capital accumulation $h_{t+1}^i - h_t^i$.

In contrast to most previous studies on the optimal taxation of capital income, human capital is modeled in a perfectly symmetric way compared to physical capital, while working time is supplied inelastically. In a model with consumptive government spending, Jones et al. (1993) show that this entails identical long-run tax rates of zero for both physical as well as human capital. Introducing a labor-leisure decision, Bull (1993) as well as Jones et al. (1997) reproduce this result using a setup where working time is supplied jointly with human capital. Consequently, the restrictive assumption of an inelastic supply of working time in the present framework does not alter the results in the basic model. Yet, it simplifies the migration dynamics in the extended version substantially. Furthermore, since the analysis focuses on the impact of migration on the optimal taxation of capital income, there is not much to be gained from introducing an additional labor-leisure choice.

Given the fiscal policy of the respective country of residence, the period t budget constraint of the household can be expressed as

$$\begin{aligned} c_t^i + a_{t+1}^i + h_{t+1}^i + b_{t+1}^i = & \left[1 + (1 - \tau_{wt}^i) w_t^i\right] h_t^i + \left[1 + (1 - \tau_{rDt}^i) r_t^i\right] a_t^{ii} \\ & + \sum_{j \neq i} \left[1 + (1 - \tau_{rEt}^i) r_t^j\right] a_t^{ij} + \left[1 + r_{bt}^i\right] b_t^i. \end{aligned} \tag{2.13}$$

The household's optimization problem is subject to each period's budget constraint, the initial endowments as well as the following transversality conditions,

$$\lim_{t\to\infty} \lambda_t^i a_{t+1}^i = 0 \qquad \lim_{t\to\infty} \lambda_t^i h_{t+1}^i = 0 \qquad \lim_{t\to\infty} \lambda_t^i b_{t+1}^i = 0 \tag{2.14}$$

where λ_t^i denotes the Lagrange-multiplier associated with the period t budget constraint.

Solving the household's problem of choosing the allocations $\left\{c_t^i, h_{t+1}^i, a_{t+1}^{ii}, a_{t+1}^{ij}, b_{t+1}^i\right\}$ yields the following first-order conditions,

$$\frac{\partial}{\partial c_t^i} \; : \; \beta^t u_{ct}^i = \lambda_t^i \tag{2.15}$$

$$\frac{\partial}{\partial h_{t+1}^i} \; : \; \lambda_t^i = \lambda_{t+1}^i \left(1 + (1 - \tau_{wt+1}^i) w_{t+1}^i\right) \tag{2.16}$$

$$\frac{\partial}{\partial a_{t+1}^{ii}} \; : \; \lambda_t^i = \lambda_{t+1}^i \left(1 + (1 - \tau_{rDt+1}^i) r_{t+1}^i\right) \tag{2.17}$$

$$\frac{\partial}{\partial a_{t+1}^{ij}} \; : \; \lambda_t^i = \lambda_{t+1}^i \left(1 + (1 - \tau_{rEt+1}^i) r_{t+1}^j\right) \tag{2.18}$$

$$\frac{\partial}{\partial b_{t+1}^i} \; : \; \lambda_t^i = \lambda_{t+1}^i \left(1 + r_{bt+1}^i\right). \tag{2.19}$$

Combining the household's first-order conditions immediately yields the no-arbitrage condition that after-tax rates of return are equalized across countries at any point in time,

$$(1 - \tau_{rDt}^i) r_t^i = (1 - \tau_{rEt}^i) r_t^j = (1 - \tau_{wt}^i) w_t^i = r_{bt}^i. \tag{2.20}$$

Especially the fact that after-tax rates of return on different physical capital investments have to be equalized will frequently be used throughout the analysis.

2.4 Primal Approach

To disentangle the effect of migration and congestion costs on the optimal taxation of capital income, the analysis proceeds in two steps: Firstly, optimal fiscal policies in the absence of migration are deduced, discussing the impact of rivalry on the results. To this end, the subsequent section reviews the primal approach that is commonly used in dynamic general equilibrium models to solve for the optimal steady-state tax rates. The technique is then applied to the basic model, that is in the absence of migration. Secondly, optimal tax policies in the presence of migration are derived and contrasted with the results of the basic model. To keep the analysis in line with previous studies, the tax system is considered from a national point of view, that is for a single, small open country i. This implies that a local welfare maximizing government does not take into account any possible influence on other countries. Rather, the optimal fiscal policy derived can be viewed as the best response given foreign tax policies, interest rates and available production factors.

Suppose the government of a country i is benevolent and intends to maximize the discounted lifetime utility of a representative resident. To ensure that the welfare optimum can be implemented in a decentralized way as a competitive market equilibrium, the government has to anticipate the reaction of private agents since the household's optimality conditions are contingent on the path of fiscal policy. Thus, the government maximizes a representative consumer's lifetime utility subject to (1) the government's budget constraint, (2) the household's budget constraint, (3) the first-order conditions of the household and the firm, and (4) the transversality conditions.

One way to integrate the household's first-order conditions into the central planning problem is to construct optimal demand functions depending on net prices and derive the indirect utility function of the representative consumer (see Diamond and Mirrlees (1971)). According to Atkinson and Stiglitz (1980, pp. 376), this approach is also referred to as the dual approach, in which the government optimizes using price variables as controls. While this method is widely used in the public finance literature on optimal taxation in static models, an alternative method employs quantities instead of prices as control variables. The primal approach builds on the observation that the tax rates and Lagrange multipliers in the consumer's first-order conditions can be regarded as functions of the allocations (see Ramsey (1927) as well as Atkinson and Stiglitz (1972)). Consequently, one can reduce the central planning problem to one of choosing allocations only, while the optimal tax rates can later be deduced using the private agents' first-order conditions.

Lucas and Stokey (1983) extended the use of the primal approach to dynamic models including a production sector with endogenous factor prices, and the method now dominates fiscal policy analysis in dynamic general equilibrium models. Following Lucas and Stokey (1983), the primal approach reduces the central planning problem to one of maximizing social welfare subject to two fairly simple constraints, guaranteeing that the optimum represents a competitive equilibrium: the *implementability constraint* and the *economy-wide resource constraint*.[19]

First, consider the implementability constraint that integrates all consumer's optimality conditions into a single expression: When deciding on the optimal fiscal policy, the government has to obey the consumer's budget constraint and must anticipate the optimal reactions of the private agents with respect

[19] Chari and Kehoe (1999) provide a formal proof that imposing the implementability and the resource constraint indeed ensures that a competitive equilibrium is attained.

to the announced fiscal policy. Except for period $t = 0$, where tax rates are fixed by assumption, the households' first-order conditions provide functional forms of net prices which can be used to eliminate the prices and tax rates from the household's budget constraint as stated in equation (2.13),

$$c_t^i + a_{t+1}^i + h_{t+1}^i + b_{t+1}^i = \frac{\lambda_{t-1}^i}{\lambda_t^i}\left(a_t^i + h_t^i + b_t^i\right) \tag{2.21}$$

$$\Leftrightarrow \beta^t u_{ct}^i c_t^i = \beta^{t-1} u_{ct-1}^i \left(a_t^i + h_t^i + b_t^i\right) - \beta^t u_{ct}^i \left(a_{t+1}^i + h_{t+1}^i + b_{t+1}^i\right). \tag{2.22}$$

Summing up over all periods and applying the transversality conditions yields the budget constraint in present value terms,

$$\sum_{t=0}^{\infty} \beta^t u_{ct}^i c_t^i = \beta u_{c0}^i \Big[\left(1 + (1-\tau_{rD0}^i) r_0^i\right) a_0^i \\ + \left(1 + (1-\tau_{w0}^i) w_0^i\right) h_0^i + \left(1 + r_{b0}^i\right) b_0^i\Big]. \tag{2.23}$$

Equation (2.23) is also referred to as the *implementability constraint*. It integrates all conditions necessary for the household's utility optimization, that is the household's budget constraint, the first-order conditions, and the transversality conditions. Consequently, imposing this restriction on the planning problem guarantees that, given the fiscal policy, the optimal allocation can be decentralized as a competitive equilibrium. Notice that initial endowments as well as tax rates in period $t = 0$ are exogenously given. Thus, the implementability constraint only depends on allocations while endogenous prices and tax rates have been eliminated.

To ensure feasibility of the optimal allocation, one has to additionally impose country i's resource constraint,

$$\begin{aligned} y_t^i = c_t^i + a_{t+1}^i - a_t^i + h_{t+1}^i - h_t^i + g_t^i \\ + \left(1 - \tau_{rIt}^i\right) r_t^i \frac{A_t^{\bullet i}}{N_t^i} - \sum_{j \neq i} (1 - \tau_{rIt}^j) r_t^j a_t^{ij}, \end{aligned} \tag{2.24}$$

where $A_t^{\bullet i} = \sum_{j \neq i} A_t^{ji} = \sum_{j \neq i} a_t^{ji} N_t^j$ denotes the aggregate capital inflow from abroad. The economy-wide resource constraint states that total production has to finance household expenditures, public spending and net capital income payments to foreigners minus net capital income received from abroad.

The last producer price, the domestic interest rate r_t^i, still has to be eliminated from the resource constraint. To this end, use the no-arbitrage condition of a particular country j (equation (2.20)), which is exogenously given from the point of view of a small country i, and express the interest rate as a function of foreign taxes and allocations as well as the domestic tax on inbound investments,

$$(1 - \tau_{rDt}^j) r_t^j = (1 - \tau_{rEt}^j) r_t^i \quad \Leftrightarrow \quad r_t^i = \frac{(1 - \tau_{rDt}^j)}{(1 - \tau_{rEt}^j)} r_t^j, \tag{2.25}$$

with $\tau_{rEt}^j = \tau_{rFt}^j + (1 - \delta_t^j) \tau_{rIt}^i$.

The benevolent government of region i maximizes the discounted lifetime utility of a representative household, $\sum_{t=0}^{\infty} \beta^t u\left(c_t^i\right)$, subject to the implementability constraint and the economy-wide resource constraint per capita of the current population. Since the implementability constraint guarantees a balanced budget on the side of the household, and the resource constraint has to be fulfilled, the government's budget is met according to Walras' law.

Consequently, it suffices to impose the implementability and the feasibility constraint as restrictions on the central planning problem. Integrating part of the implementability constraint into the objective function, one can define a modified social welfare function[20]

$$\omega\left(c_t^i, \bar{\lambda}^i\right) = u(c_t^i) + \bar{\lambda}^i u_{ct}^i c_t^i, \tag{2.26}$$

where $\bar{\lambda}^i$ denotes the Lagrange-multiplier on the implementability constraint. The social planning problem can now be written as

$$\begin{aligned} \max \sum_{t=0}^{\infty} \Big\{ \ & \beta^t \omega\left(c_t^i, \bar{\lambda}^i\right) \qquad\qquad (2.27) \\ -\bar{\lambda}^i \beta u_{c0}^i & \left[\left(1 + (1-\tau_{rD0}^i) r_0^i\right) a_0^i + \left(1 + (1-\tau_{w0}^i) w_0^i\right) h_0^i + \left(1 + r_{b0}^i\right) b_0^i\right] \\ -\mu_t^i & \left[c_t^i + a_{t+1}^i - a_t^i + h_{t+1}^i - h_t^i - \sum_{j \neq i} (1-\tau_{rIt}^j) r_t^j a_t^{ij} - \chi_t^i\right] \Big\}, \end{aligned}$$

with μ_t^i being the Lagrange-multiplier on the resource constraint. The variable χ_t^i comprises all terms in the economy-wide resource constraint that depend on the population size,

$$\chi_t^i = f_t^i(\cdot)\Phi_t^i(\cdot) - \frac{G_t^i}{N_t^i} - \left(1 - \tau_{rIt}^i\right) r_t^i \frac{A_t^{\bullet\, i}}{N_t^i} \qquad \text{with} \quad r_t^i = \frac{(1-\tau_{rDt}^j)}{(1-\tau_{rEt}^j)} r_t^j. \tag{2.28}$$

As all prices and most of the tax rates have been eliminated from the constraints, the central planner has to solely choose the allocations $\left\{c_t^i, h_{t+1}^i, a_{t+1}^{ii}, a_{t+1}^{ij}, A_t^{\bullet\, i}, G_t^i\right\}$[21] as well as the remaining tax rate τ_{rIt}^i that enters the op-

[20] Lucas (1990) refers to this as the pseudo-utility function, replacing the current period utility function.

[21] Since the domestic capital stock consists of domestic investments a_t^{ii} as well as aggregate capital imports from abroad $A_t^{\bullet\, i}$, which are subject to different tax rates, the optimization has to explicitly distinguish between the two sources of investment.

timization problem via the effective tax rate τ^j_{rEt}. The other tax rates $\{\tau^i_{rDt}, \tau^i_{rFt}, \tau^i_{wt}\}$ as well as the optimal credit rate $\{\delta^i_t\}$ can later be deduced using the household's and firm's first-order conditions. The first-order conditions of the social optimization problem are stated in Appendix A.1.

2.5 Optimal Fiscal Policy in the Absence of Migration

In order to replicate the Ramsey result of zero long-run capital income taxes in the present model specification of open economies with local public good provision, the following section focuses on a setup with perfectly mobile capital but immobile households. In a second step, the basic framework is extended to include a migration decision of households and discuss under what circumstances labor mobility influences the optimal taxation of capital income in the long-run.

First, consider the optimality condition for the allocation of investments between the domestic economy and the rest of the world by combining equations (A.3) and (A.4). Efficiency requires that the marginal productivity of capital invested in country i equals the after-tax rate of return to investments abroad,

$$f^i_{kt}\Phi^i_t(\cdot) = r^i_t = (1 - \tau^j_{rIt})r^j_t. \tag{2.29}$$

This is an application of production efficiency from the point of view of a small country that cannot influence foreign tax policies and has no impact on the net rate of return on outbound investments: The allocation of investments is efficient when the marginal productivity of capital invested at home equals the after-tax rate of return to investments abroad.

The domestic economy can achieve this condition by applying the deduction method[22] and, moreover, imposing identical tax rates on residents' domestic and foreign source capital income ($\tau^i_{rDt} = \tau^i_{rFt}$). To see this, consider the no-arbitrage condition that investors residing in i face (equation (2.20)), and make use of the fact that the effective tax rate under the deduction system equals $\tau^i_{rEt} = \tau^i_{rFt} + (1 - \tau^i_{rFt})\tau^j_{rIt}$ (see Table 2.1),

$$(1 - \tau^i_{rDt})r^i \underset{(2.20)}{=} (1 - \tau^i_{rEt})r^j = (1 - \tau^i_{rFt} - (1 - \tau^i_{rFt})\tau^j_{rIt})r^j \tag{2.30}$$

$$\Leftrightarrow (1 - \tau^i_{rDt})r^i_t = (1 - \tau^i_{rFt})(1 - \tau^j_{rIt})r^j \tag{2.31}$$

$$\Leftrightarrow r^i_t = (1 - \tau^j_{rIt})r^j \quad \text{if} \quad \tau^i_{rDt} = \tau^i_{rFt}. \tag{2.32}$$

Given the after-tax rate of return to investments abroad, a small open economy can establish production efficiency by levying identical tax rates on residents' domestic source capital income and the net returns to outbound investments.

Moreover, since a benevolent small open economy aims at establishing production efficiency, it refrains from taxing non-residents' capital income at source. To derive the optimal tax rate on inbound investments, rewrite the first-order condition with respect to $A^{\bullet i}_t$ (equation (A.5)),

$$f^i_{kt}\Phi^i_t(\cdot) = r^i_t \underset{(A.5)}{=} \left(1 - \tau^i_{rIt}\right) r^i_t \;\; \Leftrightarrow \;\; \tau^i_{rIt} = 0. \tag{2.33}$$

[22] See Homburg (1999).

Obviously, it is optimal not to tax inbound investments at all.[23] This is due to the fact that with perfectly mobile capital the domestic net rate of return to inbound investments has to equal the rate of return available in the rest of the world. Put differently, foreign investors have to be compensated for any tax increase, implying that a source-based capital income tax raises the domestic cost of capital. As a consequence, capital imports decline and the source tax levied is shifted to the immobile factor labor. To avoid this welfare loss of source-based taxation of mobile capital, the optimal tax on non-residents capital income will be zero.[24]

Proposition 1 *To ensure an efficient allocation of investments, a small open economy intends to achieve production efficiency. This entails that the residence principle of taxation with $\tau^i_{rDt} = \tau^i_{rFt} = \delta^i$ and $\tau^i_{rIt} = 0$ is welfare maximizing in the absence of migration.*

Since the domestic economy does not tax non-residents, it is irrelevant whether the rest of the world applies the crediting or the deduction system. To see this, recall that deduction can be interpreted as a special case of crediting with the credit rate $\delta^j_t = \tau^j_{rFt}$. The first-order condition with respect to the tax rate on inbound investments (equation (A.9)) reveals that any distinction

[23] Using a two-period model, Homburg (1999) refers to this standard result as the *national production efficiency theorem* according to which a small open economy should not tax capital at source.

[24] Assuming symmetry, one can easily reveal that the pure residence principle of international taxation is welfare maximizing: If the rest of the world refrains from taxing inbound investments, production efficiency ($r^i_t = r^j_t$) will be established and the no-arbitrage condition reduces to $(1 - \tau^i_{rDt})r^i_t = (1 - \tau^i_{rFt})r^j_t$. Combining these results immediately yields the residence principle with $\tau^i_{rDt} = \tau^i_{rFt}$ and $\tau^i_{rIt} = 0$. The efficiency of the residence principle has been established by Razin and Sadka (1991) in a two-period model and by Razin and Sadka (1995) in a dynamic general equilibrium framework.

between crediting and deduction becomes redundant,[25]

$$1-\tau^j_{rFt}-(1-\delta^j_t)\tau^i_{rIt} \underset{Def.}{=} 1-\tau^j_{rEt} \underset{(A.9)}{=} (1-\tau^i_{rIt})(1-\delta^j_t) \Leftrightarrow \tau^j_{rFt}=\delta^j_t. \quad (2.34)$$

While the above results are valid for all time periods, the optimal tax rates on residents' income can only be derived in the long-run. This is due to the fact that matching the household's and the central planner's first-order conditions requires the private and the social intertemporal marginal rates of substitution in consumption to be identical ($\frac{\lambda^i_t}{\lambda^i_{t+1}}=\frac{\mu^i_t}{\mu^i_{t+1}}$). This, however, will only be the case if the intertemporal elasticity of substitution is constant over time - a condition that is fulfilled in the steady state.

To see this, take the definition of the government's objective function (equation (2.26)) and apply it to the central planner's first-order condition on consumption (equation (A.1)) to get

$$\frac{\mu^i_t}{\mu^i_{t+1}} \underset{(A.1)}{=} \frac{\beta^t\omega^i_{ct}}{\beta^{t+1}\omega^i_{ct+1}} = \frac{\beta^t u^i_{ct}\left[1+\bar{\lambda}^i\left(\frac{u^i_{cct}c^i_t}{u^i_{ct}}+1\right)\right]}{\beta^{t+1}u^i_{ct+1}\left[1+\bar{\lambda}^i\left(\frac{u^i_{cct+1}c^i_{t+1}}{u^i_{ct+1}}+1\right)\right]}. \quad (2.35)$$

Now suppose that the system converges to a steady state[26] in which consumption and, consequently, the reciprocal of the intertemporal elasticity of substitution $\sigma=-\frac{u^i_{cct}c^i_t}{u^i_{ct}}$ are constant. Using this fact as well as the household's first-order condition on consumption (equation (2.15)), according to which $\lambda^i_t=\beta^t u^i_{ct}$, indicates that the private and social intertemporal marginal

[25] See Razin and Yuen (1999).

[26] In the following analysis, the optimal tax rates are deduced assuming that such a steady-state exists.

rates of substitution will be identical in the steady state,

$$\frac{\mu_t^i}{\mu_{t+1}^i} = \frac{\beta^t u_{ct}^i \left[1 + \bar{\lambda}^i (1-\sigma)\right]}{\beta^{t+1} u_{ct+1}^i \left[1 + \bar{\lambda}^i (1-\sigma)\right]} = \frac{\beta^t u_{ct}^i}{\beta^{t+1} u_{ct+1}^i} \underset{(2.15)}{=} \frac{\lambda_t^i}{\lambda_{t+1}^i}. \tag{2.36}$$

It is important to notice that the identity of the private and the social intertemporal marginal rates of substitution in consumption requires that the intertemporal elasticity of substitution is constant over time. This will be the case once the system has converged to a steady state, or whenever specific utility functions are assumed that display a constant elasticity of substitution.

Given the isoelastic utility function assumed above, the private and social intertemporal marginal rates of substitution in consumption are identical for all periods $t \geq 1$. Still, the subsequent derivation of optimal tax rates refers to the more general steady state assumption to emphasize that the results do not hinge on the underlying utility function: In the present model setup with perfectly mobile capital, the economy jumps to the steady state immediately. As will be shown below, this implies that capital income taxes are zero from period $t = 2$ onwards, irrespective of assumptions concerning the underlying utility function.[27] Observe, however, that in either case the equality of the marginal rates of substitution does not extend to period $t = 0$ since the central planner's first-order condition with respect to consumption involves an additional term (see Appendix A.1).

To derive the optimal tax on residents' domestic source capital income, combine the household's and central planner's first-order conditions on domestic

[27] This argumentation carries over to the extended version with perfectly mobile labor: Although the level of human capital accumulated cannot be adjusted by immigration, the aggregate labor supply can still be balanced instantaneously by increasing the size of the workforce.

investments (equations (2.17) and (A.3)) and use the fact that capital is paid according to its marginal product,

$$1 + (1 - \tau^i_{rDt}) r^i_t \underset{(2.17)}{=} \frac{\lambda^i_{t-1}}{\lambda^i_t} \underset{(2.36)}{=} \frac{\mu^i_{t-1}}{\mu^i_t} \underset{(A.3)}{=} 1 + f^i_{kt} \Phi^i_t(\cdot) = 1 + r^i_t \tag{2.37}$$

$$\Leftrightarrow \tau^i_{rDt} = 0. \tag{2.38}$$

Equation (2.38) reveals that the optimal tax on residents' domestic source capital income is zero for all periods $t \geq 2$.

The result of zero long-run taxes on residents' domestic source capital income is due to Chamley (1986).[28] It can be viewed as an application of the uniform taxation principle, according to which goods with identical compensated demand elasticities should be taxed at a uniform rate (Atkinson and Stiglitz, 1972). In the present case of inelastic labor supply and time-additive utility,[29] the compensated demand elasticity of consumption exactly equals the inverse of the intertemporal elasticity of substitution σ that was used to derive the zero tax result. Only when σ is constant over time, it is optimal to tax present and future consumption at a uniform rate: Since a positive tax on capital income amounts to taxing future consumption at a rate increasing in time, although demand elasticities are constant, capital income taxes should be zero.

Furthermore, residents' foreign capital income is not taxed in the domestic economy. To see this, combine the household's and the government's first-order conditions with respect to outbound investments (equations (2.18) and

[28] Judd (1985) derives the same result in a setup with heterogenous households showing that capital income taxes are not efficient to redistribute income.

[29] Chamley (1986) establishes a far more general result, allowing for elastic labor supply and a broader class of utility functions.

(A.4),

$$1+(1-\tau^i_{rEt})r^j_t \underset{(2.18)}{=} \frac{\lambda^i_{t-1}}{\lambda^i_t} \underset{(2.36)}{=} \frac{\mu^i_{t-1}}{\mu^i_t} \underset{(A.4)}{=} 1+(1-\tau^j_{rIt})r^j_t \tag{2.39}$$

$$\Leftrightarrow \tau^i_{rFt}+(1-\delta^i_t)\tau^j_{rIt} \underset{Def.}{=} \tau^i_{rEt} = \tau^j_{rIt} \tag{2.40}$$

$$\Leftrightarrow \tau^i_{rFt} = \delta^i_t \tau^j_{rIt} \tag{2.41}$$

The exemption system, leaving outbound investments effectively untaxed in the domestic economy, is welfare maximizing. Combined with the zero-tax result with respect to residents' domestic source capital income, this implies that a benevolent government does not distort it's residents' decision to accumulate capital in the steady state. Again, this is an implication of the uniform taxation principle since any residence-based tax on capital income amounts to an increasing tax on future consumption.

