ESSAYS ON THE ECONOMICS OF EDUCATION: MORE ABOUT SOCIAL MOBILITY AND (IN)EQUALITY AND THE WORKING OF THE ACADEMIC JOB MARKET

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1 Introduction

This doctoral thesis consists of four independent papers (Ch. 2-5), and all of them contribute to the *Economics of Education*. As a young researcher familiar with the international publication system I could be tempted to describe the work presented here just as Y4 (Dissertation) and I2 (Education and Research Institutions) taken from the *Journal of Economic Literature* classification system. However, this may be a little too frugal for the main part of the readers, and in the following some closer insights will be given into the general theme and the specific topics. Thus, this introduction aims at two points: First, I will give a short review of the history of the *Economics of Education* and describe the research field at present. Second, I will summarize and accentuate the four manuscripts that are the main part of this thesis.

The current importance of the *Economics of Education* is more or less evident. Controversies about the PISA ranking, the Bologna process and tuition fees are omnipresent in Germany. However, the roots of the *Economics of Education* lie in the ancient world. Plato already said about the importance of education:

For if a right education makes of them reasonable men they will easily discover everything [...]
(Plato, The Republic, Book IV, Part 3).

Due to its prominent role education became the government's responsibility, and there it is (more or less) up to now irrespective of the division of responsibilities between the German Länder and the federal level.

Now nobody would dispute that the education of the young requires the special attention of the lawgiver (Aristotele, Politics, Book VIII, Part 1).

Now readers may argue that nearly everything has its roots in the ancient world, and so this fact does not prove the special importance of education. Therefore, one should remember the arguments made by two other well-known philosophers. With his 'Some thoughts concerning education' John Locke (1693) wrote a whole book on this topic and says:

I think I may say, that of all the Men we meet with, Nine Parts of Ten are what they are, Good or Evil, useful or not, by their Education
(John Locke 1693, Some thoughts concerning education, Para. 1).

Adam Smith can be seen as the founding father of the theory of human capital. In his *Wealth of Nations* (1776) he wrote that education is a necessary precondition to exert certain professions. And since education is a costly investment it necessarily requires a wage premium. More precisely, he says about a skilled worker:

The work which he learns to perform, it must be expected, over and above the usual wages of common labour, will replace to him the whole expence of his education [...](Adam Smith 1776, The nature and causes of the wealth of nations, Book I, Ch. X, Part 1).

The probably most important person for the development of the German university system has been Wilhelm von Humboldt. We will recur to Humboldt's major idea of the 'Einheit von Forschung und Lehre' and the academic job market in Chapter 4. In addition to his central idea he postulates that it is the most important task of schooling to teach students how to learn. At the university level, finally, the doctoral candidate should be enabled to do his/her own research:

[The] university professor [is] not a teacher, the university student not a learner anymore, but the latter does research on his own, and the university professor supervises his research and supports it (Humboldt (1767-1835), 102).

To close this short sketch of citations, its surely convincing that education has always played an important role in society. However, the establishment of the modern *Economics of Education* took part not until the 1960s. At this time, Jacob Mincer (1958, 1974), Theodore W. Schultz (1963) and Gary S. Becker (1964) built the fundaments of the current research with their theoretical analyses. Their elaborations are still cited in nearly every paper about education and human capital theory.

There may be other reasons why people should educate but in an economic sense education is always related to productivity, and there are three main approaches explaining the effects of education on productivity.

- First, there is the human capital theory originating in the works of Gary S. Becker (1964). According to his theory, and following Adam Smith (1776), education fosters specific abilities of a person which in turn increase its productivity. So, education is an investment, and the person who educates can expect a higher return. This approach has become so well-established that the notion of human capital became the German 'Unwort des Jahres' (negative buzzword of the year) in 2004.[1] Although this is rather a doubtful honor, it clearly emphasizes the importance of this topic.
- Second, Schultz (1963, 1975) as well as Nelson and Phelps (1966) describe the effect of education on productivity as an indirect one. Education does not directly improve

[1] More about this on http://www.unwortdesjahres.org. The official explanation for this choice is that the word tends to humilate people treating them as a factor of sole economic interest.

a worker's abilities but helps to adjust to changed working conditions. Even though economists like to focus on long-term equilibria without shocks (see Ch. 2 and 3) in reality economies are often characterized by short term dynamics and a situation out of equilibrium. In such a case the Schultz-Nelson/Phelps idea is highly relevant since the ability to adapt becomes a central element of productivity.

- Third, there is the signaling theory developed by Michael Spence (1973, 1974). For him, it is not primarily relevant whether education has a direct or indirect effect on a worker's abilities. Instead, he considers abilities as inherent and, therefore, as private information. However, since workers simply differ in their abilities and firms always try to employ highly talented labor, the situation reveals a state of asymmetric information. According to Spence education exactly works as an instrument to solve this situation. Highly talented labor can signal high education efforts to separate themselves from the low-talented ones, and this approach is a key element of the analysis in Chapter 4.[2]

After getting familiar with these basic approaches to the effects of education on productivity, I will now turn the focus on the payoffs of education. There are different kinds of private as well as social payoffs. Clearly, the main private payoff is the wage premium (Mincer 1958; Mincer 1974; Card 1999) but there are other ones too. However, readers hoping to become happier with more education will be disappointed; there is either no direct effect of education on happiness (Helliwell 2003) or the effect is only very small (Di Tella et al. 2003). On the other hand, there is evidence of a positive impact of education on the health of the workers (e.g. Cutler and Lleras-Muney 2006; Lindelow 2006; Silles 2009) as well as on his/her children's health (e.g Doyle et al. 2007) and on their cognitive development (e.g. Carneiro et al. 2007). These benefits are private as well as social, and the latter always serves as justification for public interventions. In particular, social payoffs of education consist of an increase in technological progress and growth (e.g. Bils and Klenow 2000; Krueger and Kumar 2004; Ciccone and Papaioannou 2009), a reduction in crime (e.g. Lochner and Moretti 2004) and a boost of civic engagement (e.g. Dee 2004; Glaeser et al. 2007). As an example, Table 1 summarizes private and social returns of different school types for various groups of countries. Numbers have to be interpreted as: 1 Euro of investment in education leads to 1.xx Euro aggregated social/ private return. Obviously, social returns are always lower than private ones, and both are larger in primary than in secondary or higher education.

Additionally it should be noted that the demand for education has intensified in the last years. Years of schooling have increased (e.g. Cohen and Soto 2007), and more people have attended higher education (see Figure 1.1).

[2] Clearly, this introduction can only give a short overview of the different theoretical concepts concerning education. If the reader should be more interested in such theories, (Arai 1998) is a good point to start.

