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Preface

“ **In teaching, there should be no distinction of classes.**”

Confucius (551 – 479 B.C.), Chinese thinker and social philosopher of the Spring and Autumn Period.

The preliminary idea of publicly available education irrespective of classes, political power or financial ability, developed by the ancient philosopher Confucius, goes far beyond a simple participation suggestion but was a fundamental part of his comprehensive philosophical understanding of human dignity. The first to reinvigorate this ancient idea of free access to education was Martin Luther in the 15th century in the course of the Reformation. In the 18th and 19th century school attendance became not only free, but even compulsory (at least nominally) throughout Europe.[1] By now, almost all countries largely agree on the idea of free access to education and enacted a human right, as proclaimed in 1966 by the United Nations General Assembly in Article 26,1 of the Universal Declaration of Human Rights (UDHR): “Everyone has the right to education. Education shall be free, at least in the elementary and fundamental stages.”[2]

However, the motives of the early Protestant Reformer for claiming free school attendance where mostly religiously inspired. The first who assumed economical implications from education was Adam Smith (1776) in his classic work *The Wealth of Nations*, where he argues that acquired skills of individuals might be a fundamental source of prosperity (he did not use the phrase ‘human capital’ yet). About 150 year later,

[1] The first compulsory schooling was implemented in the territory of the Ducal Pfalz-Zweibrücken in 1592. The first modern state-wide system was established in Prussia of Frederick the Great in 1763, followed by the implementation in Austria in 1774. One of the last areas in Europe that made attendance compulsory was England in 1880. See van Horn Melton (1988) and Sehling (2006).

[2] United Nations (1966): Article 26,1.

Alfred Marshall (1920) extended the concept to non-monetary benefits from human capital investments. However, Mincer (1958), Schultz (1961) as well as Becker (1964) were the first to study the role of education and human capital theoretically and empirically by use of modern economic methods. Their revolutionary work initiated a large body of literature measuring the returns of education, which can be categorized in the following way:[3] On the one hand *private* returns, which are only enjoyed by the educated individual and are the driving force for education demand. These benefits involve monetary and non-monetary returns to education as for instance larger wage income, better health condition or longevity. On the other hand, *social* returns as for instance accelerated economic growth, or non-market effects such as less crime or improved political stability and democratic behavior. The magnitude of these returns can be interpreted as the social desirability for public education investments (see Venniker (2001)).

The related empirical literature agrees on overwhelmingly positive effects from school education on both, the private and the social returns.[4] For instance, Psacharopoulos and Patrinos (2004) estimate private returns on investments for primary education of 13.4% on OECD average, and social returns of 8.5% (figures are similar for secondary education). This justifies the superior interest of societies to compulsorily grant a fundamental school education to every individual in order to raise individual and social welfare, which is expressed by Milton Friedman in his work *Capitalism and Freedom* as follows: "A stable and democratic society is impossible without a minimum degree of literacy and knowledge on the part of most citizens and without widespread acceptance of some common set of values. Education can contribute to both."[5]

However, the situation is quite different in the case of higher education. In contrast to the compulsory school education, admission is here optional and implicitly restricted to individuals with high ability. This is in accordance with the UDHR, merely claiming in Article 26,1 that "...higher education shall be equally accessible to all on the basis of merit."[6] But in turn, this means that a large number of individuals of a society is ex ante excluded from obtaining the related private benefits. There also exists large empirical evidence for highly positive private as well as social returns for higher ed-

[3] For an extensive categorization of benefits from education see McMahon (2006, 2009).

[4] See for instance the classical work of Mincer (1974), or for recent references Card (2001), Heckman, Lochner and Todd (2006) and Bezil (2007). See also Gunderson and Oreopoulos P. (2010) for an extensive overview.

[5] Friedman (1962): p. 86.

[6] See United Nations (1966): Article 26,1.

ucation.[7] Referring again to Psacharopoulos and Patrinos (2004), they estimate the private returns of higher education investments to 11.6% on OECD average, and the social returns to 8.5%. The latter figure clearly speaks in favor of government subsidies to the costs of higher education. Since individuals ignore these positive externalities on society, their education investments will be inefficiently low. Besides, there is an additional argument in favor of government intervention: Since individual human capital cannot be used as collateral, private market solutions fail and bright children from poor families face binding budget constraints. Hence, they are excluded from higher education, even though their participation would be efficient.[8]

These arguments have been well recognized by almost all developed countries. They subsidize higher education and finance the subsidies of general tax revenue. But due to the recent reforms on higher education (mainly initiated by the Bologna Process), a public debate has started about letting students participate to a larger extent in the true costs of higher education, since the present 'traditional tax-subsidy scheme' (TS) is identified to produce 'reverse' redistribution: poor households contribute to finance subsidies to higher education but their children are less likely to go to college compared to children from rich households.[9]

For quite a while, several economists have indicated the fact of 'reverse' redistribution of the TS system: Fernandez and Rogerson (1995) analyze a tax-subsidy scheme with fixed wages where households differ in financial endowment. They show how the rich and middle class students vote for relatively small subsidies to prevent the poor from studying in order to extract tax revenues from them (see also De Fraja (2001)). Instead, Anderberg and Balestrino (2008) argue that TS schemes may entail a regressive and a progressive element, where middle class students gain from both, the tax con-

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[7] Measuring the social returns of higher education causes serious methodological problems. For this reason, some economists as for instance Heckman and Klenow (1997) argue that the social returns might be zero, where some authors even go further and suggest negative social returns from higher education via job market signaling effects (see Spence (1973) in this context).

[8] Some economists argue that capital market failure for financing education and the absence of insurance is due to emerging moral hazard, see De Meza (2000) and Judd (2002). Besides, the importance of market failure for financing higher education is still under discussion in the empirical literature: For instance, Plug and Vijverberg (2005) find strong evidence for the relevance of capital market failure, whereas Cameron and Taber (2000), Cameron and Heckman (2001) and Carneiro and Heckman (2002) find no significant importance.

[9] The controversy about 'reverse' redistribution was initiated by Hansen and Weisbrod (1969) and Hansen (1970) who argued that subsidies for higher education might be progressive rather than regressive. Since then, a growing body of empirical literature has investigated this issue, as for instance Radner and Miller (1970) or Bishop (1977) for the US, or Grüske (1994) and Holtzmann (1994) for Germany. See also Johnson (2006) for a recent reference. Creedy (1995) provides an overview.

tributions of poor non-student as well as the high tax payments of rich students. In all these models any social returns to higher education – mainly wage spill-overs – are absent. As a consequence, all non-students strictly opt for zero financial support. In fact, in the case of proportional taxation, also the rich students vote against positive subsidies. All these model give rise for an outcome similar to the 'ends against the middle' equilibrium, introduced by Epple and Romano (1996). They study the provision of public primary and secondary education with private alternatives and find that poor and rich households may form a coalition against the middle class in favor of low public provision. Applying the Epple-Romano logic to the models above, this implies that positive subsidies within a TS system only survive in equilibrium if a highly educated middle class establishes the majority in a society. Since such a constellation is implausible for almost all developed countries, the economic models must be developed further in order to explain the persistence of the traditional financing system.

The papers investigating this puzzle rely on varying forms of the already mentioned wage spill-overs: Johnson (1984) argues that households which do not directly benefit from higher education may nevertheless opt for positive subsidies. They gain indirectly via complementarities between low-skilled and high-skilled labor in the production process. He shows that under several conditions the benefits of non-students even exceed the benefits to students. A similar effect is identified by Creedy and Francois (1990). They assume a positive enrollment-dependent externality on the growth rate of a country. But in contrast to Johnson (1984) this externality affects the wage levels of all households equally. If the enhancing effect is sufficiently strong, also non-students prefer to participate in financing higher education. A more recent work is the intergenerational approach of Bevía and Iturbe-Ormaetxe (2002). They model larger wages for individuals which obtained higher education when young. Hence, a larger number of current students raises GDP in the future and consequently tax revenues. Since they assume transfer payments to poor households to be positively correlated to the tax base, parents of children excluded from higher education have an incentive to vote for positive subsidies in order to raise today's enrollment. They anticipate the larger transfer payments to their children in the future (see also Nerlove (1972)). All these theoretical results seem to be partly confirmed by the empirical work of Johnson (2006). He finds that the distributional effects of a tax-subsidy scheme are indeed slightly progressive if including changes in households' behavior and wage adjustments.

But even though the latter theoretical contributions provide reasonable explanations for the preferred positive subsidies of non-students, another question still remains unanswered: Why does financing mainly occur via the traditional tax-subsidy scheme?

In fact, several alternative systems are well known: Among them are 'pure loan schemes' (PL), where the government makes loans available to every student. These loans have to be paid back at market interest rates (or below). While such systems eliminate credit constraints, they do not provide subsidies and insurance against the risk of failure. A system that does provide insurance are 'income contingent loans' (IC).[10] Under IC, every student is entitled a loan, where repayments are due after graduation according to an income contingent schedule. The uncovered amount from unsuccessful students must be borne by general tax revenue. This system redistributes from non-students to students, as well as from successful students to unsuccessful students, thereby providing insurance against the risk of failure.[11] The last scheme under consideration, is a 'graduate tax scheme' (GT) where every student is entitled a loan again. But different to an IC system, the total amount of provided loans must be repaid by successful students.[12] This system avoids 'reverse' redistribution, and provides extensive insurance against the risk of failure.[13]

In fact, despite the political considerations, criticism of the traditional tax-subsidy scheme has been also formulated by economists: García-Peñalosa and Wälde (2000) evaluate several financing schemes with respect to equity and efficiency targets. Considering first a TS system where subsidies are financed by lump-sum taxes, the authors find a trade-off between equity and efficiency: On the one hand, an optimal tax rate generates the efficient number of students but at the same time produces 'reverse' redistribution. On the other hand, setting a higher tax rate in order to equalize lifetime income distorts efficient human capital accumulation, since too many students are enrolled. In view of alternative financing schemes, the authors identify a GT system to

[10] The terminology IC is not yet stabilized. Chapman (2006) uses the terminology IC with risk sharing, whereas Vandenberghe and Debande (2008) denote it as risk shifting to highlight the fact that defunct loans are shifted to tax payers. Some authors such as Palacios (2004) talk of loans with income forgiveness.

[11] IC schemes have proven effectiveness in several countries as for instance Sweden, Australia, New Zealand and the UK. See Chapman (2006) for an overview.

[12] Chapman (2006) calls this type IC with risk pooling. Barr (2001) and Chapman (2006) argue that what is generally meant with GT does not necessarily balance the higher education budget. However, García-Peñalosa and Wälde (2000) refer to IC schemes with risk pooling as GT system with balanced budget. Their terminology is followed here for better comparability.

[13] There is a large body of literature discussing country-specific problems and implications of introducing IC and GT systems. For instance, Vandenberghe and Debande (2008) find for Germany, the UK and Belgium that increasing students' contributions to the costs of higher education via IC systems does not affect the private return of higher education significantly. See also Nerlove (1975) and Barr (2001, 2004) for general insights, Becker and Fenge (2005) and Wissenschaftlicher Beirat beim Bundesministerium für Finanzen (2010) for Germany, Chapman (1997, 2001, 2006) for Australia, Greenaway and Haynes (2003) for the UK or Jacobs (2002) for the Netherlands.

be most advantageous if households are risk-averse and educational success is uncertain. The efficiency-equity trade-off is then absent and insurance is provided. For an IC system, the efficiency implications are analogous. However, 'reverse' redistribution appears. An other related study is Del Rey and Racionero (2010), who abstract from equity considerations and solely focus on the efficient number of students. They also identify the TS system to be most inefficient since any insurance for students is absent. In fact, a GT system (they use the terminology IC with risk pooling) that covers both education costs and forgone earning may even induce optimal enrollment.

With these results in mind, the question must be repeated even more sharply: Why do most countries still finance the costs of higher education by a traditional tax-subsidy scheme?

This issue is analyzed in Chapter 1 by a political economics approach.[14] Households differ with respect to financial endowment and wages are endogenous. The tax and subsidy rates for each financing system are determined by majority voting. Since general equilibrium effects are involved a numerical analyses is applied to study the implications of varying parameters on the equilibrium tax and subsidy levels, as well as the support for the different systems. It turns out that preferences of households for a TS over an GT or IC system are larger when risk aversion falls (since the TS scheme does not provide insurance), the elasticity of substitution between high-skilled and low-skilled workers falls, or the income distribution becomes either more skewed, or the median and average income both rise for given skewness (since tax revenue of the TS system increases, making redistribution more efficient). Besides, even though the model reveals large 'reverse' redistribution for the tax-subsidy scheme, in particular poor non-student households favor a TS system. The reason is that the tax-subsidy scheme generates the highest low-skilled wages. This highlights the importance of including general equilibrium effects when studying the preferences of households for subsidies as well as different financing schemes.

Previous to our paper, no study has addressed voting between different financing schemes for higher education.[15] So far the only paper that has followed is Del Rey and Racionero (2011). They consider voting solely between a TS and an IC system. Individuals are heterogeneous in income and ability, but wages are fixed. Compared

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[14] The model presented in Chapter 1 is joint work with Rainald Borck.

[15] There exists a large body of literature on the political economics of financing systems for primary and secondary education. Those models mainly focus on the decision between public vs. private provision, as done for instance by Stiglitz (1974), Glomm and Ravikumar (1992) and Epple and Romano (1996). See also Borck (2008) for a more recent reference.

to the financing schemes considered in Chapter 1 (and also in Chapter 2 and 3), their systems are rather inflexible in that they do not model voting on subsidy rates and assume lump-sum taxes. They find that with rising income and ability, students tend to prefer a TS system due to larger redistribution benefits. This is a direct consequence of the exogenously given lump-sum taxes and stands in contrast to the results for proportional taxation in Chapter 1.

Note that the model presented in Chapter 1 pictures a simple one region setting. However, when looking at Germany, financing of higher education is more complex because of fiscal linkages between the federal states and the central government: The direct costs of providing higher education are largely under the authority of the federal states. The indirect costs – the costs of funding students – are traditionally subsidized by the federal BAföG system. This system is designed as means-tested support, where subsidies are financed by a general tax, similar to TS.[16]

But recently, the German Federal Constitutional Court conceded the competence of raising tuition fees to the federal states. Moving towards greater reliance on user fees is usually coupled with a loan scheme. Since this marked change in the authority of financing higher education, several German states have introduced fees at moderate levels.[17] While the theoretical literature consistently identifies efficiency enhancing effects from the implementation of tuition fees in decentralized systems (see Büttner and Schwager (2004), Schwager (2007), Hübner (2009) and Kemnitz (2010)), the aspect of financing these additional costs on the household level has been totally neglected so far. Most authors assume sufficient family income or perfect capital markets to avoid binding budget constraints for individuals. In fact, the German states have also ignored the implementation of the suggested local loan systems, and the costs for students (including also tuition fess now) are still subsidized by the federal BAföG system.

Of course, one possible explanation for this might be student and worker mobility in the context of political economics. The emerging fiscal implications and wage adjustments from migration flows determine individual preferences for regional education policy (see Chapter 3). Despite this, there might also be a purely fiscal motive for the rejection

[16] In fact, a certain proportion of the total BAföG grant is treated as full subsidy, whereas the other proportion as repayable loan. However, as already argued by Johnstone (2005), several aspects actually suggest a subsidy also for the repayable portion, as for instance a nominal interest rate of zero (actually amounting to a negative real interest rate) or additional deferments.

[17] For a general overview of the current situation in Germany concerning tuition fees see Wissenschaftlicher Beirat beim Bundesministerium für Finanzen (2010).

of regional loan schemes by the states: Conditional on an existing federal tax-subsidy system (BAföG system), individuals might gain from intra- and interregional transfers and therefore reject the local subsidy schemes, in particular if regions are heterogeneous.

This fiscal argument for the persisting federal TS system in Germany is analyzed in Chapter 2. The model considers voting on the implementation of optional regional income contingent loans, given an existing federal tax-subsidy scheme (BAföG system). Households are heterogeneous in income and decide on sending their children to college. They also vote on the subsidy rates of the federal and the regional schemes. It turns out that if the degrees of skewness of the regional income distributions are sufficiently large, purely federal financing can be indeed established as a voting equilibrium. Interestingly, heterogeneity of regions with respect to the degree of skewness is minor for the voting outcome. Furthermore, the model also explains differences in regional education policy for heterogeneous wealth: In consequence of interregional transfers from the rich to the poor region, the latter may reject the implementation of a local scheme in order to extract more tax revenue from the rich region. Then, it may happen that the federal number of students decreases with increasing federal wealth. The intuition is that the fall of the equilibrium federal subsidy through the voting dominates the enhancing effect of large income of households.

There is only a small body of literature concerned with investigating higher education policy for federations, mainly studying the effects of tuition fees on education quality for centralized and decentralized provision.[18] Kemnitz (2010) shows that the implementation of tuition fees may lead to a higher quality of education if provided decentralized. The mobility of students reduces the ability of regional governments to perfectly substitute their funding by private tuition fees. This raises total education investments. Hübner (2009) obtains similar results. He argues that under certain circumstances the quality of education increases for decentralized and centralized provision. Furthermore, the implementation of tuition fees may even increase enrollment in the decentralized case, if the regional tax base can be enlarged by attracting students from other regions. A slightly different approach is the model of Justman and Thisse (2000) who abstract from tuition fees. In contrast to Hübner (2009) and Kemnitz (2010) they assume only labor mobility, but allow for endogenous wages. They find that decentralization results in underprovision due to regional spill-overs. However, all these studies rely on student

[18] There is a large body of literature analyzing the political economics of centralized versus decentralized school financing. See for instance Fernandez and Rogerson (2003) for voting on purely public school provision and Bearse, Glomm and Ravikumar (2001), Nechyba (2003) and Borck (2008) for voting with private alternatives to public schools.

and labor mobility, but do not account for fiscal motives.

Note that the models presented in Chapter 1 and 2 totally prohibit the just mentioned mobility of students and workers. For a long time this had been a realistic scenario since migration of individuals between countries was minor. But when looking at the targets of the Bologna Process, this is supposed to change since increasing the mobility of students and graduates between the participating countries is a major objective.[19] The first to introduce mobility in the analysis of (higher) education were Grubel and Scott (1966) and Bhagwati and Hamada (1974), who investigate 'brain drain' in the context of labor mobility. In their spirit, Justman and Thisse (1997, 2000) find underprovision of publicly provided education. In contrast, Del Rey (2001) models mobile students which return to their country of origin after graduation. However, she obtains a similar result, since regions may face the incentive to free ride on the provision of education of the other region.[20] There are several models assuming mobility of students and workers: For instance, Lange (2009) shows that in this case public provision of education might be also inefficiently high, since regions want to attract mobile students.[21] To sum up, the results of all these models mainly base on the interaction of the following two effect: On the one hand, regions want to free ride on the education provision of the other region, in particular if the return probability of exchange students is sufficiently high. On the other hand, regions want to attract foreign students and provide extensively large education quality. This strategy is optimal if the stay rate of graduates is sufficiently high.

These two motives can be also found in the model presented in Chapter 3, where voting on regional subsidies of TS schemes is studied for mobile students and workers.[22] Households differ in income and ability. Students decide where to obtain education, but return home after graduation with an exogenous probability. In addition to the two described motives, households also include the migration effects on the endogenous wages. The voting process reveals a strong attraction effect since positive subsidies emerge for a large range of stay rates. Only for small rates a coalition of non-students

[19] For a theoretical model analyzing the policy targets of the Bologna Process see Mechtenberg and Strausz (2008). They find a trade-off between the two policy goals, the development of students' multicultural skills and the increase of the quality of education, where the quality might be either inefficiently high or inefficiently low, depending on student mobility.

[20] In this context, see also Stark, Helmenstein and Prskawetz (1997), Beine, Docquier and Rapoport (2001), Stark and Wang (2002) and Poutvaara (2004, 2008) for additional private investment in education.

[21] See also Demange, Fenge and Übelmesser (2008) who provide a general equilibrium model including student and labor mobility.

[22] The model presented in Chapter 3 is joint work with Silke Übelmesser and Rainald Borck.

and rich students votes against positive financial support. Hence, the model reveals that pure fee financing does not seem to be a voting equilibrium if regions are more integrated as targeted by the Bologna Process.

There are some studies which address mobility in combination with subsidies to higher education: Poutvaara (2004) analyses the incentive for governments to invest in internationally applicable education when graduates are mobile. He finds that a graduate tax system (he considers the original form of a graduate tax scheme, where tax revenues are not related to subsidy payments) is welfare improving compared to a traditional tax-subsidy scheme since governments provide more internationally applicable education. Gérard (2007) analyses optimal funding of exchange students, and finds that moving away from a system where the costs are financed by the host country (which is typical for a tax-subsidy system) to a system where education is supported by the country of origin is a Pareto improvement as it reduces the underprovision of education. Both authors speak against a traditional tax-subsidy scheme in view of rising student and labor mobility. However, the results of Chapter 3 show that if student financing is determined by voting, the subsidies increase with larger mobility.

The model presented in the last Chapter 4 stands thematically apart from the preceding three ones. It analyses government admission policy with respect to foreign applicants to higher education for a varying stay rate of graduates. The government can not observe the individual ability, but only draws benefits from high types. Hence, screening the applicants is necessary. Individuals invest in education under uncertainty, since they are initially uninformed about their types but learn from observing the screening process. Besides, students return home with an exogenous probability. If so, all benefits from education are zero for the government and for the students, and their education investments are lost. It turns out that screening activity is inefficiently high for small stay rates, but inefficiently low for high stay rate. Besides, the government accepts to many applicants for low stay rates but accepts too few for high stay rates. Interestingly, the results are qualitatively equal to a scenario of perfectly informed individuals.

When taking a look at the education literature, one can see that most papers model restricted access to education for perfect information.[23] The government can observe the individual types and determine the cut-off level, and students invest in human

[23] For a classical example see Busch (2007). See also De Fraja (2001) who studies voting on the ability cut-off.

capital without facing any uncertainty.[24] However, a few studies assume imperfect information for individuals which base their actions on noisy signals coming from a screening process, as is the case in the model of Chapter 4.

Eckwert and Zilcha (2008) study the effects of different higher education financing schemes on private education investments and economic welfare. Individuals are initially uninformed about their own ability, but learn from a noisy screening signal. The individual human capital depends on individual ability and private education investments. These investments are funded by a financing system, where the income contingent character of the repayment schedule varies between the discussed types. The authors identify a financing system which pools the risks for each signal class to be most efficient. The intuition is that individuals' residual risks are optimal insured, which stimulates private education investments. In that spirit, Eckwert and Zilcha (2010) investigate the effects of a better information system on aggregate education investments, aggregate human capital and social welfare. Individual human capital depends again on ability and private education investments. These investments are financed by an income contingent loan system. They find that more precise information enhances aggregate human capital but may simultaneously reduces aggregate education investments. The better signal allows a more efficient pooling of ability risks. Subsequently, investments of high ability individuals increase and those of low ability individuals decrease. However, the effects on social welfare are ambiguous and depend on the screening technology and the relative risk aversion.

An other related study is Oshio and Yasuoka (2009). While Echwert and Zilcha (2008, 2010) discuss different financing systems for students, Oisho and Yasuoka (2009) analyze different school systems. Pupils are uncertain about their own ability but gradually update their beliefs on receiving informations from exams. Then, every pupil decides about staying in school or participate the labor market. They find that screening reduces the demand of education, since low-ability pupils become more aware of their low types. Nevertheless, they might be overeducated. In addition, the authors identify a mixed system of public and private provision to be most efficient.

However, all these models study screening as costless information for the government and individuals, which does not imply any admission restrictions for education.

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[24] See Groot and Oosterbeek (1992), Altonji (1993) and Dominitz and Makski (1996) for studies concerned with education demand under uncertainty.

In summary, the present doctoral dissertation discusses several aspects of higher education. The derived results may help to understand the real-world financing structure of higher education, and provide some new insights with respect to government immigration policy towards foreign applicants to higher education.

Chapter 1

Political Economics of Higher Education Finance

1.1 Introduction

In this paper, we study household preferences over different systems of higher education finance. Traditionally, most western democracies have subsidized higher education costs, with the subsidies financed by general tax revenue. But this 'traditional tax-subsidy scheme' (TS) has been criticized on several grounds. First, since subsidies are financed by general taxes, but children from rich families are more likely to go to college, this financing scheme may lead to 'reverse' redistribution from poor to rich.[1] Second, even with subsidies, private education choices may not be efficient. For instance, poor but able students might not be capable of affording higher education if the subsidy is too low.[2] García-Peñalosa and Wälde (2000) show that, with risk neutral students and credit constraints, it is impossible to attain efficiency and equity at the same time with the TS system.

Recently, therefore, several countries have reformed higher education finance or are considering doing so. While some countries are moving towards greater reliance on user fees, proposals are usually coupled with a form of loan scheme. Among these schemes are what are called 'pure loan schemes' (PL), where the government makes loans available to students who are credit constrained. These loans then have to be paid back at (or below) market rates. While this system eliminates credit constraints, it has the disadvantage that it does not provide insurance against the risk of failure. A typical figure is that 25% of college students do not complete graduation. Hence, studying is a gamble, and individuals who wish to go to college will demand insurance against the risk of failure. If such insurance is not available in private markets, there is a role for insurance provided through the financing system.

Systems that do provide this type of insurance are income contingent loans (IC) or graduate taxes (GT).[3] Under IC, students receive loans which have to be repaid only after graduation, with repayment schedules typically depending on income. Loans to unsuccessful students are covered by general tax revenue. Under the GT system, again only successful graduates repay their loans, but defunct loans are now financed

[1] See Johnson (2006) for a recent reference.

[2] Fernandez and Rogerson (1995) argue that rich households may keep subsidies low in order to prevent the poor from obtaining education and at the same time extract resources from the poor through general income taxation.

[3] Chapman (2006) uses the terminology IC with risk sharing for what we call IC system, and IC with risk pooling for what we term GT. In his definition, under graduate taxes, there is no connection between total taxes and the costs of education. We follow the definition by García-Peñalosa and Wälde (2000) here.

only by the graduates. Different forms of IC systems have been introduced in Sweden, Australia, New Zealand and the UK (see Chapman (2006) for an overview). Many other countries are now discussing such schemes. Chapman (2006) cites the regressivity of traditional subsidy financing as one of the reasons that led to the adoption of income contingent loans in Australia, New Zealand and the UK.

We study voting on the financing schemes just described: TS, PL, IC and GT. We assume risk-averse households that differ in income. In the first period, individuals may study or work as low-skilled workers. In the second period, successful graduates work as high-skilled, whereas unsuccessful students work as low-skilled workers. Households are risk-averse and wages are endogenous. Within each system, taxes and subsidies are determined by majority voting. We simulate the model numerically and study how changing parameters changes the support for the different systems. We find that majorities for GT or IC over TS become larger when risk aversion rises, the elasticity of substitution between high-skilled and low-skilled workers rises (although this effect may be non-monotonic) or when the income distribution becomes either less skewed, or median and average income both fall for given skewness. There are also a number of other interesting findings. For instance, we find that poor households tend to prefer traditional subsidy financing to graduate taxes or income contingent loans, which runs against the logic of the regressivity of the traditional subsidy system. The reason lies in the fact that this system leads to high low-skilled wages (see below).

The paper is related to two strands of literature. One part of the literature studies equity and efficiency of different higher education systems.[4] García-Peñalosa and Wälde (2000), for instance, argue that the TS system cannot achieve efficiency and equity at the same time. Del Rey and Racionero (2010) advocate an IC system which covers tuition and living costs to achieve efficiency. We use the same type of model as García-Peñalosa and Wälde (2000) and Del Rey and Racionero (2010), but, whereas both assume risk aversion and exogenous wages, we allow wages to be endogenously determined. This has some important effects, as already argued by Johnson (1984): for instance, the poor may benefit from the TS system, because increasing the number of students increases low-skilled wages. The same effect will also be important in analyzing the choice among systems. Also, Del Rey and Racionero (2010) focus exclusively on efficiency whereas García-Peñalosa and Wälde (2000) look at efficiency and equity. We also analyze redistributional effects, but we go beyond the analysis of García-Peñalosa and Wälde (2000) in that we compare the systems with endoge-

[4] See Barr (2004), Greenaway and Haynes (2003), Chapman (2006), García-Peñalosa and Wälde (2000) and Del Rey and Racionero (2010).

nously determined equilibrium subsidies and taxes and explicitly analyze household preferences over these systems.

There is also a relatively large body of literature on the political economy of education, though much of it focuses on primary and secondary education. For example, Epple and Romano (1996) and Stiglitz (1974) study the provision of public education with private alternatives. Epple and Romano (1996) argue that rich and poor voters may prefer low public education provision while middle-class voters want high provision. Fernandez and Rogerson (1995) study subsidies for education and show how the rich and middle class may vote for relatively low subsidies to keep the poor from studying. This results in 'reverse' redistribution. A similar finding is obtained by Anderberg and Balestrino (2008), who apply the Epple-Romano logic to subsidies to higher education with credit constraints.[5] De Fraja (2001) studies voting on higher education subsidies and finds that it may result in a (partial) 'ends against the middle' equilibrium as in Epple and Romano (1996): some low ability/low income households vote with the rich for low subsidies. None of these papers, however, explicitly determines households' preferences over different financing schemes.

Our paper proceeds as follows: The next section presents the model, and Section 1.3 describes the equilibrium. Section 1.4 presents results from a numerical simulation, with varying parameters. The last section concludes.

1.2 The Model

We start with describing the economy. Afterwards the considered financing schemes are introduced.

1.2.1 The Economy

Our model economy contains an infinite number of heterogeneous households containing one parent and one child, and we assume that all decisions are taken by the parent. We normalize the size of each generation to one. Households differ in their initial wealth ω_i, which is distributed with cumulative distribution function $G(\omega_i)$ and density $g(\omega_i)$. We assume that higher education costs are a fixed amount $e > 0$ for all households. Because of imperfect credit markets households cannot borrow against future income.

[5] Creedy and Francois (1990) also study voting on higher education expenditures. They assume that subsidizing higher education benefits non-students through an aggregate externality.

Therefore, without financial aid households that are credit constrained will be excluded from obtaining higher education.

Individuals live for two periods. Parents are assumed to be altruistic towards their children and maximize a well-behaved utility function

$$U_i = u(c_i^J + \delta c_i^O), \tag{1.1}$$

with $u' > 0 > u''$, where c_i^J is consumption of household i when the child is young and c_i^O consumption when the child is old (and parents have died), and δ is the discount factor. For simplicity, we assume that individuals care about their lifetime consumption.[6]

When their children are young, parents choose whether to let them study or work. Young workers work in a low-skilled job and earn a wage w_L. When old, the low skilled again work for wage w_L. The 'young' period consists of that period during which students obtain their education (say, 16 to 25 years), which is shorter than the working life period (say, 25 to 65). Therefore, we will assume that the young who work earn wages for a fraction $\gamma < 1$ of an entire period.

Individuals who study do not work during the first period. Successful students earn a high-skilled wage w_H in the second period, and we assume that every student is successful with probability p. With probability $(1 - p)$ a student fails and works in a low-skilled job, earning a wage w_L.

Since utility is concave in consumption, households are strictly risk-averse. This implies that financing higher education has two functions: a redistributive function and an insurance function against the risk of failure. Throughout the analysis, we assume decreasing absolute risk aversion.

Total output is given by the linearly homogeneous production function $y_t = AF(H_t, L_t)$, where H_t is the number (mass) of high-skilled and L_t the number of low-skilled workers in period t. The parameter A reflects technology. The production function satisfies $F_H, F_L > 0, F_{HH}, F_{LL} < 0$, and $F_{HL} \geq 0$, where subscripts denote partial derivatives. Since we focus on one generation from a model of endless overlapping generations, the high-skilled and low-skilled consist of young individuals of generation t, as well as the

[6] In other words, the intertemporal elasticity of substitution is infinite (see also García-Peñalosa and Wälde (2000)).This assumption can be relaxed. In fact, we have also simulated some examples where the elasticity of intertemporal substitution is equal to the inverse of the coefficient of relative risk aversion ρ, but the determination of voting equilibria becomes more complicated.

old of generation $t-1$. There are

$$H_t = pN_{t-1}$$

high-skilled in period t, where N_{t-1} denotes the successful students from the previous generation. There are

$$L_t = (1-p)N_{t-1} + (1-N_{t-1}) + (1-N_t) = 1 - H_t + 1 - N_t$$

low-skilled in period t, i.e., those of the current period who do not study, plus those who either have not studied or not studied successfully in the previous period. We assume profit maximizing firms and perfectly competitive labor markets. Therefore, workers are paid their marginal product in each period, and the wages for high-skilled and low-skilled, w_H and w_L are given by:

$$w_H = AF_H \tag{1.2}$$
$$w_L = AF_L. \tag{1.3}$$

Since $F_{HL} \geq 0$, increasing the number of high-skilled workers will reduce the high-skilled wage and increase the low-skilled wage (since the number of low-skilled falls). Likewise, increasing the number of low-skilled will decrease the low-skilled wage and increase the high-skilled wage. This is one important channel through which education finance affects household preferences.[7]

1.2.2 Financing Schemes

We analyze four different financing schemes for higher education: a pure loan scheme (PL), a traditional tax-subsidy scheme (TS), a graduate tax scheme (GT) and income contingent loans (IC).

Pure loan scheme. Consider first the PL scheme. Here, all students are eligible for a loan to cover the direct education costs e. This implies that credit constraints are

[7] A large body of literature has analyzed changes in the US wage structure. This literature shows that because of imperfect substitutability between high-skilled (college-educated) and low-skilled (non-college educated) labor, the skill premium can be explained by the relative supply of high-skilled over low-skilled labor. See, e.g., the surveys by Katz and Autor (1999) and Acemoglu and Autor (2011) who report elasticities of substitution between high-skilled and low-skilled workers in the range of 1.4 to 2.

never binding. Letting $EU(\omega_i)$ denote the expected utility of studying and $U(\omega_i)$ the (certain) utility of not studying, the endowment of the household who is just indifferent between letting its child study or not, $\hat{\omega}^{PL}$, is implicitly defined by

$$\begin{aligned}\Delta(\omega^{PL}) \equiv EU^{PL}(\hat{\omega}^{PL}) - U^{PL}(\hat{\omega}^{PL}) &= 0 \qquad (1.4)\\ \text{where } EU^{PL}(\hat{\omega}^{PL}) &= pu(\hat{\omega}^{PL} - e + \delta w_H) + (1-p)u(\hat{\omega}^{PL} - e + \delta w_L)\\ U^{PL}(\hat{\omega}^{PL}) &= u(\hat{\omega}^{PL} + (\gamma + \delta)w_L).\end{aligned}$$

We assume that the loan scheme is 'pure' in that the interest to be paid equals the market interest rate. Students pay their education costs e (they receive a loan of e in the first period and repay the loan plus interest, e/δ in the second period) and obtain a wage w_H if successful and w_L if unsuccessful in the second period.[8] Non-students obtain the wage w_L in both periods (where again first period length is a fraction γ of the second). Since all loans are repaid in period 2, government financing occurs only on paper, that is, government subsidies prepay for the loans of credit constrained students, but the government's intertemporal budget constraint always balances. Therefore, we do not explicitly model subsidies or tax payments, since in fact each student pays for her own education costs.

Since we assume decreasing absolute risk aversion, all households with endowment larger than $\hat{\omega}^{PL}$ will let their children study and all others will not.[9] The number of students under PL is then $N^{PL} = 1 - G(\hat{\omega}^{PL})$.

Traditional tax-subsidy scheme. In the TS scheme, the fraction s of the costs of studying is covered by the government. These public expenditures are financed by a proportional tax levied on the endowments of all households. In contrast to graduate tax or income contingent loan schemes, the TS scheme is financed by taxes on the *current* working generation.[10] In purely fiscal terms, this system redistributes

[8] Implicitly, we assume that even unsuccessful students will be able to repay their loans. In the benchmark simulations, this poses no problem since the low-skilled wage always exceeds the loans to be repaid including accrued interest. In the sensitivity analysis where we vary the elasticity of substitution (see Table 1.3), the low-skilled wage does fall below the repayable loan in two cases. We have also simulated the PL system by assuming that the maximum loan to be repaid cannot exceed the low-skilled wage, with defaults covered by a tax on the successful graduates. Doing so leads to relatively small changes in majorities. These results are available on request.

[9] It can be shown that under decreasing absolute risk aversion, Δ is increasing in ω (see García-Peñalosa and Wälde (2000): p.713).

[10] García-Peñalosa and Wälde (2000) analyze a quite similar set-up of education finance with lump-sum taxes but argue that a tax on current income seems like a more natural scheme. See also De Fraja (2001).

from non-students to students, since non-students pay taxes but do not directly benefit from subsidies towards higher education. However, they may benefit indirectly through higher wages (Johnson, 1984).

Households whose child goes to college obtain the following expected utility

$$EU_i^{TS} = pu((1-t^{TS})\omega_i - (1-s^{TS})e + \delta w_H) \; + \; (1-p)u((1-t^{TS})\omega_i - (1-s^{TS})e + \delta w_L), \tag{1.5}$$

where s is the subsidy rate and t the income tax rate, and the superscript TS denotes the financing scheme.

Households whose children do not pursue higher education achieve utility

$$U_i^{TS} = u((1-t^{TS})\omega_i + (\gamma + \delta)w_L). \tag{1.6}$$

To ensure a balanced budget, total tax revenue must cover subsidies to all students:

$$\left(t^{TS} - \frac{(t^{TS})^2}{2}\right)\omega^{av} \;\; = \;\; s^{TS}eN^{TS}, \tag{1.7}$$

where N^{TS} is the fraction (or number, since total population is set to one) of students and $\omega^{av} = \int_0^\infty \omega_i g(\omega_i)d\omega_i$ denotes average income. We assume that when the tax rate increases, there is a quadratic deadweight cost (perhaps because of incentive effects on labor supply). The reason for this assumption is that without such a cost, under GT all households would choose full insurance.

Households decide whether or not to let their child study by comparing EU_i^{TS} and U_i^{TS}. Then, the number of students will be determined by the endowment level $\hat{\omega}^{TS}$, where the expected utility of studying equals the utility level for a non-student, if this endowment is larger than the net costs of studying. This endowment is implicitly defined by:

$$EU_i^{TS}(\hat{\omega}^{TS}) \;\; = \;\; U_i^{TS}(\hat{\omega}^{TS}). \tag{1.8}$$

If, on the other hand, the household with income $\hat{\omega}_i^{TS}$ is credit constrained, the equilibrium number of students is given by all those with income above $\bar{\omega}^{TS}$, which is the income level that just covers net education costs:

$$\bar{\omega}^{TS} = \frac{(1-s^{TS})}{(1-t^{TS})}\, e. \tag{1.9}$$

The equilibrium number of students is then given by:

$$N^{TS} = 1 - G(\tilde{\omega}^{TS}) \quad \text{with} \quad \tilde{\omega}^{TS} = \max\{\hat{\omega}^{TS}, \bar{\omega}^{TS}\}. \tag{1.10}$$

Graduate tax scheme. Under the GT scheme, every student takes out a loan from the government in period 1. In addition, government subsidizes part of the education costs and finances these subsidies by issuing public debt. The debt is repaid in period 2 by a tax on successful graduates. Hence, this system is entirely self-financing and does not require any funding from general taxation.[11]

Consequently, the GT system redistributes from successful to unsuccessful graduates (García-Peñalosa and Wälde, 2000). It also provides insurance against the risk of failure to graduate.

The expected utility level of a household whose child studies under GT is

$$EU_i^{GT} = pu(\omega_i - e + \delta(1 - t^{GT})w_H) + (1 - p)u(\omega_i - (1 - s^{GT})e + \delta w_L), \tag{1.11}$$

whereas households with non-students realize utility

$$U_i^{GT} = u(\omega_i + (\gamma + \delta)w_L). \tag{1.12}$$

Since graduates finance the entire loans through their tax revenue – i.e. the loans they take out plus those taken out by the unsuccessful students – only the unsuccessful students are in fact subsidized.

Since the expenses for loans distributed in the first period will not be covered until graduation, i.e. the identification of lucky and unlucky students in period 2, government finances educational grants through public debt. The government budget constraint is:

$$\delta \left(t^{GT} - \frac{(t^{GT})^2}{2} \right) w_H p N^{GT} = (1 - p) N^{GT} s^{GT} e, \tag{1.13}$$

where the left side of equation (1.13) reflects discounted tax revenue. As can be seen, only successful students pN are taxed to finance the education expenditures granted in effect only to the unsuccessful students.

[11] This definition of a graduate tax follows García-Peñalosa and Wälde (2000). On the other hand, Del Rey and Racionero (2010), following the terminology of Chapman (2006), call this type income-contingent loans with risk-pooling. In the generally known graduate tax system, there is no specific link between tax revenues and the costs of higher education, but we keep the definition for reasons of comparability.