Proposition 2 *A welfare maximizing local government refrains from taxing residents' capital income in the long-run since any residence-based tax on capital violates the uniform taxation principle.*

Similarly, equating the private and social first-order conditions with respect to human capital (equations (2.16) and (A.2)) yields

$$1+(1-\tau^i_{wt})w^i_t \underset{(2.16)}{=} \frac{\lambda^i_{t-1}}{\lambda^i_t} \underset{(2.36)}{=} \frac{\mu^i_{t-1}}{\mu^i_t} \underset{(A.2)}{=} 1+f^i_{ht}(\cdot)\Phi^i_t(\cdot)+f^i_t(\cdot)\Phi^i_{ht}. \tag{2.42}$$

Recall that the marginal rate of return to human capital as perceived by private firms exceeds the social rate of return. One can use this fact to rearrange equation (2.42) and derive the optimal tax rate on wage income,

$$(1-\tau^i_{wt})f^i_h\Phi^i_t(\cdot) \underset{(2.42)}{=} f^i_h\Phi^i_t(\cdot)+f^i_t(\cdot)\Phi^i_h \tag{2.43}$$

$$\Leftrightarrow\ (1-\tau^i_{wt})(1-\alpha)\frac{y^i_t}{h^i_t} = (1-\alpha-\eta\gamma)\frac{y^i_t}{h^i_t} \tag{2.44}$$

$$\Leftrightarrow\ \tau^i_{wt}(1-\alpha)\frac{y^i_t}{h^i_t} = \eta\gamma\frac{y^i_t}{h^i_t}\ \Leftrightarrow\ \tau^i_{wt}=\frac{\eta\gamma}{1-\alpha}. \tag{2.45}$$

As equation (2.45) reveals, the optimal long-run tax on wage income is constant and depends on the degree of rivalry η exerted by the factor human capital. This is plausible since the wage rate exceeds the social rate of return to human capital by the congestion costs induced. The optimal long-run tax on human capital reduces the private rate of return by $\eta\gamma$, capturing the additional social cost.[30] Thus, the wage tax is an efficient instrument to equate the private and social rate of return to human capital. Further than internalizing the congestion externality, human capital should not be taxed in the long-run. To see this observe that the optimal wage tax vanishes for the case of a pure public good ($\eta = 0$) or government consumption ($\gamma = 0$). This is, again, in line with the uniform taxation principle, as human and physical capital formation are perfectly symmetric in the present setup.

Proposition 3 *If the factor human capital imposes congestion costs, the long-run tax on labor income is used to internalize the involved social costs, equalizing the private and social rates of return. Consequently, the tax rate depends positively on the degree of rivalry η.*

Next, consider the first-order condition with respect to the public input

[30] This is in line with Turnovsky (1996) who developed a closed economy model with productive public infrastructure to show that optimal capital income tax rates depend on the degree of congestion.

(equation A.6) to derive the optimal provision of the public good,

$$\frac{1}{N_t^i} \underset{(A.6)}{=} f_t^i(\cdot)\Phi_{Gt}^i = \gamma \frac{y_t^i}{G_t^i} \quad \Leftrightarrow \quad g_t^i = \gamma y_t^i. \tag{2.46}$$

As equation (2.46) reveals, the public input is optimally provided if the per capita costs of provision equal the marginal productivity of public spending. This, however, implies that the long-run tax system is not necessarily sufficient to finance the optimal level of the public good. While residence-based capital income taxes vanish in the long-run, the wage tax depends on the degree of rivalry. Substituting the optimal wage tax into the government's budget constraint demonstrates that the revenue raised by taxing labor income is only sufficient in case of a publicly provided private good ($\eta = 1$),

$$g_t^i = \tau_{wt}^i w_t^i h_t^i = \eta\gamma y_t^i. \tag{2.47}$$

For other cases of rivalry ($0 \leq \eta < 1$), the government has to rely on initially high tax rates in period $t = 1$ to finance the entire stream of remaining revenue requirements. If government spending is purely consumptive ($\gamma = 0$), the whole path of expenditures has to be financed by initial income taxation, combined with an appropriate debt policy.[31]

Note that in the presence of a publicly provided private good, a benevolent government has no incentive to deviate from the optimal tax plan. This is due to the fact, that the tax system establishes a first-best allocation. Even if a commitment mechanism is not available, entailing that the possibility

[31] The government will optimally only tax returns to investments in the first period, thereby imitating an initial tax on endowments. If the tax rate is bounded from above, the optimal policy comprises positive income taxes for a limited period of time, dropping to zero as the system converges to the steady-state. For a more detailed description of this second-best policy, see Lucas (1990).

to revise the policy in succeeding periods exists, the government will stick the optimal tax plan announced in period 0. Thus, the policy derived is time-consistent.

As the analysis of the optimal tax system reveals, Chamley's result of zero long-run taxes on capital income can be reproduced in the present framework. While residence-based taxes on capital income are zero in the long-run, taxing labor income is optimal to internalize the congestion externality. This is due to the fact that aggregate human capital induces an externality as it lowers the productivity of the public good. Moreover, since a small open economy aims at establishing production efficiency, it refrains from taxing inbound investments. In a next step, this basic model is extended to include mobile labor and to analyze the impact of migration on optimal capital taxation. For ease of comparison, Table 2.2 summarizes the optimal fiscal policy in the absence of migration.[32]

[32] Although the table refers to the more general steady state results, the optimal income tax rates in the present model setup are valid for all periods $t \geq 2$.

General Results		
Production efficiency	(A.3)=(A.4)	$r_t^i = (1 - \tau_{rIt}^j) r_t^j$
Public good provision	(A.6)	$g_t^i = \gamma y_t^i$
Tax Rate on Non-Residents		
Domestic source capital income	(A.5)	$\tau_{rIt}^i r_t^i = 0$
Steady State Tax Rates on Residents		
Domestic source capital income	(2.17)=(A.3)	$\tau_{rDt}^i r_t^i = 0$
Foreign source capital income	(2.18)=(A.4)	$\tau_{rFt}^i = \delta_t^i \tau_{rIt}^j$
Labor income	(2.16)=(A.2)	$\tau_{wt}^i w_t^i = \eta\gamma \frac{y_t^i}{h_t^i}$

Table 2.2: Optimal fiscal policy in the absence of migration

2.6 Capital Income Taxation and Migration

While the basic model reproduces standard findings of the literature on optimal taxation in dynamic general equilibrium, this section evaluates the relevance of migration for the results derived. To this end, the basic framework is extended to incorporate perfect mobility of households across countries. Subsequently, optimal income tax rates are deduced emphasizing the impact of labor mobility for the optimal taxation of capital income.

2.6.1 Migration

Households are perfectly mobile across countries and migration can take place in every period and can go in any direction. Thus, the possibility of return migration is explicitly allowed for. This implies, that in period $t = 0$ a potential migrant not only decides on the entire consumption path when optimizing her lifetime utility given her initial endowments. Rather, the migrant additionally plans the path of migration, that is at which point in time to migrate to which country. The migration decision can, therefore, be interpreted as one of choosing between different optimal consumption paths each being contingent on one specific migration history. In planning the sequence of migration and the consumption path the household regards the fiscal policies of all possible residence countries as given.

Once a sequence of migration and a corresponding consumption path have been chosen, the household carries out these decisions in the following way: at the beginning of each period, the household migrates to another country, e.g. changes her place of residency. It is important to recognize, that at this point in time, the household's acquired level of bond holdings, human as well as physical capital is predetermined. The household will take this acquired wealth with her when migrating, implying that all decisions on investments and consumption are carried out after migration has taken place. As a consequence, they will resemble decisions of other residents of the receiving country, who are confronted with the same fiscal policy.

While the path of migration is planned initially, migration really is a one-period decision only, since the change in the place of residence might take place in every period. One can, therefore, focus on each period's migration equilibrium to determine the driving factors of migration. Remember that by migrating, a potential migrant in period t decides on where to reside given her acquired wealth, or, similarly, as a resident of which country to invest. This implies that the migration decision reduces to a choice between potentially different net rates of return across countries.

To keep the migration dynamics tractable, the analysis abstracts from any costs of moving such as language, cultural or administrative barriers to migration. Consequently, a migration equilibrium will be characterized by a situation in which all migration incentives vanish completely. From the point of view of a potential migrant this entails that net rates of return across countries are identical in every period t,

$$\left.\begin{array}{l} 1+(1-\tau^i_{wt})w^i_t \\ 1+(1-\tau^i_{rDt})r^i_t \\ 1+(1-\tau^i_{rEt})r^j_t \\ 1+r^i_{bt} \end{array}\right\} = \frac{\lambda^i_{t-1}}{\lambda^i_t} = \frac{\lambda^j_{t-1}}{\lambda^j_t} = \left\{\begin{array}{l} 1+(1-\tau^j_{wt})w^j_t \\ 1+(1-\tau^j_{rDt})r^j_t \\ 1+(1-\tau^j_{rEt})r^i_t \\ 1+r^j_{bt}. \end{array}\right. \tag{2.48}$$

Notice that, due to arbitrage, each investment form will earn the same net rate of return in a particular country of residence.

Taking the reciprocal and applying the isoelastic utility function, one can rearrange equation (2.48) to

$$\frac{\lambda^i_{t+1}}{\lambda^i_t} = \frac{\lambda^j_{t+1}}{\lambda^j_t} \underset{(2.15)}{\Leftrightarrow} \frac{u^i_{ct+1}}{u^i_{ct}} = \frac{u^j_{ct+1}}{u^j_{ct}} \Leftrightarrow \frac{c^i_{t+1}}{c^i_t} = \frac{c^j_{t+1}}{c^j_t} \Leftrightarrow \widehat{c}^i_t = \widehat{c}^j_t, \tag{2.49}$$

where $\widehat{c}_t$ is the growth rate of per capita consumption. Equation (2.49) indicates that the differences in the intertemporal marginal rates of substitution in consumption and, thus, consumption growth determine migration: In any migration equilibrium the growth rates of per capita consumption have to be equalized across countries.

As has been shown by Razin and Yuen (1996), growth rate convergence will only occur under the source principle: Facing equal after-tax rates of return to capital, consumers' intertemporal marginal rates of substitution are identical, and consumption efficiency is established. This entails that savings decisions are independent of the place of residence. Consequently, consumption growth rates converge, implying that the source principle is optimal in the presence of migration. Under the residence principle, in contrast, migration flows no longer react to productivity differences across countries but to differences in the level of taxation.

Observe that prior to migration households can differ by their initial endowments, implying that the chosen consumption paths might equally differ. As a consequence, the population of a country i in any period $t > 0$ will be heterogenous as it consists of remaining natives as well as immigrants who have previously entered the country and stayed. To avoid this and keep the analysis in line with the representative consumer setup that dominates the literature on optimal taxation in dynamic general equilibrium models, it is assumed that all households in the world economy possess the same amount of initial wealth. This involves not only assuming identical endowments, but also requires that initial tax rates, which have been exogenously fixed to avoid lump sum taxation, are independent of the respective jurisdiction.

The equality of the intertemporal rates of substitution in consumption together with the equality of initial endowments entails that households choose the same consumption path, no matter in which country they live.[33] Hence, the population of a country, that consists of natives and migrants, is homogeneous. It is, thus, sufficient to take into account changes in the size of the population of a country, N_t^i, while migration flows can be neglected. Since

[33] Assuming initially identical endowments in all countries implies that, ex-post, utility levels will be equalized in any migration equilibrium.

the possibility of return migration is not excluded, the size of the population can rise or decline over time.

One can utilize equation (2.48) to derive a functional form of the evolution of the domestic population. This allows to explicitly trace back the influence of labor mobility on the fiscal policy chosen. To separate the migration dynamics from the problem of optimal public good provision,[34] equate country i's net wage rate ($(1-\tau^i_{wt})w^i_t$) and the foreign net rate of return on outbound investments ($(1-\tau^j_{rEt})r^i_t$). Since both rates of return depend on the production function $y^i_t = f(k^i_t, h^i_t)\Phi^i_t(\mathcal{G}^i_t)$, one can eliminate the public good from the migration equilibrium,

$$(1-\tau^i_{wt})(1-\alpha)\frac{y^i_t}{h^i_t} \underset{(2.48)}{=} (1-\tau^j_{rEt})\alpha\frac{y^i_t}{k^i_t} \Leftrightarrow k^i_t = \frac{(1-\tau^j_{rEt})}{(1-\tau^i_{wt})}\frac{\alpha}{(1-\alpha)}h^i_t, \quad (2.50)$$

with $k^i_t = a^{ii} + \frac{A^{\bullet\, i}_t}{N^i_t}$. Solving for the domestic population, N^i_t, yields

$$N^i_t = \frac{A^{\bullet\, i}_t}{\frac{(1-\tau^j_{rEt})}{(1-\tau^i_{wt})}\frac{\alpha}{(1-\alpha)}h^i_t - a^{ii}_t}. \quad (2.51)$$

Equation (2.51) defines the population in country i depending on different tax rates, the level of human capital employed and the amount of physical capital invested in the domestic economy. While N^i_t rises with a^{ii}_t and $A^{\bullet\, i}_t$, the size of the domestic population declines with the level of human capital used in production. This is plausible since the migration equilibrium is characterized by the equivalence of the net rates of return across countries. Although foreign rates of return are given from the point of view of a small open

[34] Otherwise, competition for mobile labor will be carried out via taxation as well as government spending since the rates of return are determined jointly by taxes and public inputs. As will be shown below, detaching the migration decision from public good provision entails that governments optimally provide the public input, while migration decisions are only affected by tax policies.

economy, the marginal productivity of domestic factor inputs is determined by the capital intensity of production: A rise in a_t^{ii} or $A_t^{\bullet\, i}$ increases the wage rate and reduces the rate of return on physical capital. The household can avoid the lower rate of return on physical capital invested in i by shifting her investments abroad - the net rate of return on domestic and foreign capital investments is fixed by the no-arbitrage condition. Changes in the rate of return to physical capital will, thus, not affect migration incentives. Still, a rise in a_t^{ii} or $A_t^{\bullet\, i}$ induces a higher wage rate. This in turn leads to immigration and increases the domestic population size.

Obviously, while differences in the productivity of capital can be realized without moving, this is not the case for wage differences. Therefore, labor productivity dominates the migration decision. Whenever the physical (human) capital input is extended, the productivity of labor and, thus, the domestic population increases (falls). Based on the same mechanism, changes in fiscal policy affect the net rate of return on labor, and with it, migration incentives: A rise in the domestic wage tax lowers migration incentives, leading to a decline in N_t^i. In contrast, increasing the tax rate on inbound investments (τ_{rIt}^i) raises the effective tax rate on foreign capital investments (τ_{rEt}^j). This reduces the rate of return on capital investments in country i for residents of j and, consequently, induces capital flight and immigration. Since both allocations as well as tax rates determine the size of the domestic population, the migration dynamics constitute an important constraint for any welfare maximizing government. The following section derives the optimal tax policy a representative region chooses if migration of households is allowed for.

2.6.2 Optimal Fiscal Policy in the Presence of Migration

Just as before, consider a benevolent government that maximizes the welfare of country i's representative resident subject to the implementability as well as the economy-wide resource constraint. Due to the small open economy assumption, any influence on other countries is neglected. However, the central planner takes into account that households are mobile by treating the domestic population as a function of the allocations $\{h_t^{ii}, a_t^{ii}, A_t^{\bullet\, i}\}$ and the domestic tax rates $\{\tau_{rIt}^i, \tau_{wt}^i\}$.[35] Given this additional constraint, the primal approach to optimal taxation changes slightly: the wage tax has to be included as a further choice variable of the government as the domestic population not only depends on allocations but is also determined by taxes on inbound investment and labor income. Since prices and most tax rates have been eliminated from the optimization problem, the central planner decides on the allocations $\left\{c_t^i, h_{t+1}^i, a_{t+1}^{ii}, a_{t+1}^{ij}, A_t^{\bullet\, i}, G_t^i\right\}$ as well as the tax rates $\{\tau_{rIt}^i, \tau_{wt}^i\}$.

The planning problem can be written in the following way,

$$\max \sum_{t=0}^{\infty} \Big\{ \ \beta^t \omega\left(c_t^i, \bar{\lambda}^i\right) \tag{2.52}$$
$$-\bar{\lambda}^i \beta u_{c0}^i \left[\left(1 + (1-\tau_{rD0}^i) r_0^i\right) a_0^i + \left(1 + (1-\tau_{w0}^i) w_0^i\right) h_0^i + \left(1 + r_{b0}^i\right) b_0^i\right]$$
$$-\mu_t^i \left[c_t^i + a_{t+1}^i - a_t^i + h_{t+1}^i - h_t^i - \sum_{j \neq i} (1-\tau_{rIt}^j) r_t^j a_t^{ij} - \chi_t^i\right] \ \Big\}.$$

Since the government optimizes the welfare of a representative household,

[35] Alternatively, one can introduce the migration equilibrium as an additional constraint to the governments' optimization problem. This implies that the population is used as a direct control variable by the government.

the problem is stated in per capita terms. Hence, the population size solely affects the economy-wide resource constraint via the variable χ_t^i comprising all terms that depend on the population size N_t^i,

$$\chi_t^i = f_t^i(\cdot)\Phi_t^i(\cdot) - \frac{G_t^i}{N_t^i} - \left(1 - \tau_{rIt}^i\right) r_t^i \frac{A_t^{\bullet i}}{N_t^i} \qquad \text{with} \quad r_t^i = \frac{(1 - \tau_{rDt}^j)}{(1 - \tau_{rEt}^j)} r_t^j. \quad (2.53)$$

As a consequence, changes in one of the choice variables influencing the population size modify the optimality conditions slightly by adding a supplementary term that captures the effect of changes in the population on the resource constraint $\frac{\partial \chi_t^i}{\partial N_t^i}$. Observe that the set of choice variables now additionally includes the domestic wage tax, entailing that optimization leads to an additional first-order condition. The first-order conditions of the welfare optimization problem are stated in Appendix A.2.

Following the above procedure, one can derive the welfare maximizing tax system using the optimality conditions of the central planning problem. Consider first the efficient allocation of investments between the domestic economy and the rest of the world by combining equations (A.13) and (A.14),

$$r_t^i + \frac{\partial \chi_t^i}{\partial N_t^i} \frac{\partial N_t^i}{\partial a_t^{ii}} = (1 - \tau_{rIt}^j) r_t^j. \quad (2.54)$$

According to equation (2.54), an efficient allocation of investments from the point of view of a small open economy depends on the migration responses that a change in residents' domestic capital investments induces, $\frac{\partial N_t^i}{\partial a_t^{ii}}$, weighted by the effect of changes in the population size on the economy-wide resource constraint, $\frac{\partial \chi_t^i}{\partial N_t^i}$. Allowing for migration affects the optimal allocation of investments and, thereby, the structure of taxation.

To determine in what respect the structure of taxation changes, it is useful to derive the optimal tax rate on inbound investments first. To this end, take the first-order condition with respect to inbound investments (equation (A.15)) and observe that $\frac{\partial N_t^i}{\partial A_t^{\bullet i}} N_t^i = \frac{\partial N_t^i}{\partial a_t^{ii}}$,

$$f_{kt}^i \Phi_t^i(\cdot) = r_t^i \underset{(A.15)}{=} (1 - \tau_{rIt}^i) r_t^i - \frac{\partial \chi_t^i}{\partial N_t^i} \frac{\partial N_t^i}{\partial A_t^{\bullet i}} N_t^i \tag{2.55}$$

$$\Leftrightarrow \tau_{rIt}^i r_t^i = - \frac{\partial \chi_t^i}{\partial N_t^i} \frac{\partial N_t^i}{\partial A_t^{\bullet i}} N_t^i = - \frac{\partial \chi_t^i}{\partial N_t^i} \frac{\partial N_t^i}{\partial a_t^{ii}}. \tag{2.56}$$

Combining this result with equation (2.54) indicates that an optimal allocation of investments in the presence of migration requires identical after-tax rates of return to in- and outbound investments,

$$(1 - \tau_{rIt}^i) r_t^i = (1 - \tau_{rIt}^j) r_t^j. \tag{2.57}$$

Equation (2.57) reveals that a small open economy facing perfectly mobile labor aims at establishing consumption efficiency: the after-tax rate of return to residents' investments abroad ($(1-\tau_{rIt}^j) r_t^j$) should be equal to the net rate of return to inbound investments ($(1 - \tau_{rIt}^i) r_t^i$). This is due to the fact that a migration equilibrium is characterized by the convergence of consumption growth rates. As has been explained before, this requires that consumption efficiency holds: The allocation of investments between the domestic economy and the rest of the world will only be efficient, if migration responses to changes in the domestic capital stock have been taken into account. Since migration occurs as long as the after-tax rates of return between countries differ, consumption efficiency is a prerequisite for an efficient allocation of investments.

A small open economy can establish condition (2.57) applying the source principle of taxation, that is imposing identical tax rates on domestic source income ($\tau^i_{rDt} = \tau^i_{rIt}$) and tax-exempting residents' foreign source income ($\tau^i_{rFt} = \delta^i \tau^j_{rIt}$). To see this, consider again the no arbitrage-condition that investors residing in i face (equation (2.20)), and apply the source principle of taxation,

$$(1-\tau^i_{rDt})r^i \underset{(2.20)}{=} (1-\tau^i_{rEt})r^j \underset{Def.}{=} (1-\tau^i_{rFt}-(1-\delta^i)\tau^j_{rIt})r^j \tag{2.58}$$

$$\Leftrightarrow (1-\tau^i_{rIt})r^i_t = (1-\tau^j_{rIt})r^j. \tag{2.59}$$

While the residence principle is optimal in the absence of migration, introducing mobility of labor changes the welfare maximizing international tax regime: a small open economy facing mobile capital and labor aims at establishing consumption efficiency by applying the source principle of taxation. Source-based taxation of capital income guarantees that tax-induced migration incentives vanish as mobile consumers face identical intertemporal marginal rates of substitution. As a result, consumption growth rates converge.

Proposition 4 *To ensure an efficient allocation of mobile factors in the presence of migration, a small open economy intends to achieve consumption efficiency. Consequently, the source principle of taxation with* $\tau^i_{rDt} = \tau^i_{rIt}$ *and* $\tau^i_{rFt} = \delta^i \tau^j_{rIt}$ *is welfare maximizing.*

To derive the remaining tax rates, remember that matching the household's and the central planner's first-order conditions requires identical private and social intertemporal marginal rates of substitution in consumption ($\frac{\lambda^i_t}{\lambda^i_{t+1}} = \frac{\mu^i_t}{\mu^i_{t+1}}$). Since this condition is fulfilled in the steady state, the derived income tax rates represent the long-run fiscal policy. However, in case of an isoelastic utility function, the optimal tax system is valid for all periods $t \geq 2$. Table 2.3

provides an overview over the optimal fiscal policy a benevolent government chooses in the presence of migration.