Country	Social Prim.	Social Sec.	Social Higher	Private Prim.	Private Sec.	Private Higher
Sub-Saharan/ Africa	24.3	18.2	11.2	41.3	26.6	27.8
Asia	19.9	13.3	11.7	39.0	18.9	19.9
Europe/Middle East/North Africa	15.5	11.2	10.6	17.4	15.9	21.7
Latin America/Caribbean	17.9	12.8	12.3	26.2	16.8	19.7
OECD	14.4	10.2	8.7	21.7	12.4	12.3
World	18.4	13.1	10.9	29.1	18.1	20.3

Table 1.1: Returns to investment in education by level (percentage) (Psacharopoulos 1994)

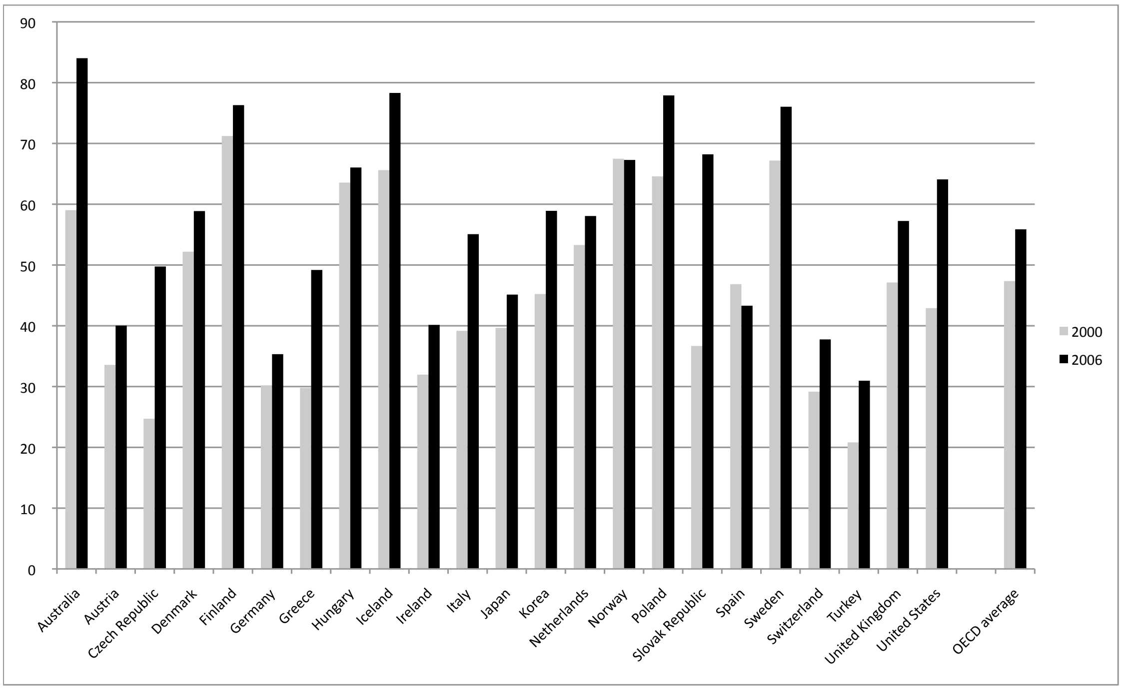

Figure 1.1: Entry rates at tertiary level 2000 and 2006 (OECD 2009, Indicator A2).

For a social planer interested in a low degree of intra- and intergenerational inequality, education is a key element to influence society. In general, we can take the following causal chain as given: even if talents are identical, inequality in education necessarily leads to inequality of income resulting in a certain degree of intragenerational inequality. This inequality of income is, furthermore, transferred to the children's generation. Since investment in human capital is always easier for the rich than for the poor, we get a high correlation between parents' and children's income at the end and a low degree of intergenerational mobility. Therefore, social mobility decreases if inequality of income in the parental generation increases and if a child's education is highly correlated with parents' income (Blanden et al. 2004). Thus, fostering education can have a positive effect on intra- and intergenerational mobility, but that this kind of public interventions are not always beneficial is shown in Chapter 3.

After analyzing the demand side of education, the supply side will be at issue now. The first question arising is how educational resources are transformed into educational output, or in other words, what is the production function of education? Hanushek (1986) gives a recommendable survey of that literature, and finds that the teacher-pupil ratio, the education and experience of the teachers as well as the teachers' salaries are the most important factors of the educational production function.

The second important research field on the supply side of the problem focuses on the financing of education. In nearly every developed country financing of primary and secondary education is mainly done by the government. However, there are remarkable differences in the expenditures for schools even among developed countries (Mitch 2004). Figure 1.2 gives some international comparable data of OECD countries in the year 2005.

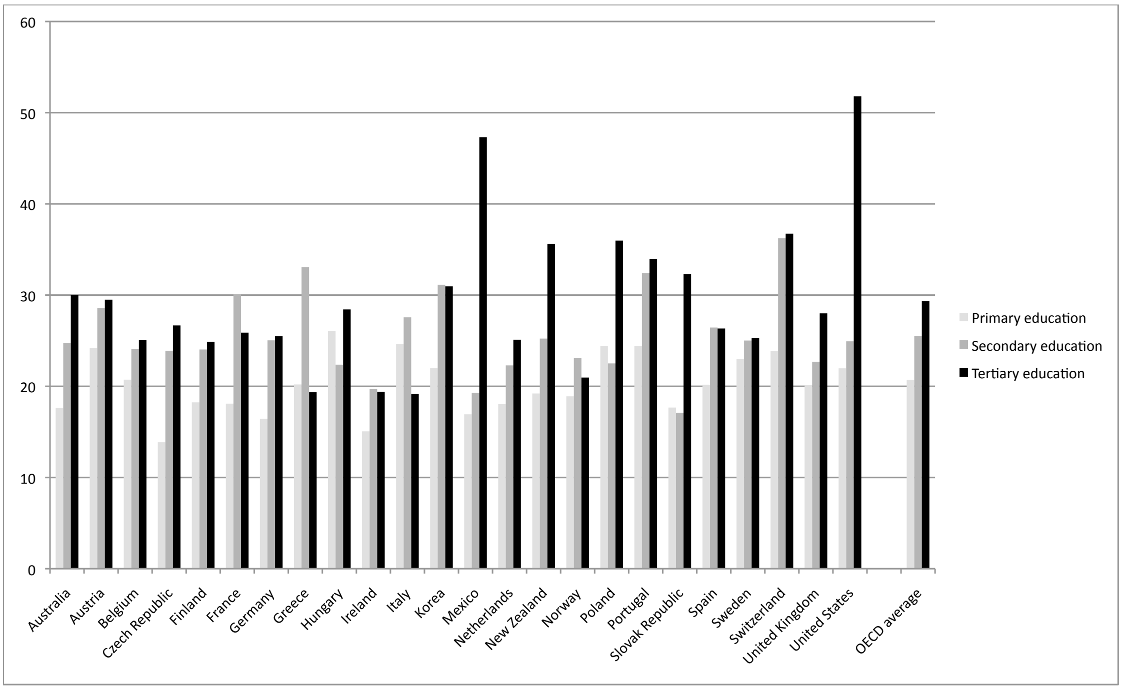

Figure 1.2: Annual expenditure on educational institutions per student for all services relative to GDP per capita (2005) (OECD 2009, Indicator B1).