The determination of the number of students proceeds like in the TS scheme. It is given by $N^{GT} = 1 - G(\tilde{\omega}^{GT})$ with $\tilde{\omega}^{GT} = \max\{\hat{\omega}^{GT}, \bar{\omega}^{GT}\}$, where again $\hat{\omega}^{GT}$ denotes the household that is indifferent between letting its child study or not and $\bar{\omega}^{GT} = (1 - s^{GT})e$ is the household whose income just suffices to pay (net of subsidy) education costs.

Income contingent loans. Under the IC system, every student is entitled to a loan from the government in period 1, but only lucky students have to pay back their loans in period 2. The loans of unsuccessful students – who number $(1-p)N$ – are borne by the entire population via a general tax.[12] The expected utility level for a household whose child studies is

$$EU_i^{IC} = pu(\omega_i - e + \delta(1 - t^{IC})w_H) + (1-p)u(\omega_i - (1 - s^{IC})e + \delta(1 - t^{IC})w_L), \quad (1.14)$$

and if the child does not study, household utility is

$$U_i^{IC} = u(\omega_i + (\gamma + \delta(1 - t^{IC}))w_L). \quad (1.15)$$

The government budget constraint in the IC system is:

$$\delta\left(t^{IC} - \frac{(t^{IC})^2}{2}\right)(pN^{IC}w_H + (1-p)N^{IC}w_L + (1 - N^{IC})w_L) = (1-p)N^{IC}s^{IC}e. \quad (1.16)$$

The left hand side is tax revenue, which comes from three sources: lucky students pN, unlucky students $(1-p)N$ and non-students $(1-N)$. The right hand side shows public expenditure for education, which consists of the loans to the unlucky that are not funded.

Again, the equilibrium number of students is given by $N^{IC} = 1 - G(\tilde{\omega}^{IC})$ with $\tilde{\omega}^{IC} = \max\{\hat{\omega}^{IC}, \bar{\omega}^{IC}\}$, where these thresholds are defined as before.

1.3 Equilibrium

We assume that our game has the following structure: at the first stage, households decide about the financing scheme, at the second stage the equilibrium subsidy is determined within each system by majority voting. And finally, households decide

[12] Chapman (2006) and Del Rey and Racionero (2010) call this type of student support income contingent loans with risk sharing.

whether to let their child study or not at stage 3. As usual, this game is solved by backward induction.

1.3.1 Education Decision

Let us first look at the last stage. Having observed the equilibrium subsidy rates for every scheme s^k with $k \in \{TS, GT, IC, PL\}$ (the subsidy level under PL is zero by definition) and the resulting number of students $N(s^k)$, determined by the political voting process in stage 2, households decide about the education of their children. As described before, students will be all children of households whose expected utility of studying exceeds the utility of not studying and who are not credit constrained. All those who either do not want to study or cannot study because of credit constraints will work in both periods.

Since there is a continuum of households, we assume that they treat the number of students as given, but the equilibrium number of students results from the joint decisions of all households, and is given by

$$N^k = 1 - G(\max\{\bar{\omega}^k, \hat{\omega}^k\}). \tag{1.17}$$

Note that under PL, the credit constraint is irrelevant as every potential student is eligible to receive a loan. Hence, $\bar{\omega}^{PL} = 0$.

1.3.2 Equilibrium Subsidy Rates

At stage 2, the subsidy level is determined within a given education finance scheme by simple majority voting. Each household votes for her preferred subsidy rate within system $k \in \{TS, GT, IC\}$.

A household with endowment level ω_i will vote for its optimal subsidy s_i^k, which maximizes utility, subject to the relevant budget constraint. A majority voting equilibrium must satisfy the condition that there is no majority favoring a subsidy different from the equilibrium subsidy s^k.

Using the results from the previous stages, we can write the subsidy rate for any system k as $s^k(t)$, where $s^k(t)$ has to satisfy the relevant budget constraint. Likewise, wages can be written as $w_H(t), w_L(t)$, which result from substituting the equilibrium number of students, $N^k(t)$ in (1.2) and (1.3). We can then write the utility a household obtains if its child studies, $EU^k(t)$ or does not study, $U^k(t)$ as

$$
\begin{aligned}
U^k(t) &= u_n(\omega_i, (\gamma+\delta)w_L(t), t) \\
EU^k(t) &= pu_{ss}(\omega_i, \delta w_H(t), s(t), t) + (1-p)u_{sn}(\omega_i, \delta w_L(t), s(t), t),
\end{aligned}
$$

where subscripts ss, sn refer to the utility of households with successful and unsuccessful students.

Each household will in general have two different optimal tax rates, one where the child studies, and one where she does not. When the child does not study, there are two effects on household utility: the direct effect, which occurs if the household has to pay taxes in the corresponding regime (as under TS and IC), and the indirect effect on the low-skilled wage. This effect depends on how increasing taxes and subsidies changes the number of students versus non-students and hence, high-skilled and low-skilled wages.

If the child studies, there is also a direct effect of a higher tax on household utility, and additionally the effect of the higher subsidy received by students. Further, the wage effect is split in two: with probability p, the child will succeed and receive the high-skilled wage, and with probability $1-p$ she will not succeed and receive the low-skilled wage. The household will vote for whichever tax rate maximizes its utility. The voting equilibrium is then determined by the aggregation of households' preferences via majority voting. Since the determination of equilibrium tax rates can be somewhat involved, we leave its description for the several systems to the numerical simulation in the next section.

1.3.3 Equilibrium Financing Scheme

At the first stage, households vote for a financing scheme. In so doing, they take into account the resulting equilibrium subsidy rate and the equilibrium number of students. We assume pairwise voting over alternatives. The equilibrium system is then defined as that system which beats all others in pairwise voting, if such an alternative exists.

1.4 Numerical Simulation

In this section, we simulate the model numerically. We calibrate our numerical example to broadly fit the levels of relevant endogenous variables from Germany. The case of Germany is chosen because recently several German states have introduced tuition fees (at moderate levels), a marked change from the previously free higher education. Some states, however, have subsequently repealed tuition fees.

1.4.1 Specification

We use a CRRA utility function:

$$u = \frac{1}{1-\rho} c^{1-\rho} \text{ for } \rho \neq 1, \tag{1.18}$$

where ρ is the coefficient of relative risk aversion. Hence, we have constant relative and decreasing absolute risk aversion. In the benchmark simulation, we set $\rho = 2$, which seems an empirically plausible value. We also set the discount rate to $\delta = 0.85$.[13] The production function is assumed to be of the CES type:

$$y = A(\alpha H^{\beta} + (1-\alpha)L^{\beta})^{\frac{1}{\beta}} \text{ for } \beta \neq 0 \tag{1.19}$$

where A describes technological knowledge and is set to $A = 200$, α is set to 0.5, and $\sigma = 1/(1-\beta)$ is the elasticity of substitution. In the benchmark, we use $\beta = 0.3$, which corresponds to an elasticity of substitution $\sigma = 1.429$.[14]

Note that the resulting wages for high and low-skilled correspond to lifetime income. The factor $\gamma < 1$ represents the fraction of the period of study to the working life of students, and in the benchmark simulation, we set $\gamma = 0.3$. The costs of education are quoted in thousand Euros and are set to $e = 50$.[15]

The financial endowment is distributed according to a lognormal-distribution, $\ln \omega_i \sim \mathcal{N}(\mu, v)$ with $\mu = 3.8$ and $v = 0.8$. This results in average endowment $\omega^{av} = 61.559$ and median endowment $\omega^m = 44.701$, with income measured in 1,000 Euros. This distribution is a combination of the data for income distribution and wealth distribution.[16] The reason for this choice is that parents might finance their children's education out

[13] In Appendix A we show how this value of δ can be derived from discounting the payment streams of students and non-students over their entire lifespans.

[14] This value is at the lower end of the range of 1.4-2 reported for the elasticity of substitution by Katz and Autor (1999) and Acemoglu and Autor (2011). In Section 1.4.4, we report results of varying σ inter alia to 2.

[15] The value for e comes from OECD (2008): *Education at a Glance*, where Table B1.1a. shows annual expenditures on all tertiary education per student for Germany in 2005 of $ 12.446 (weighted with PPP) multiplied by 4 years duration for higher education.

[16] We take the data from Isserstedt et al. (2006): *Die wirtschaftliche und soziale Lage der Studierenden in der Bundesrepublik 2006 - 18. Sozialerhebung des Deutschen Studentenwerks.*

Table 1.1: Equilibrium values for the benchmark

	TS	**GT**	**IC**	**PL**
N	0.47	0.37	0.44	0.31
s	0.4779	0.5849	1.1042	–
t	0.2008	0.2846	0.0691	–
w_H	157.29	183.07	162.25	205.69
w_L	68.45	61.89	66.99	57.69
$(w_H - w_L)/w_L$	1.30	1.96	1.42	2.57

of current income or out of accumulated savings. Since we do not distinguish between the two, we take a combination of wealth and current income to be our measure of parental support here.

Finally, the success probability is set to $p = 0.77$, which corresponds to the proportion of beginning students who graduate with a university degree.[17]

Using these functional forms and parameters, we solve the model numerically for the equilibrium number of students within each system and then determine households' optimal policy parameters for each system. We then study how equilibrium policy parameters are determined. Results are presented in the next subsection.

1.4.2 Voting on Subsidies

We first characterize the equilibria for all four schemes, and then consider the choice between regimes in the next subsection. Table 1.1 shows the equilibrium values for the four systems, TS, GT, IC and PL, under our benchmark parameters. Note that for this specification, credit constraints are never binding in equilibrium in any financing scheme.

PL. The results for the PL system are shown in the last column of Table 1.1. Computing the value of the endowment of the household that is indifferent between studying or not studying, we find $\hat{\omega}^{PL} = 66.845$, which translates into a number of students of $N^{PL} = 0.31$. Thus, about 31% of all households choose to go to college. Previewing the results from the other systems in Table 1.1, we find that the number of students under PL is lower than under the other systems. This is not surprising, given that there are no subsidies and no insurance against failure in this system. As a result, the

[17] See again OECD (2008): *Education at a Glance*, Table A4.1.

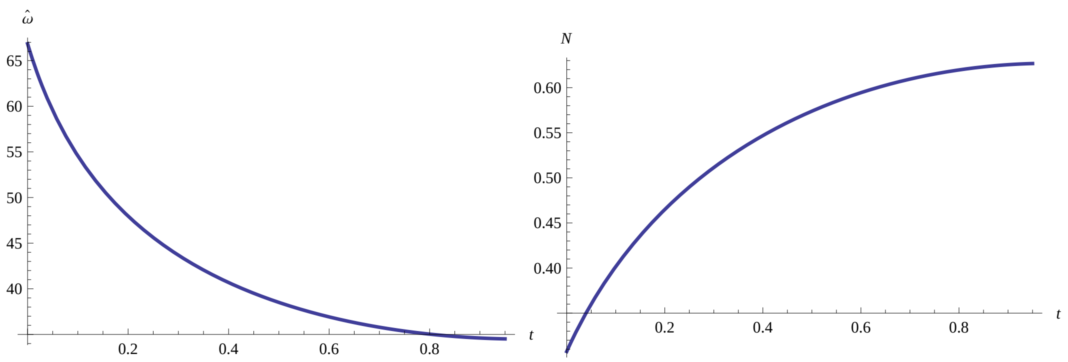

Figure 1.1: Marginal student and number of students under TS

skill premium is rather large: the high-skilled wage is $w_H = 205.69$ and the low-skilled wage $w_L = 57.69$, which gives a skill premium, $(w_H - w_L)/w_L$, of 257%.

TS. We next turn to the TS system. Here and for the other systems, we proceed as follows. Using the government budget constraint, we first compute the income of the marginal household – who is just indifferent of studying – for discretely varying tax rates. We also compute the income of the household who would just be able to finance higher education. We then calculate the number of students by taking the distribution of all households with income higher than the maximum of these two values.[18] Next, we interpolate the functions $N(t)$ and $\tilde{\omega}(t)$ relating the endogenous variables to the tax rate, which are shown in Figure 1.1.[19] We then substitute back these functions into the utility functions and determine households' optimal tax rates. The figures show that increasing the tax rate (and subsidy rate) increases the number of students. This makes intuitive sense, since subsidies increase the utility of studying relative to not studying. This implies that the endowment of the marginal household falls and the number of students rises with the tax rate.

As a result, the skill premium falls with the tax rate: Figure 1.2 shows that the high-skilled wage falls and the low-skilled wage rises with the tax rate.

Let us then analyze the determination of equilibrium taxes or subsidies. As is often the case in voting problems of this type, the equilibrium tax rate (if it exists) does not necessarily correspond to the optimal tax rate of the household with the median endowment, since preferences satisfy neither single peakedness nor single crossing. Indeed, voting under the TS system may give rise to an equilibrium similar to the 'ends against

[18] Note that for our benchmark example, under TS the credit constraint does not become binding unless the tax rate exceeds 97%.

[19] In the numerical computations, we vary the tax rate in steps of 0.001.

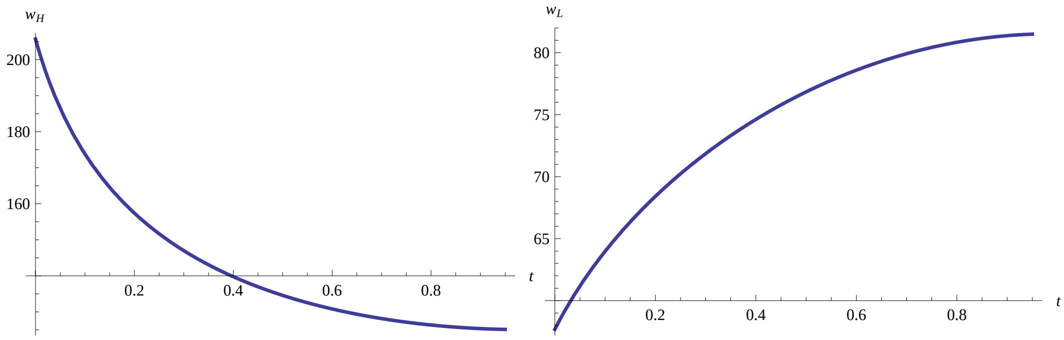

Figure 1.2: High-skilled and low-skilled wages under TS

the middle' (EATM) equilibrium introduced by Epple and Romano (1996). Intuitively, this could occur for the following reason: A household's choice of tax rate depends on whether, at a particular tax rate, the household wants its child to study or not. There are some households, which, at their preferred tax rate, do not want their child to study, and they consequently vote for a tax rate, say $t_N(\omega_i)$, which is decreasing in income. This is intuitive, since the benefit of increased low-skilled wages accrues to all households, while the financing costs increase with income. At some endowment, say, $\underline{\omega}$, the household is just indifferent between studying or not, at *its preferred tax rate*. Richer households then vote for a tax rate, say, $t_S(\omega_i)$, at which they prefer to study. Again, these tax rates are declining in income. Intuitively, this is due again to the fact that financing costs increase with income (and in addition, marginal utility is decreasing in income). But, at each income level, $t_S(\omega_i) > t_N(\omega_i)$: the optimal tax rate is higher if one were to study, because of redistribution from non-students to students. Hence, since the optimal tax rate discretely jumps upwards at $\underline{\omega}$, optimal tax rates are not monotonic in income, and the median voter theorem may not hold. Fig. 1.3 shows households' optimal tax rates computed for our numerical example.

If an equilibrium exists, the median voter might then not be the median income household. In fact, we find that the voter who is just indifferent between studying or not has endowment $\underline{\omega} = 48.697$, and this voter has an optimal tax rate conditional on studying or not of $t_N(\underline{\omega}) = 0.1642$ and $t_S(\underline{\omega}) = 0.2041$. The median income household's optimal tax rate is $t(\omega_m) = t_N(\omega_m) = 0.1976$ with $t_N(\underline{\omega}) < t_N(\omega_m) < t_N(\underline{\omega})$. Hence, more than fifty percent of households (those with endowment lower than ω_m and those with endowment in the interval $[\underline{\omega}, \overline{\omega}]$) prefer a tax rate above $t_N(\omega_m)$ (see Fig. 1.3), and, therefore, the median income household's optimal tax rate cannot be the equilibrium tax rate. The equilibrium tax rate is computed by finding two households with

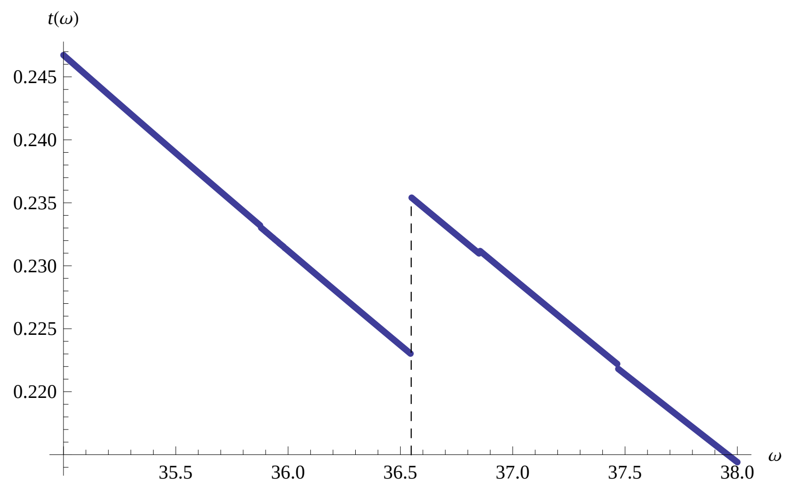

Figure 1.3: Optimal tax rates under TS

endowments ω' and $\omega'' > \omega'$ such that

$$t' = t_N(\omega') = t_S(\omega'') \quad \text{and } G(\omega') + G(\omega'') - G(\underline{\omega}) = \frac{1}{2}. \tag{1.20}$$

In other words, households ω' and ω'' have the same preferred tax rate (where ω' prefers its child not to study and ω'' does prefer its child to study), and there are fifty percent of households (those with endowment lower than ω' and those with endowments in $[\underline{\omega}, \omega'']$) who prefer a tax rate higher than t'.[20]

The corresponding subsidy rate is 47.8% and the tax rate is 20.1%. This results in a number of students $N^{TS} = 0.47$, which is actually the highest of any of the systems. The skill premium is correspondingly low: the high-skilled wage is $w_H = 157.29$, the low-skilled wage $w_L = 68.45$, and the implied skill premium is 130%.

GT. We now turn to the GT system, using the same procedure as described above. It turns out that credit constraints are not binding for any positive tax rate. Here, the functions $N(t)$ and $\hat{\omega}(t)$ are not monotonically increasing as for TS, but inversely U-shaped or U-shaped as shown in Figure 1.4. The reason can be seen as follows: let $\Delta^{GT}(\hat{\omega}^{GT}, t) \equiv EU^{GT}(\hat{\omega}^{GT}, t) - U^{GT}(\hat{\omega}^{GT}, t)$ be the utility difference between studying or not studying for the marginal household under GT. Appendix B shows that Δ^{GT} (and, hence, $\hat{\omega}^{GT}$) rises with t if $(u'_{ss} - (1-t)u'_{sn}) > 0$, which will be the case once

[20] This condition is necessary but not sufficient for an equilibrium. Therefore, one has to check that there is no other tax rate which is preferred to t' by a majority of voters Epple and Romano (1996). In our simulation, we do find that the tax rate t' cannot be beaten by any other tax rate. For our sensitivity analyses in Section 1.4.4, we generally find that the median income household is decisive.

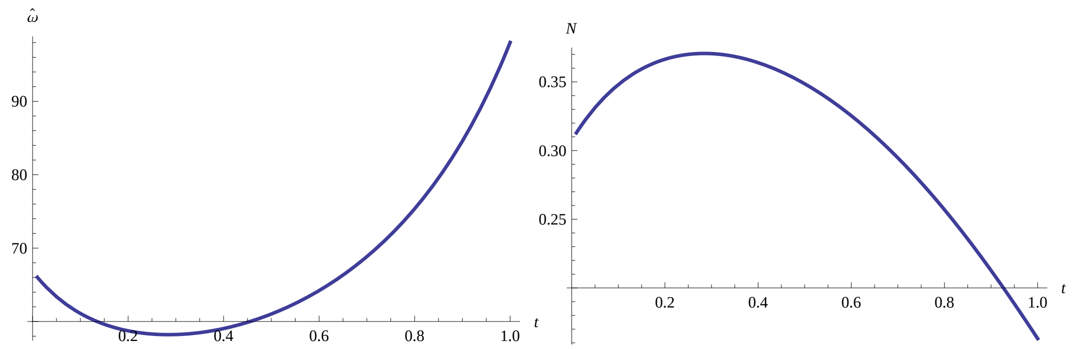

Figure 1.4: Marginal student and number of students under GT

the tax rate is high enough. Intuitively, when the tax rate is close to zero, there is no insurance so the marginal utility of the unsuccessful student is larger than the marginal utility of the successful, which implies that the income of the marginal household falls with t. When t is close to one, however, a further increase in t has a zero effect on the utility of the unsuccessful and the income of the marginal household rises with t.

Here, the pivotal voter under GT is the household with the median endowment. The preferred tax rate conditional on not studying is identical for all households at $t_N(\omega_i) = 0.2846$ (which is the tax rate that maximizes the low-skilled wage). All households with income above $\underline{\omega}^{GT}$ prefer the tax rate $t_S(\omega_i)$ which is decreasing in income. This follows because with decreasing risk aversion richer households demand less insurance against the risk of failure, and hence, the optimal subsidy rate falls with income. Further, at $\underline{\omega}^{GT}$, the optimal tax rate jumps downward: $t_S(\underline{\omega}^{GT}) < t_N(\underline{\omega}^{GT})$. Hence, optimal tax rates are monotonically decreasing in income and we find that the median income household is decisive.[21]

The equilibrium values for GT are shown again in Table 1.1. The equilibrium subsidy rate is 0.5849. The equilibrium number of students, $N^{GT} = 0.37$ is lower than under TS, which implies a higher skill premium. We find that the high-skilled wage is $w_H = 183.07$ and the low-skilled wage $w_L = 61.89$, which gives a skill premium of about 196%.

IC. Finally, we turn to the IC system. Here, too, credit constraints are not binding for any positive tax rate. As shown in Figure 1.5, both functions $N(t)$ and $\hat{\omega}(t)$ are (inversely) U-shaped. The reason is similar as described above for GT. Again, the pivotal voter is the household with median endowment. Like under GT, the optimal

[21] Again, we check for the possibility that some other tax rate may be majority preferred to the optimum of the median income household and find this is not the case.

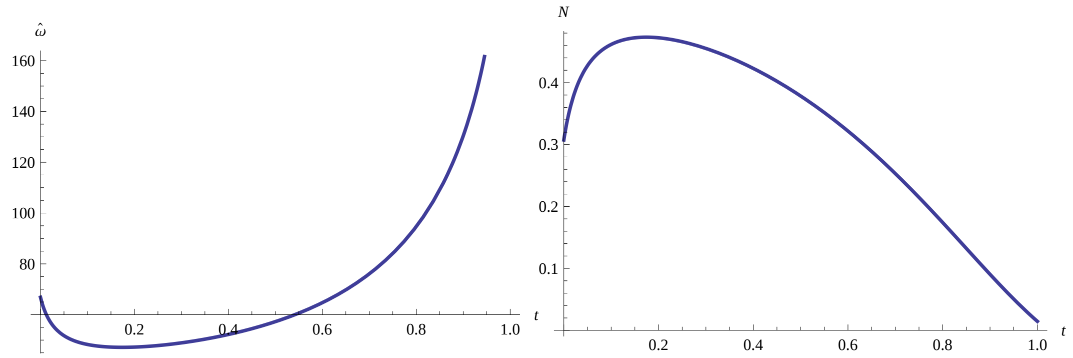

Figure 1.5: Marginal student and number of students under IC

tax rate conditional on not studying is identical for all households. Preferred tax rates $t_S(\omega_i)$ for those who prefer $t_S(\omega_i)$ to $t_N(\omega_i)$ are strictly lower than $t_N(\omega_i)$ and decreasing in income. Again, the median income household is decisive.

Table 1.1 shows the equilibrium values for IC. We find a relatively low tax rate of 7% and a subsidy rate of 110%. This is possible because the tax base includes all students and non-students, whereas under GT the tax base includes only the successful students. The number of students, $N^{IC} = 0.44$, exceeds that under GT. This can be explained by the fact that redistribution from non-students to students makes studying more attractive, despite the fact that unsuccessful students have to pay taxes under IC. However, the high subsidy rate and low tax rate more than compensate for this. We find high-skilled wages $w_H = 162.25$, low-skilled wages of $w_L = 66.99$ and a skill premium of 142%.

1.4.3 Comparison of Regimes

We now proceed to the comparison of the four financing systems by pairwise majority voting.

We start with the choice between TS and GT. Figure 1.6 plots the differences in indirect utility between GT and TS. We find that the utility difference is increasing in wealth, and that the household with endowment of 37.544 is just indifferent between GT and TS. This household's child does not study under either system. In sum, 58.63% of the voting population prefer GT over TS. Thus a majority supports GT. Interestingly, poorer households which do not study under either system tend to prefer TS over GT, even though they do not pay taxes under the GT system. However, the general equilibrium effects imply that TS makes studying attractive, which pushes up low-skilled wages. Hence, poor non-students prefer to subsidize studying through the TS system (see also Johnson (1984)). Since there are more students under TS than under GT, some households will study under TS but not under GT. It is interesting to note that these households prefer GT over TS. That is, they prefer not studying under GT to studying under TS. While studying under TS is attractive to these households, this is no longer true under GT because of the high graduate taxes and the incomplete insurance. However, because these households pay high taxes under TS and none under GT, they prefer the latter system. Finally, the rich households which study under both systems, have to relinquish the implicit subsidy from the non-students under GT. However, they still prefer the GT system since high-skilled wages are higher, and in addition the GT system provides insurance against the risk of failure.[22]

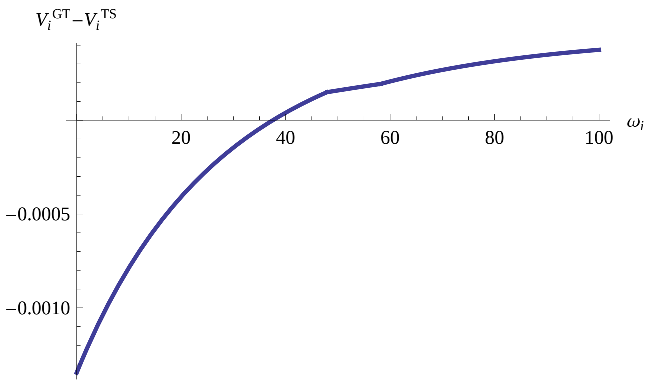

Figure 1.6: Comparison between GT and TS

Next, we look at household preferences between TS and IC, depicted in Figure 1.7. The results here parallel those of the GT-TS comparison: TS yields larger high-skilled wages. For the poor non-students, this is beneficial, even though they have to pay taxes under both the TS and IC system. For middle-income households which do not study under either system, however, IC becomes preferable because here they pay lower taxes.[23] For the rich students, again, there is the positive wage effect and the insurance effect under IC. In sum, the majority for the IC system, 72.17%, is somewhat larger than the majority for GT over TS.

These results cast some doubt on redistributional arguments for the introduction of graduate taxes or income contingent loans. In fact, if wages are endogenous and sub-

[22] With some probability, these students will receive the low-skilled wage.

[23] There is a small interval of households whose child studies under TS but not under IC. They prefer not studying under IC to studying under TS, because under TS high-skilled wages are low and the tax rate relatively high.

sidies chosen by majority voting, our results do not support the usual ‘reverse’ redistribution argument. Instead, the poor prefer the TS system against either GT or IC.

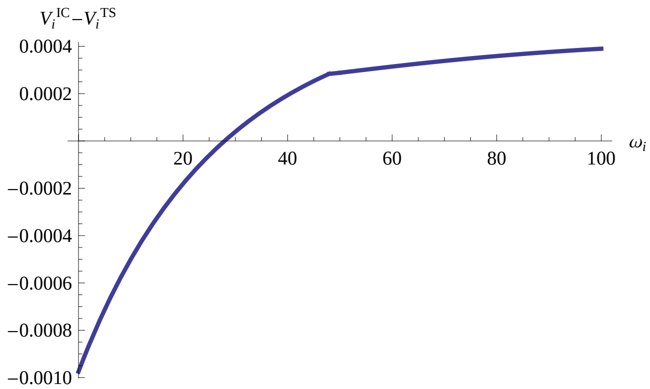

Figure 1.7: Comparison between IC and TS

The utility difference between GT and IC is shown in Figure 1.8. We find that all households with income below 118.61 prefer IC. This makes for a majority for IC over GT of 88.87%. At first sight, wealthy students might be thought to prefer IC, since there the non-students have to pay taxes. Also, the IC system provides a larger subsidy at a lower tax rate than GT. Nonetheless, rich students prefer GT because it yields larger high-skilled wages. Conversely, the poor non-students prefer IC even though they have to pay taxes. Yet the low-skilled wage is higher under IC, so the poor actually prefer this system to the GT system.[24]

The comparison between GT and IC also shows the importance of general equilibrium effects. For instance, García-Peñalosa and Wälde (2000) show that for large enough subsidy rates, a GT system would be preferable to an IC system on the grounds that it implies more insurance against risk, even though the expected income of students is higher under IC. Our example shows, however, that if subsidies are endogenously determined in the political process, the subsidy under IC can be larger than under GT. This tends to increase insurance. On the other hand, the tax on the non-successful students tends to increase the difference in income between successful and unsuccessful students. In the example, we find that IC leads to higher expected income for students but a higher variance of income. Hence, in fact there is somewhat less insurance than under GT. This insurance aspect of GT would be especially valuable for students from

[24] Again, some households study under IC but not under GT, and they prefer studying under IC to not studying under GT, even though under IC they have to pay taxes. However, the large subsidy and small tax under IC make this system attractive for these households.

middle-income families with relatively large risk aversion (since absolute risk aversion is decreasing in income).

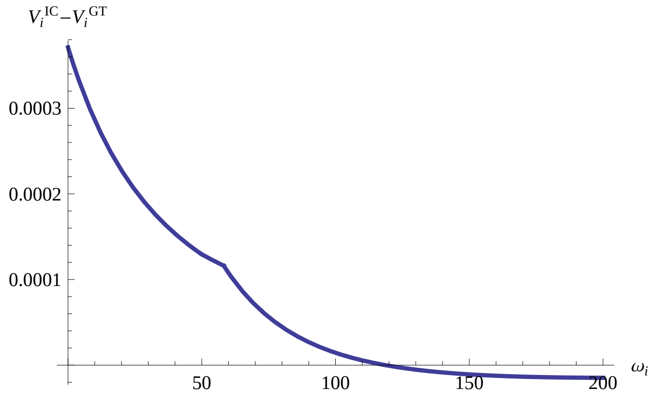

Figure 1.8: Comparison between GT and IC

Finally we analyze the preferences over the PL system against GT, IC, and TS.[25] As can be seen in Figures 1.9 and 1.10 only households with a high financial endowment vote for PL over either IC or GT. There are large majorities against PL of 81.84% for GT and 83.02% for IC. For poorer students the insurance function of IC and GT outweighs the taxes they have to pay. Very rich students, on the other hand, have a sufficiently low degree of risk aversion that they benefit from the absence of subsidies and the high-skilled wages under PL. For the poor non-students, PL is not attractive even though under this system they do not have to subsidize students. The same, of course, is true under GT, so non-students prefer the system with higher low-skilled wage, which is GT. They also prefer IC over PL, however, even though they have to pay taxes, because here the low-skilled wage under IC is even higher than under GT, and in addition the tax rate under IC is low. The majority for TS over PL is somewhat lower at 70.21%. Fig. 1.11 displays the utility difference between PL and TS. While non-students benefit from the high low-skilled wage under TS, the middle-class students benefit from redistribution from non-students and rich students under TS, even though they receive lower high-skilled wages if successful. Rich students have a preference for PL, since they have to bear the highest taxes under TS and because high-skilled wages are highest under PL. This finding again shows that the TS system may not be regressive, as argued by Johnson (1984) and others: if subsidies were abolished and students had to pay their own way, the rich, not the poor, would stand to gain.

[25] Here, as before, there are some households whose child would study under GT, TS or IC but does not study under PL.

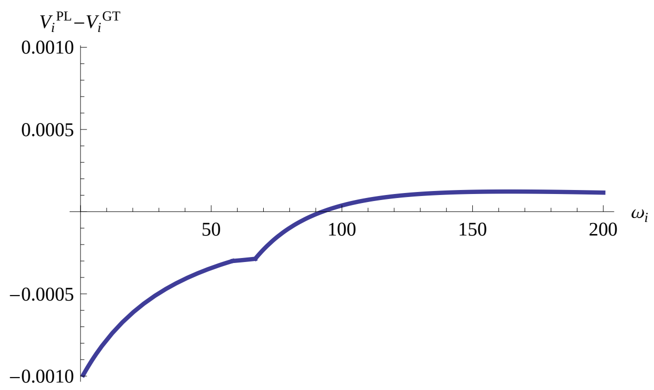

Figure 1.9: Comparison between GT and PL

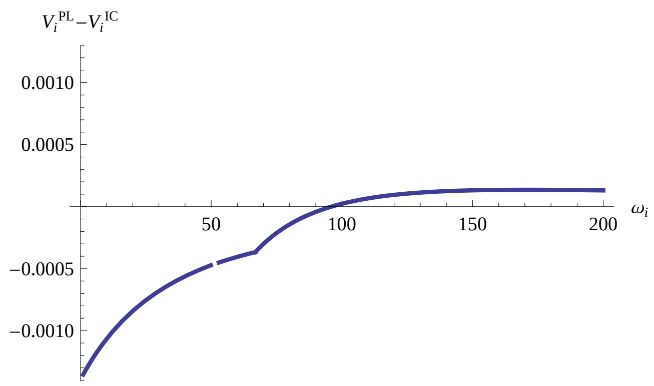

Figure 1.10: Comparison between IC and PL

In summary, in the benchmark example, IC beats all other systems and would be chosen in a pairwise majority vote among the four systems. The PL system loses against all others. In the next subsection, we explore how varying parameters changes our results.

1.4.4 Sensitivity Analysis

In this subsection, we study the effects of varying parameters on the equilibrium of our model. Here, we present variations of the coefficient of relative risk aversion, the elasticity of substitution and the parameters of the income distribution. Risk aversion is obviously important since the systems insure against the risk of failure to different degrees. The elasticity of substitution is important for how wages react to an increase in the high-skilled population. The income distribution plays a decisive role in political-economic models of redistribution with linear income taxes (see Borck (2007) for a survey).

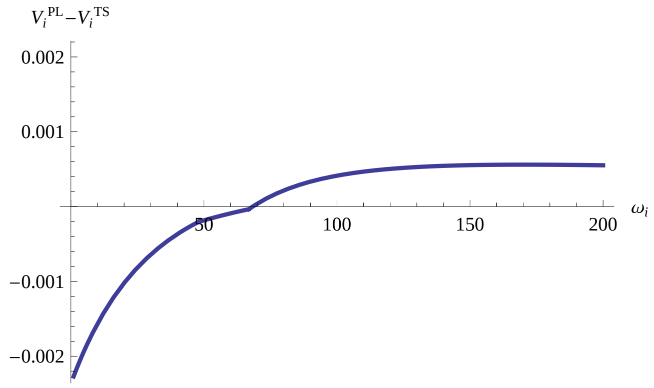

Figure 1.11: Comparison between TS and PL

First, we increase ρ from 2 to 2.5. This increased risk aversion will make studying less attractive, other things equal. In the PL system, the number of students consequently falls from 31% in the baseline case to 26%. Consequently, high-skilled wages rise and low-skilled wages fall. However, in the other systems, there will be a response through changed subsidies. Indeed, the subsidy rate increases in all systems, reflecting the increased demand for insurance. Tax rates rise as well. As a result, the equilibrium numbers of students change by relatively little (compare the first column of the upper panel of Table 1.2 with Table 1.1). The effects on the voting equilibrium are mostly relatively small as well. Support for PL against all systems decreases somewhat.

Increased risk aversion would tend to increase the demand for insurance, and one would tend to think that this increases support for those systems that provide more of it. In fact, the majority for GT over TS increases from 59% to 61% and that for IC over TS from 72% to 75%. However, the majority of IC over GT increases from 89% to 92%. This despite the fact, as mentioned above, that the variance of incomes for students is larger under IC than under GT. However, the increased risk aversion actually reduces the difference in those variances between IC and GT. In fact, as can be seen from Table 1.2, the high-skilled wage rises under GT with increasing ρ whereas it falls under IC. Therefore, the majority of IC over GT actually rises.

Next, we look at the effect of varying the parameters of the income distribution. We first decrease m to 3.7. This leaves the skewness unchanged, but decreases both mean and median income. As the table shows, the effect on the numbers of students and wages does not seem huge. However, there is a clear political effect: since the median voter gets poorer, she votes for a higher tax rate under TS. Since the average tax base has fallen, however, the subsidy rate under TS rises only very slightly. This makes

Table 1.2: Sensitivity analysis (1)

System	N	w_H	w_L	s	t	$(w_H - w_L)/w_L$
		$\rho = 2.5$				
TS	0.47	155.25	69.08	0.5638	0.2478	1.25
GT	0.36	185.34	61.42	0.6615	0.3257	2.02
IC	0.45	161.70	67.15	1.1576	0.0729	1.41
PL	0.26	228.26	54.42	–	–	3.19
		$m = 3.7$				
TS	0.46	158.51	68.08	0.4755	0.2208	1.33
GT	0.37	183.54	61.79	0.6017	0.2935	1.97
IC	0.45	162.14	67.02	1.1147	0.0699	1.42
PL	0.30	210.29	56.96	–	–	2.69
		$v = 0.9$				
TS	0.49	150.57	70.60	0.5621	0.2352	1.13
GT	0.37	182.92	61.99	0.5792	0.2815	1.95
IC	0.44	162.27	66.99	1.1025	0.0690	1.42
PL	0.31	203.68	58.02	–	–	2.51

TS less attractive. Consequently, we find that the majorities for GT and IC over TS increase to 60% and 75%.

This exercise suggests that varying the income distribution affects TS most, and the effect comes through (1) varying mean income, with constant median to mean income ratio, and (2) varying the mean to median income ratio.[26] In order to look at the second effect, we increase v to 0.9. This does not affect median endowment, but mean income rises, so the median to mean income ratio falls. Again, the results do not change dramatically in terms of the number of students and wages under the several systems. Again, however, there is an interesting political effect: since the tax base rises with higher v, the median voter now benefits more from redistribution and votes for a higher tax rate under TS. Since the average tax base has increased, this strongly increases the subsidy rate. The result is to increase support for TS. We find that the majority for GT over TS shrinks to 52% and the majority of IC over TS shrinks to 61%. Increasing v even further eventually leads to a majority for TS over GT and IC. Thus, a reform of higher education finance to a graduate tax or income contingent loans is more likely, the lower per capita income or the more equal the income distribution is.

[26] One might think that this effect is the result of our assumption that initial endowments are heterogeneous while post-education wages are not. However, we obtain similar results if we assume that second period wages have some 'inherited' component which depends on first-period endowments. In this case, under GT and IC, taxes on second-period wages redistribute from rich to poor, similarly to TS.

Table 1.3: Sensitivity analysis (2)

System	N	w_H	w_L	s	t	$(w_H - w_L)/w_L$
			$\sigma = 0.999$			
TS	0.47	229.19	122.94	0.5547	0.2414	0.86
GT	0.42	259.51	114.39	0.7049	0.2352	1.27
IC	0.46	236.29	120.78	1.3334	0.0525	0.96
PL	0.39	278.60	109.78	–	–	1.57
			$\sigma = 2$			
TS	0.32	135.85	38.86	0.2780	0.0742	2.50
GT	0.27	146.32	37.28	0.4891	0.3005	2.92
IC	0.38	125.89	40.77	0.9350	0.0756	2.09
PL	0.21	162.97	35.38	–	–	3.61
			$\sigma = 0.77$			
TS	0.45	317.78	184.96	0.5964	0.2473	0.71
GT	0.42	350.24	176.20	0.8349	0.2026	0.99
IC	0.44	323.38	183.37	1.5763	0.0417	0.76
PL	0.40	366.63	172.14	–	–	1.13

Finally, we vary the elasticity of substitution. To do this, we calibrate parameters A and α using the procedure described by Klump and de La Grandville (2000) (see Appendix C for further details). We use the same parameters for the calibration of A and α than in the previous subsection, namely $A = 200$ and $\alpha = 0.5$. We then solve the PL system for $\beta = 0.3$ and find the benchmark values of L_H^0 and L_U^0. Using these, we then calibrate α and A as described in Appendix C. The results are described in Table 1.3. We use four values of β: 0.3 (the starting value, corresponding to $\sigma = 1.429$), -0.0001 (which approximates the Cobb-Douglas case with $\sigma = 0.999$), 0.5 ($\sigma = 2$) and -0.3 ($\sigma = 0.77$).[27]

We would expect the variation of β to affect the skill premium. From (1.19), we can write the skill premium as

$$\ln\left(\frac{w_H}{w_L}\right) = \ln\left(\frac{\alpha}{1-\alpha}\right) - \frac{1}{\sigma}\ln\left(\frac{H}{L}\right). \tag{1.21}$$

If $H > L$, increasing σ increases the skill premium, for given share of the high-skilled, and conversely, when $H < L$, increasing σ reduces the skill premium. Second, increasing the share of high-skilled obviously decreases the skill premium, but less so the larger is the elasticity of substitution. In fact, what we find is that the combined

[27] According to Katz and Autor (1999) and Acemoglu and Autor (2011), most studies find values of σ between 1.4 and 2. We include the smaller values mainly for completeness.

effect is that in all systems, fewer families will send their children to university when σ increases, which increases the equilibrium skill premium.