General Results		
Consumption efficiency	(A.13)=(A.14)	$(1-\tau^i_{rIt})r^i_t = (1-\tau^j_{rIt})r^j_t$
Public good provision	(A.16)	$g^i_t = \gamma y^i_t$
Tax Rate on Non-Residents		
Domestic source capital income	(A.15)	$\tau^i_{rIt} r^i_t = -\frac{\partial \chi^i_t}{\partial N^i_t} \frac{\partial N^i_t}{\partial A^{\bullet\, i}_t} N^i_t$
Steady State Tax Rates on Residents		
Domestic source capital income	(2.17)=(A.13)	$\tau^i_{rDt} r^i_t = -\frac{\partial \chi^i_t}{\partial N^i_t} \frac{\partial N^i_t}{\partial a^{ii}_t}$
Foreign source capital income	(2.18)=(A.14)	$\tau^i_{rFt} = \delta^i_t \tau^j_{rIt}$
Labor income	(2.16)=(A.12)	$\tau^i_{wt} w^i_t = \eta\gamma \frac{y^i_t}{h^i_t} - \frac{\partial \chi^i_t}{\partial N^i_t} \frac{\partial N^i_t}{\partial h^i_t}$

Table 2.3: Optimal fiscal policy in the presence of migration

Table 2.3 reveals that the efficient fiscal policy is contingent on the term $\frac{\partial \chi^i_t}{\partial N^i_t}$. If $\frac{\partial \chi^i_t}{\partial N^i_t} = 0$, the optimal tax system reduces to the fiscal policy derived in the absence of migration. This is plausible since any influence of changes in the population size will naturally vanish if labor is immobile. Yet, if one allows for migration, that is N^i_t can vary with changes in the allocations or tax rates, $\frac{\partial \chi^i_t}{\partial N^i_t}$ need not vanish. Rather, it expresses the net social benefit of further immigration. To see this, differentiate the economy-wide resource constraint with respect to the population size to get

$$\frac{\partial \chi_t^i}{\partial N_t^i} = -f_{kt}^i \Phi_t^i(\cdot)\frac{A_t^{\bullet\, i}}{(N_t^i)^2} + f_t^i(\cdot)\Phi_{Nt}^i + \frac{G_t^i}{(N_t^i)^2} + (1-\tau_{rIt}^i) r_t^i \frac{A_t^{\bullet\, i}}{(N_t^i)^2} \tag{2.60}$$

$$= f_t^i(\cdot)\Phi_{Nt}^i + \frac{G_t^i}{(N_t^i)^2} - \tau_{rIt}^i r_t^i \frac{A_t^{\bullet\, i}}{(N_t^i)^2}. \tag{2.61}$$

Equation (2.61) indicates that the impact of a marginal change of the population size on the economy-wide resource constraint can be interpreted as the net social benefit of migration: An additional immigrant imposes social costs in terms of congestion costs ($f_t^i(\cdot)\Phi_{Nt}^i < 0$) and reduced tax revenue on inbound investments ($\tau_{rIt}^i r_t^i \frac{A_t^{\bullet\, i}}{N_t^i}$) that now has to be shared by more residents. At the same time, the migrant contributes to welfare as the per capita costs of public good provision ($\frac{G_t^i}{N_t^i}$) decline. As long as the social benefit of migration is greater than zero ($\frac{\partial \chi_t^i}{\partial N_t^i} > 0$), further immigration is beneficial until the gains from cost sharing are offset by the congestion costs plus the loss from revenue sharing.[36]

Obviously, the term $\frac{\partial \chi_t^i}{\partial N_t^i}$ can be interpreted as the shadow price of migration according to which the optimal population size will be established if the marginal migrant contributes as much in terms of reduced per capita public good costs as she imposes in terms of congestion costs and reduced per capita tax revenue on inbound investments. Consequently, the first-order condition with respect to the wage rate (equation (A.18)) reveals that an interior solution to the optimization problem requires $\frac{\partial \chi_t^i}{\partial N_t^i} = 0$.[37] If this can be achieved, the optimal tax system supporting the first-best coincides with

[36] Since natives and migrants are homogenous, per capita variables do not affect the net social benefit of migration.

[37] Note that the optimality condition is equivalent to the one obtained by differentiating with respect to N_t^i in a setup in which the planner directly controls the population size.

the fiscal policy derived in the absence of migration (see Table 2.3): While all capital income taxes should be zero in the long-run, labor income taxation is an efficient instrument to internalize the social costs associated with the degree of rivalry of the public good.

It remains to be shown under which conditions a small open economy can achieve $\frac{\partial \chi_t^i}{\partial N_t^i} = 0$. To this end, make use of the fact that the optimal tax on inbound investments equals zero ($\tau_{rIt}^i = 0$) once the net social benefit of migration vanishes. Furthermore, using the specific production function to rewrite the congestion costs reduces the net social benefit to

$$\frac{\partial \chi_t^i}{\partial N_t^i} = f_t^i(\cdot)\Phi_{Nt}^i + \frac{g_t^i}{N_t^i} = 0 \tag{2.62}$$

$$\Leftrightarrow g_t^i = \eta\gamma y_t^i. \tag{2.63}$$

According to equation (2.63) the optimal population size will be achieved if the average costs of public good provision (g_t^i) equal the marginal congestion costs ($\eta\gamma y_t^i$) that are induced by further immigration. This finding resembles a standard result of the literature on club theory that was originated by Buchanan (1965).[38] This strand of literature derives conditions for the optimal community size in the presence of rival public consumption goods: For a given level of public good provision, the optimal size of clubs consuming this good will be achieved when the average costs of provision equal the marginal congestion costs induced by the last entrant.[39]

Yet, in the present model setup the level of public good provision is not given but determined endogenously by the production technology. The op-

[38] A general overview on club theory can be found in Rubinfeld (1987).

[39] McGuire (1974) derives the optimal club size in the presence of congestion costs in a stylized model economy.

timal provision of the public good entails $g_t^i = \gamma y_t^i$ (see Table 2.3).[40] This implies that an interior solution for the optimal population size is only feasible in case of a publicly provided private good: average and marginal costs of providing the public input will only be equivalent if $\eta = 1$. In this case, the entire costs of public good provision can be raised by taxing labor income to internalize the congestion costs. The actual size of the domestic population is indeterminate since costs and benefits of migration always equalize. Consequently, migration flows are irrelevant for fiscal policies, and the efficient tax system is equivalent to the one deduced when labor is immobile.

Proposition 5 *In case of a publicly provided private good, the net social benefit of migration vanishes. As a consequence, the optimal tax system coincides with the one derived in the absence of migration.*

For other cases of rivalry, it is optimal to share the remaining costs of public good provision among an increasing number of residents, that is to extend the domestic population to infinity.[41] This is due to the fact that there is no additional immobile factor such as land that can be taxed without efficiency loss. Introducing such an immobile factor, an interior solution for the optimal population size can be achieved for intermediate degrees of rivalry ($0 \leq \eta < 1$): Adding a fixed factor introduces a trade-off between the positive effect of cost sharing and the negative effect of sharing the land

[40] The optimality condition of public good provision is independent of any assumptions with respect to the mobility of labor. This is reasonable since the functional form determining the population size has been derived eliminating the rival public input: Although immigration induces congestion costs, fiscal competition will only take place via tax policy.

[41] Observe that this affects the optimal tax rate on labor income, as can be revealed by inspection of the first-order condition with respect to the wage tax. In this situation, the available tax instruments are no longer sufficient, since the government cannot regulate migration without at the same time distorting the decision to accumulate human capital. While introducing head taxes could solve this problem, lump-sum taxation has been excluded as it is not compatible with the present migration approach.

rent among an increasing population. The optimal population size will be achieved if both effects exactly balance.

Flatters et al. (1974) first considered the optimal population size from a national point of view in a setup with fully taxable land rents. In their model with provision of a pure public consumption good, the optimal population size is achieved when the aggregate land rent equals the costs of public good provision. This result is often referred to as the Henry George theorem. Extending the Henry George Theorem to frameworks with congestion costs, the condition for an optimal club size has to be modified: the optimal club size is achieved if the total costs of public good provision equal the user charges introduced to internalize the congestion costs plus the total land rent.[42]

This reasoning carries over to setups with productive public good provision. In the present framework, this would entail that the costs of providing the public input equal the revenue from taxing labor income plus the aggregate land rent. Note, however, that the net social benefit of migration would be negative in case of a publicly provided private good, where average and marginal costs of public good provision are identical. As a consequence, the optimal population size in the presence of a fixed factor and a publicly provided private good would be zero: any additional resident lowers the per capita land rent available.

Summarizing, the integration of a migration decision does alter the optimal tax policy a local government chooses. Since households respond to differences in the after-tax rates of return to capital investments when deciding on migration, migration affects the optimal international tax regime: While

[42] See Wellisch (2000) who refers to this extension as the modified Henry George theorem.

the residence principle is optimal in the absence of migration, the source principle is welfare maximizing once mobility of labor is allowed for.

An interior solution can, however, only be established in case of a publicly provided private good. This entails that the optimal size of the domestic population is indeterminate. Since the social benefit of migration vanishes, the optimal tax system coincides with the one derived in the absence of migration, including vanishing tax rates on residents' domestic capital income. In case of a publicly provided private good, the general conclusion of standard models of optimal taxation of capital income can be confirmed even in the presence of migration: From the point of view of a small open economy, it is optimal not to tax internationally mobile capital at source. Moreover, to avoid distortions in the intertemporal savings decision, capital income should not be taxed in the long-run. Taxes on labor income are only used to the extent to which this production factor induces congestion costs.

2.7 Conclusion

The present research extends previous studies on capital income taxation in dynamic general equilibrium frameworks to include migration in addition to perfect capital mobility. Moreover, deviating from the standard Ramsey problem of optimal taxation, the expenditure side is explicitly taken into account. More precisely, it is assumed that governments provide a local productive public good that is rival, but non-excludable. In such a setting, mobility of labor is especially important since immigration of workers induces congestion costs. To keep the analysis in line with previous studies, the case of purely consumptive government spending has been included as well. Two versions of this model are considered, a basic setup with mobile capital, and an extended version additionally incorporating a migration decision of households.

The basic model reproduces the standard results of the literature on optimal capital taxation, namely that residents' returns to capital investments should not be taxed in the long-run. Moreover, if public good provision entails congestion costs induced by the aggregate labor supply, a wage tax is optimal to internalize these social costs. Extending the framework to include labor mobility reveals that migration does alter the optimal tax system: since labor movements respond to changes in the after-tax rates of return to capital investments, introducing migration changes the structure of the optimal tax system: While previous studies conclude that the residence principle of taxation is optimal, it is shown that the source principle is efficient if one allows for mobile capital and labor.

Yet, an interior solution to the optimization problem can only be obtained in case of a publicly provided private good. This entails that labor income taxes used to internalize the congestion costs are sufficient to finance the public good at any point in time. Put differently, average and marginal costs of public good provision are identical, implying that the social benefit of migration vanishes, and the optimal population size is indeterminate. As a consequence, the optimal tax system coincides with the fiscal policy derived in the absence of migration.

The following chapter continues to study the effects of labor mobility in a dynamic setting, but focuses on another issue of fiscal competition: the optimal education policy if high-skilled workers are perfectly mobile. Moreover, the issue of interregional externalities resulting from migration will be discussed. While the present analysis focuses on the optimal tax system of a small open economy, this need not be efficient from a global point of view since the possibility of migration generates an interregional externality that is not accounted for at the country level. To see this, consider a situation in which all countries are endowed with a suboptimally low population size except for a single country in which the population level is optimal. This single country will try to establish a fiscal policy that maintains the initial population distribution, not taking into account the possibly larger benefits for other regions that go ahead with an alternative distribution. Hence, the regional optimum need not coincide with the global first-best. Under which circumstances local decision making can replicate the global welfare optimum will be one of the issues addressed in the proceeding chapter.

Chapter 3

Optimal Education Policies

3.1 Motivation

The introductory chapter has summarized basic empirical facts on migration trends, that suggest an increasing mobility of labor in the years to come due to a rapid decline in transaction costs. Administrative or legal barriers have been reduced in highly integrated regions such as the European Union, while language or cultural obstacles to migration are of minor importance in federal states. Moreover, the mobility of labor increases with the skill level as specialized skills of highly educated workers may be locally less demanded and, hence, require searching a geographically larger labor market. In view of the high mobility especially of skilled labor, benefits resulting from local investments in education do not necessarily accrue to the region of origin.

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Therefore, public incentives to promote mobility enhancing education might be limited. Rather, it seems to be tempting to attract skilled labor from abroad using a favorable tax system and free-ride on other regions' education policies. Hence, high-skilled mobility can be problematic for decentralized fiscal policies.

The present chapter analyzes this free-rider problem at the level of local jurisdictions in a setup that allows for social mobility across skill types. Individual underinvestment in education provides a rationale for educational subsidies from a federal point of view.[1] Local governments, however, might refrain from subsidizing education in the presence of high-skilled migration. Since the size of the educated workforce available in the respective jurisdiction is no longer determined by domestic educational investments but by migration flows, local governments might lose the incentive to correct private underinvestment. This suggests that decentralized education policies are inefficient, and educational subsidies have to be provided at the federal or supra-national level. Yet, local governments do engage in education policies and subsidize especially early education substantially. The present analysis provides an explanation for this phenomenon and shows that local governments do not free-ride on other regions' education policies, even though high-skilled workers are assumed to be perfectly mobile.

[1] Private underinvestment can result due to various reasons such as externalities or credit constraints and constitutes just one exemplary rationale for government intervention. Andersson and Konrad (2006) provide a detailed overview over various motivations for public education policies.

3.2 Related Literature

Most previous studies stress an efficiency enhancing aspect of migration that implies a reduced need for public policy. Surprisingly, the recent literature on the brain drain has emphasized this point in various studies. Typically, research on the brain drain focuses on a less developed country and analyzes the effect of outmigration of qualified labor to a high-wage region. Since the destination country is not modeled explicitly, most studies prevent depopulation by assuming that migration is restricted, e.g. the probability to emigrate is exogenously given. Against this background, the negative effects of high-skilled migration for growth and welfare in the source country are stressed.[2] Yet, the relationship between human capital formation and the possibility to emigrate as well as the potentially involved welfare gains have only been recognized recently.

The welfare improving impact of migration in new approaches to the brain drain rests on the observation that an exogenous increase in the migration probability of high-skilled labor fosters private educational investments as in Stark et al. (1998). Starting from a situation of educational underinvestment that is induced by externalities, increasing the probability to emigrate raises private incentives to accumulate human capital and, hence, promotes welfare.[3] Since educational underinvestment provides a rationale for public intervention, migration can even function as a substitute for subsidies in education (Stark and Wang, 2002). Yet, the positive effect of migration in these models is based on the presumption that a fraction of the high-skilled work-

[2] For a thorough review of the literature on brain drain see Commander et al. (2003).

[3] The possibility of an efficiency enhancing brain drain on the basis of a probabilistic approach to migration has been discussed in models with underinvestment due to production externalities (Stark (2004); Mountford (1997)) as well as intergenerational transmission of knowledge (Beine et al. (2001); Vidal (1998)).

force cannot migrate. The brain drain is thereby exogenously restricted and increased educational incentives enhance the aggregate human capital supply in the source country. One exception is the study by Stark et al. (1997), who consider asymmetric information between the migrant and the foreign employer: the latter only discovers the true productivity of the migrant with delay. Yet, once this information has been revealed, wage payments for low-productivity migrants decline and induce return migration. This implies that educational investments, which initially increase mobility but entail the possibility of return migration, turn out to be beneficial for the source country as soon as return migration becomes profitable.

Similar to new approaches to the brain drain, migration can enhance efficiency in a setup in which private underinvestment results from uncertainty. Wildasin (2000b) considers a framework in which high-skilled workers possess industry-specific human capital. This implies that qualified labor is intersectorally immobile and, therefore, exposed to earning risks. If education is privately financed and wage risks are uninsurable,[4] globalization that raises the geographical mobility of high-skilled labor provides full insurance of the involved income risks. As a consequence, investments in human capital increase to an efficient level.[5]

At the same time, migration can restore efficiency in a setup where educational subsidies are used to overcome a hold-up problem of time-inconsistent taxation. Boadway et al. (1996) consider human capital formation in a closed economy. They point out that if governments cannot commit to future tax

[4] Wildasin (2000b) analyzes the effect of high-skilled labor mobility for the case of private as well as public investments in education.

[5] In a comparable approach, Poutvaara (2000, 2001) model wage-tax financed educational transfers to students as an insurance against regions-specific shocks. Against this background, the trade-off between the efficiency enhancing effect of mobility and the possible erosion of local tax policies due to tax competition is assessed.

policies, they have an incentive to revise their policy and tax labor income excessively once human capital has been accumulated and is in fixed supply. Rational households anticipate this change in fiscal policy and underinvest in education, which implies that public intervention such as providing educational subsidies can improve efficiency. Andersson and Konrad (2003a) argue that alternatively allowing for mobility of labor reintroduces the elasticity of the tax base and serves as a commitment device for low tax rates.[6] Against this background, they determine the welfare effects of globalization when education is risky.[7]

The studies cited above suggest that an increase in labor mobility should be accompanied by a decline in public investments due to a reduced need for fiscal policies. The present research does not intend to cast doubt on this efficiency enhancing effect of migration. Yet, it is presumed that mobility of high-skilled workers will most likely not entirely restore efficiency. If migration fails to exactly offset the inefficiencies, private underinvestment persists. This calls for public policies to correct the underlying market failure. However, from the point of view of a small jurisdiction facing migration of highly educated workers, the size of the high-skilled workforce available depends on migration flows alone and not on previous local investments in education.

[6] The fact that mobility of labor can improve efficiency as the involved elasticity of the tax base forces local jurisdictions to behave optimally is also stressed by Wellisch and Richter (1995). Here long-lived pollutants impose a cost on future generations that is not accounted for today. Yet, mobility of households introduces the possibility to escape these costs and induces optimizing governments to properly internalize the intergenerational pollution externality.

[7] Thum and Uebelmesser (2003) build on this efficiency enhancing effect of migration in a setup where human capital accumulation can contain country-specific as well as internationally applicable knowledge such as language skills. By investing in mobility-increasing education of the young, the old generation who decides on redistributive fiscal policies can bind itself to low tax rates. In contrast, Leviathan governments try to prevent mobility-increasing education in the first place, as Andersson and Konrad (2003b) show in a framework with just one type of education.

Therefore, the possibility to free-ride on other regions' educational investments arises, and decentralized policies in the presence of labor mobility might not be efficient anymore. As Sinn (1997) puts it, fiscal competition reduces the incentives of governments to correct market failures.

The above-mentioned study by Wildasin (2000b) additionally considers the case of public investment in human capital. It is shown that if education is financed publicly, tax competition for high-skilled workers results in public underinvestment. Hence, decentralized education policies turn out to be inefficient. Similarly, Justman and Thisse (1997, 2000) develop a model in which the number of school places and, consequently, the supply of skilled workers is entirely determined by public instead of private investments. Their analysis demonstrates that mobility of high-skilled labor induces underprovision of public education if regions interact strategically.[8] To restore local incentives for public provision of education, a system of interjurisdictional transfers based on migration flows is suggested.

Poutvaara and Kanniainen (2000) focus on a situation of private underinvestment in human capital that results from intragenerational spillovers between students. They point out that low-ability agents have an incentive to partly finance corrective educational policies in a closed economy setup. This is due to the fact that low-skilled workers gain directly from efficient levels of educational investments as their wage income increases with the size of the complementary high-skilled workforce. Yet, once the educated are able to migrate, it is not clear whether the domestic economy can fully capture the benefits of previous educational investments. Therefore, analogously to small open jurisdictions, low-ability workers have an incentive to free-ride on other

[8] This result has recently been confirmed by Egger et al. (2007), allowing for an endogenous educational choice of individuals and asymmetries between countries.

regions education policies instead of correcting educational underinvestment themselves. Similarly, Del Rey (2001) analyzes possible free-riding of foreign students who benefit from public education, but do not contribute to the tax system. It is shown that fiscal competition results in underprovision of education if price discrimination is not allowed for.

The cited studies on education policies in the presence of migration conclude that government activity in this area will decline if mobility rises, either due to a reduced need for fiscal intervention or due to diminished incentives to correct market failures. Nevertheless, comparing the years 1995 and 2001, 78 percent of all OECD countries for which data is available refrained from lowering their public expenditures on education relative to the aggregate public budget, despite of the rising mobility of labor. In fact, the proportion of total public expenditures that were spent on education was increased on average from 11.8 to 12.7 percent.[9] This trend can be confirmed if one considers education policies of the fifteen EU member states in 1995 and 2001. Between these countries, barriers to migration have been reduced substantially resulting in a labor market that by far exceeds national boundaries. Consequently, they seem to be natural candidates to observe a reduction in public educational expenditures as a response to increased labor mobility. Figure (3.1) depicts the change in the educational expenditure ratio, that is the change in public educational spending relative to the aggregate public budget, between 1995 and 2001. The graph reveals that public spending on education grew faster than total public spending in nearly all EU member

[9] The calculations are based on the OECD indicator "Relative proportion of public and private investment in educational institutions" (OECD (2004), Table B4.1). The indicator relates public expenditures on education to total public spending for the years 1995 and 2001. Note that public education comprises direct public spending on educational institutions as well as public subsidies such as scholarships and subsidies on student living costs.

states covered. The following analysis provides a theoretical explanation why

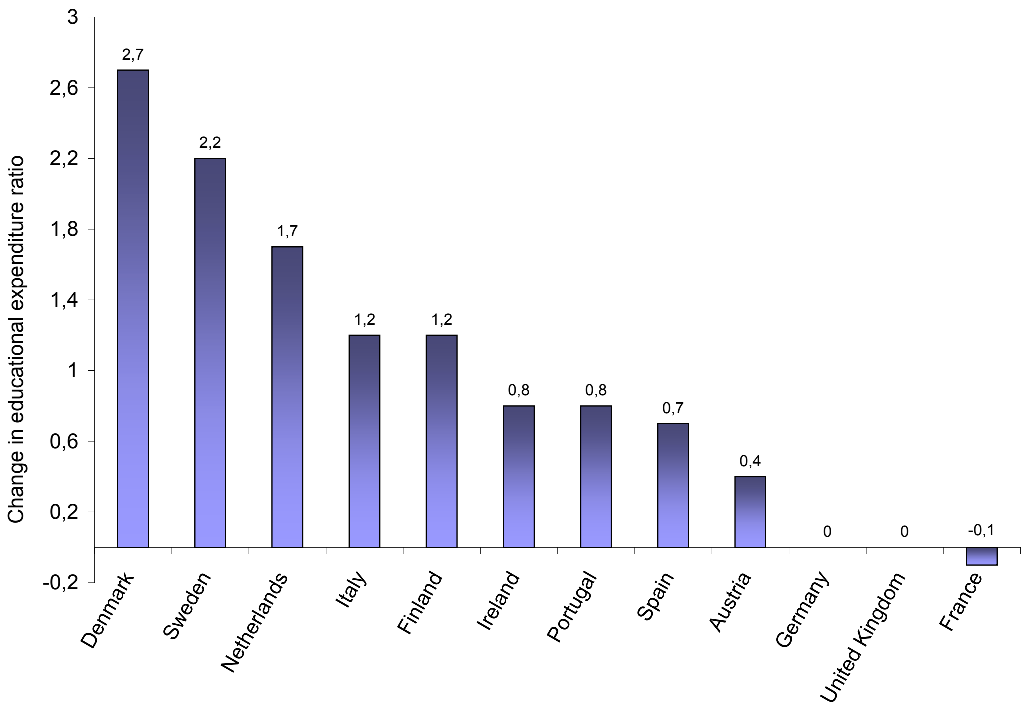

Figure 3.1: Change in public expenditure on education as percentage of total public spending, 1995-2001
Source: Author's calculations based on OECD (2004), Table B4.1.

public expenditure on education does not decline despite of the observable increase in high-skilled mobility.

The focus of the present study lies on the incentives of local jurisdictions to correct underinvestment in education, while positive efficiency enhancing effects of migration at the private level are ignored. This research contributes to the literature as it develops a dynamic framework capable of integrating social mobility as an additional dimension of labor mobility. Consequently, lacking governmental support of education cannot be compensated by immigration as it additionally affects the number of immobile low-skilled workers in a respective region. As a result, local governments stick to the optimal decision rule for subsidizing education despite of the mobility of educated workers, and decentralized decision making remains to be efficient.

Only if one allows for high- and low-skilled mobility, local incentives to correct the underinvestment problem vanish as education policies neither affect the size of the domestic high- nor of the low-skilled workforce. This implies that private underinvestment in education persists. To correct the market failure and establish the social optimum in a decentralized setting in which both types of workers are perfectly mobile across regions, a federal matching grant can be used. However, such a federal matching grant effectively assigns the education policy to the federal or supranational level.

The subsequent chapter is organized as follows: In Section 3.3, the basic model setup is described with a special emphasis on the educational process and the migration dynamics. Section 3.4 and 3.5 derive the optimal fiscal policies a unitary state government chooses and discuss what policy instruments are needed to decentralize the welfare optimum. Firstly, the case of perfect mobility of the educated workforce is considered, and then migration of high- as well as low-skilled labor is allowed for. The last section concludes.

3.3 The Model

Consider a federal economy with a large number of small local jurisdictions $i = 1, ..., m$.[10] Each of these jurisdictions represents a local tax authority that can raise lump-sum taxes to finance educational subsidies, given the fiscal policy decided by the central government. Initially, and before any migration takes place, the population of region i consists of a fixed number of high-skilled ($N^H_{0,i}$) and low-skilled households ($N^L_{0,i}$).

Moreover, the federation is populated by successive generations. Every household or parent has one offspring and invests an amount e^n_t in the education of this child, where $n = H, L$ indicates the respective type of the parent. This educational investment determines the child's probability of becoming high-skilled. Thus, while the overall size of the population is fixed over time with $\bar{N} = \sum_{i=1}^{m} \left(N^H_{t,i} + N^L_{t,i}\right) \forall t \geq 0$, the evolution of types depends on the regional investments in education.