For higher education private and public forms of financing often co-exist (Greenaway and Haynes 2004). To illustrate this, Table 1.2 lists the percentage distribution of public and private expenditures for tertiary education for a couple of OECD countries. Obviously, see the public share of funding tertiary education reaches from 34.7% in the United States to 96.7% in Denmark and Greece.

Country	Public sources	Private sources
Australia	47.8	52.2
Belgium	90.6	9.4
Canada	55.1	44.9
Denmark	96.7	3.3
Finland	96.1	3.9
France	83.6	16.4
Germany	85.3	14.7
Greece	96.7	3.3
Hungary	78.5	21.5
Ireland	84.0	16.0
Italy	69.6	30.4
Japan	33.7	66.3
Korea	24.3	75.7
Mexico	69.0	31.0
Portugal	68.1	31.9
Spain	77.9	22.1
Sweden	88.2	11.8
United Kingdom	66.9	33.1
United States	34.7	65.3
OECD average	73.1	26.9

Table 1.2: Relative proportions of public and private expenditures on educational institutions, as a percentage, for tertiary education (OECD 2009, Indicator B3)

As the last research field on the supply side of the *Economics of Education* I would like to mention a strand of literature focusing on the universities as the institutions equipping students with knowledge, or in other words, what do we know about ourselves? Already in 1974, William E. Becker described the optimal behavior of a professor as utility maximizing, and according to him a professor's teaching quality can be improved by raising his salary. Although there are some doubts if that always works in reality due to intrinsic and extrinsic motivations, it was the first approach that looked inside the university. But there has been some development in this field too, and nowadays research interests have moved to the optimal design of labor contracts for university professors (Walckiers 2008) and to the relationship between research and teaching as the two main outputs of a university (Hattie and Marsh 1996). Chapter 4 and 5 contribute to this literature analyzing the optimal appointment system of future professors and the publication behavior of German academic economists.

At this point the reader may have won an impression of what the *Economics of Education* is all about. In the following, I will summarize the four manuscripts that are presented in Chapter 2-5, and since each of these chapters has an introduction of its own referring to the existing literature, I will keep the following passages quite general.

The *first* paper is based on joined research with Stefan Napel from the University of Bayreuth, and it has been published in *Economics Letters* in 2008. Using an intergenerational framework parents have to decide whether they want to invest in their children or not. This dynastic view is based on the work of Gary S. Becker (1964). As a standard assumption of this kind of models parents have to finance the education of their children out of current income. Former studies by Banerjee and Newman (1993) or Mookherjee and Ray (2003) assume that children are homogenous with respect to their talents and, therefore, the education costs necessary to become a skilled worker are identical. Under such conditions it is always easier for rich parents to invest than for poor ones. This, however, leads to the long-term result that rich parents invest in the education of their children whereas poor parents do not invest, obviously leading to a poverty trap. Since children from poor parents will stay poor, there will not be any social mobility which implies that the aggregate skill level of the society does not change over time. Countries with a low aggregate skill level cannot catch up with highly developed countries. However, Mookherjee and Napel (2007) show that these results crucially depend on the assumption of homogenous children. With at least some heterogeneity of talents - in their case randomly distributed - there is the possibility that rich parents have children with low talents which makes it, from an economic point of view, unattractive to invest in their education; in this case investment costs are too high in relation to the return on human capital. The other side of the coin is that there will also be some poor parents who invest in their highly talented children. In the joint effect there will be upward and downward social mobility, and the aggregate skill level of the population can change over time. Since the kind of talent distribution seems to be decisive, Stefan Napel and I tested the robustness of the results of Mookherjee and Napel (2007) if talents are not randomly distributed. The basic idea here is that the ability of a child depends on the abilities of its parents where the connection between the generations may be genetically or socially determined. At the end, our model proves the results in Mookherjee and Napel (2007) to be stable. In addition, the assumption of intergenerationally connected talents makes it possible to analyze the influence of the degree of dependence between parent's and child's talents on social mobility and inequality. The paper shows that a high degree of dependence reduces social mobility but does not affect inequality. Thus, if the talent of a child mainly depends on the talent of its parents' (and less on luck or fortune) there will only be a low degree of social mobility in the society. Interestingly, the degree of talent dependence does not influence the aggregate skill level and the inequality of wages in a generation. That is a plausible result because there are some children from poor parents that get educated, but there are also some children from rich parents that do not get an education. Since the analysis is based on a long-term equilibrium approach upward and downward mobility are equal. If this would not be the case, the aggregate skill level would change from one period to the next which would result in an unstable situation. In equilibrium social mobility only depends on the fraction of highly talented children which we assume to be fixed over time. Summarizing, policy interventions that try to weaken the social dependence of parent's and children's abilities can raise social mobility but cannot reduce inequality. Therefore, entry quota regulations at universities in the United States for ethnic minorities increase social mobility but do not change the aggregate skill level in the society. Affirmative action helps children from poor parents (or special minorities) to get an education, the inequality in a generation, however, persists.

The *second* manuscript is in preparation for resubmission to the *Economics of Education Review*. Using the same framework as in the first paper the question here is what kind of policy interventions are necessary to raise social mobility *and* to reduce inequality. Although there is no complete answer to this question at the time, analyzing redistributive taxation and subsidization of education might give some hints since both policy interventions are important in practice. The analyzed redistributive tax is a flat rate tax where the tax amount is equally redistributed between all agents (see e.g. Piketty 1995). The construction of this tax-subsidization-mechanism increases the net wages of the unskilled while it decreases the net wages of the skilled. Consequently and ceteris paribus, the inequality in a generation determined by the wage gap will decrease. Thus, it becomes easier for poor parents to invest in their children while rich parents see their budgets squeezed and refrain from educational investment into their children to a certain extent. Since 'no man is an island' (Donne 2008, 344), there are interdependencies between families, e.g. if many families invest in education the aggregate number of skilled workers increases which implies a decrease in wages of the skilled, determined by their marginal productivities. In other words, the increased supply of skilled workers decreases the price that is paid for their work. Therefore, wages are endogenous, i.e. the higher the aggregate skill level, the lower the wages of the skilled et vice versa. Since the redistributive tax lowers the investment incentives of skilled parents, this may reduce the aggregate skill level which in turn increases pre-tax wages of the skilled et vice versa. Thus, there are two contrary effects occurring: a *direct tax effect* reduces the net-wage gap, an *indirect tax effect* can reduce the aggregate skill ratio which can lead to an increase in the pre-tax wage gap. Obviously, the overall effect is ambigious. In the paper situations for both possible outcomes are described - increased aggregate skill level and decreased inequality as well as decreased aggregate skill level and increased inequality. Although redistributive taxation makes it easier for poor parents to invest in the education of their children, there may be a negative effect on inequality because of the *indirect tax effect*. As the aggregate skill level determines the investment decisions of the parents (if the skill level is high, the return on human capital is low), it also determines the degree of social mobility. Depending on the initial investment situation without taxation, social mobility can increase or decrease. The paper describes these different situations more precisely.