The results of our exercise are shown in Table 1.3. For instance, in the TS system, the skill premium falls from 130% to 86% and 71% as β decreases from 0.3 to -0.0001, -0.3, but increases to 250% as β rises to 0.5. The same is true in the other systems. The change in skill premium is most pronounced in the TS system. For instance, increasing β from 0.3 to 0.5 increases the skill premium by about 92% in the TS system, while the increase is between 40% and 49% for the other systems. There are also effects on the tax and subsidy rates. As β increases, the tax and subsidy rate decreases under TS. For GT and IC, the subsidy rate falls and the tax rate rises if β increases. Thus, IC and GT should become less attractive with rising β on the account of increasing taxes and falling subsidies. However, the relatively minor fall in the skill premium should make them more attractive to students.

And lastly, the majority for or against one of the systems also depends on the identity of the decisive voter and the marginal voter, i.e. the household that is just indifferent between the two systems. The decisive voter does not study under any system and any elasticity of substitution discussed. The marginal voter for the choice between IC and GT is always a household with a child that studies. We find that increasing β monotonically increases support for GT over IC, as the marginal voter is made better off. For the choice between GT and TS, however, the marginal voter is a household whose child is not studying under any value of β. Going successively from $\beta = -0.3$ to $\beta = -0.0001$, the majority for GT decreases slightly from 54.68% to 54.65%, then going to $\beta = 0.3$ and 0.5 the majority increases to 58.63% and finally to 77.46%. The reason for the non-monotonicity is that at $\beta = 0.3$, the decisive voter under TS is not the median income household. A similar pattern holds for the comparison between IC and TS. The majorities between IC or GT and PL are extreme except for $\beta = 0.3$: for $\beta = -0.3$ or $\beta = -0.0001$, all households prefer GT or IC over PL, while conversely for $\beta = 0.5$ everyone prefers PL. In summary, the effects of varying the elasticity of substitution are relatively complex and may be non-monotonic.

1.5 Conclusion

We have studied the political determination of higher education finance. In particular, our interest was to analyze what factors might contribute towards reforming higher education finance from a traditional tax-subsidy scheme to income contingent loan schemes (also called income contingent loans with risk sharing) or graduate taxes (viz. income contingent loans with risk pooling). Because we have allowed for endogenous wage determination, general equilibrium feedback effects are present, which implies that comparative statics are mostly non-trivial. Nonetheless, under our assumptions, we find that majorities for GT or IC become larger when risk aversion rises, the elasticity of substitution rises (although this effect may be non-monotonic) or when the income distribution becomes less skewed, or median income falls for given skewness. In principle, one could test whether societies with different degrees of inequality or risk aversion, or different production technologies, have differing propensities to choose one or the other financing system.

There are some possible extensions of the model that come to mind. For one thing, we have assumed that the elasticity of intertemporal substitution is infinite. It may be desirable to relax this assumption. A straightforward way to do this would be to assume a separable intertemporal utility function with the elasticity of intertemporal substitution being the inverse of the coefficient of risk aversion. We have actually computed examples with this specification, but do not report them here, since the determination of voting equilibria gets even more complex. Another way forward would be to allow for heterogeneous abilities see Del Rey and Racionero (2010). Doing this would be relatively straightforward, but combining income and ability heterogeneity would again complicate the determination of voting equilibria. Another interesting extension would be to allow for the possibility of moral hazard especially in the GT system. Individuals may not have the proper incentive to study successfully if they know that they will not have to repay their loans. This would reduce the incentives to vote for higher subsidies and would obviously affect the voting equilibrium.[28] Finally, an interesting question that we plan to pursue in future work is what happens if different countries choose different financing regimes, with students and possibly workers selecting into countries based on their preferences.

[28] See Nerlove (1975). Chapman (2006) argues that the moral hazard problem is less pronounced with income contingent loans (what he calls IC with risk sharing).

Appendix

A The value of δ

The parameter γ captures the length of the first period (studying for students, working for non-students) relative to the length of the second period (working for both). Taking additionally the discount factor δ into account, the multiplier for generating lifetime income for uneducated workers amounts to $q_n = \gamma + \delta$. Relating this to the multiplier for educated workers, $q_s = \delta$, reveals the ratio $\frac{q_n}{q_s} = \frac{\gamma+\delta}{\delta}$. Applying the values of the numerical simulation with $\gamma = 0.3$ and $\delta = 0.85$ then results in $\frac{q_n}{q_s} = 1.35$. This ratio is almost identical to a more realistic calculation via annuity value factors with payments in arrear. The particular formula for non-students is $\tilde{q}_n = \frac{(1+r)^T-1}{r(1+r)^T}$, where r denotes the market interest rate and T the total years of working life from entering the labor market until retirement. Instead, the annuity value factor for students modifies to $\tilde{q}_s = \frac{1}{(1+r)^{T_e}} \frac{(1+r)^{T_s}-1}{r(1+r)^{T_s}}$ with $T_s = T - T_e$ and T_e is the length of the study period. Note that the number of wage payments is now reduced by the years of higher education. Therefore, the present value must be additionally discounted by this period. Considering a realistic scenario with average labor market participation by the age of 20, retirement by the age of 60, duration of studies of 5 years and an interest rate of 5% leads to $\tilde{q}_n = 17.159$ and $\tilde{q}_s = 12.830$, which results in $\frac{\tilde{q}_n}{\tilde{q}_s} = 1.34$.

B Derivation of $d\hat{\omega}^{GT}/dt$

The income of the indifferent voter $\hat{\omega}^{GT}$ is implicitly defined by

$$\begin{aligned}\Delta^{GT}(\hat{\omega}^{GT}, t) =& EU^{GT}(\hat{\omega}^{GT}, t) - U^{GT}(\hat{\omega}^{GT}, t) = pu(\hat{\omega}^{GT} - e + \delta(1-t)w_H) \\ &+ (1-p)u\left(\hat{\omega}^{GT} - e + \delta\left(t - \frac{t^2}{2}\right)pw_H + \delta w_L\right) \\ &- u(\hat{\omega}^{GT} + \delta w_L + (\gamma+\delta)w_L) = 0,\end{aligned} \tag{1.B.1}$$

use having been made of (1.13). Differentiating (1.B.1) gives

$$d\hat{\omega}^{GT}/dt = -(d\Delta^{GT}/dt)/(d\Delta^{GT}/d\hat{\omega}^{GT}),$$

where

$$
\begin{aligned}
\frac{d\Delta^{GT}}{d\hat{\omega}^{GT}} &= pu'_{ss} + (1-p)u'_{sn} - u'_{n} &\quad (1.B.2)\\
\frac{d\Delta^{GT}}{dt} &= \delta p w_H((1-t)u'_{sn} - u'_{ss}), &\quad (1.B.3)
\end{aligned}
$$

where u'_n, u'_{ss}, u'_{sn} refer to the marginal utility of non-students, successful and unsuccessful students. Since decreasing absolute risk aversion implies that with small risk, $d\Delta^{GT}/d\hat{\omega}^{GT} > 0$, the sign of $d\hat{\omega}^{GT}/dt$ is given by sign of

$$(u'_{ss} - ((1-t)u'_{sn}). \quad (1.B.4)$$

In our CRRA example, the sign of the term in parentheses of (1.B.4) is given by the sign of

$$(y - e + \delta(1-t)w_H)^{-\rho} - 1 - t)\left(y - e + \delta\left(w_L + \frac{p}{1-p}\left(t - \frac{t^2}{2}\right)w_H\right)\right)^{-\rho}. \quad (1.B.5)$$

With $\rho > 1$, it is easy to see that the expression in (1.B.5) is negative at $t = 0$ and positive at $t = 1$. Then there must be some tax rate $\tilde{t} \in (0,1)$ where $d\hat{\omega}^{GT}/dt = 0$.

C Calibration of α and A

Our procedure follows Klump and de La Grandville (2000). Writing the production function in intensive form and the marginal rate of substitution, we have

$$
\begin{aligned}
y &= A\left(\alpha\left(\frac{L_H^0}{L_U^0}\right)^{\beta} - \alpha + 1\right)^{\frac{1}{\beta}} &\quad (1.C.1)\\
m &= \frac{(1-\alpha)(L_H^0)^{1-\beta}(L_U^0)^{\beta-1}}{\alpha} &\quad (1.C.2)
\end{aligned}
$$

This system can be solved for A and α to give:

$$
\begin{aligned}
A &= y_0\left(\frac{L_U^0 m_0 (L_H^0)^{\beta} + L_H^0 (L_U^0)^{\beta}\left(\frac{L_H^0}{L_U^0}\right)^{\beta}}{L_U^0 m_0 (L_H^0)^{\beta} + L_H^0 (L_U^0)^{\beta}}\right)^{-1/\beta} &\quad (1.C.3)\\
\alpha &= \frac{L_H^0 (L_U^0)^{\beta}}{L_U^0 m_0 (L_H^0)^{\beta} + L_H^0 (L_U^0)^{\beta}}, &\quad (1.C.4)
\end{aligned}
$$

which are functions of L_H^0, L_U^0, y_0 and m_0. Using the benchmark values for L_H^0 and L_U^0, found by solving the PL system for $A = 200, \alpha = 0.5$ (see Table 1.3), we then substitute into (1.C.1) and (1.C.2) to find y_0 and m_0. Substituting these into (1.C.3) and (1.C.4) finally gives A and α as functions of β only. For our example, we get $A(-0.3) = 396.144$, $A(-0.0001) = 298.164$, $A(0.5) = 145.132$, $\alpha(-0.3) = 0.2517$, $\alpha(-0.0001) = 0.3670$ and $\alpha(0.5) = 0.5898$.

Chapter 2

Political Economics of Student Financing in Federations

2.1 Introduction

Traditionally, developed countries subsidize students by a large number of justifications. One aspect for instance are gross social benefits which go beyond the associated increase in GDP such as a better understanding of democracy, less crime or better health conditions for individuals.[1] Besides, another argument in favor of government provided financial support are binding budget constraints for students. Since individual human capital cannot be used as collateral, private market solutions fail and bright children from poor families are excluded from higher education even though their participation would be efficient.

Therefore, most countries have implemented a 'traditional tax-subsidy scheme' (TS), where subsidies are granted to every student and financed by general taxes. These systems have two important implications: First, students' net benefit of redistribution fall with (family) income due to proportional taxation. And second, 'reverse' redistribution occurs, since poor households contribute to finance the subsidies but are less likely to go to college.[2]

Looking at Germany, financing of higher education is complex. Funding comes predominantly either from the central government or from the federal states, depending on the nature of the subsidy: The provision of higher education is mainly under the authority of the federal states and access to higher education is more or less free (apart from moderate tuition fees in some states).[3] These direct costs are financed by general taxes, similar to a traditional tax-subsidy scheme.[4] Besides, the indirect costs of higher education – the financing of students – are subsidized by the BAföG system, which is largely federal funded. It is designed as means-tested study support.[5] In fact, a certain portion of the total BAföG grant is treated as full subsidy, whereas the other propor-

[1] See for instance Davies (2002) for on overview of empirical evidence on human capital externalities, considering economic and non-economic aspects.

[2] For early empirical evidence on 'reverse' redistribution see for instance Radner and Miller (1970) and Bishop (1977) for the US, or Grüske (1994) and Holtzmann (1994). See also Johnson (2006) for a recent reference. Creedy (1995) provides an overview.

[3] According to Hetmeier et al. (2010), the states bear 87.7% of the total direct costs for providing higher education in 2009. However, the so called 'Länderfinanzausgleich' (LFA), the German financial equalization system balances fiscal heterogeneity between regions to a large extent, which makes the state-financing character debatable (see Büttner and Schwager (2004)).

[4] For further reading on the distinction of direct and indirect costs of higher education see Wissenschaftlicher Beirat beim Bundesministerium für Finanzen (2010).

[5] Note that the need-based character even intensifies the situation of falling redistribution benefits with rising income.

tion is treated as a repayable loan. However, as already argued by Johnstone (2005), several aspects actually suggest a subsidy for the repayable portion, as for instance a nominal interest rate of zero (actually amounting to a negative real interest rate) or additional deferments.[6]

Recent reforms of higher education in Germany have allocated larger fiscal autonomy to the states. Probably most important, in 2005 the German Federal Constitutional Court conceded the competence of raising tuition fees to the federal states. However, since the capital market is not able to provide the necessary funding for the reasons above, raising tuition fees is usually coupled with a government-provided loan system. Such schemes are typically 'income contingent loans' (IC), where all students obtain a credit from the government and repayments are due after graduation, contingent on individual wage income.[7] In contrast to the TS systems, the IC schemes additionally provide insurance against the risk of failure in higher education or in labor market participation.[8]

When looking at the situation in Germany, we find that several states charge tuition fees at moderate levels. But interestingly, no state has seriously considered introducing an IC system yet. Students are still subsidized by the federal BAföG system. This surprises as the implementation of IC schemes has been recommended for Germany in the literature (see for instance Becker and Fenge (2005) and Wissenschaftlicher Beirat beim Bundesministerium für Finanzen (2010)). Besides, one would expect a strong political support from non-students in favor of a greater reliance on user fees, since tax payments are usually lower under IC than under TS.

There are two possible explanations for this: One argument is based on student and worker mobility. The emerging fiscal consequences and wage adjustments from migration flows determine individual preferences for regional education policy.[9] But besides wage adjustments, there might also exist an additional channel determining households' preferences with respect to student financing: fiscal federalism. Conditional on an ex-

[6] An alternative financing form available is the 'Bildungskredit', which is known in the literature as 'pure loan scheme': every student is entitled a government provided loan and repayment falls due after graduation. However, the number of recipients is comparatively low, since subsidization or insurance against the risk of failure are absent.

[7] Varying forms of that scheme have already proven effective in many countries such as Chile, Australia, Sweden, New Zealand or the UK. See Chapman (2006) for an overview.

[8] For detailed equity and efficiency analyses of financing schemes see García-Peñelosa and Wälde (2000) and Del Rey and Racionero (2010).

[9] The impact of mobility on education policy is intensively discussed in the literature. See for instance Gérard (2007), Büttner and Schwager (2004), Demange, Fenge and Übelmesser (2008), Lange (2009) and Kemnitz (2010).

isting country-wide TS system (BAföG system), individuals might face the incentive to rely on interstate grants, in particular for asymmetric regional wealth.

Therefore, this model investigates voting on an existing federal TS system and on the implementation of regional IC schemes, where both subsidize the indirect costs of higher education. The federation consists of two regions, populated by immobile and risk-averse households which decide whether to send their children to college or not. Households differ with respect to financial endowments, where distributions may vary between regions. Regional wages for high- and low-skilled workers are endogenous.

We will see that a symmetric increase of the degrees of skewness raises the extend of the federal TS system and reduces the extent of the regional IC systems. This even results in purely federal financing for sufficiently large degrees, and purely regional financing for sufficiently low degrees. Regional heterogeneity only plays a minor role for the voting outcome. Due to interregional transfers from the more skewed region to the less skewed region, subsidies of the federal system are still equal in both regions. Considering symmetric shifts of regions' endowment distributions for constant degrees of skewness, we find that the financing mix is more or less unchanged. The constant relative wealth of the pivotal median voters prohibits large political effects. However, heterogeneity in this respect plays an important role for regional financing policies. Since the endowments of the pivotal voters differ now between regions, their redistribution benefits from the federal system fall apart. Hence, the decisive household of the poor region opts for large federal and low regional tax and subsidy rates. The decisive household of the rich region prefers the opposite financing mix. If the difference between regions is sufficiently large, a majority of households in the poor region votes against a regional IC system in order to commit on zero regional grants and enforce large federal subsidies in equilibrium. Then, the interregional transfers even result in an unilateral implementation.

This model is related to the large body of literature concerned with financing schemes for higher education. For instance, García-Peñelosa and Wälde (2000) argue that a TS system can never achieve efficiency and equity at the same time, whereas IC schemes fare better. Del Rey and Racionero (2010) also identify IC systems which cover tuition fees and living costs to be most efficient. However, even though we discuss the same financing schemes, our model focuses on political economics considerations. Several papers study voting on subsidies for higher education but focus on traditional tax-subsidy schemes: Fernandez and Rogerson (1995) show that the rich and the middle-class households may vote for small subsidies in order to prevent a large number of poor individuals from studying. This results in 'reverse' redistribution. Instead, Anderberg and Balestrino (2008) argue that TS schemes entail a regressive as well as a progressive element, where the middle-class students gain from tax contributions of poor non-student as well as high tax payments of rich students. This ends up in an 'ends against the middle' equilibrium as introduced by Epple and Romano (1996), where poor and rich households vote for small tax rates and the middle-class households opt for large tax rates (see also De Fraja (2001)). In fact, none of these papers considers voting on different financing schemes. This is done by Del Rey and Racionero (2011). They consider voting between a TS and an IC system. Individuals are heterogeneous in income and ability, but wages are fixed. Compared to the financing schemes of this model, their systems are rather inflexible in that they do not study voting on subsidy rates and assume lump-sum taxes. They find that with rising income and ability, students tend to prefer a TS system due to larger redistribution benefits. This is a direct consequence of the exogenously given lump-sum taxes and stands in contrast to the results for proportional taxation of this model. Another related paper is Borck and Wimbersky (2009), who assume heterogeneity in financial endowment and allow for endogenous wages. They apply the Epple-Romano logic and find 'reverse' redistribution: however, in their model non-students vote for positive subsidies since they benefit from the subsequently larger low-skilled wages (see also Johnson (1984) and Creedy and Francois (1990)).[10] Besides, Borck and Wimbersky (2009) find that the implementation of IC over TS is more likely when the income distribution becomes either less skewed, or median and average income both fall for given skewness. However, they do not model financing in a federation, where different forms of subsidies are simultaneously payed by different federal levels.

We proceeds as follows: The next section presents the structure of the model, and Section 2.3 describes the equilibrium. Section 2.4 presents a numerically simulation, followed by a sensitivity analysis in Section 3.5. The last section concludes.

2.2 The Model

Let us first consider the basic structure of the model, and afterwards introduce the federal TS and the optional regional IC schemes.

[10] This is partly confirmed by the empirical work of Johnson (2006), which reveals that if including changes in households' behavior and prices, the net of taxes effect from redistribution may be neutral or even slightly progressive, due to tax payments of high income households above their subsidies.

2.2.1 The Economy

We assume a federation with two equally populated regions $r \in (A, B)$, each with an infinite number of heterogeneous households, where every generation in region r is normalized to the size of one. All households consist of one parent and one child, and we assume that all decisions are taken by the parent. Households within a region differ with respect to financial endowment $\omega_{i,r}$, which is distributed with cumulative distribution function $G_r(\omega_{i,r})$ and density $g_r(\omega_{i,r})$. The distributions might vary across regions. The indirect costs of education are equal in both regions and fix for all students with $\epsilon > 0$. Note that these indirect costs do not include foregone earnings from higher education. Due to imperfect capital markets, households cannot borrow against future income and may face binding individual budget constraints. In that case, their children are excluded from higher education.

Individuals live for two periods and are immobile, hence, they always obtain education and work in their region of birth. Parents are altruistic towards their children and maximize a well-behaved utility function which is the same for all households of the federation:

$$U_{i,r} = u(c_{i,r}^J + \delta c_{i,r}^O), \tag{2.1}$$

with $u' > 0 > u''$, where $c_{i,r}^J$ is consumption of individual i from region r when young and $c_{i,r}^O$ is consumption of individual i when old, and δ is the discount factor. Note that individuals only care about lifetime consumption which implies that the intertemporal elasticity of substitution is infinite.[11]

When children are young, parents decide about their education: If they let them study, children do not earn wage income in the first period. If they work they receive the regional wage of low-skilled workers $w_{t,r}^L$. As the first period of education (say, 16 to 25 years) is much shorter than the second period of lifetime work (say, 25 to 65), low-skilled wages of non-students earned in period one are reduced by the factor $\gamma < 1$.

In period 2, non-students obtain again the wage of low-skilled workers $w_{t,r}^L$. However, students find success with probability p and earn the wage of high-skilled workers $w_{t,r}^H$, whereas with probability $(1 - p)$ they fail and receive the wage of low-skilled workers $w_{t,r}^L$.

Since utility is concave in consumption, households are strictly risk-averse. This implies two functions of financing systems: a redistributive function, and an insurance function

[11] This is a standard assumption in the literature, see for instance García-Peñelosa and Wälde (2000), Borck and Wimbersky (2009) or Del Rey and Racionero (2010, 2011).

against the risk of failure.

Regional output is produced by the following Cobb-Douglas production function:[12]

$$Y_{t,r} = \phi F(H_{t,r}, L_{t,r}) = \phi H_{t,r}^{\alpha} L_{t,r}^{1-\alpha}, \tag{2.2}$$

with $0 < \alpha < 1$, where $H_{t,r}$ is the number of high-skilled and $L_{t,r}$ is the number of low-skilled workers in period t and region r. The parameter ϕ reflects technology.

We focus on one point in time from a model of endless overlapping generations. Hence, the number of high-skilled workers in region r and period t is

$$H_{t,r} = pN_{t-1,r}, \tag{2.3}$$

where $pN_{t-1,r}$ denotes the successful students from the previous generation. The number of low-skilled workers in region r and period t sums up to

$$L_{t,r} = (1 - N_{t,r}) + (1 - p)N_{t-1,r} + (1 - N_{t-1,r}). \tag{2.4}$$

The first term depicts all non-students of the current generation. The second and third term are individuals of the previous generation who either have not studied successfully or have not studied at all. As generations are of same size in each period due to zero population growth, the time index will be neglected.

We assume profit maximizing firms and perfectly competitive labor markets for region A and B. Hence, all workers are paid their regional marginal product in each period. Note that net wage arbitrage is prevented due to immobile households, and marginal products as well as wages for high-skilled and low-skilled workers may differ between regions:

$$w_r^H = \phi \frac{\partial F(H_r, L_r)}{\partial H_r} = \phi\alpha \left(\tfrac{L_r}{H_r}\right)^{1-\alpha} \tag{2.5}$$

$$w_r^L = \phi \frac{\partial F(H_r, L_r)}{\partial L_r} = \phi(1-\alpha) \left(\tfrac{H_r}{L_r}\right)^{\alpha}. \tag{2.6}$$

Increasing the number of regional high-skilled workers decreases the local wage of high-skilled workers, but increases the local wage of low-skilled workers. Likewise, increasing

[12] There is large empirical evidence for spatially separated labor markets within political areas like countries, resulting in wage disparities between regions. See for instance Combes, Duranton and Gobillon (2008). See also Kanbur and Rapoport (2005), Südekum (2004, 2005), Südekum, Blien and Ludsteck (2006) and Epifani and Gancia (2005).

the number of regional low-skilled workers decreases the local wage of low-skilled workers, but increases the local wage of high-skilled workers.[13] These adjustments in wage levels are one channel through which households' preferences for the regional and the federal financing systems are affected.

The structure of the model is as follows: At stage 1, households decide on the implementation of a local IC systems in their regions. At stage 2, the entire population of the federation votes on the equilibrium subsidy of the federal TS system. At stage 3, households of each region simultaneously determine the equilibrium subsidies of the local IC systems. And finally at stage 4, parents decide on sending their children to college or not. As usual, this game is solved by backward induction.

2.2.2 Financing Schemes

Two financing schemes may be considered: An already existing federal tax-subsidy scheme (TS) and optional regional income contingent loans (IC).

Federal tax-subsidy scheme. The federal TS scheme pays every student a fraction z of the indirect education costs ϵ. These public expenditures are financed through a general tax f on endowments of the *current working generation of the federation*, leading to the following federal budget constraint:[14]

$$f(\omega_A^{av} + \omega_B^{av}) \; = f \; 2 \; \Omega^{av} = \; z\epsilon(N_A + N_B), \tag{2.7}$$

where $\omega_r^{av} = \int_0^\infty \omega_{i,r} g_r(\omega_{i,r}) d\omega_{i,r}$ shows the regional average endowment. Since the numbers of households are identical in both regions, we can write the federal average endowment as $\Omega^{av} = \frac{1}{2}(\omega_A^{av} + \omega_B^{av})$. The number of students in region A and B are N_A and N_B.[15] Applying equation (2.7), the individual net benefits from redistribution of

[13] There exists a large body of literature which shows that because of imperfect substitutability between high-skilled and low-skilled labor, the skill premium can be explained by the relative supply of high-skilled over low-skilled labor. See for instance the surveys of Katz and Autor (1999) or Acemoglu and Autor (2011).

[14] See García-Peñelosa and Wälde (2000) who analyze a similar set-up for a TS system in a single region frame but with lump-sum taxes. However, they argue that a tax on current income seems like a more realistic scheme. See also De Fraja (2001).

[15] Note that tax costs are not considered in this model, neither for the federal TS nor for the regional IC systems. Their implementation would complicate the model, however, does not affect the qualitatively results. For instance, Borck and Wimbersky (2009) apply tax costs for avoiding corner solution in the graduate tax system, which is not discussed here. Despite, their analysis does not consider different financing schemes paying subsidies simultaneously as is the case here.

the federal TS scheme for household i from region r with endowment $\omega_{i,r}$ amount to

$$\pi_{i,r} = z\,\epsilon \;-\; f\,\omega_{i,r} = f\left(\frac{\omega_A^{av} + \omega_B^{av}}{N_A + N_B} - \omega_{i,r}\right) = f\left(\frac{2\,\Omega^{av}}{N_A + N_B} -\; \omega_{i,r}\right), \tag{2.8}$$

where the first terms show the subsidy and the second terms denote the individual tax payments. As can be seen, the net benefits of redistribution fall in individual endowment, but rise in the federal average endowment.

In purely fiscal terms, this system is regressive since poor non-students contribute to finance subsidies to rich students but do not benefit directly via grants. However, as we will see, they benefit indirectly via larger low-skilled wages.[16]

Regional income contingent loans. In addition to the federal TS system, each region may implement an IC system. The regional government provides each local student a loan $s_r\epsilon$ in period 1, with s_r as the subsidy rate of region r. The loans only need to be paid back in period 2 by successful students pH_r, whereas unlucky students $(1-p)H_r$ are exempted from repayments. The uncovered amount must be borne by *all regional households of the same generation* via a general tax t_r levied on second period wages.[17] This generates the following regional budget constraint:

$$\delta t_r(pN_r w_r^H + (1-p)N_r w_r^L + (1-N_r)w_r^L) = (1-p)N_r s_r \epsilon. \tag{2.9}$$

The left side of equation (2.9) shows regional tax revenues, coming from three sources: successful graduates pN_r, unsuccessful graduates $(1-p)N_r$ and ex ante non-students $(1-N_r)$. The right side depicts the total amount of uncovered loans as the sum of subsidies $s_r\epsilon$ to all unlucky graduates $(1-p)N_r$. Note that regional IC subsidies are related to the total indirect education costs. Hence, they are independent of the particular federal subsidy rate. This seems like a more natural way of regional student financing than deriving regional subsidies from education costs net of federal subsidies.

Then, a household from region r with endowment $\omega_{i,r}$ obtaining higher education for

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[16] Johnson (1984) already argued that higher education may also benefit non-students via a complementarity of high-skilled and low-skilled workers in the production process. See also Creedy and Francois (1990), who find a similar result. They model a positive enrollment-dependent externality, which affects the wages of high-skilled and low-skilled workers equally.

[17] Chapman (2006) and Del Rey and Racionero (2010) call this type of student support income contingent loans with risk sharing.

its child achieves expected utility of

$$EU_{i,r} = p\, u(\omega_{i,r}(1-f) - \epsilon(1-z) + \delta w_r^H(1-t_r)) \\ + (1-p)\, u(\omega_{i,r}(1-f) - \epsilon(1-z-s_r) + \delta w_r^L(1-t_r)). \tag{2.10}$$

The utility of a household from region r with endowment $\omega_{i,r}$ not obtaining education for its child is

$$U_{i,r} = u(\omega_{i,r}(1-f) + (\gamma + \delta(1-t_r))\, w_r^L). \tag{2.11}$$

Remember that the IC system redistributes from non-students as well as successful students towards unsuccessful students, thereby providing insurance against the risk of failure.

2.3 Equilibrium

In this section, the model is solved analytically to identify the relevant effects, which are evaluated numerically in Section 2.4.

For the sake of simplicity we will only discuss the case where IC systems are implemented in both regions. However, intuition for purely federal financing or asymmetric implementation of regional schemes is identical.

2.3.1 Education Decision

When considering higher education for their children, parents are well aware of all results of the previous stages: the implementation of regional IC systems, the federal and regional tax and subsidy rates and the resulting number of students in each region.

They decide about higher education by comparing the expected utility level for studying, $EU_{i,r}$ and not studying, $U_{i,r}$. The number of students in region r is then implicitly defined by the household with endowment $\hat{\omega}_{i,r}$, which is indifferent to studying with

$$EU_{i,r}(\hat{\omega}_{i,r}) = U_{i,r}(\hat{\omega}_{i,r}). \tag{2.12}$$

However, if the indifferent household faces a binding individual borrowing constraint, the number of students in region r is defined by the household, where the endowment $\bar{\omega}_{i,r}$ net of federal taxes exactly covers the indirect costs of education net of (federal and regional) subsidies, with

$$\bar{\omega}_{i,r} = \frac{(1 - z - s_r)}{(1 - f)} \, \epsilon. \tag{2.13}$$

Note that the regional tax rate t_r does not appear in the individual budget constraint, since in an IC scheme second period wage income is taxed.[18] The equilibrium number of students in region A and B result from joint decisions of all regional households, given by

$$N_r = 1 - G_r(\tilde{\omega}_{i,r}) \quad \text{with} \quad \tilde{\omega}_{i,r} = \max\left\{\hat{\omega}_{i,r}, \bar{\omega}_{i,r}\right\}. \tag{2.14}$$

2.3.2 Equilibrium Regional Subsidy Rates

At stage three, the tax rates for the regional IC schemes are determined by simultaneous voting in each region.

Every household from region r with endowment $\omega_{i,r}$ maximizes its utility with respect to the regional tax rate t_r for given federal tax and subsidy rates, taking the regional IC budget constraint of equation (2.9) as well as the implication on enrollment rates into account.[19] This reveals households' optimal regional tax rates $t_{i,r}(\omega_{i,r}, f, z)$. The voting equilibria for each f-z combination must satisfy the condition that no regional tax rate different to the equilibrium one is preferred by a regional majority.

Let us now explain in detail the effects a household considers when deciding on its preferred regional tax rate. Using the results of the education decisions and satisfying the regional budget constraint, the subsidy rate of the IC system in region r can be rewritten as $s_r(t_r, N_r(f,z,t_r), w_r^H(N_r(f,z,t_r)), w_r^L(N_r(f,z,t_r)))$, which simplifies to $s_r(f,z,t_r)$ (see equation (2.9)). The regional number of students is equivalent to the number of recipients of IC subsidies, and the wage levels $w_r^H(f,z,t_r)$ and $w_r^L(f,z,t_r)$ are the tax base.

Now we can write the utility levels for household i from region r not sending its child

[18] For the scenario of purely federal financing in region r, the particular endowment $\bar{\omega}_{i,r}$ simplifies to $\bar{\omega}_{i,r} = \frac{(1-z)}{(1-f)} \, \epsilon$.

[19] Maximizing over tax rates is equivalent to maximizing over subsidy rates. Since the numerical analysis studies tax rates the notation is kept for clarity.

to college, $U_{i,r}$ and sending its child to college, $EU_{i,r}$ as

$$\begin{aligned} U_{i,r} &= u_n(\omega_{i,r}, f, t_r, w_r^L(f, z, t_r)) \\ EU_{i,r} &= pu_{ss}(\omega_{i,r}, f, z, t_r, w_r^H(f, z, t_r)) + (1-p)u_{sn}(\omega_{i,r}, f, z, t_r, s_r(t_r), w_r^L(f, z, t_r)), \end{aligned}$$

where subscripts ss and sn denote the utility subfunctions of a student household if being successful and unsuccessful. Differentiation with respect to t_r shows the effects a household considers when deciding on its preferred regional tax rates (as function of f and z):

$$\frac{dU_{i,r}}{dt_r} = \overbrace{\frac{\partial u_n}{\partial t_r}}^{IC\ sys.} + \overbrace{\frac{\partial u_n}{\partial w_r^L}\frac{dw_r^L}{dt_r}}^{IC\ wage} \tag{2.15}$$

$$\begin{aligned} \frac{dEU_{i,r}}{dt_r} = p&\left(\overbrace{\frac{\partial u_{ss}}{\partial t_r}}^{IC\ sys.} + \overbrace{\frac{\partial u_{ss}}{\partial w_r^H}\frac{dw_r^H}{dt_r}}^{IC\ wage}\right) \\ &+ (1-p)\left(\overbrace{\frac{\partial u_{sn}}{\partial t_r} + \frac{\partial u_{sn}}{\partial s_r}\frac{ds_r}{dt_r}}^{IC\ sys.} + \overbrace{\frac{\partial u_{sn}}{\partial w_r^L}\frac{dw_r^L}{dt_r}}^{IC\ wage}\right) \end{aligned} \tag{2.16}$$

In general, every household has two preferred tax rates, one if the child goes to college, and one if the child does not go to college. If the child does not go to college, equation (2.15) shows two different effects: The first term depicts the *IC system effect*. For non-students this effect reduces to simple tax payments, since they do not enjoy subsidies but contribute to finance the uncovered loans of unsuccessful students. The second term is the indirect *IC wage effect*, depicting adjustments of low-skilled wages. However, the sign of this second effect is a priori unclear and depends on how an increase of the regional tax rate alters the number of high- and low-skilled workers in the considered region.

If the child is sent to college, the *IC wage effect* appears again, but is split now, since students are lucky and obtain high-skilled wages with probability p, but fail and receive low-skilled wages with probability $(1-p)$. Note that the two partial *IC wage effects* are of opposite signs due to the assumed complementarity of high-skilled and low-skilled labor in the production process. Also the *IC system effect* is here more complex.

Apart from paying taxes, students also receive subsidies in case of being unsuccessful. Hence, general equilibrium effects such as adjustments of the regional enrollment rate as well as of high- and low-skilled wages are involved. Be aware that this channel is not incorporated in the subfunction for successful students u_{ss}, since they must fully repay their loans by themselves.

Remember that all these effects depend on the particular federal tax and subsidy rates.

2.3.3 Equilibrium Federal Subsidy Rate

At this stage, the entire households in the federation determine the equilibrium subsidy of the federal TS system.

A household from region r with endowment $\omega_{i,r}$ maximizes its utility with respect to the federal tax rate f, subject to the federal budget constraint of equation (2.7), taking the effects on the numbers of students and on the regional IC systems into account.

This generates households' preferred federal tax rate $f_{i,r}(\omega_{i,r})$. As before, a majority voting equilibrium must satisfy the condition that no federal tax rate different to the equilibrium one is preferred by a federal-wide majority. Inserting the equilibrium federal tax rate in the results of the previous stages reveals the equilibrium regional tax rates, the equilibrium numbers of students as well as the equilibrium high-skilled and low-skilled wages for both regions.

To see again the effects a household considers when determining its preferred federal tax rate, we rewrite the corresponding subsidy rate by use of the federal government budget constraint and all results obtained so far as $z(f, N_r(f, t_r(f)), N_q(f, t_q(f)))$, which simplifies to $z(f)$ (see equation (2.7)). The subsidy rate depends on the federal tax parameter and the number of students in region A and in region B, since their sum constitutes the number of recipients of federal grants. Hence, every household also takes the effect on the regional IC system of the other region into account. The wages levels can be written as $w_r^H(f)$ and $w_r^L(f)$.

We can now express the utility level of a household not sending its child to college, $U_{i,r}$ and sending its child to college, $EU_{i,r}$, as

$$\begin{aligned} U_{i,r} &= u_n(\omega_{i,r}, f, t_r(f), w_r^L(f)) \\ EU_{i,r} &= p\, u_{ss}(\omega_{i,r}, f, z(f), t_r(f), w_r^H(f)) + (1-p)u_{sn}(\omega_{i,r}, f, z(f), t_r(f), w_r^L(f)). \end{aligned}$$

Differentiation with respect to f reveals all effects a household considers when deciding on its preferred federal tax rate:

$$\frac{dU_{i,r}}{df} = \overbrace{\frac{\partial u_n}{\partial f}}^{TS.\ sys.} + \overbrace{\frac{\partial u_n}{\partial t_r}\frac{dt_r}{df}}^{sys.\ inter.} + \overbrace{\frac{\partial u_n}{\partial w_r^L}\frac{dw_r^L}{df}}^{TS\ wage} \tag{2.17}$$

$$\begin{aligned}\frac{dEU_{i,r}}{df} &= p\left(\overbrace{\frac{\partial u_{ss}}{\partial f} + \frac{\partial u_{ss}}{\partial z}\frac{dz}{df}}^{TS\ sys.} + \overbrace{\frac{\partial u_{ss}}{\partial t_r}\frac{dt_r}{df}}^{sys.\ inter.} + \overbrace{\frac{\partial u_{ss}}{\partial w_r^H}\frac{dw_r^H}{df}}^{TS\ wage}\right) \\ &\quad + (1-p)\left(\overbrace{\frac{\partial u_{sn}}{\partial f} + \frac{\partial u_{sn}}{\partial z}\frac{dz}{df}}^{TS\ sys.} + \overbrace{\frac{\partial u_{sn}}{\partial t_r}\frac{dt_r}{df}}^{sys.\ inter.} + \overbrace{\frac{\partial u_{sn}}{\partial w_r^L}\frac{dw_r^L}{df}}^{TS\ wage}\right).\end{aligned} \tag{2.18}$$

As before, every household has two optimal tax rates, one if the child studies and one if the child does not study. Let us begin with the effects of non-students as shown by equation (2.17): The first term depicts the *TS system effect*, which reduces to simple tax payments, since non-students do not enjoy federal subsidies. The second term introduces the *system interaction effect*, which pools all implications of a varying federal tax rate on the local IC scheme. For non-student households this effect reduces again to the simple interaction between the two tax rates, since they neither receive federal nor regional subsidies. Finally, the *TS wage effect* depicts the overall effect of an increase of the federal tax rate on low-skilled wages. This involves the direct influence through the federal system, as well as the indirect impact via adjustments of the regional IC schemes.

If the child obtains higher education, the effects are shown by equation (2.18): The *TS system effect* depicts again the federal tax payments. But in addition, it incorporates now changes of the federal subsidy rate. Note that this effect involves adjustments of the total number of students in the federation via the federal budget constraint. Hence, the effect indirectly considers variations of the local IC schemes of both regions. Besides, the *system interaction effect* covers direct and indirect effects on the regional IC schemes, and is also more complex now compared to non-student households for two reasons: First, since students receive federal subsidies, their impact on the regional IC system must be taken into account. And second, unsuccessful students additionally receive regional IC grants, which modify from variations of the federal tax and subsidy rates. Since these effects include again general equilibrium considerations, a detailed analysis is left for the numerical simulation. Finally, the *TS wage effect*, comprises here the direct impact of the federal TS system on wage levels, as well as the indirect channel via adjustments of the regional IC schemes. The effect is spread again since students are successful with probability p and receive the wage of high-skilled workers, but fail with probability $(1-p)$ and obtain the wage of low-skilled workers. Hence, the two interests are of opposite sign again.

2.3.4 Equilibrium Regional Financing Schemes

At the first stage, households vote on the implementation of regional IC systems. They solve a Nash game, taking the choice of the other region as given. The implications for the equilibrium federal and regional tax and subsidy rates as well as the equilibrium numbers of students are well known. Thus, for a given choice of the other region, a local IC system is implemented if more than 50% of all households in a region opt for it. A Nash equilibrium is reached, if both regions do not have an incentive to reverse their voting decisions as long as the other region asserts its majority choice.