The timing of events is as follows: The central government moves first, deciding on the sequence of fiscal policies that maximizes the welfare of the aggregate federal population. It is assumed that the federal government has access to a commitment technology that fully binds it to the announced tax policy. The local governments move next, behaving like small open economies when choosing the sequence of regional tax rates, followed by private agents, who take all tax rates as given. Note that time-inconsistency of local fiscal policies is not an issue here, because households are not optimizing intertemporally. Thus, the possibility of a future revision of the initially announced path of optimal policy will not influence the decisions of the working popu-

[10] This assumption allows to abstract from any strategic interaction between regions.

lation as these are only affected by current tax rates.[11]

The basic model setup follows Boadway et al. (2003), who analyze fiscal equalization in a static model with two types of mobile labor. Their work is extended to a dynamic framework with successive generations and an endogenous human capital formation process to study the consequences of labor mobility for optimal education policies. The production of human capital is based on a setup suggested by Cremer and Pestieau (2006). In their model, the educational success is determined by an endogenously derived probability of becoming high-skilled. In the present research, this is interpreted as social mobility which reflects the fact that children of both low- and high-skilled parents face a positive probability to become high-skilled themselves. The approach makes it possible to analyze fiscal policies that not only affect the allocation of the mobile factor across regions, but additionally determine the endowment with the factor across time.

3.3.1 Regional Production

In every period $t \geq 1$, firms produce a single aggregate good that can be used for consumption and investments in education. Labor is the only input factor with high-skilled ($N_{t,i}^H$) and low-skilled households ($N_{t,i}^L$) being perfect substitutes. Households supply z^n efficiency units of labor inelastically, with $n = H, L$ denoting the respective skill group, and it is assumed that high-skilled labor is more productive ($z^H > z^L$). Aggregate effective labor supply can be written as $Z_{t,i} = z^H N_{t,i}^H + z^L N_{t,i}^L$.

[11] As Kydland and Prescott (1977) point out, time inconsistencies arise solely in situations in which the current optimization behaviour of agents is influenced by their expectations of future fiscal policies.

Firms in every region have access to the production function $F(Z_{t,i})$ with $F'(Z_{t,i}) > 0 > F''(Z_{t,i})$. As an example one can think of the following production technology

$$F(Z_{t,i}) = (Z_{t,i})^{\alpha}, \tag{3.1}$$

where $0 < \alpha < 1$ denotes the production elasticity of labor. Labor markets are competitive, therefore the wage rate equals the marginal product of labor.

As the production function exhibits decreasing returns to scale, local rents arise. The rent income of region i is given by $R(Z_{t,i}) = F(Z_{t,i}) - Z_{t,i}F'(Z_{t,i})$ with $R'(Z_{t,i}) = -Z_{t,i}F''(Z_{t,i}) > 0$. It is assumed that these rents accrue to the regional government.[12] Since regions have access to the same production technology, that is fiscal capacities of local jurisdictions do not differ, there is no need for federal equalization. This implies that it is irrelevant whether the rents are appropriated by the regional or central government. In contrast, with private ownership of the fixed factor, source income arises that induces an additional fiscal externality of migration. To focus on the impact of migration on optimal education policies, additional inefficiencies resulting from private rent income should be avoided, and it is assumed that the local governments receive the entire rent income.

3.3.2 Central and Local Governments

Both the central and the regional governments are benevolent in the sense that they maximize the sum of their residents' utility, discounted over all periods. In other words, governments care about the aggregate welfare of

[12] This can be justified by the implicit assumption that either the local jurisdiction is the owner of the fixed factor who generates the rents, or that it has access to a rent tax to fully appropriate the pure profit.

each parent generation living in the respective region. The central government has access to a federal lump-sum tax $\theta^n_{t,i}$, which can be differentiated both across regions and across skill-types. Furthermore, it can choose a skill-specific matching grant $\theta^n_{et,i}$ paid to regions for every unit invested locally in education. The budget constraint of the federal government can be written as

$$\sum_i \sum_n N^n_{t,i} \left(\theta^n_{t,i} - \theta^n_{et,i} e^n_{t,i}\right) = 0. \tag{3.2}$$

The set of available tax instruments at the local level of government is restricted to a skill-specific head tax on residents (τ^n_t) and a skill-specific educational subsidy or tax (τ^n_{et}). The budget of a representative jurisdiction i additionally includes the regional rent and the federal matching grant,

$$\sum_n N^n_{t,i} \left(\tau^n_{t,i} - \left[\tau^n_{et,i} - \theta^n_{et,i}\right] e^n_{t,i}\right) + R(Z_{t,i}) = 0. \tag{3.3}$$

3.3.3 Household Behavior

Following Cremer and Pestieau (2006),[13] successive generations of two types of labor, namely low-skilled (N^L_t) and high-skilled (N^H_t), are assumed.[14] Each of these workers has one offspring and is, hence, also referred to as a parent. Parents invest an amount e^n_t in the education of their children and thereby determine the probability of their child to become high-skilled, $h(e^n_t)$ with $h^n_e > 0$ and $h^n_{ee} < 0$. While young, children undergo education, but only enter the model explicitly when old, that is, once they have completed their education and start working as either high- or low-skilled. Note that individ-

[13] Cremer and Pestieau (2006) consider an immobile workforce and study optimal education policies when private investment, which can be supplemented by public investment, is not observable.

[14] The region index i is suppressed for the moment.

uals do not decide on their own education, but only on the amount invested in their children. Thus, the model rather depicts basic or early education as compared to college or university education.

The probability to become high-skilled and, thus, high-productive is derived endogenously as a function of the different educational investments of the respective type of parent: The probability to become high-skilled is $h(e_t^H)$ if parents are high-skilled, and $h(e_t^L)$ if they are low-skilled. Since children of high- and low-skilled parents both face a positive probability of becoming high-skilled, the model allows for social mobility across skill types.

However, in the absence of any fiscal policy, children of high-skilled parents face a higher probability of becoming high-skilled themselves. This is due to the fact that high-skilled parents are more productive and earn a higher wage income. Consequently, they spend more resources on education than low-skilled parents do. As the amount invested by parents is determined by the net earnings realized by the respective type, social mobility is contingent on the productivity and eventually on the educational background of parents. Therefore, the model additionally captures intergenerational earnings persistence which can, however, be reduced using educational subsidies.

The proposed framework replicates basic findings of the recent literature that stress the importance of early investments in shaping the cognitive ability of children that in turn determines their future educational success as well as their income prospects. Restuccia and Urrutia (2004) calibrate a model in which innate ability, acquired ability, based on parental investments in early education, and college education determine the probability of successful college graduation. They show that parental investments in education, especially early education, account for nearly one-half of the observed intergenerational earnings persistence. This evidence suggests that social mobility can be increased substantially by the provision of educational subsidies on private investments in early education. Additionally, Carneiro and Heckman (2002) stress the importance of long-run factors to explain the positive correlation between college enrolment and family income. They argue that children from high-income families have better access to resources that provide them with higher quality of education early in life leading to superior cognitive ability in the long-run.

Assuming large numbers, the size of the aggregate high-skilled labor force in period t can be derived on the basis of parent's educational investment in period $t-1$,

$$N_t^H = N_{t-1}^H \cdot h(e_{t-1}^H) + N_{t-1}^L \cdot h(e_{t-1}^L). \tag{3.4}$$

Analogously, the number of low-skilled workers can be deduced,

$$N_t^L = N_{t-1}^H \cdot (1 - h(e_{t-1}^H)) + N_{t-1}^L \cdot (1 - h(e_{t-1}^L)). \tag{3.5}$$

After the educational process determined the respective type, the child enters the working period as either high- or low-skilled, supplying z^n efficiency units of labor inelastically to firms in the region of residence. The resulting labor income is spend on consumption, tax payments as well as net investment in the education of children. The household's budget constraint can be expressed as

$$z^n F'(Z_t) - \tau_t^n - \theta_t^n = c_t^n + (1 - \tau_{et}^n) e_t^n, \tag{3.6}$$

where c_t^n denotes consumption and e_t^n investment in education of children. Note that a consumption tax is not allowed for at neither level of government. As far as type-specific consumption taxes are concerned, no further insights can be expected as both the consumption tax as well as the educational subsidy decrease the opportunity cost of investments in education and are, consequently, perfect substitutes. Moreover, a consumption tax is typically not differentiated across skill-types and, therefore, displays an inferior tax instrument as it cannot mimic type-specific education policies.[15]

Parents are altruistic in the sense that they experience a joy of giving when supporting their children's education (warm glow altruism). Preferences of different skill types are identical and additively separable between consumption and educational investments. They can be expressed by the strictly concave utility function

$$U(c_t^n, e_t^n) = u(c_t^n) + \upsilon(e_t^n). \tag{3.7}$$

Households of each type maximize utility subject to their budget constraint, taking both federal and regional tax rates as given. In the optimum, the marginal rate of substitution between consumption and investment in education equals the private cost of education,[16]

$$\frac{\upsilon_{et}^n}{u_{ct}^n} = (1 - \tau_{et}^n). \tag{3.8}$$

While equations (3.4) and (3.5) underline the crucial impact of private investments in education on the composition of the future workforce, parents solely optimize their own utility disregarding the positive effect for future genera-

[15] Yet, a consumption tax will turn out to be sufficient ex post. This is due to the fact that the assumed utilitarian welfare function entails redistribution among types. In the resulting type-symmetric equilibrium, a universal consumption tax and a type-specific educational subsidy are perfect substitutes.

[16] In the absence of any tax or subsidy, the private cost of education in terms of consumption equals one. This reflects the underlying assumption that output can be transformed into consumption and education at no further resource cost.

tions. Put differently, they fail to internalize their child's benefits resulting from these educational investments. As will be shown, this intergenerational externality leads to inefficient levels of investment in education that can be corrected using an educational subsidy.

3.3.4 Migration

Two different scenarios of migration are considered: mobility of the high-skilled workforce and mobility of both the high- and the low-skilled workforce. For simplicity, the analysis abstracts from any migrations costs such as language barriers, moving costs or attachment to the home country.[17] Migration takes place at the beginning of every period $t \geq 1$, before households decide on consumption and educational spending. Hence, migration flows determine the current working population of a respective region i in every period t.

A potential migrant is indifferent between migrating or staying as soon as utility is equalized across regions.[18] Thus, a migration equilibrium between any region $i \neq j$ and an arbitrarily chosen reference region j is characterized

[17] As will be discussed below, this assumption influences the equilibrium attained. However, it has no impact on the results concerning the efficiency of regional education policies.

[18] Typically, a migration equilibrium in the presence of mobile labor is characterized by an equalization of the net wage rate. As long as the entire net income is spend on consumption, this corresponds to an equalization of utility levels. Yet, in the present setup, the net income can be spend on consumption and educational investments. Moreover, households are confronted with interregionally different shadow prices for education. Similarly to the case of provision of public consumption goods, it is, therefore, not plausible to assume that migration flows result in an equalization of net wage rates. Rather, movements of labor will occur until the attainable utility levels will be equalized.

by identical utility levels,

$$u(c_{t,i}^n) + \upsilon(e_{t,i}^n) = u(c_{t,j}^n) + \upsilon(e_{t,j}^n). \tag{3.9}$$

Equation (3.9) implicitly defines the quantity of mobile labor allocated in a particular region after a migration equilibrium has been reached.

By introducing mobility of households, the constraints for fiscal policies both at the federal and at the local level are affected. While in a closed economy the number of low- and high-skilled workers available in a particular region is fully determined by investments in education, this is no longer true if one considers migration. Rather, migration incentives are crucial for the allocation across regions. Yet, the size of the mobile population group in the federal state as a whole is still contingent on regional investments in education and is, hence, restricted. The federal government takes this into account, while the government of a small open region views the supply of the mobile factor as infinitely elastic. It is important to point out that as long as solely mobility of the high-skilled is allowed for, a local jurisdiction perceives the number of the immobile low-skilled workforce as dependent on local human capital formation. With mobility of high- and low-skilled, however, migration flows alone determine the allocation of types across regions.

3.4 Optimal Education Policies with High-Skilled Migration

In the following section, optimal education policies at both the federal and regional level of government are studied. In the first subsection, it is shown that parents underinvest in education. This inefficiency justifies federal education policies on efficiency grounds. Yet, if one considers the possibility of migration, a free-rider problem at the level of regional governments might arise. Since, from a local perspective, the size of the mobile workforce no longer depends on educational investments but on migration incentives, jurisdictions might substitute efficiency enhancing education subsidies by fiscal policies that aim at attracting migrants. In the absence of federal education policies, private underinvestment in education might, therefore, persist. The second subsection analyzes if this regional free-rider problem indeed occurs and federal education policies are needed to correct the intergenerational inefficiency. To this end, the unitary state optimum is derived as a benchmark case. Subsequently, regional policies as well as federal tax instruments capable of decentralizing the first best optimum are discussed.

3.4.1 Unitary State Optimum

Consider a unitary state government that is benevolent in the sense that it maximizes a utilitarian welfare function, summed up over all generations and discounted by the social rate of time preference, $0 < \beta < 1$. To characterize the central planning solution as a benchmark case, assume that the unitary state government does not only decide on federal taxes, but also optimally chooses the tax instruments available to regions.

The unitary state government optimizes social welfare by choosing the tax rates $\left\{\tau_{t,i}^n, \theta_{t,i}^n, \theta_{et,i}^n\right\}$ as well as the allocations $\left\{c_{t,i}^n, e_{t,i}^n, N_{t,i}^n\right\}$. The population $N_{t,i}^n$ is treated as an artificial control variable, since the human capital formation constraint as well as the migration equilibrium are added as constraints to the optimization problem. Alternatively, one can use the two constraints to determine the respective population group as an endogenous variable, depending on the different tax rates and allocations. Note that the household's first-order condition has been used to eliminate $\tau_{et,i}^n$ from the central planner's optimization problem.

The optimization problem is to solve

$$
\begin{aligned}
\max \sum_{t=1}^{\infty} \beta^t \Bigg\{ & \sum_i \sum_n N_{t,i}^n \left[u\left(c_{t,i}^n\right) + \upsilon(e_{t,i}^n)\right] \\
& + \sum_i \sum_n \kappa_{t,i}^n \left[z^n F'(Z_{t,i}) - \tau_{t,i}^n - \theta_{t,i}^n - c_{t,i}^n - \frac{\upsilon_{et,i}^n}{u_{ct,i}^n} e_{t,i}^n\right] \\
& + \lambda_t \sum_i \sum_n N_{t,i}^n \left(\theta_{t,i}^n - \theta_{et,i}^n e_{t,i}^n\right) \\
& + \sum_i \lambda_{t,i} \left[\sum_n N_{t,i}^n (\tau_{t,i}^n + \frac{\upsilon_{et,i}^n}{u_{ct,i}^n} e_{t,i}^n - \left(1 - \theta_{et,i}^n\right) e_{t,i}^n) + R(Z_{t,i})\right] \\
& + \sum_i \mu_{t,i}^L \left[N_{t+1,i}^L - \sum_n N_{t,i}^n \left[1 - h(e_{t,i}^n)\right]\right] \\
& + \mu_t \left[\bar{N} - \sum_i \sum_n N_{t,i}^n\right] \\
& + \sum_{i \neq j} \varphi_{t,i}^H \left[u(c_{t,j}^H) + \upsilon(e_{t,j}^H) - u\left(c_{t,i}^H\right) - \upsilon(e_{t,i}^H)\right] \Bigg\},
\end{aligned}
\tag{3.10}
$$

where the variables $\kappa_{t,i}^n$, λ_t, $\lambda_{t,i}$, $\mu_{t,i}^L$, μ_t and $\varphi_{t,i}^H$ denote the Lagrange-multipliers on the respective optimization constraints. The first constraint guarantees that the household's budget is balanced. The next two constraints refer to the federal and regional budget that are distinguished to keep the solution comparable to the regional optimization discussed below. The fourth constraint reflects the fact that the size of a region's immobile low-skilled population in period $t+1$ is contingent on local educational investments in period t. The remaining constraints illustrate that the exogenously given aggregate labor force $\bar{N}_t$ consists of high- and low-skilled labor allocated in one of the regions and that the mobility of high-skilled workers requires that the migration constraint is met. Since the size of the low-skilled workforce is determined by the human capital formation constraint, the population restriction characterizes the aggregate size of the high-skilled workforce. The migration constraint then identifies the allocation of theses educated workers across regions, demanding the utility level in region i to equal the utility attainable in an arbitrarily chosen reference region j. The first-order conditions of the social planning problem are stated in Appendix B.1.1.

Optimal Policy Rule

The first-order conditions with respect to $\tau^n_{t,i}$, $\theta^n_{t,i}$ and $\theta^n_{et,i}$ reveal that $\kappa^n_{t,i} = \lambda_{t,i} N^n_{t,i}$ and $\lambda_{t,i} = \lambda_t$. This reduces the first-order conditions on consumption and educational spending for the low-skilled residing in region i to

$$u^L_{ct,i} = \lambda_t \qquad \text{and} \qquad \upsilon^L_{et,i} + \mu^L_{t,i} h^L_{et,i} = \lambda_t. \tag{3.11}$$

Equations (3.11) define the equilibrium values of $c^L_{t,i}$ and $e^L_{t,i}$ and can be used to derive the social marginal rate of substitution between consumption and investments in education,

$$\frac{\upsilon^L_{et,i}}{u^L_{ct,i}} = 1 - \frac{\mu^L_{t,i}}{\lambda_t} h^L_{et,i}. \tag{3.12}$$

In the welfare optimum, the social marginal rate of substitution has to equal the private cost of education minus the term $\frac{\mu_{t,i}^L}{\lambda_t}h_{et,i}^L$ that captures an external effect of education. This external effect of education consists of the welfare impact of a declining number of low-skilled in $t+1$ ($\mu_{t,i}^L$), weighted by the marginal productivity of low-skilled educational investments ($h_{et,i}^L > 0$) and discounted by the opportunity cost, the marginal utility of consumption ($\lambda_t > 0$). If the contribution to aggregate welfare of a high-skilled worker exceeds the benefit of her being low-skilled, the external effect of education is positive. This implies that investments in education should take place until the marginal rate of substitution exceeds the private costs of education of one by additionally accounting for the social benefit of human capital formation.

Since in a decentralized market equilibrium this optimal marginal rate of substitution has to equal the private marginal rate of substitution (equation (3.8)), the optimal policy rule to determine the educational subsidy or tax for the low-skilled in region i can be deduced,

$$1 - \frac{\mu_{t,i}^L}{\lambda_t}h_{et,i}^L = \frac{\upsilon_{et,i}^L}{u_{ct,i}^L} = (1 - \tau_{et,i}^L) \quad \Leftrightarrow \quad \tau_{et,i}^L = \frac{\mu_{t,i}^L}{\lambda_t}h_{et,i}^L. \tag{3.13}$$

In the absence of any education policy, households adjust their marginal rate of substitution to the marginal private cost of educational investment of one (equation (3.8)). Hence, they do not take into account the external effect of education, and private investment will be inefficient. The educational subsidy or tax is a means of internalizing this external effect and of establishing the welfare optimum. As long as the external effect of education is positive ($\mu_{t,i}^L > 0$), it is optimal to subsidize educational investments.

Similarly, one can rewrite the first-order conditions with respect to consumption and educational investment for the high-skilled type in region i,

$$\frac{\left(N_{t,i}^H - \varphi_{t,i}^H\right)}{N_{t,i}^H} u_{ct,i}^H = \lambda_t \qquad \text{and} \qquad \frac{\left(N_{t,i}^H - \varphi_{t,i}^H\right)}{N_{t,i}^H} \upsilon_{et,i}^H + \mu_{t,i}^L h_{et,i}^H = \lambda_t. \quad (3.14)$$

Again, equations (3.14) define the equilibrium values of $c_{t,i}^H$ and $e_{t,i}^H$. Moreover, the social marginal rate of substitution between consumption and educational investments involves the external effect of education,

$$\frac{\upsilon_{et,i}^H}{u_{ct,i}^H} = 1 - \frac{\mu_{t,i}^L}{\lambda_t} h_{et,i}^H. \qquad (3.15)$$

This implies that - similarly to the low-skilled case - a subsidy or tax on educational investments should be used to internalize the social effect of education. Following the above procedure, the optimal educational subsidy or tax on high-skilled investments can be obtained as

$$\tau_{et,i}^H = \frac{\mu_{t,i}^L}{\lambda_t} h_{et,i}^H. \qquad (3.16)$$

Proposition 6 *The optimal educational policy rule of a benevolent unitary state government aims at internalizing the external effect of education.*

One can further simplify the educational subsidy using the first-order conditions on consumption and educational investments (equations (3.11) and (3.14)) to substitute out the Lagrange-multipliers λ_t and $\mu_{t,i}^L$,

$$\tau_{et,i}^n = \frac{\mu_{t,i}^L}{\lambda_t} h_{et,i}^n = \frac{u_{ct,i}^n - \upsilon_{et,i}^n}{u_{ct,i}^n}. \qquad (3.17)$$

Equation (3.17) reveals that the optimal policy rule for subsidizing education is only dependent on the realized equilibrium values of consumption and education. Therefore, it is not influenced by assumptions on the migration dynamics or the underlying production technology.[19]

Intraregional Redistribution

To determine the redistribution policy, consider a situation in which the migration equilibrium constraint is not binding ($\varphi^H_{t,i} = 0$). The welfare optimum will then coincide with the central planning solution derived in a setup where interregional migration is prohibited. Yet, it will be shown that the equilibrium deduced is symmetric and, consequently, satisfies the required utility equalization as well. Hence, the solution obtained ignoring the migration constraint coincides with the one for the fully constrained optimization problem and characterizes the unitary state optimum with high-skilled migration.

In case of a non-binding migration constraint, the first-order conditions as stated in equations (3.11) and (3.14) become

$$u^n_{ct,i} = \lambda_t \qquad \text{and} \qquad v^n_{et,i} + \mu^L_{t,i} h^n_{et,i} = \lambda_t. \tag{3.18}$$

It follows that consumption and educational investments in a particular region are type-independent ($c^n_{t,i} = c_{t,i}$ and $e^n_{t,i} = e_{t,i}$). Since preferences are the same, it follows that utility levels across types will be equalized. This is due to the fact that the unitary state government aims at maximizing a utilitarian welfare function. To see this, consider a situation in which the level of educational spending of different types is identical, but high-skilled consumption exceeds low-skilled consumption. In this case, the marginal utility of additional consumption is higher for the low-skilled type. Therefore, redistribution that increases low-skilled consumption at the expense of

[19] While the policy rule remains unaffected, the assumptions certainly influence the equilibrium obtained.

high-skilled consumption generates a welfare gain.

Notice that consumption is independent of the place of residence ($c_{t,i} = c_t$), while this need not be the case for educational investments: As long as the Lagrange-multiplier on the human capital formation constraint, $\mu^L_{t,i}$, is not identical across regions, the level of spending on education will differ as well. Alternatively, one can use equation (3.18) to express $\mu^L_{t,i}$ as a function of consumption as well as regional investments in education. Consequently, any interregional difference in $\mu^L_{t,i}$ is accompanied by different levels of educational expenditures in the respective regions.

Identical consumption and investment levels between types in a single region entail that the optimal subsidy or tax on education is independent of the respective type,

$$\tau_{et,i} = \frac{\mu^L_{t,i}}{\lambda_t} h_{et,i}. \tag{3.19}$$

This implies that in the optimum parents from either type spend an equal amount of resources on consumption and educational investments. According to the household's budget constraint, identical spending patterns can only be achieved if the net income of high- and low-skilled is equalized across types,

$$z^H F'(Z_{t,i}) - \tau^H_{t,i} - \theta^H_{t,i} = c_{t,i} + (1 - \tau_{et,i})e_{t,i} = z^L F'(Z_{t,i}) - \tau^L_{t,i} - \theta^L_{t,i}. \tag{3.20}$$

Since productivity differs, the aggregate head tax on high-skilled has to exceed the one on low-skilled workers,

$$\left(z^H - z^L\right) F'(Z_{t,i}) = \left(\tau^H_{t,i} + \theta^H_{t,i}\right) - \left(\tau^L_{t,i} + \theta^L_{t,i}\right) > 0. \tag{3.21}$$

Lump-sum taxes that account for the productivity difference between the two types, combined with type-independent educational subsidies, guarantee that the net income is identical. Such a way of redistribution between high- and low-skilled workers ensures that consumption and educational investments are the same entailing that realized utility levels are type-independent and aggregate welfare is maximized.