The second political instrument - educational subsidies as conditional transfers - reduces education costs paid by the parents. The subsidies are again financed via a proportional income tax levied on the general public. This implies a *direct tax effect* similar to the redistributive tax from above. Considering reduced costs and since the return to human capital is not affected, the investment incentives of rich and poor parents increase and lead to an increased aggregate skill level under most conditions. The paper analyzes four different initial investment situations, i.e. combinations of investment/non-investment by the skilled/unskilled, more precisely. While three out of this four initial situations (before the policy intervention is implemented) lead to an increase in the aggregate skill level there is also one exceptional case where the result is contrary. This case is characterized by an initial situation where the unskilled parents are indifferent in their investment situation, i.e. benefits and costs of investment are equal. The subsidizing intervention requires that unskilled parents start investment at a lower skill ratio because of reduced costs which implies a corresponding aggregate skill level that is lower with than without education subsidies. Keeping in mind that a general tax, necessary to finance education subsidies for parents deciding to invest in education, decreases the wage gap ceteris paribus, then this will strengthen the *positive direct effect* of an increased aggregate skill ratio on the wage gap and weaken and maybe overcompensate the *negative direct effect* of a decreased skill ratio on the wage gap. In other words, an increase in the aggregate skill ratio by subsidization always reduces the wage gap and thus inequality while a decrease in the aggregate skill ratio can lead to an increase in inequality if the *direct tax effect* is overcompensated. The latter can again appear in the exceptional case, i.e. at the lowest aggregate skill ratio that makes it beneficial for unskilled parents to invest. This situation - because of the low aggregate skill level - is more likely in developing countries. Here, inequality may be increased by education subsidies although they are implemented to reduce it. In addition, the reduction in the skill ratio means that there are less skilled parents than before. If a fixed fraction of skilled parents do not invest in its low-talented children, the absolute number of skilled parents that do not invest is higher with than without subsidization. Thus, in the exceptional case there is a decreasing downward mobility because there are simply not enough skilled parents. This leads to a reduction of social mobility in equilibrium.

Summarizing, both policy interventions are not recommendable on account of two arguments: First the effects of both policies on intra- and intergenerational inequality depend on the initial investment behavior of the skilled and unskilled parents. Thus, if the government does not completely know the initial situation - as it is often the case in reality - it cannot forecast the result of its intervention. Second, the analysis for different initial investment situations shows that in nearly all cases neither redistributive taxation nor subsidization of education can raise equality and social mobility at the same time. In some cases none of both targets is achieved, in some cases inequality is reduced but also social mobility, in other cases social mobility and inequality increase side by side. However, one situation can be identified where education subsidies can simultaneously solve both problems. The paper describes all of these situations in more detail.

The *third* paper focuses on an interior aspect of the universities, and the paper is available as a Discussion Paper of the Department of Economics, Helmut Schmidt University Hamburg. Publishing and teaching during the post-doc time are important to get an appointment at a university. Thus, universities prefer professors that are good in science and teaching.[3] Since talents are private information, universities can only use the two-dimensional signal on science and teaching ability during the post-doc time to identify highly productive professors. More precisely, the post-doc publication and teaching behavior works as a signal for a future professor's abilities. Although there is a large literature on signaling theory starting with Spence (1973) there are only few papers considering multi-dimensional signals. So the third paper contributes to the literature by analyzing separating equilibria, i.e. a situation where each type of post-docs sends a signal that identifies his ability, in a two-dimensional signaling game referring to the academic appointment system. In a first step the paper describes a separating equilibrium, if universities are only interested in science *or* teaching. This one-dimensional case serves as a benchmark later on. In line with the standard literature on signaling games highly talented future professors will invest in signaling to separate themselves from the low-talented ones. Then, the university can distinguish between good and bad teachers (or researchers) and pay the more productive one a higher wage. In a second step, separating equilibria are analyzed if future professors signal their ability to do science *and* teaching. If future professors would have unlimited time to publish and teach the two-dimensional equilibrium would consist of both parts of the two one-dimensional cases. Post-docs who are highly talented in both activities would separate themselves from low-talented researchers by publishing more, and they would separate themselves from low-talented teachers by doing more teaching. Unfortunately, both affords high costs and time, and in reality post-docs complain that they do not have sufficient time to publish *and* teach. Thus there may be not enough time for complete separation, and future professors that are highly talented with respect to both outputs - science *and* teaching - cannot separate themselves from low-talented researchers *and* low-talented teachers since such a strategy requires more time than days are long. At the end, they play the same strategy as future professors that are only highly productive in one activity. They could also invest some time in the other activity but it would not be enough to separate themselves from the low-talented post-docs. Thus, universities can identify good researchers but do not know their teaching ability *or* they separate good teachers from the bad ones without being able to identify their research ability. This results in a situation where universities can identify some but not all types of post-docs. Therefore, this case is called a partially separating equilibrium. If e.g. a university prefers research over teaching it can distinguish between future professors that are low-talented in both activities, future professors that are good in teaching but not in publishing, and a group of future professors that are highly productive in both outputs or just in publishing. The latter two types appear as one group that equally behave in their post-doc time and therefore cannot be distinguished. Since universities get no more information in this partially separating equi-

[3] Although *research* instead of *science* may be a better description of the professors' output I use *science* since the paper is related to Walckiers (2008) who introduced this formulation.

librium than in a one-dimensional signaling game where future professors signal their ability to research *or* to teach, the current appointment system - based on two-dimensional signaling - is inefficient. If there is not enough time that post-docs being highly productive in research *and* teaching can separate themselves from all other types, universities should choose their future professors only by the one criterion - science or teaching - they value more. Doing this, universities do not lose any information, future professors, however, save a lot of time and costs.