2.4 Numerical Simulation

In this section the model is simulated numerically. Parameters are calibrated to approximate the levels of relevant endogenous variables of Germany most closely.[20]

2.4.1 Specification

We use the following CRRA utility function, identical for all households of the federation:

$$u = \frac{1}{1-\rho} c^{1-\rho} \quad \text{for } \rho \neq 1, \tag{2.19}$$

where ρ is the coefficient of relative risk aversion, which we set to $\rho = 2.25$.[21] Note that we have constant relative but decreasing absolute risk aversion. The discount rate

[20] The specification of parameters for the following numerical simulation is largely taken from Borck and Wimbersky (2009) for better comparability of results.

[21] This seems to be an empirically plausible value. Katz and Autor (1999) and Acemoglu and Autor (2011) report values for ρ of around 2. See also Borck and Wimbersky (2009), who apply $\rho = 2$ as benchmark, and carry out a sensitivity analysis.

is $\delta = 0.85$.[22] For the regional Cobb-Douglas production functions from Subsection 2.2.1,

$$Y_r = \phi \, H_r^{\alpha} \, L_r^{1-\alpha}, \tag{2.20}$$

we set the technological parameter to $\phi = 100$ and the parameter α to 0.5, meaning that the output elasticities of low-skilled and high-skilled labor are equal.

As mentioned before, the wage levels for high-skilled and low-skilled workers correspond to lifetime income. Hence, the factor $\gamma = 0.3$ calibrates the duration of the first period of education (and thereby the corresponding low-skilled wages) to the duration of the second period of work.

The indirect costs of studying are measured in 1,000 Euros and are set to $\epsilon = 35$.[23] Finally, the success probability is equal for all households in the federation with $p = 0.77$. This seems to correspond well to the proportion of beginning students who graduate with a university degree.[24]

2.4.2 Benchmark Results

We assume symmetric regions as benchmark, where endowments are distributed according to lognormal-distributions $\ln \omega_{i,r} \sim \mathcal{N}(\mu_r, v_r)$ with $\mu_r = 3.8$ and $v_r = 0.8$ (equal to Borck and Wimbersky (2009)). This results in regional and federal average endowments of $\omega_r^{av} = \Omega^{av} = 61.559$ and regional and federal median endowments of $\omega_r^{m} = \Omega^{m} = 44.701$, measured in 1,000 Euros. This specification represents a mix of data for income and wealth distribution for Germany, since parents might finance the education of their children out of current labor income and accumulated savings. However, we do not distinguish between these two forms and therefore use a combination for approximating parental financial support.[25] The equilibrium values are shown in Table 2.1, where *TS* denotes the reference case of purely federal financing per definition

[22] Appendix *A* explains in detail how to derive this value of δ from discounting the payment streams of students and non-students over their entire lifespans.

[23] Be aware that the value $\epsilon = 35$ is below the education costs assumed by Borck and Wimbersky (2009) with $e = 50$. However, their e involves the sum of all direct and indirect costs of higher education, whereas the ϵ of this model only covers the indirect costs. The value for ϵ is derived from Leszczensky et al. (2009): *Die wirtschaftliche und soziale Lage der Studierenden in der Bundesrepublik 2009*, where Table 7.13. shows monthly average expenditures for a 'Normalstudent' in 2009 of 757 Euros, multiplied by 12 months and 4 years of higher education amounts to 36,336 Euros. This value corresponds well to the assumed 35,000 Euros.

[24] The value for the success probability p is from OECD (2008): *Education at a Glance*, Table A4.1.

[25] The data are taken out from Leszczensky et al. (2009).

Table 2.1: Benchmark results

Scen.	TS/TS	IC/TS	IC/IC
f	0.3234	0.2614	0.0476
z	0.8771	0.7378	0.1618
N_A	0.6485	0.6420	0.5179
N_B	0.6485	0.6042	0.5179
t_A	-	0.0459	0.0905
s_A	-	0.3914	0.9427
t_B	-	-	0.0905
s_B	-	-	0.9427
w_A^H	65.32	66.09	82.41
w_A^L	38.28	37.83	30.33
w_B^H	65.32	70.72	82.41
w_B^L	38.28	35.35	30.33

in the particular region, and IC indicates optional regional systems (which nevertheless might be rejected).

Education Decision As before, the procedure for deriving the equilibrium numbers of students will be explained solely for the case of mixed financing, where IC systems are implemented in both regions. However, the approach is the same for purely federal financing or asymmetric implementation.

Applying the government budget constraint for the IC system of equation (2.9), we first compute the endowment $\hat{\omega}_{i,r}$ of the marginal households – indifferent to studying – for discretely varying the regional tax rate t_r, as well as the federal tax and subsidy parameters f and z (since the federal budget constraint is still unconsidered at this stage).[26] We also calculate the endowments of the households which are exactly able to afford higher education, $\bar{\omega}_{i,r}$. The number of students in region r for a particular f-z-t_r combination is then defined by the region-specific distribution of households that are richer than the maximum of the two thresholds $\hat{\omega}_{i,r}$ and $\bar{\omega}_{i,r}$. From these data we interpolate the functions $\tilde{\omega}_r(f, z, t_r)$ and $N_r(f, z, t_r)$, relating the endogenous variables to the corresponding regional tax rate, the federal tax rate and the federal subsidy rate.[27]

These functions are pictured in Figure 2.1, using the equilibrium values for the federal

[26] Applying the government budget constraint of the regional IC system at this stage is actually not necessary, since the functions can also be expressed here as $N_r(f, z, t_r, s_r)$ and $\tilde{\omega}_r(f, z, t_r, s_r)$.

[27] It turns out that the individual budget constraint never binds in equilibrium.

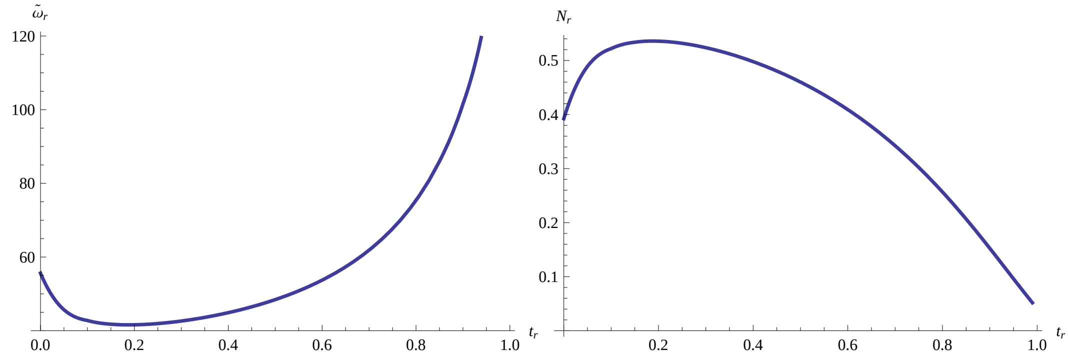

Figure 2.1: Marginal student and number of students in region r

tax and subsidy rates, $f^{IC/IC} = 0.0476$ and $z^{IC/IC} = 0.1618$ (see the right column of Table 2.1). Interestingly, the curves are U-shaped, respectively inversely U-shaped (which holds for all f-z combinations that generate a balanced budget for the federal system). The intuition is as follows: For low tax rates, the insurance of the IC schemes is almost zero, hence, the marginal utility of a student being unsuccessful is above the marginal utility of being successful. An increase of the IC tax (and subsidy) rate implies a fall of the endowment level of the marginal household, which raises the number of students. On the contrary, if the tax rate is sufficiently high, a further increase has no substantial effect on the utility level of a successful student, hence enrollment rates fall again.[28]

Equilibrium Regional Subsidy Rates At this stage the subsidy rates of the regional IC systems are determined by majority voting.

Substituting the interpolated expressions $N_r(f, z, t_r)$ in the utility functions, we can determine households' optimal regional tax rates $t_{i,r}(\omega_{i,r}, f, z)$ for all tax-subsidy combinations of the federal system. Ordering the preferences reveals that the favored tax rates strictly non-increase in endowment, conditional on a balanced federal budget. The intuition is as follows:[29] All non-student households prefer the same tax rate since the IC system taxes their equal low-skilled wages of period two. Instead, the preferred tax rate of households with children that study falls in endowment. Due to decreasing absolute risk aversion, richer households demand less insurance. Despite this, the

[28] The same functional relation between the tax rate of an IC system and the equilibrium number of students is found by Borck and Wimbersky (2009).

[29] Note that for high federal tax rates, a majority of rich households in each region favors zero tax and subsidies parameters for the IC schemes. But as we will see, these cases never constitute a voting equilibrium in this benchmark.

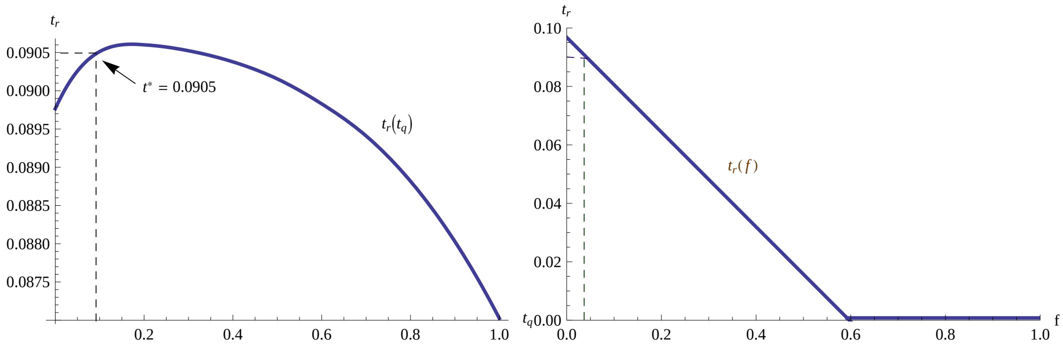

Figure 2.2: Regions' reaction functions and equilibrium regional tax rates

households with endowment $\underline{\omega}_{i,r}$, indifferent to studying conditional on *their preferred tax rates*, opt for strictly lower tax rates if obtaining education than if not obtaining education, $t_S(\underline{\omega}_{i,r}) < t_N(\underline{\omega}_{i,r})$. Hence, the existing discontinuity in preferences is an unproblematic downward jump. It follows that the households with median endowments are pivotal for voting on the tax rate of the regional IC system. We can now calculate the function $t_r(f, z)$, relating the equilibrium regional tax rates from voting to the federal tax and subsidy rates. Note that for this symmetric benchmark the functions are equal in both regions.

Equilibrium Federal Subsidy Rate At this stage the equilibrium subsidy of the federal TS system is derived, again by majority voting.

Applying the federal budget constraint of equation (2.7) modifies the functions for the equilibrium regional tax rates to $t_r(f, z(f, t_q))$, which simplify to $t_r(f, t_q)$. Inserting this in the function for the number of students reveals $N_r(f, t_r(f, t_q), t_q(f, t_r))$, which can be simplified to $N_r(f, t_r, t_q)$. As already explained, the number of students in each region is determined by the federal and both regional systems. Hence, a household in region r, deciding on its preferred federal tax rate also takes the implications on the other region's local IC system into account, since it affects enrollment there. This in turn influences the number of beneficiaries of the federal scheme, which in the end determines the federal subsidy rate.

The left panel of Figure 2.2 pictures the voting reaction function $t_r(f, t_q)$ for varying the local tax rate of the other region t_q, conditional on the equilibrium federal tax rate $f^{IC/IC} = 0.0476$ (see again the right column of Table 2.1). As can be seen, the function is inversely U-shaped for the following reason: Let us first consider the small tax rates t_q in the range to the left of the maximum. The comparison with the inversely U-shaped function for the equilibrium number of students (right panel of Figure 2.1) shows that the range corresponds to that part with the positive slope. Hence, an increase of t_q raises the number of recipients of federal grants there, and in turn reduces the federal subsidy rate ceteris paribus. However, the pivotal household of region r still sends its child to college but is poorer now in consequence of the lower federal grant. Therefore, the marginal utility of regional IC subsidies rises, causing the increases of the equilibrium regional tax rate. The intuition for the range to the right of the maximum is exactly vice versa. This part corresponds to all tax rates where the enrollment function (right panel of Figure 2.1) has a negative slope. Hence, an increase of t_q reduces here the number of recipients in region q. This fall in the number of beneficiaries raises the federal subsidy rate ceteris paribus. This makes households in region r richer and reduces their demand for the IC scheme, leading to the fall of the equilibrium tax rate t_r.

Solving the reaction functions of both regions generates the equilibrium regional tax rates from voting $t_r(f)$, solely depending on the federal tax rate. These functions represent the preferences of the pivotal households with median endowment, obtaining education for their children. As can be seen in the right panel of Figure 2.2, the preferred regional tax rates decrease in f (or are zero for sufficiently large f) for the following reason: Increasing the federal tax (and subsidy) rate makes the pivotal median households richer and thereby less risk-averse. Hence, their preferred tax rates for regional IC systems fall.

Finally, we substitute the interpolated functions for the equilibrium numbers of students and the equilibrium regional tax rates, $N_r(f)$ and $t_r(f)$, in the utility functions and determine households' optimal federal tax rates $f_i(\omega_{i,r})$. It turns out that the preferred tax rate falls in endowment for two reasons: First, a larger endowment raises tax payments due to proportional taxation, irrespective if studying or not. And second, the marginal utility from federal subsidies decreases for students. Despite, the discontinuity in preferences for the households being indifferent of studying for *their preferred tax rates*, $\underline{\omega}_{i,r}$, is again a downward jump since the preferred tax rate in the case of studying is smaller than in the case of not studying, $t_S(\underline{\omega}_r) < t_N(\underline{\omega}_r)$. This is true even though the TS system redistributes from non-students to students. Hence, the median voter theorem holds and the households with regional (here equal to federal) median endowments are pivotal. They obtain education for their children.

The equilibrium values are presented in Table 2.1. As stated in the last column, the pivotal households with median endowments prefer a financing mix, consisting of federal subsidies of $z^{IC/IC} = 0.1618$ and a corresponding tax rate of $f^{IC/IC} = 0.0476$, as well as regional grants of $s_r^{IC/IC} = 0.9427$ financed by a tax rate of $t_r^{IC/IC} = 0.0905$. The reason for the positive regional subsidies and the reduced federal system compared to purely federal financing (see the first column of Table 2.1) is as follows: First, since the pivotal households are relatively rich, they gain more from the insurance function as well as taxing of second period wages under the IC system, than from simply being richer via the federal TS subsidies and the proportional taxation. And second, poor and middle-class households in particular rely on federal grants if studying. They strongly benefit from redistribution of the TS system due to their small endowment levels. Hence, a change of the financing mix towards lower federal subsidies reduces their lifetime income and raises their risk aversion. As a consequence, sending their children to college becomes less optimal for them, and the number of students falls. This in turn raises the skill premium for students, defined as $(w_r^H - w_r^L)/w_r^L$. This finding is in accordance with the related literature, arguing that students might vote for relatively low subsidy rates to keep the poor from studying (see for instance Fernandez and Rogerson (1995) and Anderberg and Balestrino (2008)). We identify the same motive for students, but the 'lock up' effect is provoked by (partly) changing the financing mix. In fact, the total subsidy even increases here from $f^{TS/TS} = 0.8771$ to $f^{IC/IC} + s_r^{IC/IC} = 1.1045$. However, enrollment rates fall from $N_r^{TS/TS} = 0.6485$ to $N_r^{IC/IC} = 0.5179$. This increases the skill premiums from 0.71 to 1.72.

Equilibrium Regional Financing Schemes Finally, we study voting on the implementation of local IC schemes. Both regions decide for a given choice of the other region. A Nash equilibrium requires that there is no incentive for neither region to deviate unilaterally.

It turns out that if region q relies on purely federal financing, 66% of all households in region r prefer an IC system. The indifferent households have endowments of 32.05. Instead, if region q implements a regional IC scheme, a majority of 58% in region r is in favor as well. Hence, the endowments of the indifferent households are slightly higher with 38.39.

Figure 2.3 plots the differences in indirect utility between purely federal financing and mixed financing for region r, where the left panel assumes purely federal financing for region q, and the right panel mixed financing. All households with endowments to the right of the intersections with the abscissa are in favor of a regional IC system, whereas all households with endowments to the left vote against the implementation. As can be

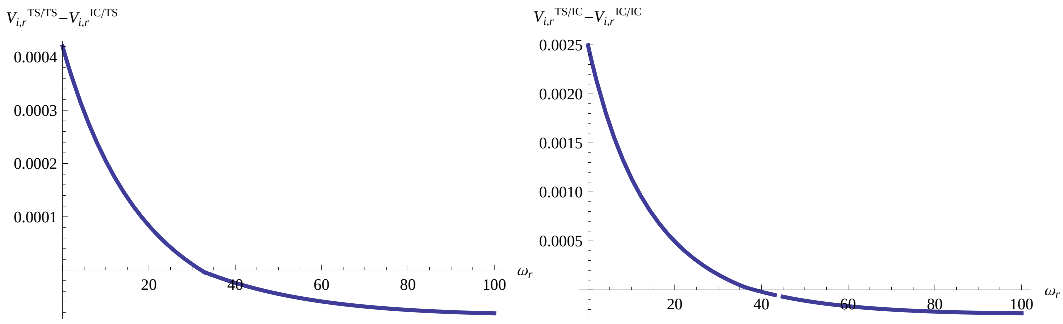

Figure 2.3: Comparison between purely federal and mixed financing

seen, rich households are strongly in favor of regional IC schemes. The implementation acts like a commitment to positive regional subsidies, which reduces the federal tax rate in equilibrium. By contrast, non-students favor purely federal financing since their tax payments are smaller under TS than under IC in consequence of their low endowments. However, they always opt for positive federal subsidies. In fact, they gain from 'reverse' redistribution since making education attractive for a larger number of households increases their low-skilled wages (see Johnson (1984) and Borck and Wimbersky (2009)).

2.5 Sensitivity Analysis

The symmetric benchmark reveals mixed financing for both regions. It is interesting now to see how education policies change as the main characteristics of regions vary, especially the skewness of the endowment distributions, and the wealth of regions.

2.5.1 Variations in Skewness of Endowment Distributions

Let us start with analyzing the effects of symmetric and asymmetric variations of the degrees of skewness of regional endowment distributions. Therefore, we leave the regional median endowments identical to the benchmark with $\omega_r^m = \Omega^m = 44.701$.[30] The equilibrium results are pictured in Table 2.2. For better comparability, the first column repeats the benchmark results.

[30] Note that one could also hold the regional (and federal) average endowments fixed. This does not affect the results for symmetric variations. However, for asymmetric variations the regional median endowments differ, which corresponds to the case of asymmetric shifts, see Subsection 2.5.2.

Table 2.2: Results for variations in skewness

	Benchmark	Symmetry (1)	Symmetry (2)	Asymmetry (1)	Asymmetry (2)
f	0.0476	0	0.4879	0	0.3721
z	0.1618	0	1.2493	0	0.9992
N_A	0.5179	0.4837	0.7479	0.4837	0.6840
N_B	0.5179	0.4837	0.7479	0.4837	0.6839
t_A	0.0905	0.0998	0	0.0997	0
s_A	0.9427	1.1015	0	1.1004	0
t_B	0.0905	0.0998	0	0.0998	0
s_B	0.9427	1.1015	0	1.1015	0
w_A^H	82.41	87.63	54.19	87.62	61.21
w_A^L	30.33	28.53	46.14	28.53	40.85
w_B^H	82.41	87.63	54.19	87.63	61.22
w_B^L	30.33	28.53	46.14	28.53	40.84

Symmetric Variations We study two scenarios of symmetric variations: The first with equally low degrees of skewness as pictured in the second column (Symmetry (1)), and the second with equally high degrees, presented in the third column (Symmetry (2)).

Let us begin with equally low degrees with $v_r = 0.5$. The identical regional and federal average endowments fall to $\omega_r^{av} = \Omega^{av} = 50.653$ compared to the benchmark. As can be seen in the second column, this results in zero federal tax and subsidy rates in equilibrium. The intuition is as follows: The smaller federal average endowment is equivalent to a smaller tax revenue of the TS system. This makes the federal scheme less efficient, since identical tax rates lead now to lower subsidies compared to the benchmark. Besides, the pivotal households with median endowments benefit less from redistribution of the federal TS system, since they are relatively rich now compared to the federal average endowment. Hence, sending their children to college is no longer optimal for them. Indeed, the numbers of students falls below one half to $N_r = 0.4837$. As explained before, non-students vote for positive student support in order to raise enrollment rates and low-skilled wages. However, since the federal system is now less efficient, the pivotal households prefer to subsidize students exclusively via the regional IC schemes. As a consequence, the tax and subsidy parameters for the IC system increase to $t_r^{IC} = 0.0997$ and $s_r^{IC} = 1.1004$.

Proceeding now with results for voting on the regional IC systems. We also find a clear political effect from the fallen efficiency of the federal TS system: Most of the poor households (except for those with endowments close to zero) form now a coalition with the rich households in favor of a regional IC system. In detail, if region q rejects the regional IC system, 94% of all households of region r vote in favor of regional subsidies (whereas only 66% in the benchmark). Instead, if region q relies on regional subsidies, a majority of 99% in region r does as well (with only 58% doing so in the benchmark).

Continuing with the second scenario of equally higher degrees of skewness compared to the benchmark with $v_r = 0.9$. This results in larger regional and federal average endowments of $\omega_r^{av} = \Omega^{av} = 67.020$. As can be seen in the third column of Table 2.2, all effects are vice versa. In consequence of the larger federal average endowment, the TS system is more efficient than in the benchmark. Besides, the redistribution benefits of the pivotal households with median endowments increase, since they are relatively poor compared to the federal average endowment. In fact, the federal system is sufficiently beneficial for a majority of households in each region so that they vote against the implementation of a regional IC scheme. They do this to commit on zero regional subsidies and raise households' preferred federal support. Indeed, the federal subsidies increase to $z = 1.2493$, even though enrollment rates grow to $N_r = 0.7479$ at the same time. The skill premium subsequently falls from 1.72 in the benchmark to only 0.17.

Asymmetric Variations In this subsection we investigate the effects of asymmetric degrees of skewness. The parameter for region A is a copy of the benchmark with $v_A = 0.8$, resulting in regional average endowment of $\omega_A^{av} = 61.559$. For region B two specifications are discussed: The first simulates a lower degree of skewness than in region A and in the benchmark with $v_B = 0.5$, presented in the forth column of Table 2.2 (Asymmetry (1)). The second specification models a larger degree than in region A and in the benchmark with $v_B = 0.9$, as shown in column 5 (Asymmetry (2)). Note that the degrees of skewness for region B are analogous to the symmetric variations in Symmetry (1) and Symmetry (2). Besides, the equal federal and regional median endowments still remain at the benchmark level with $\omega_r^{av} = \Omega^{av} = 44.701$.

Let us start with a lower degree of skewness in region B with $v_B = 0.5$, leading to regional average endowment of $\omega_B^{av} = 50.653$. This results in federal average endowment of $\Omega^{av} = 56.106$, which is below the benchmark of 61.559, but above the federal average endowment in Symmetry (1) with 50.653.

As can be seen in column 4 of Table 2.2, the results are more or less identical to the case of equal lower degrees of skewness in Symmetry (1). Even though the fall of the federal average endowment is smaller here, the federal TS system is still too inefficient for the pivotal households with median endowments, and sending their children to college is also not optimal for them. They vote again for a federal tax (and subsidy) rate of zero. As before, this separates the federation into two fiscally autarchic regions with the following consequences: First, the results are almost the same in both regions. The different degrees of skewness do not affect the regional IC schemes directly, since second period labor income is taxed. Second, the outcome for region B is obviously identical to the results in Symmetry (1), since the degrees of skewness are equal. Finally, the reason for the slightly differing results between region A and B are region-specific *IC wage effects* in consequence of the different shapes of the distribution functions. In fact, the household of region A, indifferent to studying, has an endowment of 46.183, whereas that of region B has a smaller endowment of only 45.622, although enrollment rates are (almost) perfectly identical.

Turning to the voting results, we find that the majorities in favor of regional IC schemes are larger than in the benchmark, but smaller than in Symmetry (1). This directly follows from the order of the federal average endowments: A lower tax revenue of the federal system reduces the efficiency and makes redistribution less beneficial for a larger number of households. In turn, the support for the regional IC systems rises. In fact, a majority of 84% in region A prefers local IC subsidies, irrespective of region B's decision. Instead, 78% of all households in region B are in favor of a regional IC system if region A also implements a local IC scheme, and 80% in region B are in favor if region A does not implement an IC scheme. Interestingly, the majorities are smaller in region B than in region A. Due to the lower degree of skewness in region B, a larger number of households is poorer than the federal average endowment and benefits from redistribution of the federal TS system. They enjoy large interregional transfers from region A, since they contribute less to financing the equal subsidies to all students of the federation, due to the smaller regional average endowment with $\omega_B^{av} < \omega_A^{av}$.

Let us finally assume the case of a higher degree of skewness in region B with $v_B = 0.9$, leading to regional average endowment of $\omega_B^{av} = 67.021$. This results in a federal average endowment of $\Omega^{av} = 64.290$, which is above the benchmark with 61.559, but below the average endowment in Symmetry (2) with 67.021. When looking at the last column of Table 2.2, one can see that the results are consistent with the outcome in Symmetry (2). In consequence of the larger federal average endowment compared to the benchmark, the TS system is more efficient. Then, majorities in both regions reject the implementation of IC schemes. Indeed, the extent of the federal system grows compared to the benchmark to $f = 0.3721$ and $z = 0.9902$, and subsequently, enrollment increases. However, the figures are smaller than in Symmetry (2), due to the lower federal average endowment.

Note that due to the region-specific shapes of the distribution functions, the *TS wage effects* of region A and region B differ. This implies the minimal difference of enrollment rates, as well as the fact that households with (regional) median endowments are no longer pivotal for the following reason: First of all, the preferred federal tax rates fall monotonically in income in each region due to proportional taxation. The discontinuities for the endowments of the households indifferent to studying conditional on *their preferred tax rates* are unproblematic downward jumps. If studying they are in favor of lower tax rates than if not studying with $f_S(\underline{\omega}_{i,r}) < f_N(\underline{\omega}_{i,r})$. However, the median household of region A prefers a higher tax rate than the equally endowed median household of region B with $f_A(\Omega^m) = 0.378 > f_B(\Omega^m) = 0.36$. They are obviously no longer the decisive voters, and we end up in an outcome similar to the 'ends against the middle' equilibrium introduced by Epple and Romano (1996). Then, a voting equilibrium (if one exists) is computed by finding a household in region A and a household in region B with endowments $\omega'_{i,A} > \omega'_{i,B}$ such that

$$f' = f(\omega'_{i,A}) = f(\omega'_{i,B}) \quad \text{and} \quad G_A(\omega'_{i,A}) + G_B(\omega'_{i,B}) = 1. \tag{2.21}$$

In other words, we must find a household in each region, $\omega'_{i,A}$ and $\omega'_{i,B}$, that both prefer the same tax rate with fifty percent of households in the federation that prefer larger tax rates (those of region A with endowments below $\omega'_{i,A}$ and those of region B with endowments below $\omega'_{i,B}$).[31] For our simulation, this is fulfilled for the households with endowments $\omega'_{i,A} = 44.75$ and $\omega'_{i,B} = 44.695$.

2.5.2 Linear Shifts of Endowment Distributions

In this subsection we study symmetric and asymmetric shifts of regional endowment distributions, conditional on constant degrees of skewness with $v_r = 0.8$. Moreover, they are assumed equal in both regions. Table 2.3 presents the equilibrium values, where the first column repeats again the benchmark case.

Symmetric Shifts Let us begin with symmetric shifts of regional endowment distributions. We discuss two scenarios: First, we study poorer regions than in the benchmark with $\mu_r = 3.4$, where the equal regional and federal average endowments fall

[31] This condition is necessary but not sufficient for an equilibrium. Therefore one has to check that no other tax rate f exists which is preferred to f' by a majority of voters (Epple and Romano (1996)). For all simulations of this model, we find that the tax rate f' cannot be beaten by any alternative tax rate.

Table 2.3: Results for endowment shifts

	Benchmark	Symmetry (1)	Symmetry (2)	Asymmetry (1)	Asymmetry (2)
f	0.0476	0.0648	0.0371	0.3525	0.1848
z	0.1618	0.1479	0.1865	0.8091	0.6709
N_A	0.5179	0.5161	0.5213	0.6576	0.5828
N_B	0.5179	0.5161	0.5213	0.6223	0.6245
t_A	0.0905	0.0944	0.0842	0.0405	0
s_A	0.9427	0.9861	0.8725	0.3365	0
t_B	0.0905	0.0944	0.0842	0	0.0449
s_B	0.9427	0.9861	0.8725	0	0.3935
w_A^H	82.41	82.67	81.91	64.25	73.45
w_A^L	30.33	30.24	30.52	38.91	34.03
w_B^H	82.41	82.67	81.91	68.46	68.19
w_B^L	30.33	30.24	30.52	38.91	36.66

to $\omega^{av} = \Omega_r^{av} = 41.264$ and the equal regional and average median endowments fall to $\omega^m = \Omega_r^m = 29.964$ (Symmetry (1)). Second, we study richer regions than in the benchmark with $\mu_r = 4.2$, where the equal regional and federal average endowments rise to $\omega_r^{av} = \Omega^{av} = 66.686$ and the equal regional and federal median endowments increase to $\omega_r^m = \Omega^m = 91.836$ (Symmetry (2)).

We start with equal poor regions as stated in column 2 of Table 2.3. One can see that even though the equilibrium federal tax rate of $f = 0.0648$ is higher than in the benchmark, the federal subsidy level of $z = 0.1479$ is below. As before, the smaller federal average endowment is equivalent to smaller tax revenue of the TS system. This reduces the efficiency of the federal system compared to the benchmark (and is the reason for the fallen subsidy rate). In contrast to the scenarios of lower degrees of skewness, the median endowments of the pivotal households fall as well. This implies two additional effects for the decisive voters: First, their tax payments for the federal TS system fall. And second, their marginal utilities of federal subsidies rise (since their children obtain education). These two aspects in favor of higher federal tax rates dominate. This explains the rise of the federal tax rate and the simultaneous fall of the federal subsidy level. Finally, to compensate the reduced federal support the decisive voters opt for larger regional financing with $t_r = 0.0944$ and $s_r = 0.9861$ compared to the benchmark, leaving enrollment rates almost unchanged with $N_r = 0.5179$.

Proceeding to the voting results, we find that the symmetric shifts of regional endowment distributions to the left leave the majorities in favor of regional IC schemes almost unchanged. The fixed degrees of skewness prohibit large political effects. In fact, if region q implements an IC scheme, 58% of all households of region r are in favor of regional subsidies as well (whereas 58% in the benchmark). If region q does not implement an IC system, 60% of all households in region r vote for regional subsidies.

All these findings are confirmed when considering equally richer regions, as done in Symmetry (2). When looking at column 3 of Table 2.3, one can see that the federal tax rate of $f = 0.0371$ is lower than in the benchmark, but the federal subsidy rate of $z = 18.65$ is higher. The intuition is exactly reversed to Symmetry (1): The TS system is here more efficient than in the benchmark, due to the larger federal average endowment. However, the median endowments of the pivotal households increase now as well. This raises their tax payments for the federal TS system, and decreases their marginal utilities of federal subsidies. Both effects reduce the equilibrium federal tax rate. Nevertheless, this results in a larger federal subsidy rate compared to the benchmark due to the increased efficiency of the TS system. As a consequence, the regional subsidies fall to $s_r = 0.8725$, and enrollment rates are again almost unchanged with $N_r = 0.5213$.

The majorities in favor of regional IC schemes are more or less equal to those in the benchmark and in Symmetry (1). This is intuitive since benefits from redistribution within the federal TS system are limited due to the fixed degrees of skewness. As a consequence, maximizing the skill premium via the optimal financing mix becomes important. Hence, the pivotal voters choose the federal and regional subsidies in a way to exclude all poorer households from obtaining higher education. Since the decisive voters are the households with median endowment, this corresponds to a number of students in each region of (nearly) 0.5 (see Fernandez and Rogerson (1995)).

Asymmetric Shifts Let as finally examine asymmetric shifts of endowment distributions, where regional median endowments fall apart. We assume the distribution of region A to be constant and equal to the benchmark with $\mu_A = 3.8$, resulting in regional average and median endowments of $\omega_A^{av} = 61.559$ and $\omega_A^m = 44.701$. Two scenarios are considered for region B: First, the case where region B is poorer than region A and the benchmark (Asymmetry (1)), and second where region B is richer (Asymmetry (2)).

Before studying the equilibrium outcome, let us first characterize the voting equilibrium. Note that the households with regional median endowments are obviously no longer decisive for voting on the federal tax rate, since their endowments differ now across regions. Besides, we find that even the households with federal-wide median endowment (defined as Ω^m, where fifty percent of all households of the federation are poorer, $G_A(\Omega^m) + G_B(\Omega^m) = 1$) are not pivotal in equilibrium due to region-specific

TS wage effects in consequence of the heterogeneous shapes of the endowment distributions. This gives rise for an outcome similar to the 'ends against the middle' equilibrium described before. Since households' preferred federal tax rates strictly fall in endowment in both regions, we can directly apply the Epple-Romano logic of the previous subsection. Then, an equilibrium (if one exists) is established if

$$f' = f(\omega'_{i,A}) = f(\omega'_{i,B}) \quad \text{and} \quad G_A(\omega'_{i,A}) + G_B(\omega'_{i,B}) = 1. \tag{2.22}$$

We begin with Asymmetry (1), where region B is poorer than region A. The shift to the left of region B's endowment distribution to $\mu_B = 3.4$ results in regional average and median endowments of $\omega_B^{av} = 41.264$ and $\omega_B^m = 29.964$, which are identical in Symmetry (1). This reduces the federal average and median endowments to $\Omega^{av} = 51.412$ and $\Omega^m = 36.599$, where both endowments are below the benchmark, but above the levels in Symmetry (1).

Column 4 of Table 2.3 indicates that the unilateral shift to the left of region B's endowment distribution leads to the implementation of an IC scheme only in the rich region A. In detail, if region A chooses an IC system, only a minority of 45% in the poor region B is also in favor of local subsidies. However, implementing a local IC system is a dominant strategy for region A. This heterogeneous outcome is caused by large interregional transfers from region A to region B for the following reason: The fall of household endowments in region B from the shift to the left is larger than the subsequent fall of the federal average endowment, due to the constant distribution in region A. As a consequence, redistribution benefits from the federal TS system rise for the households of region B, even though the system is now less efficient. Hence, more households of region B – constituting here the majority – vote against the implementation of a regional IC system in order to commit on zero regional grants. This raise the preferred federal tax rate of households from region B. The opposite is true for households from region A. They benefit now less from redistribution of the federal system since household endowments are unchanged but the federal average endowment falls. Hence, the majority in favor of a regional IC scheme rises relative to the benchmark.

In fact, the pivotal voters for the federal system, $\omega'_{i,A} = 33.85$ and $\omega'_{i,B} = 39.5$, choose a higher federal tax and subsidy rate of $f = 0.3525$ and $z = 0.8091$ in equilibrium compared to the benchmark. However, the contributions from region B for financing these equal subsidies fall compared to the benchmark, whereas they increase in region A, since $\omega_A^{av} = 61.599 > \omega_B^{av} = 41.264$. This difference is an implicit transfer from the rich region A to the poor region B. The extent of the regional scheme in region A is lower than in the benchmark, with $t_A = 0.0405$ and $s_A = 0.3365$, due to the larger federal support. Pivotal for determining the equilibrium IC tax rate in region A is again the household with regional median endowment. The numbers of students increase in consequence of the extended federal support to $N_A = 0.6576$ and $N_B = 0.6223$, although the federation is poorer.

Let us now consider the second scenario of a shift to the right of region B's distribution to $\mu_B = 4.2$. This leads to regional average and median endowments of $\omega_B^{av} = 91.836$ and $\omega_B^m = 66.686$, which are identical to the levels in Symmetry (2). Then, the federal average and median endowments increase compared to the benchmark to $\Omega^{av} = 76.697$ and $\Omega^m = 54.598$, but both figures are below the endowments in Symmetry (2).

When looking at the last column of Table 2.3, one can see that the results are consistent with the findings in Asymmetry (1). The poor region, here region A, opts for purely federal financing in equilibrium and enjoys interregional transfers from the rich region, here region B. The asymmetric implementation arises since the federal average endowment increases from the shift to the right of region B's distribution, whereas region A's household endowments remain constant. Hence, the latter benefit now stronger from redistribution of the federal TS system than in the benchmark. Therefore, they are less in favor of a regional IC system. In fact, a majority of them rejects the implementation in order to commit on zero regional subsidies and increase the preferred federal tax rates of households in region A. By contrast, households in region B benefit less from redistribution of the federal TS system. Their endowments increase by more than the federal average endowment, due to the unchanged distribution in region A. Hence, they are less in favor of the federal system, even though it is more efficient now.

In equilibrium, we find indeed a higher federal subsidy rates of $f = 0.1848$ than in the benchmark. Since the contributions to financing are lower in region A than in region B, interregional transfer payments occur again. In turn, the additional IC scheme in region B is smaller with $t_B = 0.0449$ and $s_B = 0.3935$. However, due to the large federal support, enrollment rates are higher than in the benchmark with $N_A = 0.5828$ and $N_B = 0.6245$.

Let us finally compare the results in Asymmetry (1) and Asymmetry (2). One can see that the extent of the federal system is lower in Asymmetry (2), whereas the tax and subsidy rates of the regional system are higher. The reason is that the entire federation is richer, since region A's distribution remains equal and region B's distribution shift here to the right compared to the benchmark (whereas to the left in Asymmetry (1)). This reduces the preferred federal tax rates of all households relative to Asymmetry

(1). Surprisingly, the political process even reveals smaller total enrollment in the federation in Asymmetry (2). The positive aspect of better endowed households is overcompensated by the negative implication of the lower equilibrium federal subsidy rate from voting.

2.6 Conclusion

This paper studied voting on the implementation of regional IC schemes in the face of an existing federal TS system. Immobile households differ with respect to financial endowment and wages are determined endogenously. They vote on the subsidy rates of the federal as well as the regional systems.

We find that the degrees of skewness of regional endowment distributions determine the type of student financing: For low degrees the extend of the federal TS system is small and the extent of the regional IC systems is large, and financing exclusively via regional subsidies is a possible outcome. With rising degrees of skewness, the extent of the regional IC systems falls, and the extend of the federal scheme increases, which ends up in purely federal TS financing. Heterogeneity of regions with respect to the degrees of skewness is negligible for the voting outcome, as long as the regional median endowments remain constant.

Symmetric shifts of regional endowment distributions for constant degrees of skewness do not change the financing mix substantially. By contrast, assuming asymmetric shifts has serious implications: The poorer region strongly benefits from interregional transfers within the federal system and prefers low (or even zero) regional, but extensively high federal subsidies. Instead, the rich region obviously prefers low federal tax and subsidy rates due to small redistribution benefits in consequence of high interregional transfers to the poor region. For sufficiently large heterogeneity between regions, an outcome where only the rich region implements an IC scheme is possible. A majority of households in the poor region votes against the implementation in order to commit on zero regional subsidies and raise the preferred federal tax rate of households. Interestingly, this asymmetric financing may result in lower federal enrollment, even though the entire society is richer.

To sum up, the degrees of skewness determine the type of subsidies: purely federal, purely regional or mixed financing. The wealth of regions accounts for differences in region-specific education policy. Hence, this model provides a plausible explanation for the German situation of heterogeneous education policy of states (concerning the tuition fees), and the persistence of the federal BAföG system for financing the indirect costs of higher education (students).

A lot of extensions to this model are possible. For instance, it would be interesting to additionally implement mobility of students and workers. This clearly changes the incentives of households for regional education policy since migration effects must be taken into account. This aspect is for instance studied in Chapter 3, however, for exogenously given numbers of students. The combination of both models would allow a comprehensive analysis of regional financing of higher education, where both, the education as well as the location decisions are determined endogenously. In addition, implementing individual ability as second heterogeneity would result in further insights. Then, coalitions forming is more complex. For instance, bright children may prefer a TS system since they are more likely to be successful in education and then face higher tax payments under an IC system (see Del Rey and Racionero (2011)). However, the complexity of this model from accounting for general equilibrium effects makes extensions difficult.