Proposition 7 *A benevolent unitary state government redistributes income from high- to low-skilled labor to achieve a type-symmetric intraregional equilibrium.*

Still, it is not clear a priori whether education should be subsidized or taxed. To determine the sign of the educational subsidy, one needs to evaluate the shadow price $\mu^L_{t,i}$ associated with the probability of being low-productive. Using the first-order conditions on $\tau^n_{t,i}$, $\theta^n_{t,i}$ and $\theta^n_{et,i}$ as well as the fact that $R'(Z_{t,i}) = -Z_{t,i}F''(Z_{t,i})$ and $\frac{\upsilon^n_{et,i}}{u^n_{ct,i}} = (1-\tau^n_{et,i})$, one can simplify the first-order condition with respect to $N^H_{t,i}$ to

$$\mu_t = U^H_{t,i}(\cdot) + \lambda_t \left(\theta^H_{t,i} + \tau^H_{t,i} - \tau^H_{et,i}e^H_{t,i}\right) - \mu^L_{t,i}\left[1 - h(e^H_{t,i})\right]. \tag{3.22}$$

Equation (3.22) captures the contribution to social welfare of an additional high-skilled individuum. This net benefit of being high-skilled comprises the attained level of utility and the fiscal revenue raised, weighted by the marginal utility of consumption (λ_t), minus the probability that the respective type's child will later become low-skilled, weighted by the social value of education ($\mu^L_{t,i}$).

Similarly, one can rewrite the first-order condition with respect to $N^L_{t,i}$,

$$\mu_t = U^L_{t,i}(\cdot) + \lambda_t \left(\theta^L_{t,i} + \tau^L_{t,i} - \tau^L_{et,i}e^L_{t,i}\right) - \mu^L_{t,i}\left[1 - h(e^L_{t,i})\right] + \beta^{-1}\mu^L_{t-1,i}. \tag{3.23}$$

To solve for the shadow price $\mu^L_{t-1,i}$ that captures the social benefit of turning a child in period $t-1$ into a high-skilled instead of a low-skilled worker, equate (3.22) with (3.23),

$$\begin{aligned}\beta^{-1}\mu^L_{t-1,i} &= U^H_{t,i}(\cdot) - U^L_{t,i}(\cdot) + \mu^L_{t,i}\left[h(e^H_{t,i}) - h(e^L_{t,i})\right] \\ &\quad +\lambda_t\left[\left(\theta^H_{t,i} + \tau^H_{t,i} - \tau^H_{et,i}e^H_{t,i}\right) - \left(\theta^L_{t,i} + \tau^L_{t,i} - \tau^L_{et,i}e^L_{t,i}\right)\right]. \end{aligned} \tag{3.24}$$

This social benefit of education consists of the differences in each type's contribution to social welfare, that is the differences with respect to the utility levels achieved, the net fiscal revenue raised, as well as the impact on human capital formation.

According to the optimal policy rule (equation (3.17)), it is efficient to subsidize education as long as the contribution to social welfare of an additional high-skilled exceeds the contribution of a low-skilled worker ($\mu^L_{t,i} > 0$). Given the symmetric equilibrium outcomes derived above and accounting for intraregional redistribution policies (equation (3.21)), the net social benefit of education reduces to the difference in productivity between the two types,

$$\begin{aligned}\beta^{-1}\mu^L_{t-1,i} &= \lambda_t\left[\left(\theta^H_{t,i} + \tau^H_{t,i}\right) - \left(\theta^L_{t,i} + \tau^L_{t,i}\right)\right] \\ &= \lambda_t\left(z^H - z^L\right)F'(Z_{t,i}) > 0. \end{aligned} \tag{3.25}$$

For the subsequent analysis it is important to note that equation (3.25) can be used to express the marginal productivity of labor as a function of the Lagrange-multipliers λ_t and $\mu^L_{t-1,i}$. Interregional differences in the aggregate effective labor supply, therefore, involve differences in the Lagrange-multiplier $\mu^L_{t-1,i}$, which in turn is determined by the level of local educational spending.

The analysis reveals that the social benefit of turning a child into a high-instead of a low-skilled individual is strictly positive. This is due to the fact that high-skilled workers are more productive and, hence, contribute more in terms of tax payments than low-skilled do. Since individual households do not take this positive external effect into account, they underinvest in education. This explains why the optimal educational subsidy is strictly positive with

$$\tau_{et,i} = \frac{\mu_{t,i}^L}{\lambda_t} h_{et,i} > 0. \tag{3.26}$$

Proposition 8 *To correct private underinvestment in education, a unitary state government subsidizes educational investments.*

Note that this result hinges on the assumption that the types are perfect substitutes in production with $z^H > z^L$. With complements, the net social benefit of education would be positive for low levels of human capital intensity, implying the optimality of a subsidy ($\mu_{t,i}^L > 0$). However, raising the fraction of high-skilled workers would decrease the net social benefit and eventually a tax on private educational investments would become efficient ($\mu_{t,i}^L < 0$). Yet, the optimal decision rule for subsidizing education (equation (3.17)) is independent of assumptions concerning the production technology.

Interregional Redistribution

An efficient allocation of labor across regions requires that the contribution to social welfare of an additional high-skilled immigrant (equation ((3.22)) is the same for all regions. To determine the optimality condition for the allocation of mobile high-skilled workers, equate (3.22) across regions,

$$U^H_{t,i}(\cdot) + \lambda_t \left(\theta^H_{t,i} + \tau^H_{t,i} - \tau^H_{et,i} e^H_{t,i}\right) - \mu^L_{t,i} \left[1 - h(e^H_{t,i})\right] = \mu_t$$
$$= U^H_{t,j}(\cdot) + \lambda_t \left(\theta^H_{t,j} + \tau^H_{t,j} - \tau^H_{et,j} e^H_{t,j}\right) - \mu^L_{t,j} \left[1 - h(e^H_{t,j})\right]. \quad (3.27)$$

The left-hand side of equation (3.27) can be interpreted as the net social benefit of migration that consists of the contribution of a high-skilled immigrant in terms of the additional utility and the net tax payments region i receives, minus the social cost, which arises if the immigrant's child becomes low- instead of high-skilled ($\mu^L_{t,i}$), weighted by the probability to become low-skilled ($1 - h(e^H_{t,i})$). The optimal allocation of high-skilled between regions i and j is attained when the net migration inefficiency, that is the difference in the net social benefit between regions, vanishes.

One can rearrange equation (3.27) using the household's budget constraint to replace the individual tax payments by the difference between the wage income and expenditures for consumption as well as educational investments,

$$U^H_{t,i}(\cdot) + \lambda_t \left(z^H F'(Z_{t,i}) - c^H_{t,i} - e^H_{t,i}\right) - \mu^L_{t,i} \left[1 - h(e^H_{t,i})\right] = \mu_t$$
$$= U^H_{t,j}(\cdot) + \lambda_t \left(z^H F'(Z_{t,j}) - c^H_{t,j} - e^H_{t,j}\right) - \mu^L_{t,j} \left[1 - h(e^H_{t,j})\right]. \quad (3.28)$$

As previously pointed out, with a non-binding migration constraint consumption is not only type-independent but additionally identical across regions, $c^n_{t,i} = c_t$. This implies that utility resulting from consumption is independent of the place of residence, $u\left(c^H_{t,i}\right) = u\left(c^H_t\right)$, and reduces equation (3.28) further to

$$\upsilon(e^H_{t,i}) + \lambda_t \left(z^H F'(Z_{t,i}) - e^H_{t,i}\right) - \mu^L_{t,i}\left[1 - h(e^H_{t,i})\right] = \mu_t$$
$$= \upsilon(e^H_{t,j}) + \lambda_t \left(z^H F'(Z_{t,j}) - e^H_{t,j}\right) - \mu^L_{t,j}\left[1 - h(e^H_{t,j})\right]. \qquad (3.29)$$

Recall that interregional differences in the aggregate effective labor supply $Z_{t,i}$ are associated with differences in the Lagrange-multiplier $\mu^L_{t-1,i}$ which, in turn, results from unequal educational spending levels across regions. Consequently, the optimal allocation of labor according to equation (3.29) only depends on current and previous local investments in education. Focussing on the steady-state where $e_{t,i} = e_i$, one can reveal that the social benefit of migration will only be equalized across regions whenever educational spending levels are identical as well. This entails that the aggregate effective labor supply will also be independent of the respective region. An optimal interregional allocation of labor, therefore, involves an equalization of productivities across regions, that is a situation in which production efficiency holds.[20] It is important to note that the steady state assumption is not as restrictive as it might seem on first sight. Given the optimal policy derived above, the steady state will be attained immediately as perfectly mobile households will relocate in the first-period, before decisions on consumption and educational investments have been made. This entails an equalization of the aggregate effective labor supply across regions in the first period, after which the equilibrium paths in all regions coincide.

[20] While the optimal intraregional redistribution policy as well as the educational subsidy can be derived for the entire time path, interregional redistribution can only be determined in the steady state. Notice, however, that this restriction can be avoided applying the popular symmetry assumption: If all regions are symmetric with respect to the initial effective labor supply, the local equilibrium paths will coincide and interregional redistribution becomes redundant.

Hence, the solution to the optimization problem is entirely symmetric with $c^n_{t,i} = c$ and $e^n_{t,i} = e$.[21] Moreover, it follows immediately from the educational policy rule (equation (3.17)) that the optimal subsidy is type- and region-independent with $\tau^n_{et,i} = \tau_e$. To derive the optimal interregional redistribution policy, use the steady-state equilibrium values in equation (3.27),

$$\theta^H_i + \tau^H_i = \theta^H_j + \tau^H_j . \tag{3.30}$$

In the welfare optimum, the central planner imposes federal lump-sum taxes such that the aggregate head tax of the high-skilled is independent of the region of residence.[22] Given that mobile households face the same marginal rate of substitution between consumption and investments, that is the same educational subsidy, they will evaluate locations solely in terms of the attainable net income. Since aggregate head taxes are independent of the region of residence, migration corresponds to productivity differences across regions and leads to an equalization of the aggregate effective labor supply $Z_i = Z$.

Proposition 9 *A benevolent unitary state government uses lump-sum taxes to equate the net social benefit of migration between regions. This ensures an efficient allocation of mobile labor (production efficiency).*

Figure (3.2) illustrates the result of production efficiency for a model economy that consists of two small regions 1 and 2.[23] For clarity of presentation,

[21] In contrast, the equilibrium will no longer be symmetric in the presence of migration costs as an interregional equalization of utility would violate the migration equilibrium.

[22] This result is in line with Flatters et al. (1974), who consider efficient migration in the case of a pure public good. Since an additional migrant does not impose any congestion costs, the optimal allocation of labor is equivalent to a setup without public good provision.

[23] The graphical illustration is inspired by Wellisch (1995), who undertakes a similar analysis in a static model with locally congestible public good provision.

the figure is based on the presumption that mobile households face an educational subsidy independent of the place of residence, implying that migration responds solely to net income differences across countries. The length of the horizontal axis depicts the aggregate effective labor supply in the economy as a whole, consisting of low- and high-skilled workers according to previous educational investments. Since low-skilled labor is immobile, the aggregate regional labor supply is only influenced by high-skilled migration flows between the two regions. Thus, movements on the horizontal axis from the left to the right side represent flows of high-skilled labor from region 2 to region 1, increasing the aggregate effective labor supply in 1, and vice versa. The vertical axis represent the marginal productivity of labor in the respective region, $F'(Z_i)$, that coincides with the high-skilled wage income in the absence of taxation. Consequently, the integral over $F'(Z_i)$ between the origin and a particular region's effective labor supply Z_i captures the output generated in the respective region. The aggregate production of the federal economy is maximized in A, which represents an efficient allocation of mobile labor across regions. This situation is characterized by an equalization of the aggregate regional labor supply Z_i, entailing that production efficiency is established. Any deviation from this optimum implies a partial waste of production possibilities.

For example, consider a situation in which the central government as well as the local jurisdiction 2 impose head taxes on the high-skilled labor force residing in region 2. The tax burden lowers the net income attainable in region 2, shifting the marginal productivity net of taxes downwards to $F'(Z_2) - (\theta_2^H + \tau_2^H)$. The fall in net wage income induces emigration from region 2 until a new equilibrium is reached in point C, where the decline in region 2's labor supply has increased the marginal productivity to an extent

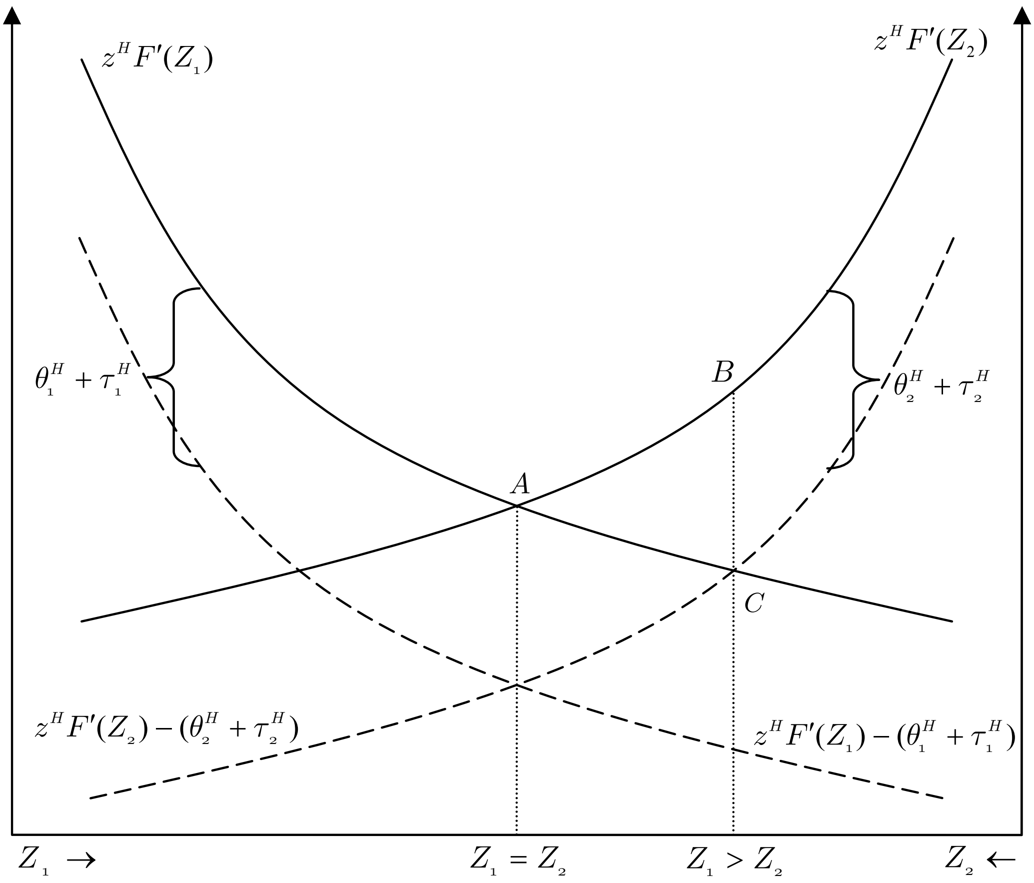

Figure 3.2: Production efficiency

that fully compensates high-skilled labor for the additional tax burden. The net income in region 2 now equals the rate of return for labor in region 1. While this situation represents a migration equilibrium, it incorporates a loss in production that comprises the triangle ABC and results from a misallocation of labor. The central government can avoid the inefficiency induced by tax-prone migration by imposing an identical tax burden on high-skilled residing in region 1. Starting from an efficient allocation of labor, this leads to an equal decline of net wages in both regions. Therefore, head taxes no longer induce migration, and the efficient allocation of labor remains unaffected.

Summarizing, the starting point of the analysis was a non-binding migration constraint. In this case, the solution to the optimization problem is entirely symmetric with consumption, educational investments, as well as educational subsidies equalized both across regions and types. The central planner aims at redistributing income across types using type-specific head taxes. In contrast, aggregate lump-sum taxation is independent of the place of residence to ensure that the net social benefit of high-skilled migration is the same across regions. As a consequence, production efficiency holds and the aggregate effective labor supply is identical in all regions. Given this symmetric solution, the migration equilibrium is fulfilled as well. Accordingly, the solution that was derived ignoring the migration constraint coincides with the optimum of the fully constrained problem. Furthermore, the solution of the central planning problem represents a unique global maximum. This is due to the fact that whenever utility is at least strictly quasi-concave, the constraints are quasi-convex, and a local maximum exists, this local maximum is a unique global maximum.[24] Notice that it is assumed throughout the entire analysis that the aggregate federal population is large enough to ensure that not region gets depopulated and the aggregate effective labor supply can be equalized across regions.

The central planning solution reveals that it is optimal to subsidize education to overcome the underinvestment problem at the private level. The following section focuses on the optimal fiscal policy a small open region opts for. A local government disregards the fact that the overall size of the high-skilled population in the federal economy is contingent on private investments in education. Hence, it might choose not to subsidize education, but try to attract high-skilled workers from other regions. Such free-riding of regional governments induces an educational underinvestment problem at the federal

[24] For a proof of the underlying theorem see Mas-Colell et al. (1995) p. 962.

level that might be corrected using an educational matching grant.

3.4.2 Decentralization of the Unitary State Optimum

Next, the optimal fiscal policy chosen by a local government is derived, and necessary policy instruments at the federal state level are deduced to decentralize the unitary state optimum. Recall that the first-best solution requires (1) consumption and educational spending to be equalized across types, (2) educational investments to be subsidized to prevent private underinvestment and (3) production efficiency to be achieved.

From the point of view of a small open region, perfect mobility of educated workers entails that the high-skilled workforce is in infinitely elastic supply. Thus, a regional government will not take into account the fact that the overall number of high-skilled available in the federal state is restricted, but only consider the migration constraint. The amount of low-skilled workers in any region i, however, is still contingent on local human capital formation. Therefore, a regional jurisdiction respects the local human capital formation constraint, it's own as well as the household's budget constraint, and the migration equilibrium constraint. The utility level attainable for mobile high-skilled workers in case of emigration is exogenous with $u(\overline{c}_t^H) + \upsilon(\overline{e}_t^H)$, where $\overline{c}_t^H$ and $\overline{e}_t^H$ denote the amount of consumption and educational investments realized outside of a small open region i. Furthermore, the regional government takes the federal head tax and the matching grant as given, since the central government is assumed to be the Stackelberg leader who moves first. Once more, the household's first-order condition is used to eliminate τ_{et}^n from the optimization problem.

The local government maximizes the social welfare of it's resident population, choosing $\{\tau_t^n, c_t^n, e_t^n, N_t^n\}$,

$$
\begin{aligned}
&\max \sum_{t=0}^{\infty} \beta^t \Big\{ \sum_n N_t^n \left[u(c_t^n) + \upsilon(e_t^n) \right] \\
&+ \sum_n \kappa_t^n \left[z^n F'(Z_t) - \tau_t^n - \theta_t^n - c_t^n - \frac{\upsilon_{et}^n}{u_{ct}^n} e_t^n \right] \\
&+ \lambda_t \left[\sum_n N_t^n (\tau_t^n + \frac{\upsilon_{et}^n}{u_{ct}^n} e_t^n - (1 - \theta_{et}^n)\, e_t^n) + R(Z_t) \right] \\
&+ \mu_t^L \left[N_{t+1}^L - \sum_n N_t^n \left[1 - h(e_t^n) \right] \right] \\
&+ \varphi_t^H \left[u(\bar{c}_t^H) + \upsilon(\bar{e}_t^H) - u(c_t^H) - \upsilon(e_t^H) \right] \Big\}.
\end{aligned}
\tag{3.31}
$$

Again, $\left\{\kappa_t^n, \lambda_t, \mu_t^L, \varphi_t^H\right\}$ denotes the set of Lagrange-multipliers. The first-order conditions are left to Appendix B.1.2.

Optimal Policy Rule

To derive the regionally optimal marginal rate of substitution between consumption and educational investments, use the first-order condition on τ_t^n to simplify the first-order conditions on consumption and investments for the low-skilled,

$$
u_{ct}^L = \lambda_t \qquad \text{and} \qquad \upsilon_{et}^L + \mu_t^L h_{et}^L = \lambda_t \left(1 - \theta_{et}^L\right), \tag{3.32}
$$

and for the high-skilled type respectively,

$$
\frac{\left(N_t^H - \varphi_t^H\right)}{N_t^H} u_{ct}^H = \lambda_t \quad \text{and} \quad \frac{\left(N_t^H - \varphi_t^H\right)}{N_t^H} \upsilon_{et}^H + \mu_t^L h_{et}^H = \lambda_t \left(1 - \theta_{et}^H\right). \tag{3.33}
$$

Rearranging yields the optimal marginal rate of substitution from the point of view of a small local jurisdiction,

$$\frac{\upsilon_{et}^n}{u_{ct}^n} = (1-\theta_{et}^n) - \frac{\mu_t^L}{\lambda_t} h_{et}^n. \tag{3.34}$$

Equating the regionally optimal and the private marginal rate of substitution immediately reveals the optimal educational subsidy or tax a local government chooses,

$$(1-\theta_{et}^n) - \frac{\mu_t^L}{\lambda_t} h_{et}^n = \frac{\upsilon_{et}^n}{u_{ct}^n} = (1-\tau_{et}^n) \quad \Leftrightarrow \quad \tau_{et}^n = \frac{\mu_t^L}{\lambda_t} h_{et}^n + \theta_{et}^n. \tag{3.35}$$

Taking the federal grant as given, the local jurisdiction increases the educational subsidy to meet the above optimality condition. Obviously, the federal matching grant (θ_{et}^n) complements regional education policies ($\frac{\mu_t^L}{\lambda_t} h_{et}^n$). This is true irrespective of whether the federal grant is paid directly to local governments or as a federal subsidy to households.[25] Yet, the federal grant becomes redundant as an instrument to correct underinvestment, since the region chooses the educational subsidy according to the optimal policy rule (equation (3.17)): If the central government refrains from providing a matching grant ($\theta_{et}^n = 0$), the local government imposes a tax rate according to the rule

$$\tau_{et}^n = \frac{\mu_t^L}{\lambda_t} h_{et}^n = \frac{u_{ct}^n - \upsilon_{et}^n}{u_{ct}^n}. \tag{3.36}$$

Equation (3.36) reveals that in the absence of federal education policies, a benevolent government of a small region sticks to the optimal educational policy rule that supports the first-best, even though high-skilled workers are perfectly mobile. Since local jurisdictions move after the central government,

[25] One can easily verify that both approaches result in the exact same optimization problem.

correcting private underinvestment in education can be delegated to the regions.

Proposition 10 *Local jurisdictions abide by the optimal decision rule for subsidizing education. Thus, decentralized education policies are efficient, although high-skilled workers are perfectly mobile.*

On first sight, the efficiency of local policies seems to be in line with the literature on public good provision where local jurisdictions facing mobile labor continue to provide public goods according to the Samuelson condition. This point has been stressed by Boadway (1982). In the present model, educational investments provide a joy of giving effect that is similar to the utility increase of public goods. Yet, this is not the motive for educational subsidies that instead aim at correcting private underinvestment in education. Consequently, the efficiency of local education policies does not carry over to a setup where all labor is mobile, as one might conjecture (this is shown in section 3.5). Despite of the remaining joy of giving effect, educational subsidies vanish since, from the point of view of a local government, the intergenerational externality is no longer relevant once the allocation of all skill-types is subject to migration flows.

This indicates that mobility in the present setup does not provide a mechanism to internalize intergenerational externalities as has been suggested by Wellisch and Richter (1995) for the case of long-lived pollutants.[26] The crucial difference is that local emissions resemble local public goods that negatively affect the utility of future generations. However, inducing emigration

[26] While already discussed in Oates and Schwab (1988), the idea has later been formalized by Wellisch and Richter (1995). Oates and Schwab (1996) derive a similar conclusion using a median-voter model.

tomorrow, pollution externalities capitalize into current land values. An environmental agency that takes changes in the value of land into account will be forced to internalize the intergenerational externality. In contrast, intergenerational externalities in the present setup are related to human capital that is embodied in mobile, high-skilled households. Consequently, benefits of previous efforts to internalize external effects to not necessarily accrue to the home region, and the possibility to free-ride on other region's education policies arises. Still, as has been shown, local education policies remain to be efficient.