The *fourth* paper is based on joined research with Klaus Beckmann from the Helmut Schmidt University Hamburg, and it is under review by the *Scandinavian Journal of Economics*. Many young researchers including the author believe that under the current system full professors do not have an incentive to do more than their compulsory teaching. An opposing co-author led us to joint research, and we tried to test the hypothesis for German academic economists. Since data for German academic appointments are not available we developed a new data set. In fact, missing data may be one reason why there are only few papers available focusing on the German academic labor market (Backes-Gellner and Schlinghoff 2004; Rauber and Ursprung 2008). Although most analyses focusing on the American academic labor market use appointment data from curricula vitae we collected data from two pertinent journals - *Das unabhängige Hochschulmagazin* and *Forschung und Lehre*. This strategy reduces the sample selection bias that appears using data from curricula vitae. Since we do not know if an appointment was accepted or only received we created an action dummy considering both cases. However, a received or accepted appointment work in a similar way since both normally imply an increase in the professor's wage. In addition we used publication data from the *Verein für Socialpolitik*. At the end, we had a new data set for 889 academic economists (post-docs and professors) to our disposal. First descriptive statistics show that there is a high variance in the publication behavior - measured with the Combes-Linnemer index (Combes and Linnemer 2003) - of German academic economists, and that the average publication output grew remarkably from 1995 to 2006. Overall, there is evidence of a positive effect of the number of publications on the probability to get an appointment at a university. This effect is relatively small for older individuals which probably means that publication output is not so important at that age to get a second or third appointment. The positive effect of publishing on getting an appointment has increased from 1980 to 2006. On the other hand, we find a small but significant drop of the publication output after an appointment. Defining a university 'star' as someone who got more than one appointment during his/her career we do not find a negative effect of an appointment on the publication behavior of theses celebrities. They either have a high intrinsic motivation to publish and/or command a high number of staff members. Interestingly, the drop in publications after an appointment was smaller before 1995 than in the recent years. This may be caused by growing administrative efforts or by rising aspirations and demands of students. Finally, the data set allows for testing gender effects. While most studies using data from curricula vitae have five to ten women in their data set, our new data consist of 100 female post-docs and professors. As it seems, the fundamental reform of the appointment system in Germany works. While before 1995 there clearly was a discrimination effect against women in the appointment system, we do not find this effect after 1995 any more.

Summing up the summaries and the description of the research field, it should be clear how broad the discipline of educational economics is dimensioned, and how important knowledge in this area can be for a positive societal development. What the author of this dissertation can do for that, is understandably only of a very minor dimension. Anyway, the articles to be presented here can add some new aspects and results concerning the link between education and societal dynamics, and they offer some deeper insights into an institution where we live and work together: the university.

2 Intergenerational talent transmission, social mobility, and inequality*

with Stefan Napel

The paper investigates the effects of intra-family talent transmission when human capital exhibits indivisibilities and parental financing of education involves borrowing constraints. Positive talent correlation reduces social mobility but steady state inequality and macroeconomic history-dependence are not affected.

JEL: D31; D91; E25; I21;J24;J62;O15

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2.1 Introduction

Intergenerational mobility matters for reasons of equity as well as efficiency if agents' abilities vary across generations.[1] It reflects dynamic inequality that may or may not be orthogonal to possible wealth differences within a generation. While Becker and Tomes (1979) and Loury (1981) originally studied both kinds of inequality as intertwined phenomena, more recent theoretical literature has inadvertently ruled out steady state mobility by presuming agents with homogenous abilities (Ljungqvist 1993; Galor and Zeira 1993; Freeman 1996; Mookherjee and Ray 2003).

Exceptions are Maoz and Moav (1999) and Mookherjee and Napel (2007). Both consider parental investment into children's education that must be financed by parents' wealth. Educated children earn a skill premium determined endogenously by aggregate investment when they join the workforce as parents of the next generation. Concave utility implies that richer parents find investment subjectively cheaper, inducing greater incentives to educate. This can prevent steady state mobility, but children's ability or talent and the associated cost of education are subject to shocks: some parents may have exceptionally talented children who require no training; education of others may be too costly even for the richest parents. For wide enough talent support, a positive fraction of skilled parents will not invest whilst some unskilled parents do. This can keep wages and the aggregate skill ratio constant, i.e., constitute a macroeconomic steady state with mobility.

In Maoz and Moav (1999) and Mookherjee and Napel (2007), talent is *independently and identically distributed* (i.i.d.) across families and occupations. This is at odds with reality regarding cognitive skills (see, e.g., Bouchard and McGue 1981; Devlin et al. 1997) and presumably other traits which influence occupational choice. In this paper, a child's ability depends on its parent's ability.[2] Apart from that, the model is a special case of Mookherjee and Napel (2007). We show that intergenerational talent correlation affects social mobility but leaves intragenerational inequality and the number of steady states unchanged.

2.2 Model

Consider a unit mass of families indexed by $i \in [0, 1]$. In each generation $t = 0, 1, 2, \ldots$ family i comprises a child and an adult; the latter supplies one unit of labor in occupation $o_t^i \in \{n, s\}$ (unskilled or skilled)[3]. The child has an observable ability which requires either a low financial investment $x^l > 0$ or a high one $x^h > x^l$ in order to become educated. Educated children can take skilled jobs when they become the family's adult in period $t + 1$. Unskilled labor requires no investment. Parents cannot borrow against their children's income. There are no financial bequests and thus education must be financed by current income. The fraction of educated agents in period t is denoted by λ_t and coincides with employment in the skilled sector in

[1] For recent empirical studies see Mazumder (2005) or Jäntti et al. (2006).
[2] See Couch and Morand (2005) for related growth analysis with exogenous educational returns.
[3] See Mookherjee and Ray (2003) on the role played by the number of occupations.

equilibrium.

A single consumption good is produced competitively according to the production function

$$H(\lambda_t) = {\lambda_t}^{\gamma}(1-\lambda_t)^{(1-\gamma)} \tag{2.1}$$

with $\gamma \in (0,1)$. Agents invest in education only if skilled jobs pay a premium. So, in equilibrium $\lambda_t < \gamma$ and wages are given by

$$w_t^s \equiv w^s(\lambda_t) = \gamma\Big(\frac{1-\lambda_t}{\lambda_t}\Big)^{(1-\gamma)} \quad \text{and} \quad w_t^n \equiv w^n(\lambda_t) = (1-\gamma)\Big(\frac{\lambda_t}{1-\lambda_t}\Big)^{\gamma}. \tag{2.2}$$

Parents care about their own consumption and the future wealth of their child. Specifically, let agents maximize

$$U(c_t^i, w_{t+1}^{o_{t+1}^i}) = \ln c_t^i + \delta \ln w_{t+1}^{o_{t+1}^i}, \tag{2.3}$$

where c_t^i denotes parental consumption ($= w_t^{o_t^i} - x$ in case of investment), $w_{t+1}^{o_{t+1}^i}$ is the child's income ($= w_{t+1}^s$ in case of investment) and parameter $\delta > 0$ scales parental altruism. If the subjective benefit from investment

$$B(\lambda_{t+1}) \equiv \delta\big[\ln w^s(\lambda_{t+1}) - \ln w^n(\lambda_{t+1})\big] \tag{2.4}$$

is strictly greater (smaller) than the subjective cost

$$C^k(\lambda_t, x) \equiv \ln w^k(\lambda_t) - \ln\big[w^k(\lambda_t) - x\big], \tag{2.5}$$

then a parent who faces pecuniary cost x and has occupation $k \in \{n, s\}$ will invest (not invest) given λ_t and λ_{t+1}; if $B(\lambda_{t+1}) = C^k(\lambda_t, x)$ he may invest with arbitrary probability.