Appendix

A The value of δ

The parameter γ captures the length of the first period (studying for students, working for non-students) relative to the length of the second period (working for both). Taking additionally the discount factor δ into account, the multiplier for generating lifetime income for uneducated workers amounts to $q_n = \gamma + \delta$. Relating this to the multiplier for educated workers, $q_s = \delta$, reveals the ratio $\frac{q_n}{q_s} = \frac{\gamma+\delta}{\delta}$. Applying the values of the numerical simulation with $\gamma = 0.3$ and $\delta = 0.85$ then results in $\frac{q_n}{q_s} = 1.35$. This ratio is almost identical to a more realistic calculation via annuity value factors with payments in arrear. The particular formula for non-students is $\tilde{q}_n = \frac{(1+r)^T-1}{r(1+r)^T}$, where r denotes the market interest rate and T the total years of working life from entering the labor market until retirement. Instead, the annuity value factor for students modifies to $\tilde{q}_s = \frac{1}{(1+r)^{T_e}} \frac{(1+r)^{T_s}-1}{r(1+r)^{T_s}}$ with $T_s = T - T_e$ and T_e is the length of the study period. Note that the number of wage payments is now reduced by the years of higher education. Therefore, the present value must be additionally discounted by this period. Considering a realistic scenario with average labor market participation by the age of 20, retirement by the age of 60, duration of studies of 5 years and an interest rate of 5% leads to $\tilde{q}_n = 17.159$ and $\tilde{q}_s = 12.830$, which results in $\frac{\tilde{q}_n}{\tilde{q}_s} = 1.34$.

Chapter 3

Political Economics of Higher Education Finance for Mobile Students

3.1 Introduction

This paper is motivated by a growing mobility of students across regions and countries. For instance, according to the German Federal Ministry of Education and Research, 3.34 million individuals world-wide obtained tertiary education in a country different from their nationality in 2008.[1] Compared to 2007 (2.73 million), this is an increase of 23%, and compared to 2002 (1.89 mio) of yet 77%.

This trend can also be detected for Germany. In 2010, for instance, 181,000 foreigners were enrolled in German higher education institutions (corresponding to 8.5% of all students in Germany), an increase of 21% compared to 1997. Also the number of German natives studying abroad has grown in recent years, by 93% between 2001 and 2008.

However, the larger mobility of students has deep implications for national policies of higher education finance. On the one hand, this gives incentives to increase subsidies in order to attract foreign students, since these foreign students generate benefits for the host country in the form of human capital externalities or positive direct wage effects.[2] However, the implementation of these benefits strongly depends on the return probability of graduates, and if this is too large, the positive aspect of attracting high-ability students falls below the costs of educating them and student financing will be reduced. On the other hand, student subsidies are in general financed by taxes levied on all households of the particular region or country. This produces 'reverse' redistribution, since families of non-students – who tend to be relatively poor – contribute to finance students, who tend to be from rich families.[3] With mobility, exchange students who do not pay taxes to finance the subsidies they enjoy in the country of education free-ride on the financing system.[4]

A recent case in point are countries in the European Union, where the Bologna process was launched in 1999 and is designed to increase student mobility by establishing a Higher Education Area by 2010.[5] In turn, this has so far led to greater interdepen-

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[1] These figures come from Leszczensky et al. (2009): *Die wirtschaftliche und soziale Lage der Studierenden in der Bundesrepublik 2009 - 19. Sozialerhebung des Deutschen Studentenwerks.*

[2] See Throsby (1991, 1998) for some cost-benefit analyses in the context of foreign student enrollment.

[3] See for instance Fernandez and Rogerson (1995) or Anderberg and Balestrino (2008).

[4] This assumes that countries or regions cannot discriminate between in-state and out-of-state students, which they may or may not be able to depending on constitutional provisions.

[5] According to the report of the European Commission (2010): *Focus on Higher Education in Europe 2010 - The Impact of the Bologna Process*, all main goals were reached successfully, except

dencies of government financed university systems. Another case in point is Germany where higher education is under the authority of the states (*Länder*). Some states have recently opted to levy tuition fees (at moderate rates) while others have kept the traditional tax financed free university system, and some states have introduced and subsequently repealed tuition fees. Obviously, these choices are guided by strategic incentives. For instance, some regions may want to keep tuition fees low in order to attract students from other regions.[6]

We develop a model which can describe the strategies of regions for subsidizing higher education in the face of student mobility. To this end we model two regions which are populated by risk-averse individuals who differ in innate ability and financial endowment. Low-ability individuals never study while high-ability individuals do. We assume non-students to be immobile while students are mobile. Those students who obtain education abroad return home after studying with a certain exogenous probability. Further, wages are determined endogenously by the supply of skilled and unskilled workers.

At the first stage, regions choose by majority voting the tax rate necessary to finance subsidies to all local (home and foreign) students. This proportional tax rate is levied on endowment levels of all natives, irrespective of the ability type or migration decision. When voting, households take three effects into account: First, a larger tax rate obviously raises individual tax payments, which we denote as *tax effect*. Second, this ceteris paribus increases the subsidies to all students enrolled in the particular region. Clearly, this *subsidy effect* does not directly benefit the utility of non-students or emigrating students. Finally, variations of the tax rate change enrollment and consequently the regional numbers of skilled and unskilled workers, which affects the related wage levels.

At the second stage, students decide where to study, based on the subsidies and the respective skill premiums in the two regions. Graduation is uncertain and, due to decreasing absolute risk aversion, the lower the endowment of a household, the more important is the subsidy in the student's migration decision, since obtaining the skill premium is uncertain.

We find that results are strongly determined by the exogenous probability with which foreign graduates return home for work: When the probability is one, both regions rely

for validation of foreign student results.

[6] In 2010, 37% of all foreign students in Germany stated to be guided by 'financial reasons' when deciding where to study, also including local subsidies. Taking only the low middle-income class this figure even rises to 42%. See again Leszczensky et al. (2009).

on pure fee financing. The reason is that the incentive of low-ability individuals (who form the majority) to subsidize higher education is zero. These low-ability individuals only vote for positive subsidies if by doing so, they can attract foreign students who stay for work and increase unskilled wages. However, this is only the case when the return probability is sufficiently low. Then, the equilibrium tax rates increase with falling return probability, but interestingly, the numbers of exchange students decrease.

There is a growing body of literature on education finance with mobile students. For instance, the idea that the mobility of students or skilled labor gives rise to underinvestment of local education finance has been modeled by Del Rey (2001) and Justman and Thisse (2000).[7] On the other hand, Lange (2009) shows that when students and skilled workers are mobile, regions might underinvest or overinvest in education. This is due to the fact that regions may want to attract mobile students, which counters the incentive for underinvestment due to mobility of skilled labor.[8] Closest to ours is Gérard (2007) who analyzes the financing of exchange students in a two country setting, where graduates return home for work with an exogenous probability, as is the case in our model. He finds that moving from a system where the costs of exchange students are financed by the host country to a system where education is supported by the country of origin is a Pareto improvement as it reduces the underprovision of education. However, our model is the only one which explicitly combines the choice of a financing system for higher education by majority voting with the mobility of students. Within this framework, we can answer the question about the optimal strategy of regions for subsidizing higher education students as well as the implications for households' decisions about the place of study.

The structure of this chapter is as follows: In the next section we introduce the general setup, and in Section 3.2.2 the financing scheme. Section 3.3 describes the equilibrium. The model is solved numerically in Section 3.4. The robustness of the results is checked using sensitivity analyzes in Section 3.5, and the last section concludes.

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[7] See Borck and Wimbersky (2009) for a model of voting on education finance with immobile students.

[8] Del Rey (2001) assumes that students return home after studying, so this incentive to attract foreign students is absent from her model.

3.2 The Model

We first consider the basic structure of the model, and afterwards introduce the financing scheme.

3.2.1 The Economy

We consider a world with two regions indexed by $r \in \{A, B\}$. The population in each region consists of households of one parent and one child, and we assume that all decisions are taken by the parent. Households are heterogeneous in two dimensions: ability a and endowment ω. Ability follows a bivariate distribution. Low-ability individuals ($a = 0$) never study and high-ability individuals ($a = 1$) have the potential to study, and we will assume that their wealth is sufficient to do so (we will interchangeably denote low-ability individuals as 'non-students' and high-ability individuals as 'students'). Financial endowment or wealth is distributed with a cumulative distribution function $G_{r,a}(\omega)$ with density function $g_{r,a}(\omega)$, where $\omega_{r,a}^{av}$ stands for average and $\omega_{r,a}^{m}$ for median endowment of natives of region r with ability a. Note that the two ability groups may differ in their endowment distribution within and across regions.

Individuals live for two periods. In the first period, low-ability individuals work and high-ability individuals study. In the second period, all individuals work. Low-ability individuals are assumed to be immobile, whereas high-ability households decide about their place of education by comparing the utility levels for studying at home or abroad. After graduation abroad, they return home with exogenous probability m or stay in the region of education with probability $(1-m)$. Those who study at home are assumed to work in their home region. One reason might be larger post-education migration costs, since these students have not obtained any international skills during their education. As a consequence of the exogenous return probability, there is no arbitrage in wages. Note that even though the sizes of all ability groups are fixed ex ante, the number of skilled workers in each region is determined endogenously by student migration.

We assume graduation to be uncertain, i.e. only the fraction p of all students finishes their studies successfully, whereas the fraction $(1 - p)$ of students fails. Those who fail receive the wage income of an unskilled worker w_r^L in period 2, whereas the successful graduates obtain the wage of a skilled worker w_r^H. Moreover, studying causes costs $e > 0$ which are the same in both regions. However, the fees payable by students might be (partly) subsidized by governments. Since we assume imperfect credit markets, students cannot borrow against their future income, and the net of subsidies education costs must be financed via students' net of tax endowments.

Parents are altruistic towards their children and maximize a well-behaved utility function

$$U_{i,r,a} = u(c^J_{i,r,a} + \delta c^O_{i,r,a}) \tag{3.1}$$

with $u' > 0 > u''$, where $c^J_{i,r,a}$ is consumption of a young individual i born in region r with ability a and endowment $\omega_{i,r,a}$, and $c^O_{i,r,a}$ is consumption of the same individual when old. Clearly, since non-students are immobile, the region of birth unambiguously determines their place of consumption in period 1 and 2, whereas for students this may vary due to migration before and after education. The parameter δ is the discount factor. Note that we assume households to care only about their lifetime consumption, so the intertemporal elasticity of substitution is infinite.[9]

Regional outputs are produced by identical Cobb-Douglas production functions

$$Y_{t,r} = \phi F(H_{t,r}, L_{t,r}) = \phi H^{\alpha}_{t,r} L^{1-\alpha}_{t,r} \tag{3.2}$$

with $0 < \alpha < 1$, where the technology parameter ϕ is the same in both regions. The number of unskilled workers in period t and region r amounts to

$$L_{t,r} = l_{t-1,r,r} + l_{t,r,r} + (1-p)N_{t-1,r,r} + m(1-p)N_{t-1,r,q} + (1-m)(1-p)N_{t-1,q,r} \tag{3.3}$$

with $r, q \in \{A, B\}$ and $r \neq q$. The first two terms on the right-hand side, $l_{t-1,r,r}$ and $l_{t,r,r}$, depict the ex ante unskilled workers in region r of the previous and the current generation.[10] The third term, $(1-p)N_{t-1,r,r}$, shows all unsuccessful students of the previous generation $t-1$ who studied at home. The fourth term, $m(1-p)N_{t-1,r,q}$, shows all native exchange students who failed abroad and returned home, and the last term, $(1-m)(1-p)N_{t-1,q,r}$, depicts the unsuccessful foreign students of the previous generation who stay in region r for work. Note that although ex ante unskilled workers are immobile, unsuccessful high-ability individuals are assumed to be mobile.

The number of skilled workers in period t and region r amounts to

$$H_{t,r} = pN_{t-1,r,r} + mpN_{t-1,r,q} + (1-m)pN_{t-1,q,r}, \tag{3.4}$$

---

[9] See also García-Peñalosa and Wälde (2000).

[10] Note that we consider in this model one cohort of endless overlapping generations, assuming a population growth rate of zero and constant ability distributions in both regions.

which is the sum of all successful home students of the previous period, $pN_{t-1,r,r}$, all successful exchange student from region r who returned home after graduation, $mpN_{t-1,r,q}$, and finally, all foreign exchange students from the previous period who succeeded and stay in region r for work, $(1-m)pN_{t-1,q,r}$. As cohorts are of same size in each generation, the time index will be dropped from now on.

We assume perfectly competitive labor markets in each region with profit maximizing firms. Hence, all workers are paid their local marginal products in each period. Notice, due to immobility of low-ability households, marginal products (and wage levels) may differ between regions as net wage arbitrage is prevented. The specific wages for skilled and unskilled workers are given by:

$$
\begin{aligned}
w_r^H &= \phi\frac{\partial F(H_r, L_r)}{\partial H_r} = \phi\,\alpha\left(\frac{L_r}{H_r}\right)^{(1-\alpha)} \\
w_r^L &= \phi\frac{\partial F(H_r, L_r)}{\partial L_r} = \phi(1-\alpha)\left(\frac{H_r}{L_r}\right)^{\alpha}.
\end{aligned} \tag{3.5}
$$

Increasing the number of skilled (unskilled) workers in region r decreases the local wage of skilled (unskilled) workers, but increases the local wage of unskilled (skilled) workers.[11] These adjustments in wage levels are one channel through which households' preferences for financing systems are affected.

3.2.2 Financing Scheme

Each region may rely on tuition fees to finance education costs. Alternatively, it may opt for a so called 'traditional tax-subsidy' system (TS), where the government subsidizes the fraction s_r of the education costs e of all local students in region r, irrespective of their region of origin. Government expenditures are covered by a proportional tax rate t_r, levied on the endowments of all native households.[12] Hence, exchange students pay taxes in their home region but do not benefit from the corresponding subsidies. Rather, they benefit from subsidies in their region of education, even though they do not contribute to finance them. This leads to the following government budget

[11] There exists a large body of literature showing that skill premiums can be largely explained by the relative supply of skilled over unskilled labor because of imperfect substitutability between these groups. See for instance the surveys by Katz and Autor (1999) and Acemoglu and Autor (2011).

[12] See also García-Peñalosa and Wälde (2000) who analyze a similar TS system with lump-sum taxes. However, they argue that a tax on current income seems like a more natural scheme. See also De Fraja (2001).

constraint:

$$\left(t_r - \frac{(t_r)^{\eta_r}}{\eta_r}\right)(\theta_r \omega^{av}_{r,0} + \omega^{av}_{r,1}) = s_r e N_r, \tag{3.6}$$

where $\omega^{av}_{r,a}$ are the average endowments of the respective ability groups and θ_r weighs the mass of low-ability to the mass of high-ability households, since both groups are not necessarily of equal size. The term in the first brackets of the left-hand side depicts the effective tax rate in region r, that is the nominal tax parameter minus the deadweight costs of taxation. These might be due to incentive effects on labor supply. The size of these costs are parametrized by $\eta > 1$. They fall with increasing η. Finally, the total number of students in one region, N_r, is the sum of all home students, $N_{r,r}$, and all exchange students from the other region q, $N_{q,r}$.

The utility of a low-ability household born in region r with endowment $\omega_{i,r,0}$ is

$$U_{i,r,0} = u\ \left(\omega_{i,r,0}(1-t_r) + \gamma w^L_r + \delta w^L_r\right). \tag{3.7}$$

As the first period, either spent in education (high-ability individuals) or working (low-ability individuals), covers a much shorter duration (say from age 15 to 25) than the second period of regular work (say from age 25 to 60), the length of the first period is adjusted to the fraction $\gamma < 1$ of the duration of the second period.

A high-ability household from region r with endowment $\omega_{i,r,1}$ whose children study at home achieves expected utility

$$\begin{aligned} EU^r_{i,r,1} &= p\, u\left(\omega_{i,r,1}(1-t_r) - e(1-s_r) + \delta w^H_r\right) \\ &\quad + (1-p)\, u\left(\omega_{i,r,1}(1-t_r) - e(1-s_r) + \delta w^L_r\right), \end{aligned} \tag{3.8}$$

where the superscript indicates the region of education. For exchange students born in region r who study in region q the expected utility is

$$\begin{aligned} EU^q_{i,r,1} &= p\, u\left(\omega_{i,r,1}(1-t_r) - e(1-s_q) + \delta(m w^H_r + (1-m) w^H_q)\right) \\ &\quad + (1-p)\, u\left(\omega_{i,r,1}(1-t_r) - e(1-s_q) + \delta(m w^L_r + (1-m) w^L_q)\right), \end{aligned} \tag{3.9}$$

where the indices for the tax and subsidy rates are different here due to education abroad. Note that the return probability m is only incorporated in the expected utility of exchange students of equation (3.9), as home students are assumed to work in their region of birth after graduation.

A region might also opt for full tuition finance, which would occur if a majority votes for a subsidy rate of zero.

3.3 Equilibrium

We assume three stages: At the first stage, natives in both regions simultaneously determine the tax rate of the financing system of their home region. At stage 2, high-ability individuals decide where to study. And at stage 3, the fractions m of all foreign graduates return to their home region and work either as skilled or unskilled, depending on whether they studied successfully or not.

3.3.1 Equilibrium Region of Work

We start with determining the region of work. Low-ability individuals are immobile by definition and always work in their region of birth. The same holds for high-ability households who obtain education at home. By contrast, high-ability households who study abroad return to their region of birth with the exogenous probability m, whereas with the probability $(1-m)$ they work abroad. It follows that the numbers of skilled and unskilled workers in each region are predetermined by the numbers of home and exchange students and the particular return probability.[13]

3.3.2 Equilibrium Region of Education

When deciding about the region of education, high-ability households know the equilibrium tax (and subsidy) rates determined at stage one, and they also take into account the resulting migration flows and numbers of skilled and unskilled workers in both regions.

Parents decide on their offspring's place of study by comparing the expected utility of studying at home, $EU^r_{i,r,1}$, and studying abroad, $EU^q_{i,r,1}$. In the case of studying abroad, two effects must be considered: on the one hand, students might obtain a subsidy rate different from their home level, and on the other hand, they face the wages of skilled and unskilled workers in the host region with probability $(1-m)$. Clearly, the last effect is only relevant for $m < 1$, as otherwise, all students definitely work at home. Then, there exists a native household in region r with endowment $\hat{\omega}_{i,r,1}$ who is just

[13] Note that some workers always leave the country of education due to the exogenous migration probability, even though the obtained wage is then lower for them. See Baruch, Budhwar and Khatri (2007) for a survey of migration determinants of foreign students in the US and the UK, also including non-economic motives. See also Dreher and Poutvaara (2011), Finn (2003), Lowell Bump and Martin (2007) or Rosenzweig (2006), who analyze permanent immigration in a more general context.

indifferent between studying at home or abroad,

$$EU^r_{i,r,1}(\hat{\omega}_{i,r,1}) = EU^q_{i,r,1}(\hat{\omega}_{i,r,1}). \tag{3.10}$$

Suppose that region r has the higher subsidy rate. Then, the skill premium is larger in region q than in region r, since for the indifferent households hold that the benefits of the extra subsidy payment if studying in region r are exactly offset by the smaller skill premium in region r. Then, all poorer households with $\omega_{i,r,1} < \hat{\omega}_{i,r,1}$ prefer education in region r. Due to decreasing absolute risk aversion, they benefit more from subsidy payments in both states of the world than from the uncertain skill premium, since with probability $(1-p)$ they fail in education and only obtain the wage of an unskilled worker. By contrast, rich households are less risk-averse, and hence, they prefer the larger skill premium and accept the lower subsidy in region q. Note that this may even result in a situation where rich households emigrate from a region paying high subsidies to a region with fee financing, if the difference in skill premiums is sufficiently large.

Since there is a continuum of households, we assume that students treat the numbers of home and foreign students as given. That is, they do not take into account the consequences of their own mobility decision on the total numbers of students and workers as well as equilibrium wages in both regions.

3.3.3 Equilibrium Subsidy Rates

At this stage, the equilibrium subsidy rates of both regions are determined endogenously by majority voting.

Low-ability households maximize their utility $U_r(\omega_{i,r,0})$ with respect to the local tax rate t_r, taking the government budget constraint of equation (3.6) as well as the implications for the numbers of students and workers in each region into account. High-ability households maximize their expected utility, which is the maximum of the expected utility of studying at home $EU^r_{i,r,1}$ and expected utility of studying abroad $EU^q_{i,r,1}$ with respect to the local tax rate t_r. They also take the government budget constraint as well as the resulting effects on the numbers of students and workers into account.

This generates the optimal tax rate for every low- and high-ability household $t_{r,a}(\omega_{i,r,a}, t_q)$. The equilibrium tax rate from voting for a given tax parameter of the other region, $t_r(t_q)$, must satisfy the condition that no other local tax rate is preferred by a majority in region r. Finally, solving the voting reaction functions of both regions reveals the equilibrium tax rates t_A^* and t_B^*. Substituting in the results of the previous stages generates the number of home and exchange students as well as total enrollment and consequently, skilled and unskilled wages for both regions in equilibrium.

Let us now analyze in detail the relevant effects a household considers when determining its optimal tax rate. Applying the government budget constraint and the results of the previous stage, we can rewrite the subsidy of region r as $s_r(t_r, N_r(t_r, t_q))$, which simplifies to $s_r(t_r, t_q)$. It clearly depends on the tax rate as well as enrollment in region r, which is equivalent to the number of beneficiaries. The wage levels can be expressed as $w_r^H(t_r, t_q)$ and $w_r^L(t_r, t_q)$. This leads to the following utility levels for low-ability households from region r,

$$U_{i,r,0} = u(\omega_{i,r,0}, t_r, w_r^L(t_r, t_q)). \tag{3.11}$$

High-ability households choose the maximum of the utility level for studying at home,

$$\begin{aligned} EU^r = {} & pu_{ss}(\omega_{i,r,1}, t_r, s_r(t_r, t_q), w_r^H(t_r, t_q)) \\ & + \ (1-p)u_{sn}(\omega_{i,r,1}, t_r, s_r(t_r, t_q), w_r^L(t_r, t_q)), \end{aligned} \tag{3.12}$$

and for studying abroad,

$$\begin{aligned} EU^q = {} & pu_{ss}(\omega_{i,r,1}, t_r, s_q(t_r, t_q), m, w_r^H(t_r, t_q), w_q^H(t_q, t_r)) \\ & + \ (1-p)u_{sn}(\omega_{i,r,1}, t_r, s_q(t_r, t_q), m, w_r^L(t_r, t_q), w_q^L(t_q, t_r)), \end{aligned} \tag{3.13}$$

where the latter depends on the wage levels of both regions (if $0 < m < 1$) because of the exogenous return probability m for exchange students. The subscripts ss and sn refer to the utility levels if being successful and unsuccessful. Differentiating equations (3.11), (3.12) and (3.13) reveals the effects of an increase of t_r on households' utilities.

Low-ability individuals

Let us begin by analyzing the effects for low-ability individuals who do not study per definition. The effects of increasing the tax rate on their utility is given by:

$$\frac{dU_r}{dt_r} = \frac{\partial u}{\partial t_r} + \frac{\partial u}{\partial w_r^L}\frac{dw_r^L}{dt_r}. \tag{3.14}$$

The first term denotes the direct *tax effect* since also non-students contribute to finance local subsidies. The second term depicts the indirect *wage effect* and captures the impact of an increase of the tax rate of region r on local unskilled wages. This involves adjustments of the numbers of home and exchange students in both regions. The sign of this effect is a priori unclear, and the size depends on the particular migration probability m. To show this let us for instance assume the extreme value $m = 1$, where all exchange students return to their home regions. It follows that the numbers of skilled and unskilled workers are completely predetermined by the initial numbers of low- and high-ability households (but not equal due to the positive probability of failure p). As a consequence, the *wage effect* is zero and all low-ability households vote for a zero tax rate. On the contrary, taking for instance $m = 0$ means that all high-ability households can be attracted permanently since they do not return home after graduation. This in turn makes the *wage effect* highly positive.

High-ability individuals

Looking now at the effects of high-ability individuals, one must distinguish between home and exchange students. Let us start with immobile home students. The effects of increasing the tax rate on their utility is given by:

$$\begin{aligned}\frac{dEU^{r}_{i,r,1}}{dt_r} &= p\left(\frac{\partial u_{ss}}{\partial t_r} + \frac{\partial u_{ss}}{\partial w^H_r}\frac{dw^H_r}{dt_r} + \frac{\partial u_{ss}}{\partial s_r}\frac{ds_r}{dt_r}\right) \\ &+ \ (1-p)\left(\frac{\partial u_{sn}}{\partial t_r} + \frac{\partial u_{sn}}{\partial w^L_r}\frac{dw^L_r}{dt_r} + \frac{\partial u_{sn}}{\partial s_r}\frac{ds_r}{dt_r}\right)\end{aligned} \tag{3.15}$$

The negative direct *tax effect* is pictured by the first terms on the first and second lines of the right-hand side of equation (3.15), and is analogous to that for low-ability individuals, since all natives contribute to finance local subsidies. Also the *wage effect* appears, but is split now. As can be seen by the second terms in both lines, students are successful and obtain the wage of skilled workers with probability p, but fail and receive the wage of unskilled workers with probability $(1 - p)$. Note that these partial wage effects are of opposite sign, due to complementarity of skilled and unskilled workers in the production process (see equation (3.5)). Finally, the third terms show the effects of a larger tax rate on the subsidy level. This *subsidy effect* is somewhat complex as it involves adjustments of the total number of students, i.e. beneficiaries of subsidies, in region r. We show this in detail in the numerical analysis.

Let us now proceed to the effects for exchange students. Clearly, their place of work is a priori ambiguous (if $0 < m < 1$) since they return home with probability m, but stay abroad with probability $(1 - m)$. The effects of increasing the tax rates on their utility is given by:

$$\begin{aligned}\frac{dEU^q_{i,r,1}}{dt_r} &= p\left(\frac{\partial u_{ss}}{\partial t_r} + m\frac{\partial u_{ss}}{\partial w^H_r}\frac{dw^H_r}{dt_r} + (1-m)\frac{\partial u_{ss}}{\partial w^H_q}\frac{dw^H_q}{dt_r}\right) \\ &\quad + \ (1-p)\left(\frac{\partial u_{sn}}{\partial t_r} + m\frac{\partial u_{sn}}{\partial w^L_r}\frac{dw^L_r}{dt_r} + (1-m)\frac{\partial u_{sn}}{\partial w^L_q}\frac{dw^L_q}{dt_r}\right).\end{aligned} \tag{3.16}$$

Note that the first terms denote again the direct negative *tax effect*. All natives contribute to finance the system in their home region, even if they study abroad and do not enjoy the related subsidies. In fact, this is the reason why the *subsidy effect* is absent here. Exchange students receive subsidies in the other region but are not allowed to vote on the tax rate of that region. Also, their *wage effects* are now twofold: Exchange students return home after graduation with probability m and obtain the corresponding skilled wage with probability p and the unskilled wage with probability $(1-p)$. However, with probability $(1-m)$ they stay abroad and receive the wage levels of the other region.

3.4 Numerical Simulation

In this section, we simulate the model numerically. We calibrate our example to broadly fit the levels of relevant endogenous variables from Germany. The case of Germany is chosen because several German states have recently introduced tuition fees (at moderate levels), a marked change from the previously free higher education. Some states, however, have subsequently repealed tuition fees.

3.4.1 Specification

We assume the following Cobb-Douglas production function:

$$Y_r = \phi H^\alpha_r L^{1-\alpha}_r, \tag{3.17}$$

where the technology parameter is set to $\phi = 100$ and the output elasticity for skilled and unskilled workers is $\alpha = 0.5$. Note that the Cobb-Douglas production function has an elasticity of substitution between skilled and unskilled workers of one.

We use the following CRRA utility function

$$u = \frac{1}{1-\rho} c^{1-\rho}, \tag{3.18}$$

where $\rho = 2.25$ is the coefficient of relative risk aversion. Hence, we have decreasing absolute but constant relative risk aversion. The discount factor is set to $\delta = 0.8$.[14] The costs of education are measured in 1,000 Euros and are set to $e = 35$.[15] The probability of educational success is $p = 0.77$, which corresponds well to the proportion of beginning students graduating with a university degree.[16] Further, we assume $\gamma = 0.3$, meaning that the period of education is 30% of the length of the working period. Finally, the parameter determining the size of the tax costs is set to $\eta_r = 2$ for both countries.

We assume lognormal distributions for financial endowments, which differ for high- ($a = 1$) and low-ability households ($a = 0$), but ability-specific distributions are equal in both regions in this benchmark. For the low-ability households we assume $\ln \omega_{r,0} \sim N(\mu_{r,0}, \nu_{r,0})$ with $\mu_{r,0} = 2.7$ and $\nu_{r,0} = 1$, resulting in average and median endowments of $\omega^{av}_{r,0} = 24.533$ and $\omega^{m}_{r,0} = 14.880$. Endowment is measured in 1,000 Euros. The distributions of high-ability natives in both regions are given by $\ln \omega_{r,1} \sim N(\mu_{r,1}, \nu_{r,1})$ which are truncated at the lower limit $\omega_{i,r,1} = 35$. This assumption ensures that all households can afford education, which seems plausible for developed countries like Germany. The parameters of the distributions are $\mu_{r,1} = 3.7$ and $\nu_{r,1} = 1$ with resulting post-truncated high-ability average and median endowments of $\omega^{av}_{r,1} = 104.523$ and $\omega^{m}_{r,1} = 72.715$. Moreover, we set the ratio of low- to high-ability households in each region to $\theta_r = 2$, with a mass of low-ability individuals of $M_{r,0} = 2$ and of high-ability individuals of $M_{r,1} = 1$.[17] Then, the regional charactersitics of the combined low- and high-ability distributions for this benchmark are an average endowment of $\omega^{av}_{r} = 51.196$ and a median endowment of $\omega^{m}_{r} = 29.209$. This distribution is a combination of the

[14] In Appendix A we show how this value of δ can be derived from discounting the payment streams of students and non-students over their entire lifespan.

[15] The value for the education costs e comes from OECD (2008), where Table B1.1a shows annual expenditures for tertiary education per student for Germany in 2005 of \$ 12,446 (weighted with PPP), multiplied by 3 years of higher education for the bachelor degree amounts to roughly 35,000 Euros.

[16] The probability p is shown in Table A4.1 of OECD (2008). Since the risk of unemployment for college graduates is generally low, this seems to be a good approximation of the probability of finding a skilled job.

[17] According to Table A1.1a OECD (2008), the OECD average participation rate for the 25-to-64-year-old population of tertiary education was 27% in 2006, which roughly corresponds to the assumed fraction of local high-ability individuals $M_{r,1}$ to the entire regional population $M_r = M_{r,0} + M_{r,1}$ of one-third.

data for income and wealth distribution.[18] The reason for this choice is that parents might finance education of their children out of current income or out of accumulated savings. Since we do not distinguish between the two forms, we take a combination of wealth and current income to be our measure of parental support.

We derive the results for three different values of the return probability: First, $m = 0$, where all individuals who graduate abroad stay there for work. Second, $m = 0.5$, meaning that 50% of all students abroad return to their home region, and finally, $m = 1$, where all graduates work in their region of birth.

3.4.2 Regions of Education

In this subsection we determine total enrollments as well as the numbers of home and exchange students for region A and B, as functions of the two regions' tax rates. We proceed as follows.

Using the government budget constraints of equation (3.6), we first compute the tax combinations where *all* students are exactly indifferent between studying in region A or region B. This is satisfied if subsidy rates as well as skilled and unskilled wages are identical in both regions. For the symmetric benchmark it is obviously fulfilled for $t_A = t_B$.[19] From that we know all tax combinations where the poor high-ability households of both regions are allocated in region A and the rich high-ability households in region B, and all tax combination where the allocation is vice versa. Assuming for instance a larger tax rate in region A increases in a first step the subsidy in region A above the level of B, conditional on the initial symmetric allocation of low-ability and high-ability households. Leaving wage adjustments aside, all students would be in favor of studying in region A. However, immigration of high-ability households to region A decreases the local skill premium and increases the skill premium in region B. For the rich students, it now becomes beneficial to study and work in region B and obtain the larger skill premium due to their low risk aversion, even though they lose

[18] The assumed average and median endowments are smaller than in Borck and Wimbersky (2009). The reason is that their model assumes a single region and data are calibrate to the German case. However, since we consider an international two region setting with mobile individuals, we additionally include OECD data for income distribution and wealth distribution. The data are taken from Isserstedt et al. (2006): *Die wirtschaftliche und soziale Lage der Studierenden in der Bundesrepublik 2006 - 18. Sozialerhebung des Deutschen Studentenwerks*, as well as the homepage of the *OECD.StatExtracts*.

[19] As we will show in the sensitivity analysis in Section 3.5, the condition $t_A = t_B$ is not necessarily true for asymmetric regions.

extra subsidy payments.

Thereafter we derive the endowments of the indifferent high-ability households for studying at home or abroad, for discretely varying tax rates t_A and t_B, taking the particular allocation of poor and rich students into account.[20] The regional numbers of poor and rich students for each tax combination are then defined by the region-specific distributions of high-ability individuals who are poorer, or richer, than the indifferent households with endowments $\hat{\omega}_{i,r,1}$.

Interpolating the data generates functions for both regions which determine the numbers of home and exchange students, $N_{r,r}(t_A, t_B)$ and $N_{r,q}(t_A, t_B)$, for all tax combinations, thereby incorporating the varying allocations of poor and rich students of both regions. Note that for the particular tax combinations where all students are indifferent between studying at home or abroad, multiple equilibria for the numbers of home and exchange students exists as long as enrollments are equal in region A and B and result in identical supply of skilled workers. In these cases we assume that all students obtain education at home.

The left panel of Figure 3.1 exemplifies the number of exchange students from region A and B as functions of t_A, if region B chooses pure fee financing (with $t_B = 0$) and the return probability is zero, $m = 0$. As a consequence, poor students gather in region A due to positive subsidies. As can be seen, the number of rich students going from region A to B is low and even decreases with rising tax rate. By contrast, region A attracts a large number of poor students from region B where the inflow even increases with A's tax rate. This can be seen in the right panel of Figure 3.1. The reason is that a higher tax rate in region A corresponds to a higher subsidy for students from region B, which makes studying abroad in region A attractive for a larger number of poor households. However, even for extensive tax and subsidy rates a substantial number of rich individuals still studies in region B, since skilled wages in B are then extremely high. The total numbers of students in region A and B are shown in Figure 3.2. As can be seen in the left panel, total enrollment in region A rises with higher tax rates, whereas the opposite is true for region B.

[20] Note that deriving the number of poor and rich students for region A as well as region B is redundant for this symmetric benchmark, since results are identical but with reversed labels. However, it becomes relevant for the heterogeneous scenarios of the sensitivity analyses.

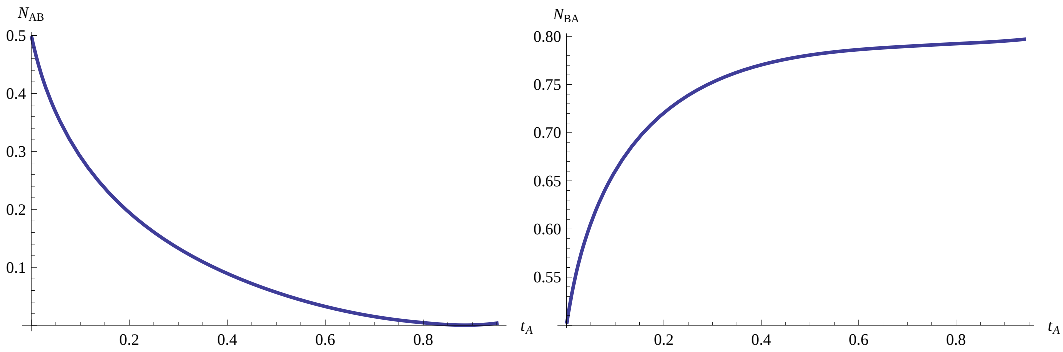

Figure 3.1: Exchange students for fee financing in region B and $m = 0$

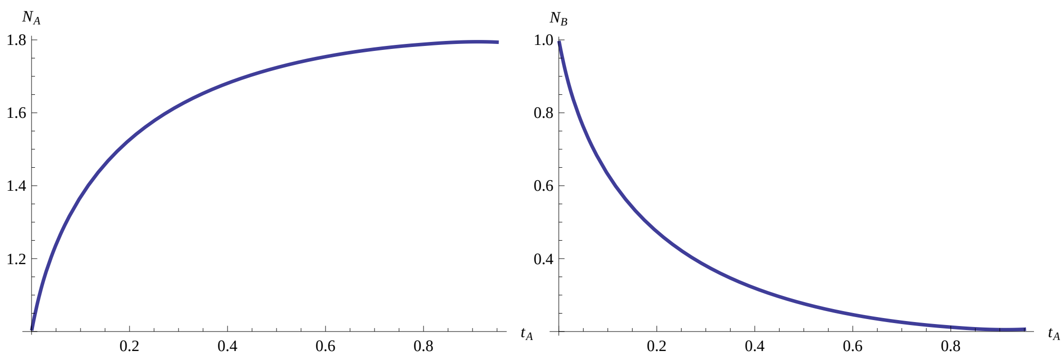

Figure 3.2: Total enrollments for fee financing in region B and $m = 0$

Table 3.1: Benchmark results

	$m = 0$		$m = 0.5$		$m = 1$	
	A	B	A	B	A	B
t_r	0.26	0.26	0.16	0.16	0	0
s_r	0.99	0.99	0.65	0.65	0	0
N_r	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.
$N_{r,r}$	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.
$N_{r,q}$	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.
L_r	2.23	2.23	2.23	2.23	2.23	2.23
H_r	0.77	0.77	0.77	0.77	0.77	0.77
w_r^H	85	85	85	85	85	85
w_r^L	29	29	29	29	29	29

3.4.3 Voting on Subsidies

In this section we analyze the equilibrium tax (and subsidy) rates for the three scenarios: First for $m = 1$, where all exchange students return home after graduation, second, for $m = 0.5$, where 50% of them do so, and finally, for $m = 0$, where all exchange students stay abroad for work. The results for region A and B are shown in Table 3.1, where 'i.d.' denotes 'indeterminate'.[21]

Let us begin with a return probability of $m = 1$, i.e. all exchange students definitely return home after graduation. Hence, all results of the previous stages are irrelevant, because the numbers of skilled workers are already defined by the initial numbers of high-ability individuals in each region who graduate successfully. As a consequence, all *wage effects* is zero since permanent migration is excluded. Then there exists no incentive for low-ability individuals to vote for positive tax rates as they only incur the negative *tax effect*. The preferred tax rates of high-ability individuals strictly decrease in endowment since the negative *tax effect* intensifies with the endowment in consequence of proportional taxation, but the positive *subsidy effect* is constant. Due to the assumed relation of low- to high-ability households of $\theta_r = 2$, students who favor a positive tax (and subsidy) rate are in the minority, which results in fully fee financing in equilibrium.

Let us now proceed to the cases of $m = 0$ and $m = 0.5$ where the numbers of skilled workers are determined endogenously. On substituting the interpolated functions for home and exchange enrollments of the previous stage into the utility functions, we can derive the optimal individual tax rates for low- and high-ability households, subject to

[21] Remember, for these cases we assume that all students obtain education in their home regions.

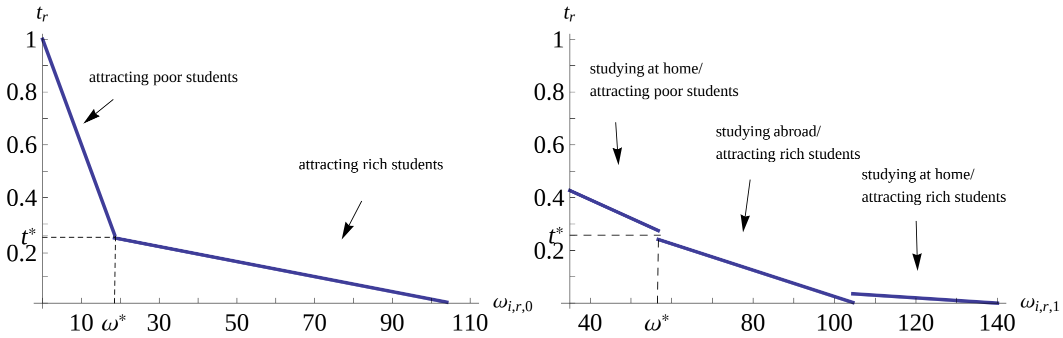

Figure 3.3: Preferences of low-ability and high-ability households for $t_B = t^*$

the other region's tax rates $t_r(\omega_{i,r,0}, t_q)$ and $t_r(\omega_{i,r,1}, t_q)$. A voting equilibrium in region r for a given tax rate t_q requires that there are two decisive households, one low-ability with endowment $\omega^*_{i,r,0}$ and one high-ability with endowment $\omega^*_{i,r,1}$, who prefer the same tax parameter and divide the total population in two equal parts. That is, all poorer low-ability households with $\omega_{i,r,0} < \omega^*_{i,r,0}$, in combination with all poorer high-ability households with $\omega_{i,r,1} < \omega^*_{i,r,1}$, who prefer a larger tax rate, make up 50% of the total population. Likewise, there are 50% households who are richer than the respective pivotal individuals and prefer lower tax rates. Hence, there is no majority that prefers a tax rate different from the optimal rate of the two pivotal households.[22]

However, determining as well as ordering the preferences for low- and high-ability households is non-trivial. The incentives for staying or going abroad for education as well as attracting the poor or rich students vary for different endowment and ability levels, and preferences may be non-monotonic in endowment. For this reason we describe in detail the preferences of households from region A for $m = 0$, conditional on the equilibrium tax rate in region B, $t^*_B = 0.26$ (see the left column of Table 3.1).