This surprising result of efficient decentralized policy making is due to the fact that regional investments in education determine the size of the future immobile low-skilled workforce, irrespective of any assumption concerning the mobility of the high-skilled. Thus, regional governments continue to respect the human capital formation constraint as well as the associated impact of education on future generations. Since parents do not take the intergenerational externality into account, local jurisdictions intend to correct this market failure, irrespective of the fact that high-skilled workers are perfectly mobile. Hence, perfect mobility of high-skilled labor does not destroy local government's incentives to correct educational underinvestment. Rather, introducing social mobility forces local governments to adhere to the optimal decision rule for education policies. Only the size and sign of τ_{et}^{n}, which is contingent on the level of consumption and education chosen by a regional government, might deviate from the optimal subsidy a unitary state government imposes. Thus, while regions stick to the optimal policy rule, it is not clear whether the implemented subsidy replicates first-best optimum, as the regional welfare optimum might entail different levels of consumption and educational investments than the unitary state outcome.

Notice that the efficiency of decentralized education policies is not dependent on assumptions concerning the production technology or the migration dynamics. While these assumptions affect the equilibrium obtained, this is true for the unitary state as well as the decentralization case. For example, if migration costs are introduced, the solution will no longer be symmetric across countries as an interregional equalization of utility would violate the migration equilibrium. This applies for the unitary state optimization as it does at the local level. Yet, the efficiency of decentralized education policies remains unaffected, as local jurisdictions abide by the optimal decision rule for subsidizing education irrespective of the realized equilibrium. The same reasoning holds true if one varies the social welfare function. One can easily reveal that the optimal policy rule is unaffected if one uses fixed weights rather than the size of the population groups. Even if jurisdictions adopt a paretian welfare objective and only take into account the welfare of their immobile, low-skilled residents, the educational policy rule remains the same. While this might, again, entail different realized equilibria, the efficiency of decentralized education policy persists.

Intraregional Redistribution

In the following, conditions replicating the welfare maximum of the unitary state scenario are analyzed. To pursue this, assume that regions are confronted with a federal decentralization policy that ensures that the migration constraint is not binding in the local optimum ($\varphi_t^H = 0$). In this case, optimal levels of consumption as well as educational investments in any region i are type-independent with $c_t^n = c_t$ and $e_t^n = e_t$ as can be revealed from the first-order conditions on consumption and educational investments (equations (3.32) and (3.33)). Consequently, utility levels are equalized in the optimum, and the local educational subsidy is identical for the different types, $\tau_{et}^{n} = \tau_{et}$. Note that this requires that any matching grant possibly provided by the federal government is type-independent. In the remaining analysis, the set of tax instruments available at the federal level will accordingly be restricted to the use of region-specific matching grants that cannot differentiate between types.

Following the above procedure, one can make use of the household's budget constraint to determine the optimal redistribution policy at the local level,

$$z^H F'(Z_t) - \tau_t^H - \theta_t^H = c_t + (1-\tau_{et})e_t = z^L F'(Z_t) - \tau_t^L - \theta_t^L \qquad (3.37)$$

$$\Leftrightarrow \left(z^H - z^L\right) F'(Z_t) = \left(\tau_t^H + \theta_t^H\right) - \left(\tau_t^L + \theta_t^L\right) > 0. \qquad (3.38)$$

Since productivity across types differs, but consumption as well as educational investments are equalized in the regional optimum, the aggregate head tax on high-skilled households has to exceed the one on low-skilled. Given the federal head taxes already chosen by the central government, a local jurisdiction levies type-specific lump-sum taxes such that the productivity difference between types is fully taxed away. As in the unitary state optimum, a benevolent regional government redistributes income from high- to low-skilled workers to raise the utility of the low-skilled and maximize utilitarian welfare.

Obviously, federal and local head taxes are perfect substitutes to establish intraregional redistribution. As long as the central government levies type-independent head taxes ($\theta_t^H = \theta_t^L$), local jurisdictions will appropriate the whole income difference between the two types ($\tau_t^H > \tau_t^L$). Such a federal tax policy leaves local redistribution unaffected. In order to focus on decentralization policies that are essential to replicate the first-best in the remainder of this section, the set of available federal tax instruments is restricted to type-independent taxes, that is both head taxes as well as the educational grant can only be differentiated across regions, but not across types.

To evaluate under which conditions the local subsidy or tax on education coincides with the educational subsidy that supports the first-best optimum (equation (3.26)), one has to determine the value of the shadow price μ_t^L associated with the probability of being low-skilled. Again, use the first-order conditions with respect to τ_t^n as well as the fact that $R'(Z_t) = -Z_t F''(Z_t)$ and $\frac{v_{et}^n}{u_{ct}^n} = (1 - \tau_{et}^n)$ to simplify the first-order conditions on high-skilled workers,

$$U_t^H(\cdot) + \lambda_t \left(\tau_t^H - \tau_{et}^H e_t^H\right) - \mu_t^L \left[1 - h(e_t^H)\right] = 0, \tag{3.39}$$

and on low-skilled workers,

$$0 = U_t^L(\cdot) + \lambda_t \left(\tau_t^L - \tau_{et}^L e_t^L\right) - \mu_t^L \left[1 - h(e_t^L)\right] + \beta^{-1} \mu_{t-1}^L. \tag{3.40}$$

Equating (3.39) and (3.40) yields the shadow price associated with the probability of being low-productive,

$$\begin{aligned} \beta^{-1}\mu_{t-1}^L = {} & U_t^H(\cdot) - U_t^L(\cdot) + \mu_t^L \left[h(e_t^H) - h(e_t^L)\right] \\ & + \lambda_t \left[\left(\tau_t^H - \tau_{et}^H e_t^H\right) - \left(\tau_t^L - \tau_{et}^L e_t^L\right)\right]. \end{aligned} \tag{3.41}$$

This shadow price consists of the difference between future high- and low-skilled workers with respect to the utility levels, the tax payments they contribute to the regional budget, and their children's probability of becoming high-skilled. As long as the social benefit of an additional high-skilled exceeds the benefit of a low-skilled worker, the shadow price is positive, and it is optimal to subsidize education. Evaluating in equilibrium and accounting for local redistribution (equation (3.38)) further reduces equation (3.41) to

$$\beta^{-1}\mu_{t-1}^{L} = \lambda_t \left(\tau_t^H - \tau_t^L\right) = \lambda_t \left[\left(z^H - z^L\right) F'(Z_t) - \left(\theta_t^H - \theta_t^L\right)\right]. \qquad (3.42)$$

If the central government uses type-independent head taxes ($\theta_t^H = \theta_t^L$), the net social benefit of migration reduces to the difference in productivities between the two types,

$$\beta^{-1}\mu_{t-1}^{L} = \lambda_t \left(\tau_t^H - \tau_t^L\right) = \lambda_t \left(z^H - z^L\right) F'(Z_t) > 0. \qquad (3.43)$$

The social benefit of turning a child into a high- instead of a low-skilled worker is strictly positive, although high-skilled labor is perfectly mobile across regions. This is due to the fact that high-skilled workers are assumed to be more productive than low-skilled workers and contribute more to social welfare in terms of higher tax payments. Put differently, the social benefit of education is entirely determined by differences in productivity among the two types, weighted by the marginal utility of consumption (λ_t). It follows that the social benefit of eduction from the point of view of a local government coincides with the social benefit of education as perceived by a federal government (equation (3.25)): Private underinvestment in education involves a welfare cost in terms of an increased number of less-productive low-skilled workers that is correctly accounted for at the local level. This explains why, even in the absence of any federal matching grant, a small region facing mobility of high-skilled labor continues to subsidize education and intends to correct private underinvestment,

$$\tau_{et} = \frac{\mu_t^L}{\lambda_t} h_{et} > 0. \qquad (3.44)$$

Yet, while a regional government will optimally subsidize education, it is not clear whether the first-best optimum can be attained, since the regional government uses the available fiscal policy instruments only to equate consumption and investments in education across types, but not across regions. This implies that the net social benefit of migration need not be equalized between regions. Therefore, labor might be misallocated and production efficiency violated.

Interregional Redistribution

In the first-best resulting from the unitary state optimization, consumption and educational investments have to be equalized not only intraregionally, but also across regions. This ensures that differences in the net social benefit of migration across regions vanish, and labor is allocated efficiently. Yet, a single jurisdiction only aims at redistributing income between types, not between regions. To avoid the migration inefficiency, a central government, therefore, has to ensure that decentralization results in an interregionally symmetric equilibrium. Since intraregional redistribution can be delegated to the regions, it suffices if the federal tax authority induces mobile high-skilled households to choose the optimal consumption and educational spending levels. This requires that the high-skilled are confronted with the optimal, region-independent marginal rate of substitution and face the same net income independent of their place of residence.

To derive the optimal decentralization policy, recall that the local government already subsidizes education according to the optimal policy rule and, additionally, passes on the federal matching grant to the households (equation (3.35)). This implies that the central government can complement the local educational policy by a region-specific educational matching grant $\theta_{et,i}$ such that the subsidy paid at the local level equals the optimal, region-independent first-best value,

$$\tau_{et,i} = \frac{\mu^L_{t,i}}{\lambda_{t,i}} h_{et,i} + \theta_{et,i} = \frac{\mu^L_t}{\lambda_t} h_{et}. \tag{3.45}$$

This guarantees that all households in the federal economy are confronted with the same shadow price of educational investments. Notice that irrespective of the fact that the federal level provides an educational matching grant, local education policies remain to be efficient: While the local level correctly accounts for the underinvestment problem, the matching grant is used to avoid migration inefficiencies and establish the first-best. Still, even in the absence of a higher-level tax authority, underinvestment in education would be efficiently corrected by regional governments.

Additionally equating the net income of mobile households across regions, the central government can decentralize the first-best optimum and establish the interregionally symmetric equilibrium,

$$\begin{aligned} z^H F'(Z_{t,i}) - \left(\tau^H_{t,i} + \theta^H_{t,i}\right) &= c^H_t + (1 - \tau_{et}) e^H_t \\ &= z^H F'(Z_{t,j}) - \left(\tau^H_{t,j} + \theta^H_{t,j}\right). \end{aligned} \tag{3.46}$$

Notice that identical local spending levels have an important implication for the allocation of workers across regions. Since the Lagrange-multipliers $\lambda_{t,i}$ and $\mu^L_{t,i}$ will now be identical in all regions, one can equate the social benefit of education as defined in equation (3.43),

$$\lambda_t \left(z^H - z^L\right) F'(Z_{t,i}) = \beta^{-1} \mu^L_{t-1} = \lambda_t \left(z^H - z^L\right) F'(Z_{t,j}) \tag{3.47}$$

$$\Leftrightarrow F'(Z_{t,i}) = F'(Z_{t,j}). \tag{3.48}$$

From equation (3.48) one can infer that production efficiency holds in the decentralized equilibrium, as the aggregate effective labor supply $Z_{t,i}$ will be equalized. Applying this result to equation (3.46) immediately reveals the optimal federal redistribution policy,

$$\left(\tau_{t,i}^{H} + \theta_{t,i}^{H}\right) = \left(\tau_{t,j}^{H} + \theta_{t,j}^{H}\right). \tag{3.49}$$

Consequently, the central government can decentralize the first-best by imposing federal head taxes such that the aggregate lump-sum tax on high-skilled labor is identical for all regions

Proposition 11 *The central government can decentralize the first-best providing a region-specific educational matching grant and imposing identical aggregate head taxes in all regions. This establishes an interregionally symmetric equilibrium and induces local governments to redistribute income from mobile high- to immobile low-skilled labor to achieve a symmetric intraregional equilibrium.*

Since local governments adhere to the optimal decision rule for education policies and use lump-sum taxes to achieve a symmetric intraregional equilibrium, the central government can replicate the first-best by equating the net income of high-skilled households across regions using region-independent federal head taxes.[27] This guarantees that consumption and educational expenditures are equalized across regions. As a consequence the migration constraint is not binding, which was the prerequisite for efficient regional redistribution policies. Furthermore, such a federal policy of interregional

[27] To ensure that intra-regional redistribution is not violated, federal head taxes have to be type-independent.

redistribution ensures that the aggregate effective labor supply is equalized across regions ($Z_{t,i} = Z_{t,j}$), and production efficiency is established.

3.5 Optimal Education Policies with High- and Low-Skilled Migration

The preceding analysis reveals that local jurisdictions abide by the optimal decision rule for subsidizing education even in the presence of perfect mobility of high-skilled labor. However, the result hinges on the assumption that low-skilled households are immobile. As the size of a region's low-skilled workforce is determined by local investments in education, regional governments respect the human capital formation constraint and efficiently correct private underinvestment in education. In the following, this assumption is relaxed and mobility of both the high- and the low-skilled population is considered. Again, the unitary state optimum is derived as a benchmark case, followed by a discussion of decentralized policies of local jurisdictions.

3.5.1 Unitary State Optimum

Introducing mobility of high- and low-skilled households imposes an additional constraint on the optimization problem of the unitary state government, namely the migration equilibrium for the low-skilled type. This equilibrium condition states, analogously to high-skilled migration, that in any migration equilibrium the utility levels of low-skilled workers have to be equalized across regions. In case of high- and low-skilled mobility, the unitary state government solves

$$\max \sum_{t=0}^{\infty} \beta^t \Big\{ \sum_i \sum_n N_{t,i}^n \left[u\left(c_{t,i}^n\right) + \upsilon(e_{t,i}^n) \right]$$
$$+ \sum_i \sum_n \kappa_{t,i}^n \left[z^n F'(Z_{t,i}) - \tau_{t,i}^n - \theta_{t,i}^n - c_{t,i}^n - \frac{\upsilon_{et,i}^n}{u_{ct,i}^n} e_{t,i}^n \right]$$
$$+ \lambda_t \sum_i \sum_n N_{t,i}^n \left(\theta_{t,i}^n - \theta_{et,i}^n e_{t,i}^n \right)$$
$$+ \sum_i \lambda_{t,i} \left[\sum_n N_{t,i}^n (\tau_{t,i}^n + \frac{\upsilon_{et,i}^n}{u_{ct,i}^n} e_{t,i}^n - \left(1 - \theta_{et,i}^n\right) e_{t,i}^n) + R(Z_{t,i}) \right] \tag{3.50}$$
$$+ \mu_t^L \sum_i \left[N_{t+1,i}^L - \sum_n N_{t,i}^n \left[1 - h(e_{t,i}^n) \right] \right]$$
$$+ \mu_t \left[\bar{N}_t - \sum_i \sum_n N_{t,i}^n \right]$$
$$+ \sum_{i \neq j} \sum_n \varphi_{t,i}^n \left[u(c_{t,j}^n) + \upsilon(e_{t,j}^n) - u\left(c_{t,i}^n\right) - \upsilon(e_{t,i}^n) \right] \Big\},$$

with the Lagrange-multipliers denoted by $\kappa_{t,i}^n, \lambda_t, \lambda_{t,i}, \mu_t^L, \mu_t$ and $\varphi_{t,i}^n$.

Note that in the case of low-skilled mobility, the allocation of both types of workers across regions is entirely determined by migration flows. Thus, the low-skilled workforce available in any region i is no longer contingent on previous local educational investments. Only the aggregate federal endowment with low-skilled tomorrow depends on parental investments in education today. In contrast to the case of high-skilled mobility, the Lagrange-multiplier on the human capital formation constraint (μ_t^L) is, therefore, independent of the respective region i. The first-order conditions to the optimization problem are stated in Appendix B.2.1.

Following the above procedure, one can reveal that the unitary state government chooses the same decision rule for subsidizing education, irrespective of whether one or all types of labor are mobile across regions. Furthermore, the first-best optimum in the presence of high- and low-skilled migration coincides with the solution derived above for the case of high-skilled mobility. This is plausible, since the migration equilibrium constraints are not binding in the optimum. Hence, introducing mobility of high- and low-skilled labor does neither change the welfare maximum nor the optimal educational subsidy chosen by a unitary state government.

Yet, regional governments might refrain from subsidizing education in the presence of high- and low-skilled mobility, since the number of both types of workers allocated in the respective region is independent of regional investments in education. This is due to the fact that local jurisdictions perceive the supply of mobile households as infinitely elastic. In the following section, optimal local fiscal policies are studied and the need for federal education policies is discussed, given that high- as well as low-skilled workers can migrate across regions.

3.5.2 Decentralization of the Unitary State Optimum

Perfect mobility of both types of workers changes the optimization constraints local governments face substantially. Since from the point of view of a small open region the mobile factor is in perfectly elastic supply, a regional government perceives the size of the respective type of worker as only dependent on migration incentives. Thus, it disregards the fact that the evolution of the different population groups is contingent on regional investments in education and no longer respects the human capital formation constraint. Hence, a local government chooses the regional tax rate $\{\tau_t^n\}$ and the allocations

$\{c_t^n, e_t^n, N_t^n\}$ to solve the following problem,

$$
\begin{aligned}
&\max \sum_{t=0}^{\infty} \beta^t \Big\{ \sum_n N_t^n \left[u(c_t^n) + \upsilon(e_t^n)\right] \\
&+ \sum_n \kappa_t^n \left[z^n F'(Z_t) - \tau_t^n - \theta_t^n - c_t^n - \frac{\upsilon_{et}^n}{u_{ct}^n} e_t^n \right] \\
&+ \lambda_t \left[\sum_n N_t^n (\tau_t^n + \frac{\upsilon_{et}^n}{u_{ct}^n} e_t^n - (1 - \theta_{et}^n)\, e_t^n) + R(Z_t) \right] \\
&+ \sum_n \varphi_t^n \left[u(\overline{c}_t^n) + \upsilon(\overline{e}_t^n) - u(c_t^n) + \upsilon(e_t^n) \right] \Big\},
\end{aligned} \tag{3.51}
$$

where κ_t^n, λ_t and φ_t^n denote the Lagrange-multipliers. The utility level attainable for mobile workers outside region i is given by $u(\overline{c}_t^n) + \upsilon(\overline{e}_t^n)$. The first-order conditions are presented in Appendix B.2.2.

Optimal Policy Rule

Again, one can simplify the first-order conditions with respect to consumption and investments using the first-order conditions on τ_t^n, c_t^n and e_t^n,

$$
\frac{(N_t^n - \varphi_t^n)}{N_t^n} u_{ct}^n = \lambda_t \qquad \text{and} \qquad \frac{(N_t^n - \varphi_t^n)}{N_t^n} \upsilon_{et}^n = \lambda_t \left(1 - \theta_{et}^n\right). \tag{3.52}
$$

From equation (3.52), region i's marginal rate of substitution between consumption and educational investments can be derived,

$$
\frac{\upsilon_e^n}{u_c^n} = \left(1 - \theta_{et}^n\right). \tag{3.53}
$$

Equating the regionally optimal and the private marginal rate of substitution immediately reveals the educational subsidy chosen by a local government,

$$(1-\theta_{et}^n) = \frac{v_e^n}{u_c^n} = (1-\tau_{et}^n) \quad \Leftrightarrow \quad \tau_{et}^n = \theta_{et}^n. \tag{3.54}$$

The optimal regional policy in the presence of high- and low-skilled mobility is not to subsidize education at all. Since the federal matching grant is conditional on local investments in education, local governments have to pass θ_{et}^n on to households, but refrain from subsidizing education themselves:[28] In the absence of any federal grant ($\theta_{et}^n = 0$), a local jurisdiction does not subsidize education ($\tau_{et}^n = 0$).

The inefficiency of local education policies can be explained by the fact that from the point of view of a small open region, the available size of both the high- and the low-skilled workforce is entirely determined by migration flows. Previous investments in education have no impact on the composition of the local workforce. Hence, educational underinvestment is not accounted for at the regional level. This entails an inefficient evolution of the composition of the federal population as private underinvestment persists.

Since local governments disregard this inefficiency, the central government has to correct the intergenerational externality. According to equation (3.19), the central government intends to set $\tau_{et} = \frac{\mu_t^L}{\lambda_t} h_{et}$ to establish the first-best optimum. The local decision rule (equation (3.54)) then requires a federal matching grant of $\theta_{et} = \frac{\mu_t^L}{\lambda_t} h_{et}$. Since the regional government has to pass the optimal federal grant on to it's residents, it is forced to implement the optimal educational subsidy. Therefore, the federal matching grant is an efficient

[28] Again, this finding is robust, irrespective of whether the grant is paid to regional governments or directly to households.

policy tool to decentralize the first-best optimum. Still, since the federal grant replaces local education policies, the first-best optimum can effectively only be established by assigning competencies in the field of education policy to the federal level.

Proposition 12 *If high- and low-skilled workers are mobile across regions, decentralized education policies are inefficient as incentives of local jurisdictions to subsidize education vanish completely. To correct educational under-investment, education policies have to be assigned effectively to the federal or supranational level.*

Similarly to the case of high-skilled mobility only, the result concerning the inefficiency of decentralized education policies carries over to a scenario in which migration costs are present. Only if mobile households face a certain probability to emigrate, part of the workforce remains immobile and is, thus, affected by local education policies with a positive probability. Consequently, local governments continue to respect the human capital formation constraint and choose an efficient education policy.

Intraregional Redistribution

In the following, the optimal local redistribution policy that supports the first-best optimum is deduced. To this end, it is again assumed that regions face a federal policy ensuring that the migration constraint is not binding in the local optimum ($\varphi_t^H = 0$). According to the first-order conditions on consumption and educational investments (equation (3.52)), this entails that optimal levels of expenditure in any region i are identical, irrespective of the type of household, $c_t^n = c_t$ and $e_{et}^n = e_t$. Recall that intraregional symmetry in consumption and education guarantees that utility levels between types are identical in the optimum, and utilitarian welfare is maximized.

Since the optimal federal grant is type-independent, one can equate the household's budget constraints and derive the optimal redistribution policy between low- and high-skilled workers,

$$z^H F'(Z_t) - \tau_t^H - \theta_t^L = c_t + (1 - \theta_{et})e_t = z^L F'(Z_t) - \tau_t^L - \theta_t^L \tag{3.55}$$

$$\Leftrightarrow \left(z^H - z^L\right) F'(Z_t) = \left(\tau_t^H + \theta_t^H\right) - \left(\tau_t^L + \theta_t^L\right) > 0. \tag{3.56}$$

Intraregional equalization of consumption and educational investments requires that the net income of the different types is equalized. Consequently, the aggregate head taxes on the high-skilled have to exceed the taxes on the low-skilled type.

The head taxes chosen by the local government will, however, be type-independent. To see this, use the first-order condition with respect to τ_t^n and the fact that $R'(Z_t) = -Z_t F''(Z_t)$ and equate the first-order condition with respect to the population groups,

$$U_t^H(\cdot) + \lambda_t \tau_t^H = 0 = U_t^L(\cdot) + \lambda_t \tau_t^L \tag{3.57}$$

$$\Leftrightarrow \tau_t^H = \tau_t^L = \tau_t. \tag{3.58}$$

The left- and right-hand side of equation (3.57) can be interpreted as the net social benefit of an additional high- and low-skilled worker from the point of view of a small open region: In the case of high- and low-skilled mobility, immigration no longer involves any educational benefits, but only contributions in terms of additional utility and tax payments of the respective type of migrant. If the central government ensures that the migration constraint is not binding, consumption and education are identical for both types. This implies identical utility levels and explains why local governments have no interest in redistributing income between the different types: High- and low-skilled workers are perfectly homogenous from the point of view of a local, welfare maximizing government. Since the gain in utility from immigration of a high- or low-skilled worker is the same, the local government does not intend to alter migration incentives for different types. Rather, the optimal policy at the local level is to distribute profits evenly among the two types, $\tau_t^n = \tau_t$.[29]

Given type-independent local head taxes, the central government has to achieve the symmetric intraregional equilibrium. One can use the local distribution policy to rewrite equation (3.56) and deduce the optimal federal head taxes,

$$\left(z^H - z^L\right) F'(Z_t) = \theta_t^H - \theta_t^L > 0. \tag{3.59}$$

The central government levies type-specific federal head taxes to ensure that expenditure levels are equalized across types. This guarantees that a symmetric intraregional equilibrium is attained. However, it is not clear whether this replicates the first-best optimum that additionally entails interregional redistribution.