The selected specification of technology and preferences guarantees that unskilled's net benefit from investment, $B(\lambda) - C^n(\lambda, x)$, changes sign in λ at most twice: rising w^n first makes investment affordable, but then non-lucrative as $w^s - w^n$ diminishes.[4] This will be required for Proposition 2.1. All other results only use the standard monotonicity and curvature properties which are exhibited by $U(\cdot)$ and $H(\cdot)$ (ensuring a unique competitive equilibrium ratio λ_{t+1} for any given $\lambda_t \in (0,\gamma)$ and treating consumption and investment as substitutes).

A child's ability depends on that of his parent in a Markov way. The conditional probability that a parent with education cost x^j has a son with cost $x^{j'}$ is given by

$$p_{j\to j'} \equiv \Pr(x_{t+1}^i = x^{j'} \mid x_t^i = x^j) \tag{2.6}$$

[4] A more general sufficient condition for this is a Cobb-Douglas technology coupled with constant relative risk aversion of one or more (Mookherjee and Napel 2007, Lemma 3).

for $j, j' \in \{l, h\}$. The *degree of dependence* is captured by[5]

$$p_{l \to l} - p_{h \to l} = p_{h \to h} - p_{l \to h} \equiv \kappa \in (-1, 1). \tag{2.7}$$

A dynamic competitive equilibrium corresponds to a sequence $\{\lambda_t\}_{t=0,1,\dots}$ such that for every $t = 0, 1, \dots$ the current skill ratio λ_t and expectations $\lambda^e_{t+1} = \lambda_{t+1}$ about next period induce a total measure λ_{t+1} of unskilled and skilled investors (all those with strict preference and market-clearing shares $\alpha_t \in [0, 1]$ and $\beta_t \in [0, 1]$ of indifferent unskilled and skilled parents).[6] We focus on equilibria with a stationary skill ratio, i.e., aggregate *steady states (SS)* where $\lambda_t = \lambda_{t+1} = \lambda^*$, and amongst these on *steady states with mobility (SSM)*, i.e., stationary equilibria in which the measure of unskilled investors is positive and equals the measure of skilled non-investors.

In t, family $i \in [0, 1]$ is in a state $r^i_t \in \{s^l, s^h, n^l, n^h\}$ where k^j indicates parental occupation k and parental cost level j. This gives rise to an aggregate parental occupation and cost distribution

$$\pi(t) \equiv (\pi_{s^l}(t), \pi_{s^h}(t), \pi_{n^l}(t), \pi_{n^h}(t)) \tag{2.8}$$

with $\pi_{s^l}(t) + \pi_{s^h}(t) = \lambda_t$. The transition from $\pi(t)$ to $\pi(t + 1)$ is governed by endogenous investment choices of parents given their respective child's realized cost type. One obtains a time-heterogenous Markov chain whose period-t transition matrix is determined by λ_t (and respective market-clearing levels of α_t and β_t). If, for example, λ_t implies that all parents invest if their child has cost x^l and skilled parents are indifferent for x^h, then we would have

$$\pi(t+1) := (\pi_{s^l}(t), \pi_{s^h}(t), \pi_{n^l}(t), \pi_{n^h}(t)) \underbrace{\begin{pmatrix} p_{l\to l} & \beta_t p_{l\to h} & 0 & (1-\beta_t) p_{l\to h} \\ p_{h\to l} & \beta_t p_{h\to h} & 0 & (1-\beta_t) p_{h\to h} \\ p_{l\to l} & 0 & 0 & p_{l\to h} \\ p_{h\to l} & 0 & 0 & p_{h\to h} \end{pmatrix}}_{P(\lambda_t)}. \tag{2.9}$$

Any stationary λ^* implies a particular stationary transition matrix $P(\lambda^*)$. If λ^* is a SSM, then each Markov chain $\{r^i_t\}_{t=0,1,\dots}$ is time-homogenous, irreducible and aperiodic (recall $|\kappa| < 1$). There is hence a unique *invariant measure* π^* such that

$$\pi^* \, P(\lambda^*) = \pi^*. \tag{2.10}$$

We will investigate such invariant measures for given technology, preference, and cost parameters.

[5] $\kappa > 0$ seems most relevant, but we do not rule out negative correlation.
[6] Existence and uniqueness follows from Mookherjee and Napel (2007, Lemma 1).

2.3 Analysis of steady states with mobility

For fixed cost type x, $w^s > w^n$ implies that an unskilled parent will only invest if a skilled one does, too. And for a given wage w, a parent will only invest in a child with cost x^h if he would invest in one with x^l, too. So only SSM with the following investment incentives may arise:

Type I	$C^s(\lambda^*, x^l) < C^n(\lambda^*, x^l) < B(\lambda^*) = C^s(\lambda^*, x^h) < C^n(\lambda^*, x^h)$
Type II	$C^s(\lambda^*, x^l) < C^n(\lambda^*, x^l) = B(\lambda^*) = C^s(\lambda^*, x^h) < C^n(\lambda^*, x^h)$
Type III	$C^s(\lambda^*, x^l) < C^n(\lambda^*, x^l) < B(\lambda^*) < C^s(\lambda^*, x^h) < C^n(\lambda^*, x^h)$
Type IV	$C^s(\lambda^*, x^l) < C^n(\lambda^*, x^l) = B(\lambda^*) < C^s(\lambda^*, x^h) < C^n(\lambda^*, x^h)$

One can check that SS without mobility generically appear in entire intervals. But there seems to exist at least some mobility in every society. Macroeconomic history dependence then becomes very limited:

Proposition **2.1**

(a) There are never more than two SSM; two SSM exist only if x^h is high enough such that $B(\lambda) < C^n(\lambda, x^h)$ for all λ.

(b) If $B(\lambda) \geq C^n(\lambda, x^h)$ for some λ and investment incentives are of type III for some λ', then there exists a unique SSM.

Proof: (a) Assume that x^h is high enough so that unskilled parents only invest for cost x^l. We consider investment incentives if agents expect λ to prevail. Presuming that fractions $\alpha, \beta \in [0,1]$ of indifferent agents invest, one can obtain a transition matrix $Q(\lambda, \alpha, \beta)$, which coincides with $P(\lambda)$ for appropriate α and β if λ is in fact a SS.