Analyzing the preferences of low-ability households as pictured in the left panel of Figure 3.3 reveals that all households with $\omega_{i,A,0} < 18.5$ prefer relatively high tax rates in order to attract a large number of poor students from both regions. This is clear since their positive *wage effects* exceed the negative *tax effects* due to their low endowments. In contrast, all rich low-ability households with $\omega_{i,A,0} > 18.5$ prefer relatively low tax rates and attract the rich students from both regions. Their negative

[22] As is often the case in voting problems of this type, the equilibrium tax rate (if it exists) does not necessarily correspond to the optimal tax rate of the household with the median endowment, since preferences satisfy neither single peakedness nor single crossing. We have to check by hand that there does not exists another tax rate which commands a majority against our proposed equilibrium.

tax effects are strong due to large endowments. The indifferent household between attracting the rich or the poor students with $\omega_{i,A,0} = 18.5$ always prefers the tax rate $t_A(\omega_{i,A,0} = 18.5, t_B = 0.26) = 0.26$. Note that the optimal tax rates decrease in endowment due to proportional taxation.

Let us proceed now to the preferences of high-ability households from region A. Every student has four optimal tax rates: One for studying at home and attracting the poor students to region A, and one for studying at home but attracting the rich students to region A. And the same if studying abroad in region B, one for attracting the poor students to the home region A, and one for attracting the rich students to region A.

First of all, we find that for all m the strategy of obtaining education abroad but attracting the poor students to the home region is strictly dominated for all high-ability households in this benchmark, as it requires large tax rates without enjoying the related subsidies.

All other three strategies are optimal depending on the particular endowment level and are pictured in the right panel of Figure 3.3 by the three sections: (i) All poor students from region A with $\omega_{i,A,1} < 56.7$ prefer to study at home and favor large tax rates, due to their small negative *tax effects*. Their high risk aversion makes them prefer the risk-free subsidies and they even accept the relatively small skill premium caused by the large inflow of poor students from region B. (ii) By contrast, all students with $56.7 < \omega_{i,A,1} < 104.5$ prefer to emigrate to region B and choose moderate tax rates for their home region A. On the one hand, the incentive for large tax rates is dampened since they are relatively rich and do not benefit directly from the subsidies. On the other hand, they want to make education in their home region A attractive for many rich students in order to reduce enrollment in region B and enjoy large subsidies and skill premiums there. (iii) All rich high-ability individuals with $\omega_{i,A,1} > 104.5$ prefer to study at home and vote for small tax rates. Their *tax effects* are highly negative due to the large endowment levels. The corresponding low subsidies only convince few rich students of obtaining education in region A, which results in a large skill premium.

Note that for each group, the preferred tax rate strictly falls with increasing endowment levels due to the intensifying negative *tax effect*. However, there are two discontinuities: The first is for the poor student household with endowment $\omega_{i,A,1} = 56.7$, indifferent between obtaining education at home with the poor or abroad with the poor (case (i) and (ii)). If staying at home the household prefers $t_A^A(\omega_{i,A,1} = 56.7, t_B = 0.26) = 0.28$ and if studying abroad $t_A^B(\omega_{i,A,1} = 56.7, t_B = 0.26) = 0.24$. The second discontinuity emerges for the rich household with endowment $\omega_{i,A,1} = 104.5$, indifferent between studying abroad with the poor students (case (*ii*)), or studying at home with the rich (case (*iii*)). In the first case she prefers $t_A^B(\omega_{i,A,1} = 104.5, t_B = 0.26) = 0$, and in the second case she chooses $t_A^A(\omega_{i,A,1} = 104.5, t_B = 0.26) = 0.04$. Note that this is an upward jump, hence, the condition of single crossing is violated which may give rise to an equilibrium akin to the 'ends against the middle' (EATM) equilibrium (see Epple and Romano (1996)). However, as depicted by the dashed line, the equilibrium tax rate from voting is above the two preferred tax rates of 0% and 4% of the indifferent high-ability household with $\omega_{i,A,1} = 104.5$. Hence, the discontinuity is irrelevant for the voting outcome conditional on the equilibrium tax rate for region B.

Repeating this procedure for all tax rates of the other region and interpolating the data generates the voting reaction functions $t_r(t_q)$, as shown in Figure 3.4 for $m = 0$. The blue curve depicts the optimal tax rates of region A and the green that of region B as functions of the tax parameter of the other region. Note that both curves are symmetric and consist of three parts, where the first two are separated at $t_q = 0.26$ by a kink, and the latter by a discontinuity jump at $t_q = 0.85$. The sections depict varying strategies of the pivotal low- and high-ability households with respect to the group of students to attract and the region of education of the decisive student:[23] In the first part, comprising tax rates of region q between 0 and 0.26, the pivotal low- and high-ability households of region r prefer to attract poor students and the latter stays at home for education. The low tax (and subsidy) rates in region q make attracting the larger number of poor students relatively cheap for region r. In the middle part, comprising the range between $t_q = 0.26$ and $t_q = 0.85$, the pivotal low- and high-ability household from region r prefer to attract the rich students, and the latter obtains education abroad in region q. The large tax rates of region q make the necessarily higher subsidies for attracting the poor students expensive for households from region r, and the negative *tax effect* is then too strong for a majority of them. Finally, for tax rates in region q beyond $t_q = 0.85$, attracting the rich students is still optimal for the pivotal voters of region r, but the decisive high-ability household prefers now to study at home. The skill premium in region r is of considerable size due to the massive outflow in consequence of the extremely high tax (and subsidy) rate in the other region q.

Interestingly, the voting reaction functions have strictly positive slopes. This is because a larger tax and subsidy rate in region q reduces the inflow of students to region r.

[23] Since monotony of the voting reaction functions is violated, we can not generally be sure about the existence of an equilibrium. However, in the cases presented here we checked the existence by hand.

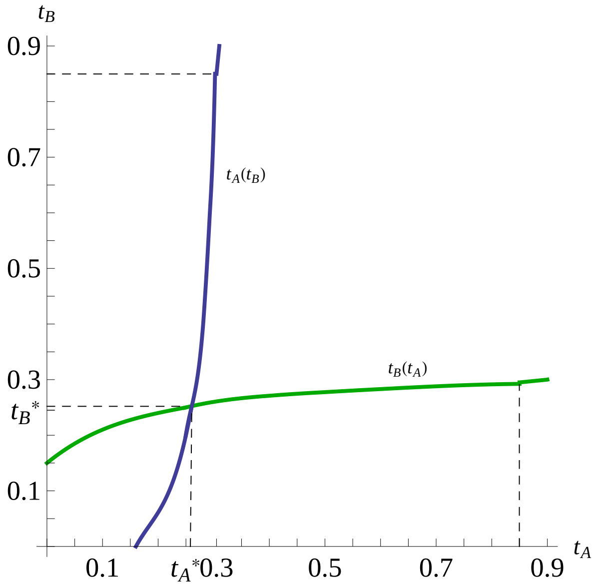

Figure 3.4: Voting reaction functions

This raises the preferred tax rates of low-ability households in order to avoid a strong fall of their own unskilled wages. Since non-students form the majority they are able to enforce their preferences.

Solving the reaction functions generates the equilibrium tax rates for region A and B. For the assumed parameters, the decisive voters are made up of the low-ability household with endowment $\omega^*_{i,r,0} = 18.5$ and the high-ability household with $\omega^*_{i,r,1} = 56.7$. Due to symmetry, the equilibrium tax rates are the same in both regions with $t^*_r = 0.26$ (see again the left column of Table 3.1). As described before, this implies that all students are indifferent where to study, and the pivotal households are also indifferent whom to attract, either the poor or the rich students. This can be seen in the right panel of Figure 3.3 since the horizontal dashed line, denoting the equilibrium tax rate, hits the function of individual preferences of high-ability households in the middle of the jump. However, the equilibrium tax rate is well-defined by the unique preference of the pivotal low-ability household.

The equilibrium tax and subsidy rates fall from $t^*_r = 0.26$ to $t^*_r = 0.16$ and from $s^*_r = 0.99$ to $s^*_r = 0.65$, if the return probability rises from $m = 0$ to $m = 0.5$. The intuition is as follows: In the case of $m = 0.5$, it is ex ante clear that at least 50% of all native students definitely work at home. If they study at home they are immobile afterwards, and if they obtain education abroad they return home with the exogenous probability. This reduces the incentive for low-ability households to opt for large tax rates as the number of skilled workers that can be attracted falls. The preferred tax rates of home students slightly increase when m rises, since the negative impact of attracting students on skilled wages only occurs with probability $m = 0.5$. By contrast, the preferred tax rates of exchange students decrease with rising m: Making the home region attractive for more students is less rewarding, since the foreign graduates return home with probability $m = 0.5$. Besides, their place of work is also uncertain. With probability $(1 - m) = 0.5$ they stay abroad for work and prefer relatively high tax and subsidy rates at home. The large inflow of students to their home region leads to a small number of skilled workers in their region of work, which raises their obtained skill premium. However, with probability $m = 0.5$ they return home, and in that case, they prefer relatively low tax and subsidy rates at home. The small number of attracted students results in a small number of skilled workers, and the obtained skill premium is large. Obviously these two aspects are of opposite signs.

Hence, the number of students whose region of work can be influenced falls with increasing return probability, attenuating the strength of the *wage-effects*.

3.5 Sensitivity Analysis

In the last section we studied the equilibrium tax and subsidy rates for the symmetric benchmark. This section now analyzes how asymmetric variations of regions' characteristics affect the results. We consider differences in the population size in Section 3.5.1, in the ability distribution in Section 3.5.2 and in the endowment distribution in Section 3.5.3. Finally, the extension in Section 3.5.4 combines a scenario of asymmetric population size with increased tax costs.

3.5.1 Heterogeneous Population Size

Let us begin with a modification of the absolute size of region A's population. We assume a mass of low-ability individuals of $M_{A,0} = 16$ and of high-ability individuals of $M_{A,1} = 8$ which sums up to $M_A = 24$. Region B retains the benchmark values with $M_B = 3$, composed of a mass of low-ability individuals of $M_{B,0} = 2$ and high-ability individuals of $M_{B,1} = 1$. Note that the population in region A is eight times that of region B, but the share of low skilled is identical in both regions with $\theta_r = 2$.[24]

First of all we can state that the increase of region A's population for constant ability

[24] This significant difference of regional populations with a relation of $8 : 1$ pictures a mix of the situations for Germany and Austria with $10 : 1$ and France and Belgium with $6 : 1$.

Table 3.2: Heterogeneous population size

	$m = 0$		$m = 0.5$		$m = 1$	
	A	B	A	B	A	B
t_r	0.14	0.30	0.10	0.23	0	0
s_r	0.61	0.73	0.47	0.51	0	0
N_r	7.46	1.54	7.23	1.77	i.d.	i.d.
$N_{r,r}$	6.76	0.30	6.34	0.11	i.d.	i.d.
$N_{r,q}$	1.24	0.70	1.66	0.89	i.d.	i.d.
L_r	17.72	2.35	17.75	2.32	17.84	2.23
H_r	5.74	1.19	5.86	1.06	6.16	0.77
w_r^H	88	70	87	74	85	85
w_r^L	28	35	29	34	29	29

distribution $\theta_A = 2$ does not alter the overall proportion of skilled to unskilled workers, hence, leaves the skilled and unskilled wages equal to the benchmark. It follows that all students are again indifferent where to obtain education if $t_A = t_B$ is fulfilled. As before, the region with the larger tax rate also provides larger subsidies and gathers the poor students in equilibrium, whereas the low-tax region contains the rich students.

However, the asymmetric variation of the population size affects individual preferences. In the populous region A, the marginal *wage effects* for skilled and unskilled workers are attenuated since permanent high-ability immigration leads to a smaller increase of unskilled and a smaller fall of skilled wages compared to the benchmark (see equation (3.5)). As a consequence, low-ability households opt for smaller tax rates and are satisfied with attracting fewer rich students. The pivotal low-ability household is here poorer with $\omega^*_{i,A,0} = 11$ compared to the benchmark.

By contrast, high-ability households from region A are now in favor of larger tax rates compared to the benchmark, even though this raises the attracted number of (either rich or poor) students. If studying at home they can enjoy higher subsidies than in the benchmark since equal immigration causes a smaller fall of skilled wages. If studying abroad, making education in their home region attractive is more effective due to the less pronounced fall of skilled wages via immigration. However, since the ability distribution is constant with $\theta_A = 2$, preferences of low-ability households for reduced tax rates dominate. Consequently, the decisive high-ability household $\omega^*_{i,A,1} = 114$ is richer than in the benchmark and prefers to be educated at home with the rich students.

In region B, wage adjustments from varying the local tax rate are stronger now, due to the increased number of immigrants from region A. As a consequence, the majority of low-ability households is in favor of attracting the large group of poor students and therefore opts for relatively high tax rates compared to the benchmark, since their unskilled wages increase by more now.

All high-ability households prefer now to study abroad in region A due to the relative insensitive skilled wages there, thus they are in favor of lower tax rates for their home region B compared to the benchmark. In fact, we find that for the equilibrium value in region A ($t_A^* = 0.14$), all students choose a tax rate of zero in order to fully avoid the negative *tax effect* (remember, the minimum endowment of high-ability households is already $\omega_{i,r,1} = 35$).

It follows that there exists only one pivotal voter in region B, since all high-ability households are in favor of a zero tax rate (but are in minority due to $\theta_r = 2$). This is the low-ability household with endowment $\omega_{i,B,0}^* = 29.2$ that prefers to attract the large number of poor students from region A.

When looking at the left column of Table 3.2, one can see that the densely populated region A chooses indeed a lower, and region B a higher tax rate in equilibrium of $t_A^* = 0.14$ and $t_B^* = 0.30$ compared to the benchmark scenario. As a consequence, the subsidy rate in region B, $s_B^* = 0.73$, exceeds the level of region A, $s_A^* = 0.61$, and all poor students migrate permanently to region B whereas all rich migrate to region A. This results in a net inflow to region B of $N_{A,B} - N_{B,A} = 0.54$ (corresponding to an equal net outflow of region A), obviously caused by the larger high-ability population in region A. However, the number of emigrants relative to the absolute population size is smaller in region A than in region B. Only a minority of students of $N_{A,B} = 1.24$ studies abroad in region B but a majority of $N_{B,A} = 0.70$ emigrates from region B to A. This implies that region A has a higher proportion of rich households than region B and a lower proportion of poor households. Remember, rich households gather in the low-tax region A. In fact, 85% of the total number of high-ability households from region A but only 70% from region B study in region A. This is caused by the substantially larger tax rate in region B, making the natives effectively poorer. Note that the decision criterion for the region of education is net of tax endowment, since tax payments are sunk.

Proceeding now to the case of $m = 0.5$, one can see in the middle column of Table 3.2 that the equilibrium tax rates in both regions fall to $t_A^* = 0.10$ and $t_B^* = 0.23$. Similar to the benchmark, the preferred tax rates of low-ability households are reduced compared to the scenario of $m = 0$, since the number of skilled workers that can be attracted for permanent immigration is smaller. Consequently, also the equilibrium subsidy rates fall to $s_A^* = 0.47$ and $s_B^* = 0.51$, and the poor households still gather in region B. But interestingly, migration flows in both directions intensify to $N_{A,B} = 1.66$ and $N_{B,A} = 0.89$, resulting in an even larger net inflow to region B of 0.77. The intuition is as follows: A positive return probability encourages more students from region A to go abroad, since they may enjoy the higher subsidy rate in region B as well as the larger skill premium at home. Instead, more rich students from region B aim at the larger skill premium in region A, since the loss of subsidies if studying in region A is smaller now. However, even though total enrollment falls in region A and increases in region B compared to the case of $m = 0$, with $N_A = 7.23$ and $N_B = 1.77$, the number of skilled workers is now larger in region A and smaller in region B with $H_A = 5.86$ and $H_B = 1.06$, due to the positive return probability.

Finally, the scenario of $m = 1$ produces full fee financing in both regions. As in the benchmark, low-ability households have no incentive to opt for positive subsidy rates since the numbers of skilled workers are predetermined. Hence, the *wage effects* are zero and they solely face the negative *tax effects*. Since the ability distribution is still $\theta_r = 2$, low-ability households can impose their preferences of $t_r = 0$ in both regions.

3.5.2 Heterogeneous Ability Distributions

In this subsection we analyze the effects of region-specific ability distributions for identical total population sizes of $M_A = M_B = 3$. For region B we assume the benchmark distribution of $\theta_B = 2$, resulting in a number of low- and high-ability individuals of $M_{B,0} = 2$ and $M_{B,1} = 1$. For region A we set $\theta_A = 1$, meaning that the numbers of low- and high-ability households are equal with $M_{A,0} = M_{A,1} = 1.5$. The simulation results are shown in Table 3.3.

Before describing the implications for the preferences of all households, let us first consider the effect on the t_A-t_B-combinations where all students are indifferent where to study. In contrast to the previous section, this is no longer fulfilled for $t_A = t_B$ but requires here a higher tax rate in region B than in region A. To show this, consider an allocation of high-ability households such that both regions exhibit the same skilled and unskilled wages. This is obviously true for a smaller number of students, i.e. skilled workers, in region A, since also the number of ex ante unskilled workers is lower there with $M_{A,0} = 1.5$ but $M_{B,0} = 2$. Assuming further identical tax rates leads to higher subsidies in region A than in B for two reasons: First, the tax base in region A is larger

Table 3.3: Heterogeneous ability distributions

	$m=0$		$m=0.5$		$m=1$	
	A	B	A	B	A	B
t_r	0.25	0.23	0.15	0.13	0	0
s_r	0.91	0.77	0.56	0.46	0	0
N_r	1.34	1.16	1.37	1.13	i.d.	i.d.
$N_{r,r}$	0.81	0.47	0.68	0.31	i.d.	i.d.
$N_{r,q}$	0.69	0.53	0.82	0.69	i.d.	i.d.
L_r	1.81	2.27	1.83	2.24	1.85	2.23
H_r	1.03	0.89	1.10	0.82	1.16	0.77
w_r^H	66	80	64	83	63	85
w_r^L	38	31	39	30	40	29

due to the modified ability distribution. And second, the number of beneficiaries, which is equivalent to all local students is smaller in region A (conditional on the allocation for equal wages in both regions).[25] To sum up, both aspects lead to higher subsidies in region A. It follows that the equilibria where *all* students are indifference where to study require a smaller tax rate in region A than in region B. The difference must exactly balance the larger tax base in region A in order to ensures again $s_A = s_B$, conditional on identical wage levels for skilled and unskilled workers in both regions. In other words, attracting the poor students is 'cheaper' for region A than for region B.

Let us proceed now with the influence of the modified ability distribution on individual preferences for $m = 0$. Beginning again with region A, we find that low-ability households are now in favor of attracting the poor students and opt for higher tax rates than in the benchmark for the following reasons: First, as already mentioned, the tax base in region A is larger, which makes subsidies less expensive. Second, due to the lower number of low-ability households in region A, the unskilled wage are more sensitive to student immigration. And third, the absolute number of students that can be attracted is larger now due to $M_{A,1} = 1.5$ instead of 1. Therefore, we find that the pivotal low-ability voter $\omega^*_{i,A,0} = 22$ is richer than in the benchmark since the equilibrium tax rate slightly falls to $t^*_A = 0.25$.

By contrast, preferences of high-ability households of region A remain more or less

25 The weighted sum of the ability-specific average endowments determines the tax base of the financing system. Since the mean of the high-ability distribution is above the level of the low-ability distribution, shifting the weight towards more high-ability households conditional on a constant total population increases the tax base.

constant, and the decisive high-ability voter who chooses $t_A^* = 0.25$ is almost identical to the benchmark with $\omega_{i,A,1}^* = 57$. However, the number of (poor) students obtaining education at home has grown. The reason is as follows: If studying at home, the positive effect of the larger tax base on student financing balances two negative effects that appear: on the one hand, the more sensitive skilled wages in region A due to the smaller number of local unskilled workers, and on the other hand, the higher total number of students, causing a stronger fall of skilled wages via enlarged immigration. Instead, region B is only affected negatively by the higher number of students, which makes studying there less attractive.

Proceeding to region B, we find that most low-ability households (apart from some very poor low-ability households) are satisfied with attracting the few rich students since providing subsidies is expensive for them relative to region A due to the smaller tax base in B. However, they nevertheless benefit from the increased total number of high-ability individuals and prefer slightly higher tax rates than in the benchmark (but smaller than region A). Hence, the endowment of the pivotal low-ability voter rises to $\omega_{i,B,0}^* = 21$.

Most of the (poor) high-ability households of region B favor education abroad in region A, and attracting the rich students to their home region B. They opt for small tax rates relative to the benchmark. This is clear since they only incur the negative effect of a higher number of students and the corresponding stronger fall of skilled wages if studying at home. The positive aspect of a larger tax base is absent for region B. Consequently the pivotal (exchange) student is poorer than in the benchmark with an endowment of $\omega_{i,B,1}^* = 47$.

Interestingly, even though the preferred tax rates of region A's households are larger (low abilities) or constant (high abilities) compared to the benchmark, the equilibrium tax rate is below with $t_A^* = 0.25$. This is caused by the positive slope of the voting reaction function, and can be explained as follows: As before, the heterogeneous ability distributions establish an implicit agreement of all decisive households about the allocation of poor students to region A and rich students to region B. Therefore, region B chooses a smaller equilibrium tax rate compared to the benchmark of $t_B^* = 0.23$, which implies that the necessarily larger tax (and subsidy) level for attracting the poor students falls. As a consequence, region A also implements a lower tax rate than in the benchmark due to the negative *tax effects*, although the preferred tax rate of the decisive households are constant or increase conditional on the benchmark tax rate in region B. However, there also exists a political effect: Due to the modified ability distribution in region A with $\theta_A = 1$, the numbers of low- and high-ability voters are now of equal size there. Hence, the constant preferences of students gain more importance in the voting process and the equilibrium tax rate increases by less (caused by the preferences of non-students for larger tax rates) compared to a situation with the benchmark ability distribution.

All results are shown in the left column of Table 3.3. One can see that the equilibrium subsidy rate in region A is substantially higher with $s_A^* = 0.91$ compared to $s_B^* = 0.77$, even though the number of beneficiaries is larger there with $N_A = 1.34$ and $N_B = 1.16$, and tax rates are almost equal in region A and B. As mentioned before, this is caused by the enlarged tax base in region A. Hence, all poor students indeed migrate to region A and all rich go to region B in equilibrium. But interestingly, despite the larger subsidy rate, region A experiences a net outflow of rich native students of $N_{A,B} - N_{B,A} = 0.16$, caused by the larger number of high-ability individuals with $M_{A,1} = 1.5$ but $M_{B,1} = 1$. However, the fractions of poor and rich students are almost equal in both regions. For instance, region A's poor (home) students, $N_{A,A} = 0.81$, make up 54% of all high-ability households of region A, and region B's poor (exchange) students, $N_{B,A} = 0.53$, make up 53% of all high-abilities individuals from B. Clearly, the opposite holds for the rich students, composed of region B's home students, $N_{B,B} = 0.47$, as well as region A's exchange students, $N_{A,B} = 0.69$, making up 47% respectively 46% of the corresponding regional number of high-ability households. This is caused by the almost identical tax rates in region A and B, leaving the relative income of high-ability households between both regions more or less unchanged.

Let us turn now to the second column for the case of $m = 0.5$. As before, the equilibrium tax rates in both regions fall to $t_A^* = 0.15$ and $t_B^* = 0.13$ since the number of attractable students is lower compared to $m = 0$. However, the numbers of exchange students in both directions increase again for the reasons given above: On the one hand, more students from region A study in region B since the loss of subsidy is now less extreme for them with $s_A^* = 0.56$ and $s_B^* = 0.46$, and the extra benefit of the skill premium in region B is even larger than for $m = 0$. On the other hand, more high-ability households from region B study in region A now, since they can enjoy the higher subsidy rate while still obtaining the larger skill premium in their home region with probability one half.

Finally, we consider the case of a return probability of $m = 1$. As before, low-ability households face zero *wage effects* but negative *tax effects*, hence, they prefer pure fee financing again. In fact, this outcome is clear for region B since low-ability households

Table 3.4: Heterogeneous endowment distributions

	$m = 0$		$m = 0.5$		$m = 1$	
	A	B	A	B	A	B
t_r	0.22	0.24	0.12	0.15	0	0
s_r	0.71	0.80	0.45	0.48	0	0
N_r	0.85	1.15	0.77	1.23	i.d.	i.d.
$N_{r,r}$	0.29	0.44	0.20	0.43	i.d.	i.d.
$N_{r,q}$	0.71	0.56	0.80	0.57	i.d.	i.d.
L_r	2.20	2.26	2.21	2.26	2.23	2.23
H_r	0.65	0.89	0.68	0.86	0.77	0.77
w_r^H	92	80	90	81	85	85
w_r^L	27	31	28	31	29	29

form the majority. However, we also observe a zero tax and subsidy rate in region A, even though the numbers of high- and low-ability households are equal. The reason is that sufficiently rich student households are also in favor of pure fee financing since they face a highly negative *tax effect* due to their large endowments. Then, low-ability households in combination with rich high-ability individuals form the majority again and vote for zero taxes.

3.5.3 Heterogeneous Endowment Distributions

In this subsection we study how differences in endowment distributions influence the results. Therefore we reduce the degree of skewness of the high-ability distribution in region A to $\nu_{A,1} = 0.5$, leading to post-truncated high-ability average and median endowments of $\omega_{A,1}^{av} = 58.616$ and $\omega_{A,1}^{m} = 52.056$. The distribution of low-ability households remains unchanged. Note that the combined average endowment of region A, $\omega_A^{av} = 35.894$, is now below the level of region B, $\omega_B^{av} = 51.196$, since region B retains the benchmark distributions for low- and high-ability households. However, the combined median levels of both regions are still identical and equal to the benchmark with $\omega_A^m = \omega_B^m = 29.209$.[26] To sum up, both regions have identical combined median levels, but the combined average endowment is lower in region A than in B. The equilibrium values are displayed in Table 3.4.

Before analyzing household preferences, we first note that the indifference of all house-

[26] Since all students are richer than the combined median in the benchmark due to the minimum endowment of 35, a variation of the endowment distribution of students leaves the overall median endowment unchanged.

holds where to study is no longer fulfilled for $t_A = t_B$, as in the case of heterogeneous ability distributions of the previous subsection. But in contrast to before, the condition is here satisfied for a larger tax rate in region A than in B. The reason is the lower skewness of the high-ability distribution and the resulting fall of the combined (as well as high-ability) average endowment in region A. This reduces the local tax base and makes subsidies more expensive compared to region B. As a consequence, almost all low- and high-ability households of both regions, also involving the pivotal voters, implicitly agree on a student allocation where the poor obtain education in region B and the rich in region A. Nevertheless, there is a second implication of the lower skewness of region A's high-ability distribution, since the (inter-) regional number of poor students rises whereas that of rich students falls.

Proceeding now to the implications on individual preferences in region A. We find that in consequence of the smaller tax base, a large majority of low-ability households (except for few very poor non-students) prefers to attract the rich students via lower tax rates than in the benchmark.

The same holds for region A's high-ability households, both for the case of studying at home or abroad. Financing their own subsidies as well as making education in region A more attractive for students from region B is now more expensive. In fact, we find that conditional on region B's equilibrium tax rate ($t_B^* = 0.24$), the strategy of attracting the poor students is rejected by all high-ability households of region A.

Then the low-ability household $\omega_{i,A,0}^* = 22.3$ that is richer than in the benchmark as well as the high-ability (exchange) household $\omega_{i,A,1}^* = 41$ that is poorer become pivotal, due to the modified endowment distribution.

Considering region B, almost all low- and high-ability households, both if studying at home or abroad, are in favor of attracting the larger number of poor students for the following two reasons: First, paying higher subsidies than region A is now relatively cheap for region B due to the larger tax base, and second, the number of poor students has additionally increased in consequence of the modified endowment distribution in region A. Hence, the preferred tax rates in region B rise and the pivotal low-ability household $\omega_{i,B,0}^* = 18.9$ as well as the decisive (home) high-ability household $\omega_{i,B,1}^* = 58.2$ are slightly richer than in the benchmark.

As can be seen in the left column of Table 3.4, the equilibrium tax rates of region A is indeed lower than that of region B, with $t_A^* = 0.22$ and $t_B^* = 0.24$. However, both values are smaller than the benchmark levels. The intuition is again the implicit agreement between all pivotal voters about the allocation of poor and rich students. As seen above, since low- and high-ability households of region A are in favor of attracting the rich students, they prefer lower tax rates compared to the benchmark. In turn, this reduces the required tax (and subsidy) level for attracting the rich students to region B. Hence, the decisive voters opt for a smaller tax, although their preferred tax rates slightly increase conditional on the equilibrium value of the benchmark in the other region A.

The corresponding subsidy rates are $s_A^* = 0.71$ and $s_B^* = 0.80$, causing the rich students indeed to go to region A and the poor students to gather in region B in equilibrium. The implications of the modified endowment distribution in region A can be clearly seen when looking at total enrollments as well as migration flows: The number of poor high-ability households, that obtain education in region B, is substantially larger in region A with $N_{A,B} = 0.71$ but $N_{B,B} = 0.44$, even though the equilibrium tax rates are more or less equal. Of course, the opposite holds for rich students, as the number of home students of region A, $N_{A,A} = 0.29$, is below the level of exchange students coming from region B, $N_{B,A} = 0.56$. This results in a net inflow of poor students to region B of 0.15.

Increasing now the return probability to $m = 0.5$, we find the same effects as before: First, the equilibrium tax rates fall in both regions, since the number of attractable permanent immigrants decreases. This attenuates the incentive for low-ability households to vote for large tax rates. And second, the number of exchange students rises. Students from region A are now more likely to enjoy the larger subsidy abroad and the higher skill premium at home. Instead, more students from region B obtain education in region A in order to enjoy the larger skill premium there, since the loss of net subsidy payments is minimal now.

Finally, the case of $m = 1$ generates fee financing in equilibrium again. Low-ability households only incur the negative *tax effect* and vote for zero tax rates. Since the ability distribution is $\theta_r = 2$, they form the majority and impose their preferences.

3.5.4 Extension: Heterogeneous Population Size and Adjusted Tax Costs

Finally, we studied asymmetric variations of regional characteristics. This led to asymmetric equilibrium tax and subsidy rates, but pure fee financing in either one or both regions was not an equilibrium, except for $m = 1$. In this section we analyze an example of asymmetric population size in combination with increased tax costs to show

Table 3.5: Heterogeneous population size and adjusted tax costs

	$m = 0$		$m = 0.5$		$m = 1$	
	A	B	A	B	A	B
t_r	0	0.07	0	0.06	0	0
s_r	0	0.04	0	0.02	0	0
N_r	7.61	1.37	6.97	2	i.d.	i.d.
$N_{r,r}$	6.81	0.18	6.09	0.09	i.d.	i.d.
$N_{r,q}$	1.19	0.80	1.91	0.88	i.d.	i.d.
L_r	17.75	2.34	17.72	2.37	17.84	2.23
H_r	5.86	1.05	5.77	1.14	6.16	0.77
w_r^H	87	74	88	72	85	85
w_r^L	29	34	29	35	29	29

that pure fee financing may be a political equilibrium. The specification is similar to Section 3.5.1 ($M_A = 24$, $M_B = 3$ but $\theta_A = \theta_B = 2$), and the modified tax costs are set to $\eta = 1.05$ instead of 2.[27] The corresponding equilibrium values are shown in Table 3.5.

Let us consider first the leftmost column, showing the case of $m = 0$. One can see that the larger tax costs strongly reduce the tax and subsidy rates of both regions in equilibrium. In fact, the densely populated region A even opts for zero tax and subsidy rates. Only very poor low- and high-ability households are in favor of positive subsidies due to their low endowment levels. Region B chooses a positive tax and subsidy rate of $t_B^* = 0.07$ and $s_B^* = 0.04$ in equilibrium.[28]

The intuition for the outcome is the same as in Section 3.5.1. Interestingly, enrollment in region A is now larger than in the scenario with moderate tax costs, even though no subsidies are paid. However, the subsidy differential is less extreme here and rich students from both regions lose fewer extra payments if studying in region A, which increases the particular groups to $N_{A,A} = 6.81$ and $N_{B,A} = 0.80$.

Let us turn now to the case of $m = 0.5$, shown in the second column of Table 3.5. As before, we find that the increase of the return probability reduces the equilibrium

[27] We are well aware that the value of η is extensively high. Therefore, we currently calculate specifications with moderate values for η and an adjusted stay rate parameter m. Intuitively, this also reduces the preferred tax rates and leads to heterogeneous outcomes.

[28] Note that some poor high-ability households in region B face a binding budget constraint and can not afford to study anymore. Their net of tax endowments are too small to finance the net of subsidy costs of education. This holds true for all high-ability households with endowments smaller than 36.13 and corresponds to a mass of individuals of 0.02 (remember the high-ability distribution is truncated at the lower limit 35). Consequently, these individuals do not study and work as unskilled workers in both periods. The total number of students amounts to $N_A + N_B = 8.98$.

subsidy rate even further to $s_B^* = 0.02$ (and zero again for region A), and raises the number of exchange students.[29]

Finally, the results for the scenario of $m = 1$ are unaffected since both countries choose here zero tax and subsidy rates anyway for the reasons given above.

3.6 Conclusion

This paper has presented a model of higher education finance where two regions compete for mobile students. Individuals differ with respect to financial endowment and ability. Low-ability individuals never study and are immobile, whereas high-ability individuals obtain higher education and decide in which region to study. Subsidies to all home and foreign students in a region are financed by a proportional tax on endowments of all natives, irrespective of ability. Wages are determined endogenously.

We find that if graduates return home with low enough probability, regions choose to subsidize higher education. In fact, the size of financial support increases with a falling return probability. Low-ability individuals are then strongly interested in attracting foreign students who immigrate permanently and raise their unskilled wages. In turn, if the return probability is too high, the pool of attractable skilled workers is small and low-ability individuals solely face the negative tax payments, hence, vote for a zero tax (and subsidy) rate. Interestingly, the numbers of exchange students rise with increasing return probability. We have also analyzed how the results are affected by asymmetric population sizes, ability distributions and degrees of skewness of endowment distributions.

Thus, it would seem that in countries linked by high mobility, complete tuition finance will not be politically feasible. This finding has implications for the political economy of higher education finance. For instance, some German states (*Länder*) have recently introduced modest tuition fees, following a ruling by the Constitutional Court which allowed them to do so. However, not all states have used this new possibility, and some which did subsequently repealed the introduced tuition fees. Obviously, these outcomes are political choices of parliaments facing mobile students, and models like ours may help us understanding of such outcomes.

Some extensions of the model suggest themselves. In particular, it would be desirable

[29] Again, we find that the budget constraint binds for poor high-ability households of region B with endowments smaller than 36.45 who cannot afford to study.

to endogenize the return decision of students who obtain education abroad. This would in effect allow us to combine the models of Del Rey (2001) and Justman and Thisse (2000). Second, endogenizing the education decision of households would also be desirable. This would allow for home enrollment effects from education policies, as in Borck and Wimbersky (2009). Finally, it would be interesting to study differentiated in-state and out-of-state tuition fees. While simple intuition might suggest a preference for reduced in-state tuition, the incentives for attracting out-of-state students may provide a countervailing force.

Appendix

A The value of δ

The parameter γ captures the length of the first period (studying for low-ability, working for high-ability individuals) relative to the length of the second period (working for both). Additionally taking additionally the discount factor δ into account, the multiplier for generating lifetime income for low-ability households amounts to $q_n = \gamma + \delta$. Relating this to the multiplier for high-ability individuals, $q_s = \delta$ reveals the ratio $\frac{q_n}{q_s} = \frac{\gamma+\delta}{\delta}$. Applying the values of the numerical simulation with $\gamma = 0.3$ and $\delta = 0.85$ then results in $\frac{q_n}{q_s} = 1.35$. This ratio is almost identical to a more realistic calculation via annuity value factors with payments in arrear. The particular formula for low-ability individuals is $\tilde{q}_n = \frac{(1+r)^T - 1}{r(1+r)^T}$, where r denotes the market interest rate and T the total years of working life from entering the labor market until retirement. Instead, the annuity value factor for high-ability households modifies to $\tilde{q}_s = \frac{1}{(1+r)^{T_e}} \frac{(1+r)^{T_s} - 1}{r(1+r)^{T_s}}$ with $T_s = T - T_e$ and T_e is the length of the study period. Note that the number of wage payments is now reduced by the years of higher education. Therefore, the present value must be additionally discounted by this period. Considering a realistic scenario with average labor market participation by the age of 20, retirement by the age of 60, duration of studies of 5 years and an interest rate of 5% leads to $\tilde{q}_n = 17.159$ and $\tilde{q}_s = 12.830$, which results in $\frac{\tilde{q}_n}{\tilde{q}_s} = 1.34$.

Chapter 4

International Students, Mobility and Optimal Screening

4.1 Introduction

In recent years, the mobility of students born within the European Union (EU) has steadily increased, in particular since the initiation of the Bologna Process. But also the number of high-ability individuals coming from Eastern European countries or Asia has grown. According to the OECD, 3.34 million students worldwide were educated in a country different to their nationality in 2008, which is an increase of 23% compared to 2005. The top 3 sending countries were China, India and South Korea. This trend is confirmed when looking at Germany, which currently hosts about 245,000 international students, amounting to 10.9% of total attendance of tertiary education. Moreover, about 50% of these foreigners are non-EU citizens.[1]

Since countries strongly gain from hosting foreign skilled workers (for instance via additional tax revenue or enhanced productivity), the question about the optimal immigration policy arises. Two strategies can be observed: Either 'importing' foreign skilled workers who already graduated abroad, or accepting foreign high potentials and educate them.[2] The second alternative might be particularly beneficial if foreign applicants come from a rather different cultural background. Then, the period of education may also serve as a cultural acclimatization, which reduces the subsequent costs of participating the local labor market (perhaps via better language skills). However, educating foreign individuals is a risky investment for the government for two reasons:

First, students might fail in education or integration, meaning that no human capital can be acquired by the host country. Hence, a preselection of international applicants is desirable. For citizens from EU countries the prospects of educational success can be evaluated quite reliably by their school results. However, assessing the qualifications of non-EU applicants via certificates of their home countries is almost impossible due to different educational and cultural backgrounds. Therefore, admission tests are the only option for potential host countries to preselect students.

Second, most of the benefits can only be acquired by the host countries if foreign graduates stay for work. Although labor income is in general higher in the (mostly more developed) countries of education, many of them return home after graduation. The decisive non-economic motives are for instance strong family ties to the country of origin or labor market frictions.[3] Nevertheless, a trend towards larger permanent

[1] All these figures come from Leszczensky et al. (2009).

[2] See Throsby (1991, 1998) for some cost-benefit analysis in the context of foreign student enrollment.

[3] See for instance Baruch, Budhwar and Khatri (2007) for a survey of migration determinants of

immigration of foreign students can be observed. This is for instance shown by the fact that the stay rate of non-EU graduates in Germany increased by roughly 100% between 2006 and 2008.[4] It is debatable whether this growth is caused by a larger international attitude of students or extended integration effort by the government.

For these reasons, we study government screening of foreign higher education applicants and the related number of accepted students for varying stay rates.[5] We assume a binominal ability distribution which is commonly known. The government only benefits from high-ability graduates, but cannot ex ante identify the individual ability. However, screening the applicants is possible, which raises the probability of revealing the true types. Students invest privately in own human capital, but are only rewarded in the case of being of high ability. With respect to individual information we discuss two scenarios: First, *informed individuals* which are fully aware of their innate types, and second, *learning individuals* which are initially unknowing but update their beliefs about own ability on observing government screening. After graduation, foreign students return home with an exogenous probability. If so, social and private benefits of graduates are zero, and individual as well as government education investments are lost.