Interregional Redistribution

In the first-best equilibrium resulting from the unitary state optimization, consumption and educational investments are equalized interregionally, implying that the net social benefit of migration is identical across regions. Yet,

[29] In the absence of a local educational subsidy, the only purpose of local fiscal policy is to distribute profits. Therefore, local lump-sum taxes are negative.

regional governments do not take into account any migration inefficiencies resulting from local tax policies. Consequently, they do not aim to establish an interregionally symmetric equilibrium. However, the first-best optimum can easily be established by the federal government that already imposes the optimal matching grant, entailing that the marginal rate of substitution between consumption and educational investments is independent of the place of residence. This implies that the unitary state level of consumption and educational investments can easily be established by equating the net income of households across regions,[30]

$$z^H F'(Z_{t,i}) - \tau^H_{t,i} - \theta^H_{t,i} = c^H_t - (1-\theta_{et})e^H_t = z^H F'(Z_{t,j}) - \tau^H_{t,j} - \theta^H_{t,j}. \quad (3.60)$$

Equation (3.60) reveals that a symmetric interregional equilibrium can be attained if the central government imposes federal head taxes that equate the net income of high-skilled households across regions.

Yet, it remains to be proven that production efficiency holds in the optimum: According to the first-order condition on consumption (equation (3.52)) and the optimal grant provided (equation (3.19)), the symmetric equilibrium entails that the Lagrange-multipliers $\lambda_{t,i}$ and $\mu^L_{t,i}$ are identical across regions. This indicates that the social benefit of education as accounted for by an intervening central government aiming to establish the first-best (equation (3.25)) is the same in all regions,

$$\begin{aligned} \lambda_{t,i}\left(z^H - z^L\right)F'(Z_{t,i}) &= \beta^{-1}\mu^L_{t-1} = \lambda_{t,j}\left(z^H - z^L\right)F'(Z_{t,j}) && (3.61)\\ &\Leftrightarrow F'(Z_{t,i}) = F'(Z_{t,j}). && (3.62)\end{aligned}$$

[30] Given the symmetric intraregional equilibrium, it is sufficient to establish identical consumption levels of the high-skilled type between regions.

The analysis reveals that federal policies can replicate the first-best optimum in which production efficiency holds. This, however, requires the central government to provide the optimal educational grant and - given type-independent local lump-sum taxation - impose a type-specific head tax to redistribute income. Furthermore, federal lump-sum taxation has to be used in a way to ensure that the aggregate head tax on mobile high-skilled labor is identical across regions. To see this, apply the result of production efficiency to equation (3.60),

$$\tau^H_{t,i} + \theta^H_{t,i} = \tau^H_{t,j} + \theta^H_{t,j}. \tag{3.63}$$

Such interregional redistribution ensures the efficient allocation of labor according to equation (3.30), as migration flows are driven by productivity differences alone. Consequently, production efficiency will be established in the optimum.

Proposition 13 *If both high- and low-skilled workers are perfectly mobile, local jurisdictions distribute profits evenly among their residents. This implies that competencies for both education policy as well as redistribution have to be assigned to the federal level.*

Instead of supporting education by subsidizing private educational investments, local governments refrain from using corrective tax instruments in the presence of high- and low-skilled mobility. A small region ignores the educational inefficiency as it regards the available amount of high- and low-skilled workers as infinite (perfect elasticity of supply). Hence, private underinvestment in education persists unless it is accounted for at the federal or supranational level. To correct the underinvestment problem, the central government can use a federal matching grant. However, such a grant will only be passed on by the local government and, thus, constitutes a perfect substitute for subsidies on education paid directly to households. Therefore, decentralization in a setting with high- and low-skilled mobility requires the fiscal authority on the field of education policy to be assigned effectively to the federal or supranational level. Furthermore, federal head taxes have to be imposed to establish both the intra- as well as the interregionally symmetric equilibrium.

3.6 Conclusion

In the view of increased mobility of high-skilled labor, local governments face the option to free-ride on other regions' education policies instead of correcting educational underinvestment themselves. Still, one can observe that education is financed substantially by local governments. The present research provides an explanation for this phenomenon that is based on the effect of social mobility across different skill-types. The notion social mobility reflects the fact that parental investments in education today determine their children's probability to become high-skilled tomorrow. The model thereby extends previous studies to a dynamic setup, endogenizing the evolution of the size of the different skill-types over time. Moreover, an intergenerational externality is introduced that leads to a situation of underinvestment in education and, hence, provides a justification for a corrective educational subsidy from a federal perspective. Against this background, the efficiency of decentralized decision making in the presence of perfect, high-skilled mobility is discussed.

It is shown that small regions abide by the optimal decision rule for subsidizing education, although high-skilled workers are perfectly mobile across regions. This is surprising, since private underinvestment in human capital can, from the point of view of a small region, be fully compensated by high-skilled immigration from neighboring jurisdictions. However, in a dynamic setup with social mobility underinvestment in education not only affects the size of the high-skilled workforce, but additionally determines the number of immobile low-skilled workers in the respective region. Consequently, the incentive to correct educational underinvestment prevails although high-skilled labor is assumed to be perfectly mobile. Thus, decentralized education policies remain to be efficient. Social mobility, therefore, provides an explanation of why local governments continue to subsidize education, even though high-skilled workers can migrate.

However, the efficiency of decentralized education policies does not persist in a scenario in which both types of labor are mobile. In such a setup, local governments lose any incentive to subsidize education since both the size of the high- and low-skilled workforce are solely determined by migration flows. From the point of view of a small region, previous local investments in education are entirely irrelevant for the composition of today's workforce. This explains why decentralized education policies turn out to be inefficient. To prevent underinvestment in this case, education policies have to be assigned to the federal or supranational level.

Though two polar cases - perfect high-skilled mobility and perfect high- as well as low-skilled mobility - are considered in the present analysis, the results carry over to more realistic migration scenarios including costs of moving. Moreover, one can conjecture that at least for some workers barriers to migration are prohibitively high. Hence, part of the low-skilled will most likely be immobile. As long as only a fraction of the low-skilled workforce continues to be immobile, the findings derived in the present chapter indicate that decentralized education policies remain to be efficient.

The results, therefore, imply that local governments facing mobility of labor do not necessarily lose their scope to correct market failures, at least not with respect to underinvestment in education. While this finding seems to be surprising given the standard reasoning of the literature on local public finance, it underlines the importance of extending fiscal federalism models to dynamic frameworks capable of analyzing the impact of factor flows on both the interregional allocation of the mobile factor as well as it's evolution over time.

Chapter 4

Concluding Remarks

Previous research on local public finance often resorts to static modeling approaches. Yet, incorporating the evolution of mobile factors over time adds an additional dimension of mobility that directly affects optimal fiscal policies. The present thesis contributes to a relatively new strand of literature focusing on these dynamic aspects of local public finance. To explore the time dimension of factor mobility, two distinct frameworks are set up, integrating a migration decision of households while additionally modeling the accumulation of mobile factors over time.

The first model developed analyzes the implications of perfect mobility of labor for the optimal taxation of capital income. To pursue this, standard models of optimal taxation in dynamic general equilibrium frameworks are extended to include both mobile capital as well as mobile labor. Moreover, to study the relevance of congestion costs arising as a consequence of immigration, it is assumed that the government provides a rival, local public good that directly enters the production process. The analysis proceeds in two steps: The first part abstracts from the possibility of migration to demonstrate that the basic model replicates the standard findings of the literature: the optimal long-run tax on capital income vanishes, while a tax on labor income is efficient to internalize the congestion costs. Moreover, the residence principle of taxation is welfare maximizing.

The second part derives the optimal fiscal policy allowing for perfect mobility of households in addition to mobile capital. The theoretical analysis indicates that integrating labor mobility into dynamic models of taxation influences optimal fiscal policies. More precisely, migration turns out to be particularly important for the structure of capital income taxation as it affects the choice of the optimal international tax regime: While the residence principle of taxation is optimal in the absence of migration, the source principle is welfare maximizing once mobility of labor is introduced. This is due to the fact that migration responds to differences in consumption growth. Since the source principle ensures a convergence of consumption growth rates across countries, it avoids tax-induced migration flows and establishes an efficient international allocation of mobile factors.

The second framework that is developed in the present thesis emphasizes the impact of labor mobility on local education policies: in view of a potential brain drain, public incentives to promote education might give way to attempts to attract mobile workers using favorable tax systems, i.e. to free-ride on other countries' education policies. Fiscal competition for mobile labor might, hence, reduce the incentives of local governments to correct market failures and, consequently, lower social welfare. This free-rider problem at the level of local jurisdictions is studied, introducing social mobility between skill-types as a dynamic dimension of labor mobility.

Deriving the optimal education policy reveals that local governments stick to the optimal decision rule for subsidizing education even though high-skilled labor is perfectly mobile. This is due to the fact that social mobility across skill-types has been introduced: Private underinvestment in education affects the long-term composition of the domestic population as it not only determines the size of the high-skilled workforce, but additionally the number of immobile low-skilled workers. As a consequence, small countries are forced to take the underinvestment problem into account and continue to support education publicly, although high-skilled workers are perfectly mobile. Again, the analysis indicates that integrating the evolution of mobile factors over time impacts the results of standard models substantially.

To summarize, the findings of this thesis demonstrate that recognizing the dynamic dimension of factor movements matters. However, although the present work presented two examples that indicate the benefits involved from modeling factor mobility in space and time jointly, more research in this direction is needed to fully realize the gains of moving towards a dynamic perspective of local public finance. The next steps in this direction should aim at relaxing unrealistic modeling assumptions, such as the perfect mobility of production factors, to be able to derive more general results and put policy recommendations on more solid grounds. The most fundamental limitation of the present work is probably the presumption that national states or federal jurisdictions that compete for mobile factors do not interact strategically. Yet, while incorporating strategic interaction in static models is a common standard in the literature on fiscal competition, applying these methods to a dynamic setting is a challenging task.

Secondly, the assumption of benevolent, welfare maximizing governments is undoubtedly unrealistic and rather represents a theoretical concept useful in normative analyses. However, the opposing view of selfish, rent-extracting Leviathan governments might be equally restrictive. Future studies on dynamic aspects of local public finance should follow the work of Edwards and Keen (1996) and try to assess these opposing views of government behavior in an integrated approach. Although worthwhile exploring, such considerations are clearly beyond the scope of the present thesis and have to be left for future research.

A Appendix to Chapter 2

A.1 Optimality Conditions in the Absence of Migration

The central planning problem leads to the following first-order conditions,

$$\frac{\partial}{\partial c_t^i} : \beta^t \omega_{ct}^i = \mu_t^i \tag{A.1}$$

$$\frac{\partial}{\partial h_{t+1}^i} : \mu_t^i = \mu_{t+1}^i \left(1 + f_{ht+1}^i \Phi_t^i(\cdot) + f_{t+1}^i(\cdot)\Phi_{ht+1}^i\right) \tag{A.2}$$

$$\frac{\partial}{\partial a_{t+1}^{ii}} : \mu_t^i = \mu_{t+1}^i \left\{\left(1 + f_{kt+1}^i \Phi_{t+1}^i(\cdot)\right)\right\} \tag{A.3}$$

$$\frac{\partial}{\partial a_{t+1}^{ij}} : \mu_t^i = \mu_{t+1}^i \left(1 + (1 - \tau_{rIt+1}^j) r_{t+1}^j\right) \tag{A.4}$$

$$\frac{\partial}{\partial A_t^{\bullet i}} : \frac{1}{N_t^i} \left(f_{kt}^i \Phi_t^i(\cdot) - (1 - \tau_{rIt}^i) r_t^i\right) = 0 \tag{A.5}$$

$$\frac{\partial}{\partial G_t^i} : \frac{1}{N_t^i} = f_t^i(\cdot)\Phi_{Gt}^i \tag{A.6}$$

$$\frac{\partial}{\partial \tau_{rIt}^i} : \left(-r_t^i + (1 - \tau_{rIt}^i)\frac{\partial r_t^i}{\partial \tau_{rIt}^i}\right) \frac{A_t^{\bullet i}}{N_t^i} = 0 \tag{A.7}$$

$$\Leftrightarrow \left(1 - (1 - \tau_{rIt}^i)\frac{(1 - \delta_t^j)}{(1 - \tau_{rEt}^j)}\right) r_t^i = 0 \tag{A.8}$$

$$\Leftrightarrow (1 - \tau_{rEt}^j) = (1 - \tau_{rIt}^i)(1 - \delta_t^j). \tag{A.9}$$

μ denotes the Lagrange multiplier on the resource constraint. Note that the above derivation with respect to consumption only applies to $t \geq 1$. For period 0 optimization yields

$$\beta^0 \omega^i_{c0} = \mu^i_0 + \bar{\lambda}^i \beta u^i_{cc0} \left[\left(1 + (1 - \tau^i_{rD0}) r^i_0\right) a^i_0 + \left(1 + (1 - \tau^i_{w0}) w^i_0\right) h^i_0 \right]. \quad \text{(A.10)}$$

A.2 Optimality Conditions in the Presence of Migration

The first-order conditions for the central planning problem in the presence of migration are as follows,

$$\frac{\partial}{\partial c^i_t} : \beta^t \omega^i_{ct} = \mu^i_t \quad \text{(A.11)}$$

$$\frac{\partial}{\partial h^i_{t+1}} : \mu^i_t = \mu^i_{t+1} \left(1 + f^i_{ht+1} \Phi^i_{t+1}(\cdot) + f^i_{t+1}(\cdot) \Phi^i_{ht+1} + \frac{\partial \chi^i_{t+1}}{\partial N^i_{t+1}} \frac{\partial N^i_{t+1}}{\partial h^i_{t+1}} \right) \quad \text{(A.12)}$$

$$\frac{\partial}{\partial a^{ii}_{t+1}} : \mu^i_t = \mu^i_{t+1} \left\{ \left(1 + f^i_{kt+1} \Phi^i_{t+1}(\cdot)\right) + \frac{\partial \chi^i_{t+1}}{\partial N^i_{t+1}} \frac{\partial N^i_{t+1}}{\partial a^{ii}_{t+1}} \right\} \quad \text{(A.13)}$$

$$\frac{\partial}{\partial a^{ij}_{t+1}} : \mu^i_t = \mu^i_{t+1} \left(1 + (1 - \tau^j_{rIt+1}) r^j_{t+1}\right) \quad \text{(A.14)}$$

$$\frac{\partial}{\partial A^{\bullet i}_t} : \frac{1}{N^i_t} \left(f^i_{kt} \Phi^i_t(\cdot) - (1 - \tau^i_{rIt}) r^i_t \right) + \frac{\partial \chi^i_t}{\partial N^i_t} \frac{\partial N^i_t}{\partial A^{\bullet i}_t} = 0 \quad \text{(A.15)}$$

$$\frac{\partial}{\partial G^i_t} : \frac{1}{N^i_t} = f^i_t(\cdot) \Phi^i_{Gt} \quad \text{(A.16)}$$

$$\frac{\partial}{\partial \tau^i_{rIt}} : \left(-r^i_t + (1 - \tau^i_{rIt}) \frac{\partial r^i_t}{\partial \tau^i_{rIt}} \right) \frac{A^{\bullet i}_t}{N^i_t} + \frac{\partial \chi^i_t}{\partial N^i_t} \frac{\partial N^i_t}{\partial \tau^i_{rIt}} = 0 \quad \text{(A.17)}$$

$$\frac{\partial}{\partial \tau^i_{wt}} : \frac{\partial \chi^i_t}{\partial N^i_t} \frac{\partial N^i_t}{\partial \tau^i_{wt}} = 0 \Leftrightarrow \frac{\partial \chi^i_t}{\partial N^i_t} = 0 \quad \text{(A.18)}$$

$$\text{with} \quad \frac{\partial \chi^i_t}{\partial N^i_t} = f^i_{kt} \Phi^i_t(\cdot) \frac{\partial}{\partial N^i_t} \frac{A^{\bullet i}_t}{N^i_t} + f^i_t(\cdot) \Phi^i_{Nt} - \frac{\partial g^i_t}{\partial N^i_t} - (1 - \tau^i_{rIt}) r^i_t \frac{\partial}{\partial N^i_t} \frac{A^{\bullet i}_t}{N^i_t}.$$

μ denotes the Lagrange multiplier on the resource constraint. Again, the first-order condition on consumption in period 0 is given by

$$\beta^0 \omega_{c0}^i = \mu_0^i + \bar{\lambda}^i \beta u_{cc0}^i \left[\left(1 + (1 - \tau_{rD0}^i) r_0^i\right) a_0^i + \left(1 + (1 - \tau_{w0}^i) w_0^i\right) h_0^i \right]. \quad \text{(A.19)}$$

B Appendix to Chapter 3

B.1 Migration of High-Skilled Workers

B.1.1 Unitary State Optimization

The first-order conditions for the central planning problem are as follows,

$$\frac{\partial}{\partial \tau^n_{t,i}} : \kappa^n_{t,i} = \lambda_{t,i} N^n_{t,i} \tag{B.1}$$

$$\frac{\partial}{\partial \theta^n_{t,i}} : \kappa^n_{t,i} = \lambda_t N^n_{t,i} \tag{B.2}$$

$$\frac{\partial}{\partial \theta^n_{et,i}} : \lambda_t N^n_{t,i} e^n_{t,i} = \lambda_{t,i} N^n_{t,i} e^n_{t,i} \quad \Leftrightarrow \quad \lambda_t = \lambda_{t,i} \tag{B.3}$$

$$\frac{\partial}{\partial c^L_{t,i}} : u^L_{ct,i} N^L_{t,i} = \kappa^L_{t,i} \left(1 - \frac{\upsilon^L_{et,i}}{\left(u^L_{cct,i}\right)^2} e^L_{t,i} \right) + \lambda_{t,i} N^L_{t,i} \frac{\upsilon^L_{et,i}}{\left(u^L_{cct,i}\right)^2} e^L_{t,i} \tag{B.4}$$

$$\begin{aligned} \frac{\partial}{\partial c^H_{t,i}} : & \left(N^H_{t,i} - \varphi^H_{t,i}\right) u^H_{ct,i} - \kappa^H_{t,i} \left(1 - \frac{\upsilon^H_{et,i}}{\left(u^H_{cct,i}\right)^2} e^H_{t,i} \right) \\ & - \lambda_{t,i} N^H_{t,i} \frac{\upsilon^H_{et,i}}{\left(u^H_{cct,i}\right)^2} e^H_{t,i} = 0 \end{aligned} \tag{B.5}$$

$$\frac{\partial}{\partial e^L_{t,i}}: N^L_{t,i}\upsilon^L_{et,i} - \kappa^L_{t,i}\left(\frac{\upsilon^L_{eet,i}}{u^L_{ct,i}}e^L_{t,i} + \frac{\upsilon^L_{et,i}}{u^L_{ct,i}}\right) - \lambda_t N^L_{t,i}\theta^L_{et,i}$$

$$+ \lambda_{t,i}N^L_{t,i}\left(\frac{\upsilon^L_{eet,i}}{u^L_{ct,i}}e^L_{t,i} + \frac{\upsilon^L_{et,i}}{u^L_{ct,i}} - \left(1-\theta^L_{et,i}\right)\right) + \mu^L_{t,i}N^L_{t,i}h^L_{et,i} = 0 \tag{B.6}$$

$$\frac{\partial}{\partial e^H_{t,i}}: \left(N^H_{t,i} - \varphi^H_{t,i}\right)\upsilon^H_{et,i} - \kappa^H_{t,i}\left(\frac{\upsilon^H_{eet,i}}{u^H_{ct,i}}e^H_{t,i} + \frac{\upsilon^H_{et,i}}{u^H_{ct,i}}\right) - \lambda_t N^H_{t,i}\theta^H_{et,i}$$

$$+ \lambda_{t,i}N^H_{t,i}\left(\frac{\upsilon^H_{eet,i}}{u^H_{ct,i}}e^H_{t,i} + \frac{\upsilon^H_{et,i}}{u^H_{ct,i}} - \left(1-\theta^H_{et,i}\right)\right) + \mu^L_{t,i}N^H_{t,i}h^H_{et,i} = 0 \tag{B.7}$$

$$\frac{\partial}{\partial N^L_{t,i}}: U^L_{t,i}(\cdot) + \left(\kappa^L_{t,i}z^L + \kappa^H_{t,i}z^H\right)z^L F''(Z_{t,i}) + \lambda_t\left[\theta^L_{t,i} - \theta^L_{et,i}e^L_{t,i}\right]$$

$$+ \lambda_{t,i}\left(\tau^L_{t,i} + \frac{\upsilon^L_{et,i}}{u^L_{ct,i}}e^L_{t,i} - \left(1-\theta^L_{et,i}\right)e^L_{t,i} + z^L R'(Z_{t,i})\right)$$

$$- \mu^L_{t,i}\left[1 - h(e^L_{t,i})\right] + \beta^{-1}\mu^L_{t-1,i} = \mu_t \tag{B.8}$$

$$\frac{\partial}{\partial N^H_{t,i}}: U^H_{t,i}(\cdot) + \left(\kappa^L_{t,i}z^L + \kappa^H_{t,i}z^H\right)z^H F''(Z_{t,i}) + \lambda_t\left[\theta^H_{t,i} - \theta^H_{et,i}e^H_{t,i}\right]$$

$$+ \lambda_{t,i}\left(\tau^H_{t,i} + \frac{\upsilon^H_{et,i}}{u^H_{ct,i}}e^H_{t,i} - \left(1-\theta^H_{et,i}\right)e^H_{t,i} + z^H R'(Z_{t,i})\right)$$

$$- \mu^L_{t,i}\left[1 - h(e^H_{t,i})\right] = \mu_t. \tag{B.9}$$

To gain symmetric first-order conditions, define the multiplier on the migration constraint for the arbitrarily chosen reference region j as $\varphi^H_{t,j} = -\varphi^H_{t,i}$.