Restrict λ to the interval in which investment incentives are of type I–IV (the location of possible SSM). There, each $Q(\lambda, \alpha, \beta)$ has a unique invariant measure $\mu^*(\lambda, \alpha, \beta)$ ($= \pi^*$ if λ is a SSM). With

$$M(\lambda) \equiv \{\mu^*(\lambda, \alpha, \beta) \colon \alpha, \beta \in [0,1]\} \tag{2.11}$$

we can define

$$u(\lambda) \equiv \left\{(1-\lambda) \cdot \left[\frac{\mu_{n^l}}{\mu_{n^l} + \mu_{n^h}} p_{l \to l} + \frac{\mu_{n^h}}{\mu_{n^l} + \mu_{n^h}} p_{h \to l}\right] \,:\, \mu \in M(\lambda)\right\} \tag{2.12}$$

as the set of all possible measures of unskilled who would invest if λ held constant and if the composition amongst unskilled were as in a SSM with the same investment incentives as in λ. This upward flow correspondence $u(\lambda)$ is convex-valued and upper-semicontinuous (u.s.c.). So too is the analogous downward flow

$$d(\lambda) \equiv \left\{\lambda \cdot \left[\frac{\mu_{s^l}}{\mu_{s^l} + \mu_{s^h}} p_{l \to h} + \frac{\mu_{s^h}}{\mu_{s^l} + \mu_{s^h}} p_{h \to h}\right] \,:\, \mu \in M(\lambda)\right\}. \tag{2.13}$$

By construction, λ is a SSM if and only if $u(\lambda) \cap d(\lambda) \neq \varnothing$ (with a nonzero element).

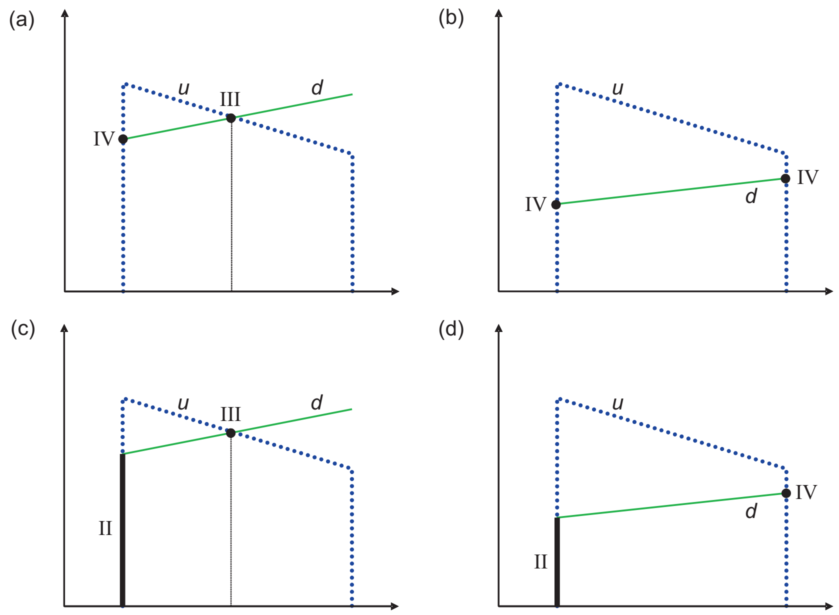

Figure 2.1: Upward and downward mobility flows for the case of two SSM

Because *all* unskilled parents with x^l-children weakly prefer to invest on the whole λ-interval for which $u(\cdot)$ is defined[7] and there are fewer such parents as λ increases, $u(\lambda)$ is decreasing in a 'saw-tooth' fashion. Similarly, $d(\lambda)$ is increasing. This allows for one or at most two nonempty intersections, with all possibilities of the latter illustrated in Figure 2.1. One can construct examples for each case.

Finally, consider the case with some λ' such that $B(\lambda') \geq C^n(\lambda', x^h)$, i.e., all unskilled might invest if λ' held constant. Since incentives are monotonic in income, every *skilled* family must invest with strict preference for all $\lambda \leq \lambda'$, excluding a SSM there. For $\lambda > \lambda'$, the total measure of unskilled wanting to invest is decreasing in λ (strictly when it is positive). Likewise the measure of skilled people preferring not to invest is increasing. So there can be at most one SSM at which both measures are positive and equal.
(b) $B(\lambda) \geq C^n(\lambda, x^h)$ at λ implies that all skilled parents invest at λ. The ratio $\hat{\lambda} > \lambda$ at which skilled parents with x^h-children become indifferent (assuming $\hat{\lambda}$ held constant) must be such that unskilled parents with x^l-children still invest with strict preference (otherwise there could be no λ', necessarily to the right of $\hat{\lambda}$, with incentives of type III). So $u(\cdot)$ is initially positive and then strictly decreasing to zero on an interval $[\hat{\lambda}, \tilde{\lambda}]$. Since $0 \in d(\hat{\lambda})$ and $d(\cdot)$ is strictly increasing on $[\hat{\lambda}, \tilde{\lambda}]$, both u.s.c. correspondences must intersect at a unique λ^*. □

SSM multiplicity (or lack thereof) is driven by the levels of education costs, not their allocation. It is therefore unaffected by partial ability correlation. This extends to the precise location of SSM and hence wage inequality $w^s(\lambda) - w^n(\lambda)$, which is strictly decreasing in λ, provided we compare economies with the same aggregate steady state talent shares. For all

[7]We exclude cases in which unskilled parents with x^l-children never invest or only for a single λ: they cannot yield multiple SSM.

variations of $p_{j\to j'}$ which leave the stationary measure of x^l-agents, σ, unchanged,[8] we have:

PROPOSITION **2.2** *The location of SSM and hence wage inequality are unaffected by* κ.

Proof: SSM which involve indifference (types I, II, and IV) are characterized by equality of $B(\lambda)$ and $C^s(\lambda, x^h)$ or $C^n(\lambda, x^l)$, respectively. Neither is affected by κ, i.e., the corresponding SSM cannot shift in response to a κ-variation. For type III-incentives parents invest if and only if they face cost x^l. So $\lambda^* = \sigma$ independently of κ. □

In contrast, intergenerational social mobility in a SSM is unequivocally reduced by increased intra-family correlation of ability:

PROPOSITION **2.3** *In any given SSM* λ^**, social mobility is strictly decreasing in* κ.

Proof: It suffices to consider the effect of a κ-variation on $u(\lambda)$ and $d(\lambda)$ when incentives are of type III because both correspondences are u.s.c. Then agents invest if and only if they face cost x^l, implying

$$u(\lambda) = \{(1-\lambda)p_{h\to l}\} \text{ and } d(\lambda) = \{\lambda p_{l\to h}\}\,. \tag{2.14}$$

Substituting $p_{l\to l} = \sigma(1-\kappa) + \kappa$ in order to keep the total x^l-share constant, we have

$$u(\lambda) = \{(1-\lambda)(1-\kappa)\sigma\} \text{ and } d(\lambda) = \{\lambda(1-\kappa)(1-\sigma)\}\,, \tag{2.15}$$

i.e., both $u(\lambda)$ and $d(\lambda)$ strictly decrease in κ.[9] □

2.4 Concluding remarks

Above investigation has been confined to the simplest case of two distinct abilities. The generalization of Proposition 2.1 is straightforward: for r discrete cost levels, up to $2(r-1)$ steady states with mobility can co-exist;[10] the sufficient condition for uniqueness stays as it is with x^h referring to the maximal cost type. Extensions of Propositions 2.2 and 2.3 are harder because it is not generally possible to capture intergenerational talent dependence adequately by a single parameter. Comparative statics – varying the degree of intra-family talent transmission while holding the aggregate talent distribution constant – may, however, still be derived for special cases. One can, e.g., compare a talent process at the family level which is described by the transition matrix $T = (p_{j\to j'})_{r\times r}$ and one which results from the latter's convex combination with talent constancy, i.e., the process described by transition matrix $(1-\kappa)T + \kappa I$ with $\kappa \in (0, 1)$

[8] Because the stationary measure is characterized by $\sigma = \sigma p_{l\to l} + (1-\sigma)p_{h\to l}$, this amounts to endogenously setting $p_{l\to l} = \sigma(1-\kappa) + \kappa$ for any reference levels of σ and κ.