Note the two implications of screening: On the one hand, it improves type identification of the government with the consequence of a larger fraction of beneficial high-ability individuals among the accepted applicants. On the other hand, screening raises students' beliefs of being a high type which stimulates their private education investments (in the scenario of learning individuals).

It turns out that private education investments, screening activity and enrollment of the social planner as well as the government strictly increase with rising stay rate. When looking at the results in detail, we find that the numbers of accepted students are inefficiently large for low stay rates, but inefficiently small for high stay rates. With respect to screening, the results additionally depend on the wage level: For low wages, government screening is always inefficiently small. Instead, if wages are sufficiently high, the screening level is above the activity of the social planner for small stay rates, whereas it is below the social optimum for high stay rates. Interestingly the qualitative results for screening as well as enrollment are identical in both scenarios.

foreign students in the US and the UK, also including non-economic motives. See also Dreher and Poutvaara (2011), Finn (2003), Lowell, Bump and Martin (2007) or Rosenzweig (2006), who analyze permanent immigration in a more general context.

[4] This growth rate comes from the homepage of the German magazine *Fokus Money Online*.

[5] Note that this model does not discuss government policy for attracting foreign students.

Besides, private education investments are inefficiently low for all stay rates in the scenario of informed individuals. In the scenario of learning individuals, effort levels may exceed the social optimum for moderate stay rates, but fall deeply below for high stay rates. The intuition is that the learning process links private education investments to screening activity, providing either too precise or imprecise signals for students.[6]

In fact, all obtained results can be ascribed to the interaction of two externalities: First, students ignore the externality on total human capital and invest inefficiently little in education.[7] This in turn reduces the expected benefits per high-ability student for the government and distorts screening activity as well as enrollment below the social optimum ceteris paribus (*human capital effect*). Second, the government ignores the negative implications of extended screening on the utility levels of emigrants. This distorts screening activity as well as enrollment above the social optimum ceteris paribus (*composition effect* and *stimulation effect*).[8]

There is a large body of literature discussing the issue of screening in the context of labor markets and optimal working contracts for asymmetric information when education provides noisy signals about individual ability (see Arrow (1973), Spence (1973), Stiglitz (1975) or Riley (1979)).[9] Instead, most of the non-signaling education literature models screening as costless sorting out according to the ability characteristic. The government can perfectly observe the individual types and determine the cut-off level, and students invest in education without facing any uncertainty. Busch (2007) analyzes such a government policy in the context of brain drain. De Fraja (2001) implements such a mechanism in a political economy context, where the ability threshold is determined by majority voting.

However, a few studies assume imperfect information on individual ability, where decisions are based on noisy signals coming from a screening process: Eckwert and Zilcha (2008) study the effects of different financing schemes for students on private education investments and economic welfare. Individuals are initially uninformed about their own ability, but learn from noisy screening signals. The individual human capital

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[6] Nerlove (1972) already argued that education investments of individuals may be inefficiently low, due to individual uncertainty with respect to innate ability.

[7] See for instance Davies (2002) for on overview of empirical evidence on externalities of investments in human capital.

[8] The *composition effect* as well as the *stimulation effect* are both based on the fact that the government ignores the costs of increasing negative utility levels of emigrating graduates from extended screening. However, since the mechanism varies for the scenario of informed and learning individuals, they are labeled differently for clarification.

[9] See also Riley (2001) for a survey of screening activity in this context.

depends on individual ability and private education investments. The authors identify a financing system which pools the risks for each signal class to be most efficient. The intuition is that individuals' residual risks are optimal insured, which stimulates private education investments. In that spirit, Eckwert and Zilcha (2010) investigate the effects of a better information system (similar to extended screening activity in the scenario of learning individuals) on aggregate education investments, aggregate human capital and social welfare. Individual human capital depends again on ability and private education investments. They find that more precise information enhances aggregate human capital but may reduces aggregate education investments at the same time. The better signal allows a more efficient pooling of ability risks. Subsequently, investments of high ability individuals increase and of low ability individuals decrease. However, the effects on social welfare are ambiguous and depend on the screening technology and the relative risk aversion. Like in the model presented in this paper, the authors assume private education investments under uncertainty. But in contrast to them, we do not consider the aspect of financing these investments and even allow for a non-monetary interpretation. An other related study is Oshio and Yasuoka (2009). Pupils are uncertain about their own ability but gradually update their beliefs on receiving informations from exams (similar to updating the beliefs in the scenario of learning individuals). Then, every pupil decides about staying in school or participate the labor market. They find that screening reduces the demand of education, since low-ability pupils become more aware of their low types. Nevertheless, they might be overeducated. Besides, the authors identify a mixed system of public and private provision to be most efficient. However, all these studies model screening as costless information for the government and individuals, which does not restrict admission to education.

We proceed as follows: In the next section the economy of the model is presented, and thereafter the first-best results. In Sections 4.4 and 4.5, the scenarios of informed and learning individuals are discussed. The last section concludes.

4.2 Economy

Consider a world where foreign individuals apply at no costs for higher education in country h.[10] This supply is inelastic in the sense that there are always more applicants than might be accepted. This seems reasonable for a single country like Germany facing demand from all over the world. The applicants differ with respect to ability a_i. For

[10] Note that the import of foreign workers is not considered in this model.

simplicity we assume only two types, a high-ability type with $a_H = 1$ and a low-ability type with $a_L = 0$. There are $\alpha = 1/2$ a_H-types which are qualified for the demands in country h, whereas the $(1-\alpha) = 1/2$ a_L-types are not.[11] Note that 'ability' is not restricted to a purely economic interpretation but also involves non-economic factors which are determining successful integration. The government only gains from high-ability students, as for the rest the education costs per capita exceed the zero benefits. However, solely the distribution of ability α is commonly known but not the individual ability types. Therefore, when deciding how much foreign students $n \geq 0$ to accept, the government can invest $s \geq 0$ in screening the applicants.[12] This testing procedure is pictured in Figure 4.1, where t_i denotes the indicated type irrespective of the true ability:

Assumption 4.1 *Positive screening activity increases the probability* $p(s) = 1 - \frac{1}{2}\, e^{-s}$ *of identifying the true ability type of the tested applicant as* $\frac{\partial p}{\partial s} = \frac{1}{2}\, e^{-s} > 0$*, but with decreasing rates as* $\frac{\partial^2 p}{\partial s^2} = -\frac{1}{2} e^{-s} < 0$*. If the screening activity is zero, type identification is totally random with* $p(0) = 1/2$*, instead* $\lim_{s\to\infty} p(s) = 1$.

The total screening costs for the government are $S(s,n) = \frac{1}{2}\, s\, \frac{n}{\alpha p(s) + (1-\alpha)(1-p(s))} = n\, s$, where the simplification is possible due to $\alpha = 1/2$. The fraction denotes the number of tested applicants, where the numerator represents all accepted students, and the denominator shows the probability that the test indicates a high-ability type. The overall education expenses for the government are $N(n) = n^2$, meaning that the costs per student increase with the number of accepted applicants. This assumption seems plausible since more scarce resources such as buildings or staff are needed. Note that these costs are independent of individual ability.

The government maximizes the following expected pay off function with respect to screening activity and enrollment,[13]

$$EZ = n\, \gamma\, \mu\, EHC + n\, \mu\, EU^h - N(n) - S(s,n) \tag{4.1}$$

[11] Setting $\alpha = 1/2$ simplifies the calculations. Choosing $\alpha \neq 1/2$ with $0 < \alpha < 1$ does not change the results qualitatively.

[12] It is implicitly assumed that native applicants can be perfectly evaluated according to their school results.

[13] The explicit government pay off function depends on the assumed scenario of either informed, or learning individuals. I will refer to this in the respective subsections.

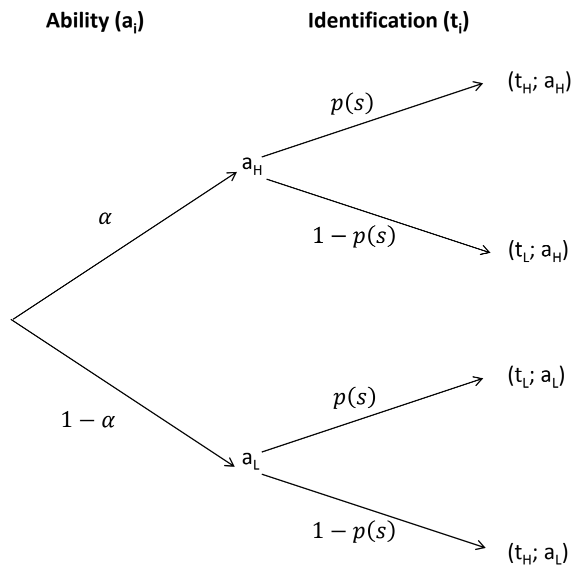

Figure 4.1: Screening process

where EHC denotes the expected human capital externality per staying graduate for country h, and γ determines its size with $\gamma = 1$ for sake of simplification.[14] EU^h is the expected utility level of an accepted applicant conditional on staying in country h for work. The parameter μ depicts the exogenous stay rate of graduates, defined as $0 < \mu \leq 1$. As can be seen, the government only draws benefits of students working in country h after graduation.

The accepted foreign applicants maximize the following utility function with respect to individual education effort z,

$$EU = \mu\, EU^h + (1-\mu)\, U = \mu\, (E(a)\, z\, \omega - Z(z)) + (1-\mu)(\Omega - Z(z)). \tag{4.2}$$

As just introduced, EU^h denotes the expected utility of a student if working in country h after graduation. It consists of effort-dependent labor income, which is the product of expected ability, private education investments z and wage per efficiency unit ω, minus the individual costs of private education investments $Z(z) = z^2$. The second term depicts the certain utility level if leaving country h after graduation. Then, private effort is unrewarded and the exogenous wage level Ω is obtained, with $\Omega = 0$

[14] I keep the general notation γ for the objective functions in order to illustrate the human capital externalities.

for simplicity. Let us finally make a second purely technical assumption concerning the wage per efficiency unit ω:

Assumption 4.2 *The wage per efficiency unit ω is defined as $\omega > \underline{\omega}$, with $\underline{\omega} := 2$.*

This minimum wage level does not affect the results qualitatively but ensures that both the social planner as well as the government always screen at least for some (high) stay rates.

The structure of the model is as follows: At the first stage, the government of country h decides about the screening activity and the number of accepted foreign applicants. At stage 2, individuals study and invest privately in education. At the last stage, they graduate and either work in country h with probability μ, or return to their home countries with probability $(1-\mu)$.

4.3 First-Best

Let us begin with deriving the first-best solutions for screening, enrollment and individual education investments. The social planner maximizes the overall welfare, which involves the utility levels of all foreign applicants, as well as the positive human capital externalities of staying high-ability graduates.[15]

Since the social planner in a first-best scenario can observe the individual ability types, we can a priori state $s^* = 0$ as screening is costly but does not cause any benefits.[16] As a consequence, only high-ability applicants are accepted by the social planner, since for low-ability individuals the social costs of education are strictly above the zero benefits. This leads to the simplified welfare function

$$\max_{z_H, n_H} WF = n_H \, \gamma \, \mu \, a_H \, z_H \; - \; n_H^2 \; + \; n_H \, (\mu \, a_H \, z_H \, \omega \; - \; z_H^2). \tag{4.3}$$

The first term depicts the human capital externalities of staying high-ability graduates, the second term shows the education costs for the government and the last term pictures the utility levels of all applicants (where rejected a_L-applicant are neglected due to $a_L = 0$). Solving with respect to individual education effort and the number of accepted

[15] Note that all rejected applicants stay in their home countries and receive the exogenous wage level $\Omega = 0$. Hence, positive individual education investment are never optimal for them.

[16] The results for the first-best case are marked by asterisks.

applicants leads to[17]

$$z_H^* = \frac{\mu(1+\omega)}{2} \qquad \text{and} \qquad n_H^* = \frac{\mu^2(1+\omega)^2}{8}. \tag{4.4}$$

Both results are strictly positive and increase in μ: A higher stay rate is equivalent to a smaller risk for the social planner of incurring social losses from unrewarded individual education investments of emigrating graduates. In turn, the larger expected social net benefits per accepted (high-ability) applicant also increase first-best enrollment. However, the first-best scenario is obviously an inappropriate benchmark with respect to screening. Hence, second-best scenarios are used as references to government policy where the social planner cannot observe the ability types.

4.4 Informed Individuals

Let us now begin with the scenario of informed individuals where foreign applicants exactly know whether they are a high-ability or a low-ability type. Instead, the government and the social planner cannot observe the innate ability. However, they take into account that more screening increases the probability $p(s)$ of identifying the true types and form the following expectation about accepting a high-ability applicant:[18]

$$P_H(s) := P(a_H|t_H) = \frac{P(a_H \cap t_H)}{P(t_H)} = 1 - \frac{1}{2}\, e^{-s} \tag{4.5}$$

The denominator shows the probability that the test indicates a high-ability type, and the numerator depicts the probability of testing a high-ability individual *and* identifying the applicant correctly. Extended screening increases the conditional probability, but with decreasing rates due to concavity of $p(s)$. The expectation about wrongly accepting a low-ability applicant is the following counter probability:

$$P_L(s) := P(a_L|t_H) = \frac{P(a_L \cap t_H)}{P(t_H)} = \frac{1}{2}\, e^{-s}. \tag{4.6}$$

Here, the numerator shows the probability of testing a low-ability individual *and* wrongly identifying the applicant as high-ability type. More screening decreases the probability of a wrong test result, again with decreasing rates. Clearly, conditional probabilities sum up to one.

[17] All second-order conditions are fulfilled throughout the model.

[18] For a detailed conditional probabilities see Appendix A.

4.4.1 Second-Best

We begin with deriving the second-best results. The perfectly informed low-ability individuals are indifferent to applying to country h: If they do, their efficient education investment is zero and so is their income (of either being accepted or rejected). If they do not apply, they receive the exogenous wage $\Omega = 0$.[19] Positive effort levels for low-ability students are never efficient due to arising education costs and zero social benefits. However, the social planner can never be sure about the ability type of an applicant due to the indifference of low-ability individuals. Hence, screening is required. The welfare function modifies to[20]

$$\begin{aligned} \max_{\tilde{z}_i^I, \tilde{s}^I, \tilde{n}^I} EWF^I = {} & \tilde{n}^I \, \gamma \, \mu \, P_H(\tilde{s}^I) \, a_H \, \tilde{z}_H^I - \tilde{n}^{I\,2} - \tilde{n}^I \, \tilde{s}^I \\ & + \tilde{n}^I \, \left(\mu \, P_H(\tilde{s}^I) \, a_H \, \tilde{z}_H^I \, \omega \; - \; P_H(\tilde{s}^I) \, \tilde{z}_H^{I\,2} \right) . \end{aligned} \tag{4.7}$$

The first term in the upper line depicts the human capital externalities from staying high-ability graduates for country h. The second term is total costs of education and the third term total costs of screening for the government. The lower line shows the utility levels of all foreign applicants, irrespective of their place of work.[21] Note that the expressions for ability are no expected values since students are perfectly informed about their types. The social planner takes this into account and 'offers' two ability-specific investment levels, where each type attains the appropriate one:

$$\tilde{z}_i^I(\mu, \omega) = \begin{cases} \frac{1}{2}\mu(1+\omega) & if \quad z_i = z_H \\ 0 & if \quad z_i = z_L. \end{cases} \tag{4.8}$$

Note that this result is identical to first-best, as screening activity is still irrelevant due to perfectly informed individuals.[22]

[19] One could easily assume some exogenous benefits to all foreign students, independent of successful graduation or integration (perhaps cultural or personal experiences). This would solve the indifference for low-ability individuals, and they all would definitely apply to country h.

[20] Throughout the model, the superscript 'I' indicates the scenario of informed individuals and the 'L' indicates the scenario of learning individuals. Within each scenario, 'tilde' denotes the results for the social planner and 'hat' equilibrium values of the government/individuals.

[21] In fact, equation (4.7) only refers to accepted high-ability students. All terms of low-ability students cancel out due to perfectly informed individuals and their ability levels of zero. The rejected applicants can not invest in education and receive the exogenous wage income $\Omega = 0$.

[22] To ensure that high-ability students are better off by investing $\tilde{z}_H^I > 0$ than by choosing $\tilde{z}_L^I = 0$ it must hold that $EU(\tilde{z}_H^I) > EU(\tilde{z}_L^I)$. Applying perfect information with $E(a_H) = 1$ and $E(a_L) = 0$, this is fulfilled for $w > 1$, hence, it is always true according to Assumption 4.2.

Let us proceed now to second-best screening activity:

$$\tilde{s}^I(\mu,\omega) = \begin{cases} 0 & for \quad 0 \; < \; \mu \; \leq \; \tilde{\mu}(\omega) \\ \ln\left[\frac{1}{8}\mu^2(1+\omega)^2\right] & for \quad \tilde{\mu}(\omega) \; < \; \mu \; \leq \; 1 \end{cases} \tag{4.9}$$

with

$$\frac{\partial \tilde{s}^I}{\partial \mu} > 0 \qquad for \qquad \tilde{\mu}(\omega) < \mu \leq 1.$$

The function $\tilde{\mu}(\omega) = \frac{\sqrt{8}}{1+\omega}$ depicts all stay rates where the social planner is indifferent to screening. Positive activity occurs for all stay rates above $\tilde{\mu}(\omega)$, and zero activity for all stay rates below.[23] Note that the larger the wage, the smaller is the particular stay rate $\tilde{\mu}(\omega)$ where the social planner starts to screen, $\frac{\partial \tilde{\mu}}{\partial \omega} < 0$. The intuition is as follows: For a given stay rate, a larger wage increases second-best education investments for high-ability students since individual effort is rewarded more highly. Hence, the social net benefits from a_H-students increase, whereas the social losses of a_L-students remain constant. This makes accepting an a_H- instead of an a_L-applicant more efficient, and positive screening becomes now optimal for the social planner. To make the social planner indifferent again, the rate of realizing these increased social net benefits must fall in order to leave the relative advantage from high-ability students constant.[24]

Mind that the second-best screening activity rises in in the stay rate. On the one hand, a larger μ raises the expected social net benefits from high-ability households: directly, because of larger stay rates of graduates as well as indirectly via simultaneously stimulated second-best education investments for a_H-students. On the other hand, the social losses of low-ability households remain constant. This makes accepting a high-ability instead of a low-ability individual more efficient and increases the optimal screening level of the social planner.

Finally, the second-best enrollment level is

$$\tilde{n}^I(\mu,\omega) = \begin{cases} \frac{1}{16}\mu^2(1+\omega)^2 & for \quad 0 \; < \; \mu \; \leq \; \tilde{\mu}(\omega) \\ \frac{1}{8}\mu^2(1+\omega)^2 - \frac{1}{2} & \\ -\frac{1}{2}\ln\left[\frac{1}{8}\mu^2(1+\omega)^2\right] & for \quad \tilde{\mu}(\omega) \; < \; \mu \; \leq \; 1. \end{cases} \tag{4.10}$$

Even for zero screening ($0 < \mu \leq \tilde{\mu}(\omega)$), the expected social benefits per student exceed the social costs, making positive enrollment efficient. Note that the optimal number of

[23] The expression $\tilde{\mu}(\omega)$ is derived by solving $\tilde{s}^I(\mu,\omega) = 0$ with respect to the stay rate.

[24] Note that situations where the social planner does not screen for any stay rate are excluded, since according to Assumption 4.2 wages are defined for $\omega > \underline{\omega}$, with $\tilde{\mu}(\underline{\omega}) < 1$ and $\frac{\partial \tilde{\mu}}{\partial \omega} < 0$.

accepted applicants by the social planner also increases in the stay rate. The intuition is as follows: A larger μ increases the expected social net benefits from high-ability students (via larger stay rates of graduates as well as stimulated second-best education investments for a_H-students), but leaves the social losses from low-ability students constant. Hence, also the expected social net benefits per accepted applicant grow. In fact, the second-best screening activity increases at the same time (if positive in equilibrium). The larger type certainty of the social planner raises the proportion of a_H-types among the accepted individuals. This increases the expected social net benefits per student additionally.

4.4.2 Equilibrium

Let us now turn to the case where students choose individual education investments and the government decides on screening activity and enrollment.

Stage 2: Individual Education Decision At stage 2, students decide about their education investments, taking enrollment as well as screening activity of the government as given. Using the modified utility function from equation (4.2) shows the following maximization problem

$$\max_{\hat{z}_i^I} EU_i^I = \mu\, a_i\, \hat{z}_i^I\, \omega \;-\; \hat{z}_i^{I\,2} \quad \text{with } i \in (H, L). \tag{4.11}$$

Solving the first-order conditions reveals

$$\hat{z}_i^I = \begin{cases} \frac{1}{2}\mu\omega & if \quad a_i = a_H \\ 0 & if \quad a_i = a_L. \end{cases} \tag{4.12}$$

This result is obvious since individuals are well informed about their types. All students face private costs from investing in education but low-ability individuals are not rewarded due to $a_L = 0$. By contrast, high-ability students choose a strictly positive amount which rises in μ due to a larger probability of realizing the effort-dependent labor income in country h.

Stage 1: Government Decisions Let us now proceed to the first stage where the government maximizes the pay off function with respect to screening activity and accepted enrollment, taking the equilibrium education investments of equation (4.12) into account[25]

$$\begin{aligned}\max_{\hat{s}^I,\hat{n}^I} EZ^I = \hat{n}^I\,\gamma\,\mu\,P_H\left(\hat{s}^I\right)\,a_H\,\hat{z}_H^I\;-\;\hat{n}^{I\,2}\;-\;\hat{n}^I\,\hat{s}^I \\ +\,\hat{n}^I\,\left(\mu\,P_H\left(\hat{s}^I\right)\,a_H\,\hat{z}_H^I\,\omega -\;\mu\,P_H\left(\hat{s}^I\right)\,\hat{z}_H^{I\,2}\right).\end{aligned} \tag{4.13}$$

In contrast to the social planner, the government does not take care of leaving graduates. This can be seen by the additional stay rate parameter μ in the last term of the second line depicting the total costs of individual education investments. But this seems reasonable as a government should not take care of non-natives living abroad. Maximizing and solving with respect to screening activity reveals

$$\hat{s}^I(\mu,\omega) = \begin{cases} 0 & for \quad 0 < \mu \leq \hat{\mu}(\omega) \\ \ln\left[\frac{1}{4}\mu^2\omega\left(1+\omega(1-\frac{1}{2}\mu)\right)\right] & for \quad \hat{\mu}(\omega) < \mu \leq 1 \end{cases} \tag{4.14}$$

with

$$\frac{\partial \hat{s}^I}{\partial \mu} > 0 \qquad for \qquad \hat{\mu}(\omega) < \mu \leq 1.$$

The function $\hat{\mu}(\omega) = \frac{2}{\omega}$ denotes all stay rates where the government is indifferent to screening. For all stay rates above $\hat{\mu}(\omega)$ the government chooses positive activity, whereas for all stay rates below the activity is zero.[26] Analogous second-best, the larger the wage level the smaller is the particular stay rate $\hat{\mu}(\omega)$ where the government starts to screen, $\frac{\partial \hat{\mu}}{\partial \omega} < 0$.[27]

The government screening activity is also a positive function of the stay rate. On the one hand, a larger μ increases the expected net benefits from high-ability students for the government: directly, via a larger stay rate of graduates, and indirectly, via stimulated private education investments of high-ability students. On the other hand, the costs of accepted low-ability individuals remain unchanged. This raises the relative advantage of accepting a high-ability individual for the government, and makes larger screening activity beneficial.

Finally, the number of accepted students follows from the results of private education

[25] The equilibrium private education investments of equation (4.12) do not affect government maximization since the results are independent of screening activity and enrollment due to perfectly informed individuals.

[26] The expressions $\hat{\mu}(\omega)$ is derived by solving $\hat{s}^I(\mu,\omega) = 0$ with respect to the stay rate.

[27] Note that situations where the government does not screen for any stay rate are excluded, since Assumption 4.2 also implies $\hat{\mu}(\underline{\omega}) < 1$ and $\frac{\partial \hat{\mu}}{\partial \omega} < 0$.

investments and screening activity with

$$\hat{n}^I(\mu,\omega) = \begin{cases} \frac{1}{8}\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega) & for \quad 0 < \mu \leq \hat{\mu}(\omega) \\ \frac{1}{4}\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega)-\frac{1}{2} & \\ -\frac{1}{2}\ln\left[\frac{1}{4}\mu^2\omega\left(1+\omega(1-\frac{1}{2}\mu)\right)\right] & for \quad \hat{\mu}(\omega) < \mu \leq 1. \end{cases} \tag{4.15}$$

Note that the level is also positive for zero screening ($0 < \mu \leq \hat{\mu}(\omega)$). Furthermore, the number of accepted students by the government rises in the stay rate: The increase of the expected net benefits from high-ability students (via higher stay rates of graduates as well as stimulated private education investments of a_H-students) in combination with the constant losses of low-ability students raises the expected benefits per accepted applicant for the government. Besides, government screening activity increases at the same time (if screening is positive in equilibrium), which raises the probability of accepting a high- instead of a low-ability applicant. This additionally increases the expected net benefits per accepted individual.

4.4.3 Efficiency Analysis

We now evaluate efficiency with respect to screening activity, accepted enrollment and education investments for varying stay rates.

Individual Education Investments To begin with let us study the efficiency of education investments. Low-ability students always invest the efficient amount of zero, whereas high-ability students invest a positive amount. However, they ignore the positive externality of their own education decision on total human capital of country h and always invest inefficiently little, $\tilde{z}^I_H(\mu,\omega) > \hat{z}^I_H(\mu,\omega)$. This can be seen in the left panel of Figure 4.2 since the continued blue curve for the social planner is strictly above the dotted blue curve for students. We will see below that this underinvestment has important implications for screening and enrollment efficiency.[28]

Screening Activity Let us proceed with analyzing the efficiency of screening. We define the difference between the activity of the social planner and the government as

[28] For all illustrations of this model, the blue curves refer to the scenario of informed and the green curves to the scenario of learning individuals, always for $\omega = 5$. The continued curves show the levels of the social planner and the dotted ones depict the results for the government (screening activity and enrollment) and for students (education investments) results.

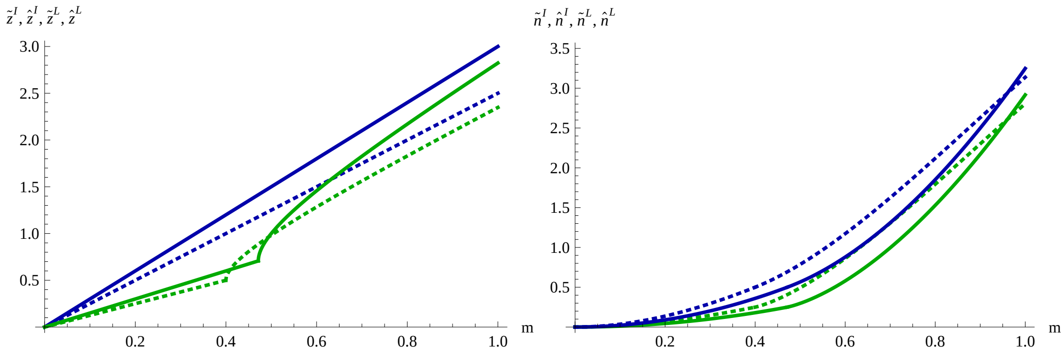

Figure 4.2: Individual education effort and enrollment

relevant criterion with $\Delta s^I(\mu,\omega) := \tilde{s}^I(\mu,\omega) - \hat{s}^I(\mu,\omega)$. A positive sign shows inefficiency from underscreening and a negative sign from overscreening. The following result emerges:

If $\underline{\omega} < \omega \leq \breve{\omega}$

$$\Delta s^I(\mu,\omega) = \begin{cases} = 0 & for \quad 0 < \mu \leq \tilde{\mu}(\omega) \\ > 0 & for \quad \tilde{\mu}(\omega) < \mu \leq 1. \end{cases} \tag{4.16}$$

If $\breve{\omega} < \omega$

$$\Delta s^I(\mu,\omega) = \begin{cases} = 0 & for \quad 0 < \mu \leq \hat{\mu}(\omega) \\ \leq 0 & for \quad \hat{\mu}(\omega) < \mu \leq \bar{\mu}(\omega) \\ > 0 & for \quad \bar{\mu}(\omega) < \mu \leq 1, \end{cases}$$

with

$$\frac{\partial \Delta s^I}{\partial \mu} = \frac{\omega}{2(1+\omega) - \mu\omega} > 0 \qquad for \qquad \mu \geq \max\left\{\tilde{\mu}(\omega), \hat{\mu}(\omega)\right\}. \tag{4.17}$$

The expression $\bar{\mu}(\omega) = \frac{\omega^2-1}{\omega^2} < 1$ represents all stay rates of efficient screening as function of the wage.[29] The parameter $\breve{\omega} = 2.414$ is defined as the unique wage level where the social planner and the government start to screen for the same stay rate, which is for $\breve{\mu} = 0.828$.[30] For all lower wages of $\underline{\omega} < \omega < \breve{\omega}$, the social planner starts

[29] The expression $\hat{\mu}(\omega)$ is derived by setting $\tilde{s}^I(\mu,\omega) = \hat{s}^I(\mu,\omega)$.

[30] Both values are derived by setting $\tilde{\mu}(\omega) = \hat{\mu}(\omega)$ and solving respectively.

to screen for smaller stay rates than the government, and $\breve{\mu} < \tilde{\mu}(\omega) < \hat{\mu}(\omega)$ holds . By contrast, for all larger wages of $\omega > \breve{\omega}$, the government starts to screen for lower stay rates than the social planner and $\hat{\mu}(\omega) < \tilde{\mu}(\omega) < \breve{\mu}$ holds (see for instance the blue curves for $\omega = 5$ in the left panel of Figure 4.3). The special case of $\omega = \breve{\omega}$ is pictured in the left panel of Figure 4.3 by the red curves.

Before continuing with explaining the results of equation (4.16), let us first introduce the two determining effects: On the one hand, as already mentioned, high-ability students ignore the positive externality on total human capital and invest inefficiently little in education (low-ability students always invest the efficient amount of zero). As a consequence, the expected net benefits from high-ability students for the government are below second-best, and screening activity is inefficiently little ceteris paribus. We denote this as (negative) *human capital effect*, where the implication on screening is determined by the ratio of effort levels with $\sigma^I := \frac{\tilde{z}^I_H}{\hat{z}^I_H} = \frac{1+\omega}{\omega} > 1$.[31] As can be seen, the fraction is independent of μ, hence, the effect is constant for all stay rates.

On the other hand, extended screening improves type identification and increases the fraction of high-ability individuals among the accepted applicants. However, this also raises the fraction of high-ability graduates among the emigrants. They face negative utility levels due to unrewarded education investments. These marginal social costs from screening are considered by the social planner, but ignored by the government. Let us refer to this as (positive) *composition effect*. It obviously fades with rising stay rate since less graduates leave the country, also involving the high-ability students with unrewarded education investments. Of course, the effect is zero for $\mu = 1$. It follows that the government screening function is strictly flatter than the second-best curve (see equation (4.17)).[32]

We proceed now with studying the results of equation (4.16). As described before, in the first case of small wages with $\underline{\omega} < \omega \leq \breve{\omega}$, the social planner starts to screen for lower stay rates than the government. Then, underscreening occurs and even grows

[31] The ratio of education investments for a general notation with respect to γ is $\frac{\tilde{z}^I_H}{\hat{z}^I_H} = \frac{\gamma+\omega}{\omega}$.

[32] The derivative of equation (4.17) is strictly positive according to Assumption 4.2 and $0 < \mu \leq 1$. Note that in the range of $\min\{\tilde{\mu}(\omega), \hat{\mu}(\omega)\} \leq \mu < \max\{\tilde{\mu}(\omega), \hat{\mu}(\omega)\}$, either the social planner or the government screens: In the first case of $\underline{\omega} < \omega \leq \breve{\omega}$, the social planner screens unilaterally in the range of $\tilde{\mu}(\omega) < \mu \leq \hat{\mu}(\omega)$, and the screening difference $\Delta s^I(\mu, \omega)$ grows. The government activity is zero but the screening function of the social planner increases with rising stay rate, $\frac{\partial \tilde{s}^I}{\partial \mu} = \frac{2}{\mu} > 0$. In the second case of $\breve{\omega} < \omega$, the government screens unilaterally in the range of $\hat{\mu}(\omega)\mu \leq \tilde{\mu}(\omega)$, and the screening difference $\Delta s^I(\mu, \omega)$ falls (in fact, becomes more negative). The second-best level is zero but government screening activity is an increasing function of the stay rate with $\frac{\partial \hat{s}^I}{\partial \mu} = \frac{3\mu\omega - 4\omega - 4}{\mu(\mu\omega - 2\omega - 2)} > 0$.

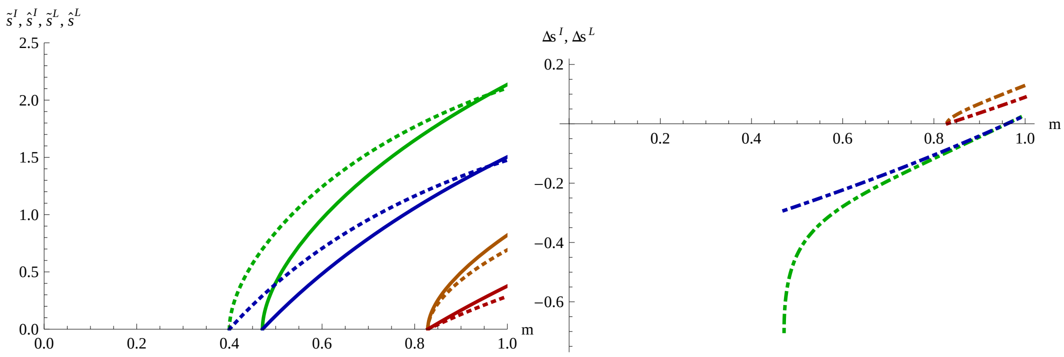

Figure 4.3: Screening activity and screening efficiency

with rising stay rate in the range of $\tilde{\mu}(\omega) < \mu \leq 1$ (see equation (4.17)). The intuition is as follows: Due to the low wages, students only invest little in education. Hence, high stay rates are necessary to generate sufficiently large expected net benefits from high-ability students and make positive screening optimal for the government. But for these large stay rates, the *composition effect* is already too weak to compensate the negative *human capital effect*. Most foreign a_H-graduates stay in country h and the total amount of negative utility levels ignored by the government is small. Instead, for $0 < \mu \leq \tilde{\mu}(\omega)$ neither the social planner nor the government screens.

In the second case of high wages with $\breve{\omega} < \omega$, the private eduction investments are larger and the government begins to screen for moderate stay rates. Hence, in the range of $\hat{\mu}(\omega) < \mu < \bar{\mu}(\omega)$, the positive *composition effect* is strong enough to dominate the negative *human capital effect* and overscreening occurs. The intuition is that many foreign a_H-graduates leave country h, and the total amount of negative utility levels ignored by the government is large. However, since the *composition effect* monotonously fades with rising stay rate but the *human capital effect* remains constant, government screening falls below the second-best level at $\bar{\mu}(\omega)$ and underscreening intensifies in the range of $\bar{\mu}(\omega) \leq \mu \leq 1$. Instead, for $0 < \mu \leq \hat{\mu}(\omega)$ activity of the social planner and the government is zero.

The screening activity is pictured in the left panel of Figure 4.3, and the corresponding inefficiencies can be seen in the right panel. Note that the blue curve for $\omega = 5$ runs from the negative to the positive quadrant, that is from over- to underscreening. In contrast, the red function for $\omega = \breve{\omega}$ emanates at the stay rate $\mu = \breve{\mu}$ for $\Delta s^I(\mu, \omega) = 0$. This curve is always in the upper quadrant since overscreening is prohibited by definition of $\breve{\omega}$.

Enrollment Let us finally analyze enrollment efficiency. As for screening, the difference between the level of the social planner and the government serves as relevant criterion with $\Delta n^I(\mu,\omega) := \tilde{n}^I(\mu,\omega) - \bar{n}^I(\mu,\omega)$. A positive sign indicates inefficiency from too few, and a negative sign from too many accepted applicants. It turns out that

$$\Delta n^I(\mu,\omega) = \begin{cases} < 0 & for \quad 0 \quad < \quad \mu \quad < \quad \bar{\mu}(\omega) \\ \geq 0 & for \quad \bar{\mu}(\omega) \quad \leq \quad \mu \quad \leq \quad 1, \end{cases} \tag{4.18}$$

where $\bar{\mu}(\omega) = \frac{\omega^2-1}{\omega^2} < 1$ denotes all stay rates of efficient enrollment as function of the wage level. Note that these stay rates are identical to those for efficient screening (see equation (4.16)).[33] This is intuitive for the range of $\omega > \breve{\omega}$: the screening functions of the social planner and the government intersect at $\bar{\mu}(\omega)$, and efficient type certainty is always ensured for the stay rates of efficient enrollment. By contrast, for the range of $\underline{\omega} < \omega \leq \breve{\omega}$ the two screening functions do not intersect, and we observe underscreening. However, the functions actually do intersect for hypothetical negative screening activities, again at $\bar{\mu}(\omega)$, which we denote from now on as $\bar{\mu}^\circ(\omega)$. And for these stay rates of hypothetical intersection still holds that the negative implications on expected benefits per student from too little private education investments exactly balance with the positive implications of ignored negative utility levels of high-ability emigrants. Moreover, screening activity of the social planner as well as the government are zero for $\bar{\mu}^\circ(\omega)$, thus, 'screening' is efficient.

It follows that for all stay rates larger than $\bar{\mu}(\omega)$, the positive implications of ignored negative utility levels of high-ability emigrants are smaller than the negative implications from too little private education investments. Hence, the expected net benefits per student are inefficiently small for the government, and so is enrollment. Moreover, underscreening occurs (or the activities of the social planner and the government are both zero) and type identification is too imprecise. This reduces the expected net benefits per accepted applicant even further.

For all stay rates below $\bar{\mu}(\omega)$, the intuition is vice versa. The positive implications of ignored negative utility levels of high-ability emigrants are now larger than the negative implications from too little private education investments. This raises the expected net benefits per student above the efficient level and the number of accepted applicants by the government is too large. In addition, overscreening occurs (or the activities of

[33] Appendix B proves that for all stay rates where the screening functions of the social planner and the government intersect also holds that the number of accepted applicants is efficient. However, the existence of additional equilibria for inefficient screening activity with $\tilde{s}^I(\mu,\omega) \neq \hat{s}^I(\mu,\omega)$ can not be excluded analytically. However, I checked by hand and could not find any.

the social planner and the government are both zero) and type identification for the government is too precise. This raises the expected benefits per student even more and intensifies the inefficiency from to many accepted applicants.

The corresponding enrollment levels are shown in the right panel of Figure 4.2 by the blue curves. Both functions have positive slopes. Extensive enrollment occurs for small stay rates of $0 < \mu \leq \bar{\mu}(\omega)$, since the dotted curve for the government is then above the continued one for the social planner. Remember, the range of extensive enrollment also involves the case of zero screening activity of both the social planner and the government.

The following proposition summarizes the obtained results for the scenario of informed individuals:

Proposition 4.1 *In the scenario of informed individuals, screening activity, the number of accepted students and individual education investments of the social planner as well as the government/students increase with rising stay rate. Considering efficiency, the following results can be stated:*

(A) For high wage levels of $\omega > \breve{\omega}$, government screening is inefficiently large for moderate stay rates of $\hat{\mu}(\omega) < \mu \leq \bar{\mu}(\omega)$, but inefficiently low for high stay rates of $\bar{\mu} < \mu \leq 1$. By contrast, for low wage levels of $\underline{\omega} < \omega \leq \breve{\omega}$ government screening is always inefficiently little in the range of $\tilde{\mu}(\omega) < \mu \leq 1$. For small stay rates of $0 < \mu \leq \min\{\tilde{\mu}(\omega), \hat{\mu}(\omega)\}$, neither the social planner nor the government screens.

(B) The number of accepted foreign applicants is inefficiently large for small stay rates of $0 < \mu \leq \bar{\mu}(\omega)$, but inefficiently low for high stay rates of $\bar{\mu}(\omega) < \mu \leq 1$.

(C) Individual education investments of students are always below the social optimum.

Besides, the stay rates for efficient screening and efficient enrollment are identical.

4.5 Learning Individuals

In the previous section we discussed the scenario of informed individuals in which private education investments are independent of screening since the certainty enhancing aspect is irrelevant for students. However, this assumption is probably too strict: Foreign applicants may not be fully informed about academic requirements as well as social and cultural demands for integrating successfully in a foreign country and labor market. For this reason, screening activity, enrollment and education investments are now studied for a scenario of learning individuals. Applicants are initially uninformed, but update their beliefs on observing the screening activity of the government.