B.1.2 Regional Optimization

The first-order conditions for the local optimization problem are

$$\frac{\partial}{\partial \tau_t^n} : \kappa_t^n = \lambda_t N_t^n \tag{B.10}$$

$$\frac{\partial}{\partial c_t^L} : N_t^L u_{ct}^L = \kappa_t^L \left(1 - \frac{\upsilon_{et}^L}{\left(u_{cct}^L\right)^2} e_t^L\right) + \lambda_t N_t^L \frac{\upsilon_{et}^L}{\left(u_{cct}^L\right)^2} e_t^L \tag{B.11}$$

$$\frac{\partial}{\partial c_t^H} : \left(N_t^H - \varphi_t^H\right) u_{ct}^H = \kappa_t^H \left(1 - \frac{\upsilon_{et}^H}{\left(u_{cct}^H\right)^2} e_t^H\right) + \lambda_t N_t^H \frac{\upsilon_{et}^H}{\left(u_{cct}^H\right)^2} e_t^H \tag{B.12}$$

$$\begin{aligned}\frac{\partial}{\partial e_t^L} &: N_t^L \upsilon_{et}^L - \kappa_t^L \left(\frac{\upsilon_{eet}^L}{u_{ct}^L} e_t^L + \frac{\upsilon_{et}^L}{u_{ct}^L}\right) + \lambda_t N_t^L \left(\frac{\upsilon_{eet}^L}{u_{ct}^L} e_t^L + \frac{\upsilon_{et}^L}{u_{ct}^L} - \left(1 - \theta_{et}^L\right)\right) \\ &\quad + \mu_t^L h_{et}^L N_t^L = 0\end{aligned} \tag{B.13}$$

$$\begin{aligned}\frac{\partial}{\partial e_t^H} &: \left(N_t^H - \varphi_t^H\right) \upsilon_{et}^H - \kappa_t^H \left(\frac{\upsilon_{eet}^H}{u_{ct}^H} e_t^H + \frac{\upsilon_{et}^H}{u_{ct}^H}\right) \\ &\quad + \lambda_t N_t^H \left(\frac{\upsilon_{eet}^H}{u_{ct}^H} e_t^H + \frac{\upsilon_{et}^H}{u_{ct}^H} - \left(1 - \theta_{et}^H\right)\right) + \mu_t^L N_t^H h_{et}^H = 0\end{aligned} \tag{B.14}$$

$$\begin{aligned}\frac{\partial}{\partial N_t^L} &: U_t^L + \left(\kappa_t^L z^L + \kappa_t^H z^H\right) z^L F''(Z_t) + \lambda_t \left[\tau_t^L + \frac{\upsilon_{et}^L}{u_{ct}^L} e_t^L - \left(1 - \theta_{et}^L\right) e_t^L\right] \\ &\quad + \lambda_t \left[z^L R'(Z_t)\right] - \mu_t^L \left[1 - h(e_t^L)\right] + \beta^{-1} \mu_{t-1}^L = 0\end{aligned} \tag{B.15}$$

$$\begin{aligned}\frac{\partial}{\partial N_t^H} &: U_t^H + \left(\kappa_t^L z^L + \kappa_t^H z^H\right) z^H F''(Z_{t,i}) + \lambda_t \left[\tau_t^H + \frac{\upsilon_{et}^H}{u_{ct}^H} e_t^H - \left(1 - \theta_{et}^H\right) e_t^H\right] \\ &\quad + \lambda_t \left[z^H R'(Z_t)\right] - \mu_t^L \left[1 - h(e_t^H)\right] = 0.\end{aligned} \tag{B.16}$$

B.2 Migration of High- as well as Low-Skilled Workers

B.2.1 Unitary State Optimization

Optimization of the unitary state government in case of high- and low-skilled mobility yields the following first-order conditions,

$$\frac{\partial}{\partial \tau^n_{t,i}} : \kappa^n_{t,i} = \lambda_{t,i} N^n_{t,i} \tag{B.17}$$

$$\frac{\partial}{\partial \theta^n_{t,i}} : \kappa^n_{t,i} = \lambda_t N^n_{t,i} \tag{B.18}$$

$$\frac{\partial}{\partial \theta^n_{et,i}} : \lambda_t N^n_{t,i} e^n_{t,i} = \lambda_{t,i} N^n_{t,i} e^n_{t,i} \quad \Leftrightarrow \quad \lambda_t = \lambda_{t,i} \tag{B.19}$$

$$\begin{aligned} \frac{\partial}{\partial c^n_{t,i}} &: \left(N^n_{t,i} - \varphi^n_{t,i}\right) u^n_{ct,i} - \kappa^n_{t,i} \left(1 - \frac{\upsilon^n_{et,i}}{\left(u^n_{cct,i}\right)^2} e^n_{t,i}\right) \\ &- \lambda_{t,i} N^n_{t,i} \frac{\upsilon^n_{et,i}}{\left(u^n_{cct,i}\right)^2} e^n_{t,i} = 0 \end{aligned} \tag{B.20}$$

$$\begin{aligned} \frac{\partial}{\partial e^n_{t,i}} &: \left(N^n_{t,i} - \varphi^n_{t,i}\right) \upsilon^n_{et,i} - \kappa^n_{t,i} \left(\frac{\upsilon^n_{eet,i}}{u^n_{ct,i}} e^n_{t,i} + \frac{\upsilon^n_{et,i}}{u^n_{ct,i}}\right) - \lambda_t N^n_{t,i} \theta^n_{et,i} \\ &+ \lambda_{t,i} N^n_{t,i} \left(\frac{\upsilon^n_{eet,i}}{u^n_{ct,i}} e^n_{t,i} + \frac{\upsilon^n_{et,i}}{u^n_{ct,i}} - \left(1 - \theta^n_{et,i}\right)\right) + \mu^L_t N^n_{t,i} h^n_{et,i} = 0 \end{aligned} \tag{B.21}$$

$$\begin{aligned} \frac{\partial}{\partial N^L_{t,i}} &: U^L_{t,i}(\cdot) + \left(\kappa^L_{t,i} z^L + \kappa^H_{t,i} z^H\right) z^L F''(Z_{t,i}) + \lambda_t \left[\theta^L_{t,i} - \theta^L_{et,i} e^L_{t,i}\right] \\ &+ \lambda_{t,i} \left(\tau^L_{t,i} + \frac{\upsilon^L_{et,i}}{u^L_{ct,i}} e^L_{t,i} - \left(1 - \theta^L_{et,i}\right) e^L_{t,i} + z^L R'(Z_{t,i})\right) \\ &- \mu^L_t \left[1 - h(e^L_{t,i})\right] + \beta^{-1} \mu^L_{t-1} = \mu_t \end{aligned} \tag{B.22}$$

$$\begin{aligned} \frac{\partial}{\partial N^H_{t,i}} &: U^H_{t,i}(\cdot) + \left(\kappa^L_{t,i} z^L + \kappa^H_{t,i} z^H\right) z^H F''(Z_{t,i}) + \lambda_t \left[\theta^H_{t,i} - \theta^H_{et,i} e^H_{t,i}\right] \\ &+ \lambda_{t,i} \left(\tau^H_{t,i} + \frac{\upsilon^H_{et,i}}{u^H_{ct,i}} e^H_{t,i} - \left(1 - \theta^H_{et,i}\right) e^H_{t,i} + z^H R'(Z_{t,i})\right) \\ &- \mu^L_t \left[1 - h(e^H_{t,i})\right] = \mu_t. \end{aligned} \tag{B.23}$$

B.2.2 Regional Optimization

The first-order conditions of the regional optimization, when high- and low-skilled workers are mobile, are

$$\frac{\partial}{\partial \tau_t^n} : \kappa_t^n = \lambda_t N_t^n \tag{B.24}$$

$$\frac{\partial}{\partial c_t^n} : \left(N_t^n - \varphi_t^n\right) u_{ct}^n = \kappa_t^n \left(1 - \frac{\upsilon_{et}^n}{\left(u_{cct}^n\right)^2} e_t^n\right) + \lambda_t N_t^n \frac{\upsilon_{et}^n}{\left(u_{cct}^n\right)^2} e_t^n \tag{B.25}$$

$$\begin{aligned} \frac{\partial}{\partial e_t^n} : &\left(N_t^n - \varphi_t^n\right) \upsilon_{et}^n - \kappa_t^n \left(\frac{\upsilon_{eet}^n}{u_{ct}^n} e_t^n + \frac{\upsilon_{et}^n}{u_{ct}^n}\right) \\ &+ \lambda_t N_t^n \left(\frac{\upsilon_{eet}^n}{u_{ct}^n} e_t^n + \frac{\upsilon_{et}^n}{u_{ct}^n} - \left(1 - \theta_{et}^n\right)\right) = 0 \end{aligned} \tag{B.26}$$

$$\begin{aligned} \frac{\partial}{\partial N_t^n} : &U_t^n(\cdot) + \left(\kappa_t^L z^L + \kappa_t^H z^H\right) z^n F''(Z_t) \\ &+ \lambda_t \left[\tau_t^n + \frac{\upsilon_{et}^n}{u_{ct}^n} e_t^n - \left(1 - \theta_{et}^n\right) e_t^n + z^n R'(Z_t)\right] = 0. \end{aligned} \tag{B.27}$$

Bibliography

Aiyagari, S. Rao (1995): Optimal Capital Income Taxation with Incomplete Markets, Borrowing Constraints, and Constant Discounting, *Journal of Political Economy*, Vol. 103, No. 6, pp. 1158–1174.

Andersson, Frederik and Kai A. Konrad (2003a): Globalization and Risky Human-Capital Investment, *International Tax and Public Finance*, Vol. 10, No. 3, pp. 211–228.

Andersson, Frederik and Kai A. Konrad (2003b): Human Capital Investment and Globalization in Extortionary States, *Journal of Public Economics*, Vol. 87, pp. 1539–1555.

Andersson, Frederik and Kai A. Konrad (2006): Taxation and Education Investment in the Tertiary Sector, in: Torben Andersen and Per Molander (Eds.), *Alternatives for Welfare Policy*, Chapter 13, Cambridge University Press.

Atkeson, Andrew, V.V. Chari and Patrick J. Kehoe (1999): Taxing Capital Income: A Bad Idea, *Federal Reserve Bank of Minneapolis Quarterly Review*, Vol. 23, No. 3, pp. 3–17.

Atkinson, A.B. and J.E. Stiglitz (1972): The Structure of Indirect Taxation and Economic Efficiency, *Journal of Public Economics*, Vol. 1, pp. 97–119.

Atkinson, Anthony B. and Joseph E. Stiglitz (1980): *Lectures on Public Economics*, London: Mc Graw-Hill.

Beine, Michel, Frederic Docquier and Hillel Rapoport (2001): Brain Drain and Economic Growth: Theory and Evidence, *Journal of Development Economics*, Vol. 64, No. 1, pp. 275–289.

Benhabib, Jess and Aldo Rustichini (1997): Optimal Taxes without Commitment, *Journal of Economic Theory*, Vol. 77, pp. 231–259.

Boadway, Robin (1982): On the Method of Taxation and the Provision of Local Public Goods: Comment, *American Economic Review*, Vol. 72, No. 4, pp. 846–851.

Boadway, Robin, Katherine Cuff and Maurice Marchand (2003): Equalization and the Decentralization of Revenue-Raising in a Federation, *Journal of Public Economic Theory*, Vol. 5, No. 2, pp. 201–228.

Boadway, Robin, Nicolas Marceau and Maurice Marchand (1996): Investment in Education and the Time Inconsistency of Redistributive Tax Policy, *Economica*, Vol. 63, pp. 171–189.

Brennan, Geoffrey and James M. Buchanan (1980): *The Power to Tax: Analytical Foundations of a Fiscal Constitution*, 1 Edn., London: Cambridge University Press.

Brueckner, Jan K. (1999): Fiscal Federalism and Capital Accumulation, *Journal of Public Economic Theory*, Vol. 1, No. 2, pp. 205–224.

Brueckner, Jan K. (2006): Fiscal Federalism and Economic Growth, *Journal of Public Economics*, Vol. 90, No. 10-11, pp. 2107–2120.

Buchanan, James M. (1965): An Economic Theory of Clubs, *Economica*, Vol. 32, No. 125, pp. 1–14.

Bucovetsky, Sam and Michael Smart (2006): The Efficiency Consequences of Local Revenue Equalization: Tax Competition and Tax Distortions, *Journal of Public Economic Theory*, Vol. 8, No. 1, pp. 119–144.

Bull, Nicholas (1993): When All the Optimal Dynamic Taxes are Zero, *Federal Reserve Board Working Paper Series*, No. 137.

Carneiro, Pedro and James J. Heckman (2002): The Evidence on Credit Constraints in Post-Secondary Schooling, *The Economic Journal*, Vol. 112, pp. 705–734.

Chamley, Christophe (1986): Optimal Taxation of Capital Income in General Equilibrium with Infinite Lives, *Econometrica*, Vol. 54, No. 3, pp. 607–622.

Chamley, Christophe (2001): Capital Income Taxation, Wealth Distribution and Borrowing Constraints, *Journal of Public Economics*, Vol. 79, pp. 55–69.

Chari, V.V. and Patrick J. Kehoe (1999): Optimal Fiscal and Monetary Policy, in: J.B. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*, Vol. 1, Chapter 26, North Holland: Amsterdam: Elsevier Science B.V., pp. 1671–1745.

Commander, Simon, Mari Kangasniemi and L. Alan Winters (2003): The Brain Drain: Curse or Boon?, *IZA Discussion Paper*, No. 809.

Correia, Isabel H. (1996a): Dynamic Optimal Taxation in Small Open Economies, *Journal of Economic Dynamics and Control*, Vol. 20, pp. 691–708.

Correia, Isabel H. (1996b): Should Capital Income be Taxed in the Steady State?, *Journal of Public Economics*, Vol. 60, pp. 147–151.

Corsetti, Giancarlo and Nouriel Roubini (1996): Optimal Government Spending and Taxation in Endogenous Growth Models, *NBER Working Paper*, No. 5851.

Cremer, Helmuth and Pierre Pestieau (2006): Intergenerational Transfer of Human Capital and Optimal Education Policy, *Journal of Public Economic Theory*, Vol. 8, No. 4, pp. 529–545.

Del Rey, Elena (2001): Economic Integration and Public Provision of Education, *Empirica*, Vol. 28, pp. 203–218.

Diamond, Peter A. and James A. Mirrlees (1971): Optimal Taxation and Public Production I: Production Efficiency, *American Economic Review*, Vol. 61, No. 1, pp. 8–27.

Docquier, Frédéric and Abdeslam Marfouk (2006): International Migration by Education Attainment, 1990-2000, in: Caglar Özden and Maurice Schiff (Eds.), *International Migration, Remittances, and the Brain Drain*, Washington: The World Bank / Palgrave Macmillan.

Doménech, Rafael and Jose Ramón García (2002): Optimal Taxation and Public Expenditure in a Model of Endogenous Growth, *Topics in Macroeconomics*, Vol. 2, No. 1, pp. 1–24.

Edwards, Jeremy and Michael Keen (1996): Tax Competition and Leviathan, *European Economic Review*, Vol. 40, pp. 113–134.

Egger, Hartmut, Josef Falkinger and Volker Grossmann (2007): Brain Drain, Fiscal Competition, and Public Education Expenditure, *IZA Discussion Paper*, No. 2747.

Erosa, Andrés and Martin Gervais (2001): Optimal Taxation in Infinitely-Lived Agent and Overlapping Generations Models: A Review, *Federal Reserve Bank of Richmond Economic Quarterly No. 00-2*, Vol. 87, No. 2, pp. 23–44.

Erosa, Andrés and Martin Gervais (2002): Optimal Taxation in Life-Cycle Economies, *Journal of Economic Theory*, Vol. 105, pp. 338–369.

European Comission (2006): *Employment in Europe 2006*.

Flatters, Frank, Vernon Henderson and Peter Mieszkowski (1974): Public Goods, Efficiency, and Regional Fiscal Equalization, *Journal of Public Economics*, Vol. 3, No. 2, pp. 99–112.

Frenkel, Jacob A., Assaf Razin and Efraim Sadka (1991): *International Taxation in an Integrated World*, Cambridge: MIT Press.

Garriga, Carlos (2000): Optimal Fiscal Policy in Overlapping Generations Models, *University of Barcelona Working Paper*, No. 66.

Glomm, Gerhard and B. Ravikumar (1994): Public Investment in Infrastructure in a Simple Growth Model, *Journal of Economic Dynamics and Control*, Vol. 18, pp. 1173–1187.

Gordon, Roger H. (1986): Taxation of Investment and Savings in a World Economy, *American Economic Review*, Vol. 76, No. 5.

Homburg, Stefan (1999): Competition and Co-ordination in International Capital Income Taxation, *FinanzArchiv*, Vol. 56, No. 1, pp. 1–17.

Janeba, Eckhard (2000): Tax Competition When Governments Lack Commitment: Excess Capacity as a Countervailing Threat, *American Economic Review*, Vol. 90, No. 5, pp. 1508 – 1519.

Jones, Larry E., Rodolfo E. Manuelli and Peter E. Rossi (1993): Optimal Taxation in Models of Endogenous Growth, *Journal of Political Economy*, Vol. 101, No. 3, pp. 485–517.

Jones, Larry E., Rodolfo E. Manuelli and Peter E. Rossi (1997): On the Optimal Taxation of Capital Income, *Journal of Economic Theory*, Vol. 73, pp. 93–117.

Judd, Kenneth (1985): Redistributive Taxation in a Perfect Foresight Model, *Journal of Public Economics*, Vol. 28, No. 59-83.

Judd, Kenneth L. (1997): The Optimal Tax Rate for Capital Income is Negative, *NBER Working Paper*, No. 6004.

Justman, Moshe and Jacques-Francois Thisse (1997): Implications of the Mobility of Skilled Labor for Local Public Funding of Higher Education, *Economics Letters*, Vol. 55, No. 3, pp. 409–412.

Justman, Moshe and Jacques-Francois Thisse (2000): Local Public Funding of Higher Education when Skilled Labor is Imperfectly Mobile, *International Tax and Public Finance*, Vol. 7, No. 3, pp. 247–258.

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

Kellermann, Kersten (2006): A Note on Intertemporal Fiscal Competition and Redistribution, *International Tax and Public Finance*, Vol. 13, p. 18.

Koskela, Erkki and Leopold von Thadden (2003): Optimal Factor Taxation Under Wage Bargaining - A Dynamic Perspective, *CESifo Working Paper*, No. 836.

Kydland, Finn E. and Edward C. Prescott (1977): Rules Rather than Discretion: The Inconsistency of Optimal Plans, *Journal of Political Economy*, Vol. 85, No. 3, pp. 473–491.

Lee, Kangoh (1997): Tax Competition with Imperfectly Mobile Capital, *Journal of Urban Economics*, Vol. 42, pp. 222–242.

Lejour, Arjan M. and Harrie A. A. Verbon (1997): Tax Competition and Redistribution in a Two-Country Endogenous-Growth Model, *International Tax and Public Finance*, Vol. V4, No. 4, pp. 485–497.

Lucas, Robert E. (1990): Supply-Side Economics: An Analytical Review, *Oxford Economic Papers*, Vol. 42, No. 2, pp. 293–316.

Lucas, Robert E. and Nancy L. Stokey (1983): Optimal Fiscal and Monetary Policy in an Economy without Capital, *Journal of Monetary Economics*, Vol. 12, pp. 55–93.

Mas-Colell, Andreu, Michael Dennis Whinston and Jerry R. Green (1995): *Microeconomic Theory*, New York NY: Oxford Univ. Press.

McGuire, Martin (1974): Group Segregation and Optimal Jurisdictions, *Journal of Political Economy*, Vol. 82, No. 1, pp. 112–132.

Milesi-Ferretti, Gian Maria and Nouriel Roubini (1994): Taxation and Endogenous Growth in Open Economies, *NBER Working Paper*, No. 4881.

Mountford, Andrew (1997): Can a Brain Drain be Good for Growth in the Source Economy?, *Journal of Development Economics*, Vol. 53, No. 2, pp. 287–303.

Oates, Wallace E. (1999): An Essay on Fiscal Federalism, *Journal of Economic Literature*, Vol. 37, pp. 1120–1149.

Oates, Wallace E. and Robert M. Schwab (1988): Economic Competition among Jurisdictions: Efficiency Enhancing or Distortion Inducing?, *Journal of Public Economics*, Vol. 35, pp. 333 – 354.

Oates, Wallace E. and Robert M. Schwab (1996): The Theory of Regulatory Federalism: The Case of Environmental Management, in: Wallace E. Oates (Ed.), *The Economics of Environmental Regulation*, Cheltenham, UK: Elgar, pp. 319 – 331.

OECD (2004): *Education at a Glance - OECD Indicators 2004*, Paris.

OECD (2006): *International Migration Outlook*, Paris.

Palokangas, Tapio (2005): Optimal Taxation with Capital Accumulation and Wage Bargaining, *University of Helsinki Discussion Paper*, No. 617:2005.

Poutvaara, Panu (2000): Education, Mobility of Labour and Tax Competition, *International Tax and Public Finance*, Vol. 7, No. 6, pp. 699–719.

Poutvaara, Panu (2001): Alternative Tax Constitutions and Risky Education in a Federation, *Regional Science and Urban Economics*, Vol. 31, No. 2-3, pp. 355–377.

Poutvaara, Panu and Vesa Kanniainen (2000): Why Invest in Your Neighbor? Social Contract on Educational Investment, *International Tax and Public Finance*, Vol. 7, No. 4-5, pp. 864–888.

Ramsey, F. P. (1927): A Contribution to the Theory of Taxation, *The Economic Journal*, Vol. 37, pp. 47–61.

Rauscher, Michael (2005): Economic Growth and Tax-Competeting Leviathans, *International Tax and Public Finance*, Vol. V12, No. 4, pp. 457–474.

Rauscher, Michael (2007): Tax Competition, Capital Mobility and Innovation in the Public Sector, *German Economic Review*, Vol. 8, No. 1, pp. 28–40.

Razin, Assaf and Efraim Sadka (1991): International Tax Competition and Gains from Tax Harmonization, *Economics Letters*, Vol. 37, pp. 69–76.

Razin, Assaf and Efraim Sadka (1995): The Status of Capital Income Taxation in the Open Economy, *FinanzArchiv*, Vol. 52, pp. 21–32.

Razin, Assaf and Chi-Wa Yuen (1996): Capital Income Taxation and Long-Run Growth: New Perspectives, *Journal of Public Economics*, Vol. 59, pp. 239–263.

Razin, Assaf and Chi-Wa Yuen (1999): Optimal International Taxation and Growth Rate Convergence: Tax Competition vs. Coordination, *International Tax and Public Finance*, Vol. 6, pp. 61–78.

Restuccia, Diego and Carlos Urrutia (2004): Intergenerational Persistence of Earnings: The Role of Early and College Education, *American Economic Review*, Vol. 94, No. 5, pp. 1354–1378.

Rubinfeld, Daniel L. (1987): The Economics of the Local Public Sector, in: Alan J. Auerbach and Martin Feldstein (Eds.), *Handbook of Public Economics*, ii Edn., Chapter 11, North Holland: Elsevier, pp. 571 – 645.

Sinn, Hans-Werner (1997): The Selection Principle and Market Failure in Systems Competition, *Journal of Public Economics*, Vol. 66, pp. 247–274.

Stark, Oded (2004): Rethinking the Brain Drain, *World Development*, Vol. 32, No. 1, pp. 15–22.

Stark, Oded, Christian Helmenstein and Alexia Prskawetz (1997): A Brain Gain with a Brain Drain, *Economics Letters*, Vol. 55, No. 2, pp. 227–234.

Stark, Oded, Christian Helmenstein and Alexia Prskawetz (1998): Human Capital Depletion, Human Capital Formation, and Migration: a Blessing or a "Curse"?, *Economics Letters*, Vol. 60, pp. 363–367.

Stark, Oded and Yong Wang (2002): Inducing Human Capital Formation: Migration as a Substitute for Subsidies, *Journal of Public Economics*, Vol. 86, No. 1, pp. 39–46.

Thum, Claudio and Silke Uebelmesser (2003): Mobility and The Role of Education as a Commitment Device, *International Tax and Public Finance*, Vol. 10, pp. 549–564.

Tiebout, Charles M. (1956): A Pure Theory of Local Expenditures, *Journal of Political Economy*, Vol. 64, pp. 416 – 426.

Turnovsky, Stephen J. (1996): Optimal Tax, Debt, and Expenditure Policies in a Growing Economy, *Journal of Public Economics*, Vol. 60, pp. 21–44.

Vidal, Jean-Pierre (1998): The Effect of Emigration on Human Capital Formation, *Journal of Population Economics*, Vol. 11, No. 4, pp. 589–600.

Wellisch, Dietmar (1995): *Dezentrale Finanzpolitik bei hoher Mobilität*, Tübingen: Mohr (Paul Siebeck).

Wellisch, Dietmar (2000): *Theory of Public Finance in a Federal State*, Cambridge: Cambridge University Press.

Wellisch, Dietmar and Wolfram F. Richter (1995): Internalizing Intergenerational Externalities by Regionalization, *Regional Science and Urban Economics*, Vol. 25, pp. 685–704.

Wildasin, David E. (2000a): Factor Mobility and Fiscal Policy in the EU: Policy Issues and Analytical Approaches, *Economic Policy*, pp. 338–378.

Wildasin, David E. (2000b): Labor-Market Integration, Investment in Risky Human Capital, and Fiscal Competition, *American Economic Review*, Vol. 90, No. 1, pp. 73–95.

Wildasin, David E. (2003): Fiscal Competition in Space and Time, *Journal of Public Economics*, Vol. 87, pp. 2571–2588.

Wildasin, David E. (2006): Global Competition for Mobile Resources: Implications for Equity, Efficiency, and Political Economy, *CESifo Economic Studies*, Vol. 52, No. 1/2006, pp. 61–110.

Wildasin, David E. and John Douglas Wilson (1996): Imperfect Mobility and Local Government Behaviour in an Overlapping-Generations Model, *Journal of Public Economics*, Vol. 60, pp. 177–198.

Wilson, John D. (1986): A Theory of Interregional Tax Competition, *Journal of Urban Economics*, Vol. 19, pp. 296 – 315.

Wilson, John D. (1996): The Tax Treatment of Imperfectly Mobile Firms: Rent-Seeking, Rent-Protection, and Rent-Destruction, in: Robert C. Feenstra (Ed.), *The Political Economy of Trade Policy*, Cambridge/Mass., pp. 225 – 244.

Wilson, John D. and David E. Wildasin (2004): Capital Tax Competition: Bane or Boon?, *Journal of Public Economics*, Vol. 88, No. 6, pp. 1065 – 1091.

Wilson, John Douglas (1999): Theories of Tax Competition, *National Tax Journal*, Vol. 52, No. 2, pp. 269–304.

Zodrow, George R. and Peter Mieszkowski (1986): Pigou, Tiebout, Property Taxation, and the Underprovision of Local Public Goods, *Journal of Urban Economics*, Vol. 19, pp. 356 – 370.

Erklärung

Ich versichere, dass ich diese Dissertation selbstständig verfasst habe. Bei der Erstellung der Arbeit habe ich mich ausschließlich der angegebenen Hilfsmittel bedient. Die Dissertation ist nicht bereits Gegenstand eines erfolgreich abgeschlossenen Promotions- oder sonstigen Prüfungsverfahrens gewesen.

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Christiane Schuppert