4.5.1 Second-Best

We begin again with calculating the second-best levels. Using the conditional probability of equation (4.5) modifies the welfare function to

$$\begin{aligned} \max_{\tilde{z}^L,\tilde{s}^L,\tilde{n}^L} EWF^L = & \ \tilde{n}^L \, \gamma \, \mu \, P_H\left(\tilde{s}^L\right) \, a_H \, \tilde{z}^L \ - \ \tilde{n}^{L\,2} - \tilde{n}^L \, \tilde{s}^L \\ & + \tilde{n}^L \ \left(\mu \, P_H\left(\tilde{s}^L\right) \, a_H \, \tilde{z}^L \, \omega \ - \ \tilde{z}^{L\,2}\right). \end{aligned} \tag{4.19}$$

The last term of the lower line depicts here the costs of individual education investments of all students, since they are initially uninformed about their innate types and invest the same amount. Maximizing and solving the first-order conditions generates the following second-best result for individual effort

$$\tilde{z}^L(\mu,\omega) = \begin{cases} \frac{1}{4}\mu(1+\omega) & for \quad 0 \quad < \quad \mu \quad \leq \quad \tilde{\mu}(\omega) \\ \frac{1}{4}\mu(1+\omega) + \frac{1}{4}\sqrt{\mu^2(1+\omega)^2 - 8} & for \quad \tilde{\mu}(\omega) \quad < \quad \mu \quad \leq \quad 1. \end{cases} \tag{4.20}$$

In contrast to the scenario of informed individuals, second-best education investments must distinguish between zero ($0 < \mu \leq \tilde{\mu}(\omega)$) and positive ($\tilde{\mu}(\omega) < \mu \leq 1$) screening, where the investment level is larger in the second case. The social planner takes into account that positive screening activity improves type identification. This raises the probability of accepting a beneficial high-ability instead of a low-ability individual. In turn, it reduces the risk for the social planner of incurring social losses from unrewarded education investments of low-ability students. Remember, this aspect was irrelevant in the previous scenario, where the social planner 'offered' ability-specific first-best education investment levels due to perfectly informed individuals.

In fact, type uncertainty also implies that the second-best education investments for high-ability students are smaller than in the previous scenario, $\tilde{z}^L(\mu,\omega) < \tilde{z}^I_H(\mu,\omega)$. This can be seen in the left panel of Figure 4.2 as the continued blue curve for the scenario of informed individuals is strictly above the continued green one for learning individuals. The kink in the green curve depicts the transition between zero and positive screening of the social planner.

Besides, the stimulating effect of higher stay rates on the second-best effort level is now twofold: On the one hand, a larger μ increases the rate of realizing the effort-dependent social benefits from high-ability students for the social planner. On the other hand, that social planner takes into account that the second-best screening activity rises at the same time. The larger type certainty ensures a greater proportion of beneficial high-ability individuals among the students. This reduces the risk of social losses from unrewarded education investments of low-ability individuals.

This second-best screening activity is

$$\tilde{s}^L(\mu,\omega) = \begin{cases} 0 & for \quad 0 \ < \ \mu \ \leq \ \tilde{\mu}(\omega) \\ \ln\left[\frac{1}{8}\mu^2(1+\omega)^2 \right. & \\ \left. +\frac{1}{8}\mu(1+\omega)\sqrt{\mu^2(1+\omega)^2-8}\right] & for \quad \tilde{\mu}(\omega) \ < \ \mu \ \leq \ 1 \end{cases} \tag{4.21}$$

with

$$\frac{\partial \tilde{s}^L}{\partial \mu} > 0 \qquad for \qquad \tilde{\mu}(\omega) < \mu \leq 1,$$

where $\tilde{\mu}(\omega) = \frac{\sqrt{8}}{1+\omega}$ denotes the particular stay rates where the social planner is indifferent to screening. Note that these stay rates are identical to those in the scenario of informed individuals, and also falls with rising wage, $\frac{\partial \tilde{\mu}}{\partial \omega} < 0$.

As in the previous scenario, second-best screening is an increasing function of the stay rate. However, the implications are slightly different: On the one hand, a larger μ causes greater expected social net benefits from high-ability students for two reasons: first, because of higher stay rates of graduates, and second, because of stimulated second-best education investments. On the other hand, it increases the social losses of low-ability students at the same time: they also invest the stimulated second-best level in education. This obviously makes accepting a high- instead of a low-ability applicant more efficient for the social planner, and second-best screening activity rises.

Mind that this second-best screening activity is here larger than in the scenario of informed individuals, $\tilde{s}^L(\mu,\omega) > \tilde{s}^I(\mu,\omega)$. The intuition is as follows: Screening also stimulates now the second-best education investments. This increases the expected social net benefits of staying high-ability students, and it raises the social losses of low-ability students. However, since type certainty rises simultaneously, the overall effect is positive and second-best screening is here larger than for informed individuals. This can be seen in the left panel of Figure 4.3, since the continued green curve is above the continued blue one.

Finally, second-best enrollment is

$$\tilde{n}^L(\mu,\omega) = \begin{cases} \frac{1}{32}\mu^2(1+\omega)^2 & for \quad 0 \ < \ \mu \ \leq \ \tilde{\mu}(\omega) \\ \frac{1}{16}\mu^2(1+\omega)^2 + \frac{1}{16}\mu(1+\omega)\sqrt{\mu^2(1+\omega)^2-8} - \frac{1}{4} & \\ -\frac{1}{2}\ln\left[\frac{1}{8}\mu^2(1+\omega)^2 + \frac{1}{8}\mu(1+\omega)\sqrt{\mu^2(1+\omega)^2-8}\right] & \\ & for \ \ \tilde{\mu}(\omega) \ < \ \mu \ \leq \ 1. \end{cases} \tag{4.22}$$

Both expressions are strictly positive and increases in μ: The larger expected social net benefits per high-ability student (via larger stay rates of emigrants as well as stimulated second-best education investments) also increase the expected social net benefits per accepted applicant, although the social losses of low-ability students rise as well (through stimulated second-best education investments). Moreover, screening activity of the social planner rises at the same time (if positive in equilibrium). The increased type certainty enhances the proportion of high-ability individuals among the accepted applicants. In turn, the lower risk of educating a low-ability individual makes larger enrollment even more efficient for the social planner.

Interestingly, also second-best enrollment is smaller than in the scenario of informed individuals, $\tilde{n}^L(\mu,\omega) < \tilde{n}^I(\mu,\omega)$, although screening activity and consequently type certainty are larger for the social planner. However, the smaller second-best education investments as well as the resulting negative utility levels of low-ability students reduce expected benefits per student and make enrollment less efficient. This is shown in the right panel of Figure 4.2, since the continued green function for the scenario of learning individuals is strictly below the continued blue one for informed individuals.

4.5.2 Equilibrium

Before deriving the equilibrium values, let us first study the learning process of individuals. Their initial expectations about their ability are the average value of the basic distribution with $A = \alpha a_H + (1-\alpha)a_L = 1/2$. On observing the screening activity they update their beliefs in the following way:

$$A \longrightarrow A(\hat{s}^L) \qquad \text{with} \qquad A(\hat{s}^L) = P(a_H|t_H)\,a_H + P(a_L|t_H)\,a_L = 1 - \frac{1}{2}\,e^{-\hat{s}^L}, \tag{4.23}$$

where $P(a_H|t_H)$ and $P(a_L|t_H)$ are the conditional probabilities of testing a high-ability and a low-ability individual *and* a high type is indicated (see equation (4.5)).

Stage 2: Individual Education Decision Applying the expression $A(\hat{s}^L)$, the utility function of foreign students can be rewritten as

$$\max_{\hat{z}^L} EU^L = \mu\, A(\hat{s}^L)\, \hat{z}^L\, \omega \;-\; \hat{z}^{L\,2}. \tag{4.24}$$

Solving the first-order condition with respect to private education investments, we obtain

$$\hat{z}^L(\hat{s}^L) = \left(\frac{1}{2} - \frac{1}{4} e^{-\hat{s}^L}\right) \mu\, \omega \qquad \text{with} \qquad \frac{\partial \hat{z}^L}{\partial \hat{s}^L} = \frac{1}{4}\, e^{-\hat{s}^L}\, \mu\, \omega \,>\, 0. \tag{4.25}$$

Obviously, private education investments increase with rising screening activity. The reason is the extended certainty of being a high-ability type and receive effort-dependent labor income in country h. However, the levels are definitely smaller than for informed individuals (see equation (4.12)): For zero screening, education investments are exactly one half with $\hat{z}^L|_{s=0} = \frac{1}{4}\mu\omega$, and if screening goes to infinity, they approach the level of informed individuals, as $\lim_{s\to\infty} \hat{z}^L = \frac{1}{2}\mu\omega$. This can be seen in the left panel of Figure 4.2, since the continued green curve is strictly below the continued blue one, but both functions converge with rising stay rate in the range to the right of the kink.

Stage 1: Government Decisions Let us now proceed to the first stage where the government chooses screening activity and enrollment, taking the effects on private education investments into account. Substituting equation (4.25) modifies the government pay off function to

$$\begin{aligned} \max_{\hat{s}^L, \hat{n}^L} EZ^L = {} & \hat{n}^L\, \gamma\, \mu\, P_H\left(\hat{s}^L\right)\, a_H\, \hat{z}^L\left(\hat{s}^L\right) \;-\; \hat{n}^{L\,2} \;-\; \hat{n}^L\, \hat{s}^L \\ & + \hat{n}^L\, \left(\mu\, P_H\left(\hat{s}^L\right)\, a_H\, \hat{z}^L\left(\hat{s}^L\right)\, \omega \;-\; \mu\, \left(\hat{z}^L\left(\hat{s}^L\right)\right)^2\right). \end{aligned} \tag{4.26}$$

Deriving the first-order conditions and solving with respect to screening activity leads to

$$\hat{s}^L(\mu,\omega) = \begin{cases} 0 & for \quad 0 \,<\, \mu \,\leq\, \hat{\mu}(\omega) \\[2ex] \ln\left[\frac{1}{4}\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega) \right. \\ \quad \left. +\frac{1}{4}\sqrt{\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega)\left(\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega)-4\right)}\right] \\ & for \quad \hat{\mu}(\omega) \,<\, \mu \,\leq\, 1 \end{cases} \tag{4.27}$$

with

$$\frac{\partial \hat{s}^L}{\partial \mu} > 0 \qquad for \qquad \hat{\mu}(\omega) < \mu \leq 1.$$

The function $\hat{\mu}(\omega) = \frac{2}{\omega}$ denotes all stay rates where the government is indifferent to screening. As for the social planner, these particular stay rates are identical to those in the scenario of informed individuals. Hence, they also fall in wage for the same intuition as before, $\frac{\partial \hat{\mu}}{\partial \omega} < 0$.

Equally second-best, government screening rises in the stay rate: On the one hand, because a higher μ increases the expected net benefits from high-ability students for the government. On the other hand, because the losses of wrongly accepted low-ability individuals rise as well. Hence, accepting a high-ability individual becomes relatively more beneficial for the government and larger screening activity is optimal.

In fact, government screening activity is larger than for the scenario of informed individuals, $\hat{s}^L(\mu, \omega) > \hat{s}^I(\mu, \omega)$: Screening stimulates here private education investments (see equation (4.25)). This raises the expected net benefits of high-ability students, and it increases the losses from low-ability students. The overall effect is again positive due to the simultaneously growing type certainty for the government. This is exemplified in the left panel of Figure 4.3, as the dotted green curve is always above the dotted blue curve ($\omega = 5$), and the dotted orange curve is above the dotted red one ($\omega = \breve{\omega}$).

Substituting the result for government screening in equation (4.25) reveals the equilibrium private education investments as

$$\hat{z}^L(\mu, \omega) = \begin{cases} \frac{1}{4}\mu\omega & for \quad 0 < \mu \leq \hat{\mu}(\omega) \\ \frac{1}{2}\mu\omega - \frac{\omega}{\mu\omega(1+\omega-\frac{1}{2}\mu\omega)+\sqrt{\omega(1+\omega-\frac{1}{2}\mu\omega)(\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega)-4)}} & \\ & for \ \hat{\mu}(\omega) < \mu \leq 1. \end{cases} \tag{4.28}$$

The first line shows education investments for zero government screening ($0 < \mu \leq \hat{\mu}(\omega)$), and the second line for positive activity ($\hat{\mu}(\omega) < \mu \leq 1$). In both cases, the effort level increases in the stay rate: On the one hand, due to the larger probability of enjoying effort-dependent labor income in the case of being a high-ability individual. On the other hand, due to the greater certainty of actually being such an a_H-type in consequence of extended government screening (if screening is positive in equilibrium).

Finally, applying the equilibrium results for screening activity and individual education investments reveals the number of accepted students by the government as

$$\hat{n}^L(\mu,\omega) = \begin{cases} \frac{1}{16}\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega) & for \quad 0 \ < \ \mu \ \leq \ \hat{\mu}(\omega) \\ \frac{1}{8}\mu^2\omega\left(1+\omega-\frac{1}{2}\mu\omega\right) & \\ +\frac{1}{8}\Psi-\frac{1}{4}-\frac{1}{2}\ln\left[\frac{1}{4}\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega)+\frac{1}{4}\Psi\right] & \\ & for \ \ \hat{\mu}(\omega) \ < \ \mu \ \leq \ 1, \end{cases} \tag{4.29}$$

with

$$\Psi := \sqrt{\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega)\left(\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega)-4\right)}. \tag{4.30}$$

Both expressions are strictly positive and increase in the stay rate. A larger μ raises the expected net benefits from high-ability students. Consequently, this increases the expected net benefits per accepted applicant, even though the losses from low-ability students grow as well. Furthermore, the rising screening activity of the government enhances the proportion of a_H-types among the students. This additionally increases the expected net benefits per accepted applicant and raises optimal enrollment even further.

Note that the equilibrium number of students is also below the level for informed individuals, $\hat{n}^L(\mu,\omega) < \hat{n}^I(\mu,\omega)$, although the larger screening activity provides greater type certainty for the government. But this is clear for two reasons: First, high-ability students invest less in education due to imperfect information, and second, wrongly accepted low-ability students produce additional costs if staying in the country after graduation. Both aspects reduce the expected net benefits per student for the government compared to the scenario of informed individuals.

4.5.3 Efficiency Analysis

Let us now evaluate the efficiency of screening, enrollment and individual education investments.

Screening Activity Starting with screening efficiency, we define again the difference between the activity of the social planner and the government as relevant criterion, that is $\Delta s^L(\mu,\omega) := \tilde{s}^L(\mu,\omega) - \hat{s}^L(\mu,\omega)$. As before, a positive sign indicates inefficiency from underscreening and a negative sign from overscreening:

If $\underline{\omega} < \omega \leq \breve{\omega}$

$$\Delta s^L(\mu,\omega) = \begin{cases} = 0 & for \quad 0 < \mu \leq \tilde{\mu}(\omega) \\ > 0 & for \quad \tilde{\mu}(\omega) < \mu \leq 1. \end{cases} \tag{4.31}$$

If $\breve{\omega} < \omega$

$$\Delta s^L(\mu,\omega) = \begin{cases} = 0 & for \quad 0 < \mu \leq \hat{\mu}(\omega) \\ \leq 0 & for \quad \hat{\mu}(\omega) < \mu \leq \bar{\mu}(\omega) \\ > 0 & for \quad \bar{\mu}(\omega) < \mu \leq 1, \end{cases}$$

with

$$\frac{\partial \Delta s^L}{\partial \mu} > 0 \qquad for \qquad \mu > \max\{\tilde{\mu}(\omega), \hat{\mu}(\omega)\}. \tag{4.32}$$

The expression $\bar{\mu}(\omega) = \frac{\omega^2-1}{\omega^2} < 1$, depicting all stay rates of efficient government screening as function of the wage, is identical to the scenario of informed individuals.[34] Hence, also the particular wage level $\breve{\omega}$ where the social planner and the government start to screen for the same stay rate $\breve{\mu}$ is identical. This special case of $\omega = \breve{\omega}$ for the scenario of learning individuals is pictured in the left panel of Figure 4.3 by the orange curves.

Note that the *composition effect* is absent now. Larger screening activity of the government still changes the composition of accepted applicants towards more high-ability types. But this does no longer affect the total amount of negative utility levels of emigrants since all students invest here the same in education. Instead, students learn from observing the screening activity and increase their private education investments according to equation (4.25). This 'learning' is taken into account by the government and gives rise for extensive screening, since the corresponding growth of the negative utility levels of emigrants is again ignored by the government. Let us denote this as (positive) *stimulation effect.*

Comparing now equation (4.31) to screening efficiency in the scenario of informed

[34] In the range of $\min\{\tilde{\mu}, \hat{\mu}\} \leq \mu < \max\{\tilde{\mu}, \hat{\mu}\}$, either the social planner or the government screen. In the first case of $\underline{\omega} < \omega \leq \breve{\omega}$, the social planner screens unilaterally in the range of $\tilde{\mu}(\omega) < \mu \leq \hat{\mu}(\omega)$, where the screening difference $\Delta s^L(\mu,\omega)$ grows. The government activity is zero but the screening function of the social planner increases with rising stay rate since $\frac{\partial \tilde{s}^L}{\partial \mu} > 0$, see Appendix C. In the second case of $\breve{\omega} < \omega$ the government screens unilaterally in the range of $\hat{\mu}(\omega) < \mu \leq \tilde{\mu}(\omega)$, and the screening difference $\Delta s^L(\mu,\omega)$ falls (in fact, becomes more negative). The second-best activity is zero but government screening is an increasing function of the stay rate with $\frac{\partial \hat{s}^L}{\partial \mu} > 0$, see Appendix C. Despite, the positive sign of equation (4.32) for all defined stay rates can only be proven analytically for $\omega > \breve{\omega}$, see Appendix C.

individuals of equation (4.16), one can see that both results are qualitatively identical:

For $\underline{\omega} < \omega \leq \breve{\omega}$ the social planner starts to screen for smaller stay rates than the government, $\tilde{\mu}(\omega) < \hat{\mu}(\omega)$. The reason is that for these low wages private education investments are relatively small. Hence, large stay rates are necessary in order to raise the advantages from high-ability over low-ability students sufficiently and make positive screening beneficial for the government. However, for these large stay rates, the positive *stimulation effect* is already dominated by the negative *human capital effect*. It follows that screening activity is inefficiently low in the range of $\tilde{\mu}(\omega) < \mu \leq 1$. For $0 < \mu \leq \tilde{\mu}(\omega)$ neither the social planner nor the government screens.

By contrast, for $\breve{\omega} < \omega$ the government starts to screen for lower stay rates than the social planner, $\tilde{\mu}(\omega) > \hat{\mu}(\omega)$. In consequence of the high wages private education investments are sufficiently stimulated to make government screening optimal also for middle-range stay rates. There, the positive *stimulation effect* dominates the negative *human capital effect* and overscreening occurs for $\hat{\mu}(\omega) < \mu \leq \bar{\mu}(\omega)$. However, with rising stay rate, the positive *stimulation effect* fades and screening activity of the government falls below the second-best level at $\bar{\mu}(\omega)$. Then, the inefficiency of underscreening intensifies with rising stay rate in the range of $\bar{\mu}(\omega) < \mu \leq 1$ (see equation (4.32)). For small stay rates of $0 < \mu \leq \hat{\mu}(\omega)$ neither the social planner nor the government screens.

Besides, the intuition says that the two determining effects in the scenario of informed individuals are weaker than the two effects in the scenario of learning individuals, resulting in larger inefficiency from over- and underscreening in the second case. This can be shown for any numerical example. However, the analytical proof is missing due to the complexity of the functional forms. Nevertheless, let us briefly discuss the intuition:

We begin with the negative *human capital effects*. In both scenarios, high-ability students ignore the positive externality on human capital and invest inefficiently little in education. Instead, low-ability students invest zero in the scenario of informed individuals, equal to the second-best level. In the scenario of learning individuals, low-ability students invest a positive amount. However, they ignore the human capital externality and choose education investments below second-best (identical to a_H-students). Hence, the expected costs of wrongly accepting a low-ability applicant are smaller for the government than incurred by the social planner. This additional inefficiency from a_L-students exclusively arises in the scenario of learning individuals. It reduces the screening incentive of the government for more than in the scenario of informed individuals (where only a_H-students invest inefficiently little in education).[35] See for instance the left panel of Figure 4.3, where the distance between the green curves is larger than the distance between the blue curves for the stay rate $\mu = 1$, since the *composition effect* as well as the *stimulation effect* are absent there.

Let us now analyze the difference between the *composition effect* (informed individuals) and the *stimulation effect* (learning individuals). In the scenario of informed individuals, low-ability students choose the second-best education investments of zero. By contrast, in the scenario of learning individuals, all students invest in education. Hence, increasing the screening activity also stimulates private education investments of emigrating low-ability students. This raises their negative utility levels. These marginal costs of screening are ignored by the government (equal to the negative utilities of a_H-emigrants). Since they exclusively arises in the scenario of learning individuals, the screening incentive for the government relative to second-best is raised by more than in the scenario of informed individuals.[36]

The right panel of Figure 4.3 pictures the inefficiency of screening for learning individuals by the green function. As can be seen, the curve runs from the negative to the positive quadrant, i.e. from over- to underscreening. Note that the inefficiencies are here indeed larger than for informed individuals, since the green curve is below the blue one in the negative range, but above the blue one in the positive area. However, as stated before, both curves cross the abscissa at the same stay rate $\bar{\mu}(\omega)$.

Individual Education Investments Let us proceed with the efficiency of education investments. We apply again the ratio of effort levels with $\sigma^L := \frac{\tilde{z}^L}{\hat{z}^L}$. Remember, the ratio for informed individuals $\sigma^I(\omega) = \frac{1+\omega}{\omega}$ exactly depicts the ignored human capital externality:

If $\underline{\omega} < \omega \leq \breve{\omega}$

$$\sigma^L(\mu,\omega) = \begin{cases} = \sigma^I(\omega) & for \quad 0 < \mu \leq \tilde{\mu}(\omega) \\ > \sigma^I(\omega) & for \quad \tilde{\mu}(\omega) < \mu \leq 1. \end{cases}$$

[35] Note that education investments of high-ability households do not affect the difference between the *human capital effect* for informed and learning individuals. Students equally ignore the positive human capital externality in both scenarios.

[36] As for the *human capital effects*, inefficiencies from high-ability emigrants do not affect the varying strength between the *composition effect* and the *stimulation effect*, since they are ignored by the government but considered by the social planner in both scenarios equally.

(4.33)

If $\breve{\omega} < \omega$

$$\sigma^L(\mu,\omega) = \begin{cases} = \sigma^I(\omega) & for \quad 0 < \mu \leq \hat{\mu}(\omega) \\ \leq \sigma^I(\omega) & for \quad \hat{\mu}(\omega) < \mu \leq \bar{\mu}(\omega) \\ > \sigma^I(\omega) & for \quad \bar{\mu}(\omega) < \mu \leq 1. \end{cases}$$

As can be seen, the result is directly linked to screening efficiency of equation (4.31):

Starting with the first case of $\underline{\omega} < \omega \leq \breve{\omega}$: High stay rates of $\tilde{\mu}(\omega) < \mu \leq 1$ reveal inefficiently low screening activity by the government. In consequence of the imprecise signal, the inefficiency of private underinvestment in education is larger than simply caused by the ignored human capital externality, and $\sigma^L(\mu,\omega) > \sigma^I(\omega)$ holds. Instead, for low stay rates of $0 < \mu \leq \tilde{\mu}(\omega)$ neither the social planner nor the government screens ('screening' is efficient), and the ratios of both scenarios are identical with $\sigma^L(\mu,\omega) = \sigma^I(\omega)$.

In the second case of high wages with $\breve{\omega} < \omega$, three parts must be considered: First, in the range of $\bar{\mu}(\omega) < \mu \leq 1$, screening activity and consequently type certainty is inefficiently small. Hence, private underinvestment is again larger than just caused by the ignored human capital externality, resulting in $\sigma^L(\mu,\omega) > \sigma^I(\omega)$. Second, in the middle range of $\hat{\mu}(\omega) < \mu \leq \bar{\mu}(\omega)$, overscreening occurs due to the dominant *stimulation effect*. In consequence of the extensive type certainty, private education investments are either still below the second-best level, but the inefficiency is then smaller than caused by the ignored human capital externality with $1 < \sigma^L(\mu,\omega) < \sigma^I(\omega))$, or private investments are even above the second-best level with $\sigma^L(\mu,\omega) \leq 1 < \sigma^I(\omega)$. In the latter case, the stimulating effect of extensive student beliefs of being a high-ability type overcompensates the negative implication of the ignored human capital externality.[37] This case of private overinvestment in education with $\sigma^L(\mu,\omega) < 1$ is exemplarely pictured in the left panel of Figure 4.2. The dotted green curve is partly above the continued green one. Finally, the third part covers small stay rates of $0 < \mu \leq \hat{\mu}(\omega)$, where neither the social planner nor the government screens. The ratios are then

[37] To show that private overinvestment in education is indeed a possible outcome, let as evaluate the necessary condition $\hat{z}^L(\mu,\omega) > \tilde{z}^L(\mu,\omega)$ for the stay rate $\tilde{\mu}(\omega)$ where the social planner is indifferent to screening (depicted by the kink of the green continued function in the left panel of Figure 4.2). There it holds that ratio of effort levels falls with rising wage, $\frac{\partial \sigma^L}{\partial \omega}|_{\mu=\tilde{\mu}} < 0$, for $\omega > \breve{\omega}$. If overinvestment is fulfilled for a particular wage level, it must also be true for all larger wages. Taking for instance the plotted case of $\omega = 5$, it indeed holds that $\tilde{z}^L(\tilde{\mu},5) < \hat{z}^L(\tilde{\mu},5)$. Hence, for all $\omega > 5$ overinvestment definitely occurs at $\tilde{\mu}(\omega)$.

identical again, $\sigma^I(\omega) = \sigma^L(\mu, \omega)$.

Enrollment Finally, we evaluate enrollment efficiency. As before, we use the difference between the level of the social planner and the government as relevant criterion, $\Delta n^L(\mu, \omega) := \tilde{n}^L(\mu, \omega) - \hat{n}^L(\mu, \omega)$, and find

$$\Delta n^L(\mu, \omega) = \begin{cases} < 0 & for \quad 0 < \mu < \bar{\mu}(\omega) \\ \geq 0 & for \quad \bar{\mu}(\omega) \leq \mu \leq 1. \end{cases} \tag{4.34}$$

The expression $\bar{\mu}(\omega) = \frac{\omega^2 - 1}{\omega^2} < 1$ denotes all stays rate of efficient enrollment as function of the wage. Again, these stay rates are equal to those for efficient screening.[38] Furthermore, the result is qualitatively identical to the scenario of informed individuals (see equation (4.18)).

However, the effects of over- and underscreening on enrollment efficiency are more complex now. To illustrate this let as for instance assume the case of underscreening: On the one hand, this implies too little type certainty for the government. As a consequence, the proportion of high-ability individuals among the accepted applicants is inefficiently small, which reduces the expected net benefits per student below the efficient level. On the other hand, the imprecise signal for students also intensifies private underinvestments in education. The inefficiency is now larger than just caused by the ignored human capital externality, and the expected benefits per accepted applicant for the government fall additionally.

Of course, the opposite is true for overscreening. Then, private underinvestment in education is smaller than just caused by the ignored human capital externality. In fact, for private investments above the social optimum, the inefficiency switches from under- to overinvestment in education.

The left panel of Figure 4.2 shows enrollment for the scenario of learning individuals by the green curves. For small stay rates the dotted function for the government is above the continued one for the social planner, and for large stay rates the dotted curve is below the continued one.

The following proposition summarizes the obtained results for the scenario of learning individuals:

[38] A general proof of $\bar{\mu}(\omega)$ is not possible due to the complexity of the functional form. However, I checked wages by hand as well as by assistance of the math program 'Mathematica' and could not find any solution for efficient enrollment different to $\bar{\mu}(\omega)$.

Proposition 4.2 *In the scenario of learning individuals, screening activity, the number of accepted students and individual education investments of the social planner as well as the government/students increase in the stay rate. Considering efficiency of all three variables, the following results can be stated:*

(A) For high wage levels of $\omega > \breve{\omega}$, government screening is inefficiently large for moderate stay rates of $\hat{\mu}(\omega) < \mu \leq \bar{\mu}(\omega)$, but inefficiently low for high stay rates of $\bar{\mu} < \mu \leq 1$. By contrast, for low wage levels of $\underline{\omega} < \omega \leq \breve{\omega}$ government screening is always inefficiently little in the range of $\tilde{\mu}(\omega) < \mu \leq 1$. For small stay rates of $0 < \mu \leq \min\{\tilde{\mu}(\omega), \hat{\mu}(\omega)\}$, neither the social planner nor the government screens.

(B) The number of accepted foreign applicants is inefficiently large for small stay rates of $0 < \mu \leq \bar{\mu}(\omega)$, but inefficiently low for high stay rates of $\bar{\mu}(\omega) < \mu \leq 1$.

(C) The efficiency of private education investments depends on screening: If neither the social planner nor the government screens, $0 < \mu \leq \min\{\tilde{\mu}(\omega), \hat{\mu}(\omega)\}$, the result is identical to the scenario of informed individuals. By contrast, in the range of overscreening, that is for $\omega > \breve{\omega} \wedge \hat{\mu}(\omega) < \mu \leq \tilde{\mu}(\omega)$, the inefficiency of underinvestment in education is smaller than in the scenario of informed individuals, and students' education investments may even partly exceed the socially optimal level. In the range of underscreening, that is for $\omega > \breve{\omega} \wedge \bar{\mu}(\omega) < \mu \leq 1$ and for $\omega \leq \breve{\omega} \wedge \tilde{\mu}(\omega) < \mu \leq 1$, the inefficiency of too little private education investments is larger than in the scenario of informed individuals.

Besides, the stay rates for efficient screening and for efficient enrollment are identical.

4.6 Conclusion

This paper studied screening activity, enrollment and individual education investments for varying stay rates. Foreign individuals differ with respect to ability and apply for education. The government only benefits from high-ability graduates but cannot observe the individual type. However, screening the applicants is possible which raises the probability of identifying the true ability. Students invest privately in education, but may also feel uncertain about their own type. Two scenarios are considered: perfectly informed individuals and learning individuals. The latter update their belief on observing the government screening activity. Despite this, graduates return to their home country after graduation with an exogenous probability. If so, no benefits are obtained by the government and the graduates.

For sufficiently large wages, we find underscreening and too little enrollment for high stay rates, but extensively large (or zero) screening activity as well as enrollment for small stay rates. For low wage level, screening of the government is always too little, and the inefficiency even intensifies with rising stay rate. Interestingly, these results are qualitatively the same in a scenario of informed and a scenario of learning individuals. Hence, government effort aiming at a larger rate of permanent immigration of foreign graduates may distort government admission policy, that is, inefficiently low screening activity and too few accepted foreign applicants.

Besides, the size of the inefficiencies tends to fall, the better the informations given to applicants about the demands for being successful in the foreign country (in this model depicted by the scenario of learning individuals and the extreme case of perfectly informed individuals). This speaks in favor of developing multicultural skills of children in school and align study courses as well as degrees on an international level in order to reduce the uncertainty of foreign students. In fact, these are two main policy targets of the Bologna Process.

This model offers plenty of scope for further research. It would be interesting to endogenize the stay rate of graduates, for instance by implementing an allocation mechanism of working permits for the government. This produces a trade-off between costly preselecting via screening and costless sorting out of already educated graduates. Another aspect is to introduce an endogenous number of applicants which react on observing the screening policy. This clearly changes the results as the government must additionally incorporate supply effects when optimizing its admission policy.

In any case, this model presents a new approach of studying government admission policy of foreign applicants to tertiary education. Further research on this issue is clearly needed, since governments must be prepared for the growing mobility of individuals from all over the world.

Appendix

A Conditional probabilities

The probability of being a high-ability type conditional that the test indicates a high type is

$$P(a_H|t_H) = \frac{P(a_H \cap t_H)}{P(t_H)} = \frac{\alpha\, p(s)}{\alpha\, p(s) + (1-\alpha)(1-p(s))} = 1 - \frac{1}{2}\, e^{-s}. \tag{4.A.1}$$

The numerator shows the probability of being a high-ability individual *and* being identified correctly. The denominator depicts the probability that the test indicates a high type. This is the sum of being indeed a high-ability individual and the test is correct, plus being a low-ability individual but the test is false and indicates a high type.

The probability of being a low-ability individual, conditional that the test indicates a high type is

$$P(a_L|t_H) = \frac{P(a_L \cap t_H)}{P(t_H)} = \frac{(1-\alpha)(1-p(s))}{\alpha\, p(s) + (1-\alpha)(1-p(s))} = \frac{1}{2}\, e^{-s}. \tag{4.A.2}$$

Here, the numerator shows the probability of being a low-ability individual *and* the test indicates a high type. The denominator is again the overall probability that the test indicates a high type.

The derivatives of $P(a_H|t_H)$ and $P(a_L|t_H)$ are:

$$\begin{aligned} \frac{\partial P(a_H|t_H)}{\partial s} &= \frac{1}{2}e^{-s} > 0 \quad \text{and} \quad \frac{\partial^2 P(a_H|t_H)}{\partial s^2} = -\frac{1}{2}e^{-s} < 0 \\ \frac{\partial P(a_L|t_H)}{\partial s} &= -\frac{1}{2}e^{-s} < 0 \quad \text{and} \quad \frac{\partial^2 P(a_L|t_H)}{\partial s^2} = \frac{1}{2}e^{-s} > 0. \end{aligned} \tag{4.A.3}$$

B Informed individuals - Enrollment efficiency

Let us begin with the case where the level of efficient screening is zero. This occurs for small wages of $\omega < \breve{\omega}$. As described before, in this range the screening functions of the social planner and the government intersect for hypothetical negative screening levels at the stay rate $\bar{\mu}^{\circ}(\omega)$. Setting $\tilde{n}^I(\mu,\omega) = \hat{n}^I(\mu,\omega)$ for $\tilde{s}^I(\mu,\omega) = 0$ and $\hat{s}^I(\mu,\omega) = 0$, which is equivalent to

$$\frac{1}{16}\mu^2(1+\omega)^2 = \frac{1}{8}\mu^2\omega(1+\omega-\frac{1}{2}\mu\omega) \tag{4.B.1}$$

and solving with respect to the stay rate, it turns out: $\mu = \bar{\mu} = \frac{\omega^2-1}{\omega^2}$.

We continue now with the case where the level of efficient screening is positive. This occurs for high wages of $\omega > \breve{\omega}$. Rewriting the particular expressions for the number of accepted students, we get

$$\tilde{n}^I = \frac{1}{8}(\mu^2(1+\omega)^2 - 4 - 4\tilde{s}^I) \tag{4.B.2}$$

$$\hat{n}^I = \frac{1}{8}(\mu^2\omega(2-(\mu-2)\omega) - 4 - 4\hat{s}^I). \tag{4.B.3}$$

Applying now the condition for efficient screening $\tilde{s}^I(\mu,\omega) = \hat{s}^I(\mu,\omega)$, and solving $\tilde{n}^I = \hat{n}^I$ leads again to $\mu = \bar{\mu} = \frac{\omega^2-1}{\omega^2}$.

C Learning individuals - Screening efficiency

To prove the sign of $\frac{\partial \Delta s^L}{\partial \mu}$, let us start with the ranges where either the social planner or the government screens. In the first case of low wages with $\omega < \breve{\omega}$, the social planner screens unilaterally in the range $\tilde{\mu}(\omega) < \mu \leq \hat{\mu}(\omega)$, and the screening difference $\Delta s^L(\mu,\omega)$ rises, since government activity is zero but the screening function of the social planner increases in the stay rate with

$$\frac{\partial \tilde{s}^L}{\partial \mu} = -\frac{8}{m(-8+m^2(1+w)^2 - \sqrt{m^2(1+w)^2(-8+m^2(1+w)^2)})} > 0. \tag{4.C.1}$$

In fact this derivative is positive for the condition of positive screening of the social planner, that is $\mu > \tilde{\mu}(\omega)$.

By contrast, for $\omega > \breve{\omega}$ the government screens unilaterally in the range of $\hat{\mu}(\omega) < \mu \leq \tilde{\mu}(\omega))$. Then, the screening difference falls (in fact, becomes more negative) since second-best activity is zero, but the government screening function rises in the stay rate:

$$\frac{\partial \hat{s}^L}{\partial \mu} = \frac{\mu\omega((3\mu-4)\omega-4)(4+\mu^2\omega((\mu-2)\omega)-2-\Phi)}{\Phi(\mu^2\omega(2-(\mu-2)\omega)+\Phi)} > 0 \tag{4.C.2}$$

with

$$\Phi := \sqrt{\mu^2\omega((\mu-2)\omega-2)(\mu\omega-2)((\mu-2)\mu\omega-4)}.$$

Finally, to show that for $\omega > \breve{\omega}$ (the government starts to screen for smaller stay rates than the social planner), the difference of screening increases with rising stay rates in the range $\tilde{\mu}(\omega) < \mu \leq 1$, that is for simultaneous screening of the social planner and the government, we apply the math program 'Mathematica' due to the complexity of the functional forms. The following excerpt shows the proof in detail:

In[1]:= **Clear[m, w, ω, μ]**

In[2]:= **w = 2.414213562373095`;**

In[3]:= **m = 0.8284271247461903`;**

In[4]:= $\mathbf{sSP = Log\left[\frac{1}{8}\mu^2\,(1+\omega)^2 + \frac{1}{8}\mu\,(1+\omega)\sqrt{-8+\mu^2\,(1+\omega)^2}\right];}$

In[5]:= $\mathbf{sG = Log\left[\frac{1}{4}\mu^2\,\omega\left(1+\omega-\frac{\mu\,\omega}{2}\right)+\frac{1}{4}\sqrt{\mu^2\,\omega\left(1+\omega-\frac{\mu\,\omega}{2}\right)\left(-4+\mu^2\,\omega\left(1+\omega-\frac{\mu\,\omega}{2}\right)\right)}\right];}$

In[6]:= **Δs = sSP − sG;**

In[7]:= **DΔs = FullSimplify[D[Δs, μ]]**

Out[7]= $$\frac{1}{\mu}+\frac{1+\omega}{\sqrt{-8+\mu^2\,(1+\omega)^2}}+\left(\mu\,\omega\,(-4+(-4+3\,\mu)\,\omega)\left(-4+\mu^2\,\omega\,(2-(-2+\mu)\,\omega)+\sqrt{\mu^2\,\omega\,(-2+(-2+\mu)\,\omega)\,(-2+\mu\,\omega)\,(-4+(-2+\mu)\,\mu\,\omega)}\right)\right)\Big/\left(\sqrt{\mu^2\,\omega\,(-2+(-2+\mu)\,\omega)\,(-2+\mu\,\omega)\,(-4+(-2+\mu)\,\mu\,\omega)}\left(\mu^2\,\omega\,(2-(-2+\mu)\,\omega)+\sqrt{\mu^2\,\omega\,(-2+(-2+\mu)\,\omega)\,(-2+\mu\,\omega)\,(-4+(-2+\mu)\,\mu\,\omega)}\right)\right)$$

In[8]:= **Reduce[{DΔs > 0, w < ω, 0 < μ ≤ 1}, μ, Reals]**

Out[8]= $$\omega > 2.41421\ \&\&\ 2.82843\sqrt{\frac{1}{(1.+\omega)^2}} < \mu \leq 1.$$

The input lines In[2] and In[3] define the two parameters $\breve{\omega}$ and $\breve{\mu}$ as 'w' and 'm', and the input lines In[4] and In[5] show the equilibrium screening activity of the social planner and the government, where sSP and sG denote $\tilde{s}^L$ and $\hat{s}^L$. Input line In[6] shows the difference of screening levels Δs^L, and the command for the corresponding derivative with respect to the stay rate is shown in In[7] with the related result in the output line Out[7]. The curly brackets of the command 'Reduce' shows three conditions: The first is '$D\Delta s > 0$', stating that the screening difference increases with rising stay rate, whereas the second and the third, '$w < \omega$' and '$0 < \mu \leq 1$', define the ranges for possible solutions. Finally, the command 'Reals' restricts the outcome to real numbers. The results are presented in the output line below: The screening difference rises if '$\omega > 2.41421$', which is equivalent to $\omega > \breve{\omega}$, and if '$2.82843\sqrt{\frac{1}{(1+\omega)^2}} < \mu \leq 1$', which is equivalent to $\tilde{\mu}(\omega) < \mu \leq 1$.

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