[9] Vertical distance between $u(\lambda)$ and $d(\lambda)$ is $(\kappa-1)(\lambda-\sigma)$. Its sign is determined entirely by $(\lambda-\sigma)$, implying that SSM cannot disappear or change type as a result of a κ-variation.

[10] The upward flow exhibits $r-1$ 'saw-tooth'-like increases if unskilled parents invest in all cost types $x < x^h$, before it decreases monotonically. The downward flow can then cut through each 'saw-tooth' twice (as in Figure 2.1(a) with $r-2$ more upward jumps to the right of λ^{**}).

and I denoting the identity matrix: greater κ does not affect the aggregate talent distribution but formalizes more inertia. Propositions 2.2 and 2.3 then extend very naturally: the upward and downward flows are scaled down by factor $(1-\kappa)$ and all SSM are preserved at their original location. This admittedly concerns only a particular parameterization of dependence,[11] but illustrates that above results are not driven by the assumed type dichotomy.

The key qualitative feature of our model is that persistence of non-market determinants of occupational choice – here referred to as educational talent – is compounded by market forces: the equilibrium wage gap needed to induce investment implies that unskilled parents require more beneficial ability draws than skilled ones in order to invest. This applies also if 'ability' or 'talent' is transmitted via cultural or social channels rather than biology: for example, well-connected parents may get their children into a well-paying job more cheaply than others, or children of alumni benefit from preferential admission to top colleges which imply a smaller total cost of getting a highly paid job. Such children stand a good chance of respectively being well-connected themselves or becoming an alumnus, too.

Societies differ substantially in the degree to which ability in this wider sense is transmitted across generations. The non-market determinants of social permeability are therefore an important policy issue: intergenerational mobility and equality of opportunity are greater, the less easily the relevant 'traits' can be passed on. A range of corresponding policy interventions exist – most notably legislation on (non-)discriminatory recruitment and affirmative action. Our model suggests that such programs have an effect on social mobility,[12] but not automatically on total output or cross-sectional inequality.

If, say, preferential admission of alumni's children was banned, hitherto unprivileged families would benefit and upward mobility would rise. But a fixed number of slots in top schools is being allocated – corresponding to a fixed stationary proportion of low cost draws in our comparative static analysis. Increased downward mobility must then keep the total number of skilled families and hence their wage premium constant. The situation would be different if individual productivity in the skilled sector rose with innate talent, assuming the latter determines total educational costs jointly with admission rules, availability of scholarships, and other policy-sensitive variables. Banning preferential admissions might then raise total output and, more speculatively, lower wage inequality by educating children who will be more productive. This cannot arise in a model that assumes a homogeneous skilled input factor, and represents a promising direction for future research. Redistributive policy interventions are another worthwhile topic: a social planner who can observe children's talents and make lump sum transfers can rather easily achieve a Pareto improvement; but this seems much harder – and perhaps is impossible – with a more realistic set of policy instruments.

[11] Convex combinations with other transition matrices may shift SSM of type III: the conditional stationary distributions of talent amongst the skilled and unskilled can change even if the aggregate distribution stays constant. Flow changes prompted by κ-variations may then differ across occupations.

[12] So do the empirical studies that we are aware of – see, e.g., Chan and Eyster (2003) or Arcidiacono (2005). Interestingly, the latter only finds a weak effect of affirmative action in higher education on individual earnings – despite noticeable changes in the composition of students admitted to colleges in general and top colleges in particular.

Appendix (unpublished)

Characterization of the four types of SSM

At this point every type of SSM is described by its transition matrix as well as by a figure that also shows the influence of κ, i.e. the degree of dependence of parent's and child's ability, on the SSM.

Type I: Both occupation types invest in a child with low education costs x^l, skilled parents are indifferent with respect to a child with education costs x^h, and unskilled parents do not invest in the high-cost type. Thus, the SSM is characterized by the transition matrix

$$\begin{array}{c} \\ s^l \\ s^h \\ n^l \\ n^h \end{array} \begin{array}{c} \begin{array}{cccc} s^l & s^h & n^l & n^h \end{array} \\ \begin{pmatrix} p_{l\to l} & \beta p_{l\to h} & 0 & (1-\beta)p_{l\to h} \\ p_{h\to l} & \beta p_{h\to h} & 0 & (1-\beta)p_{h\to h} \\ p_{l\to l} & 0 & 0 & p_{l\to h} \\ p_{h\to l} & 0 & 0 & p_{h\to h} \end{pmatrix} \end{array}.$$

This can be illustrated by Figure 2.2.

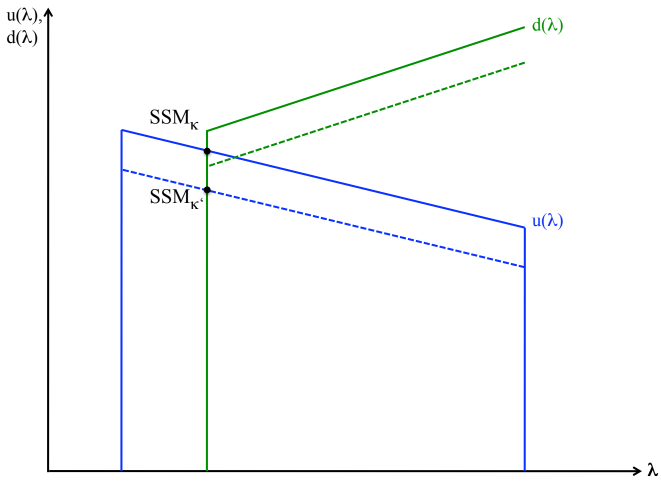

Figure 2.2: SSM of type I

While in this and all other figures of this appendix solid lines represent the up- and downflows for κ dashed lines result from $\kappa' > \kappa$. The figure illustrates the main results of our analysis: The SSM and therefore inequality are unaffected by a higher degree of dependence (no horizontal shift of the point of intersection of up- and downflow). However, it reduces the social mobility, i.e. $SSM_{\kappa'}$ is in the figure located below SSM_{κ}.

Type II: Skilled parents invest in a child with costs x^l and are indifferent with respect to a high-cost type. Unskilled parents are indifferent with respect to a low-cost type and do not invest in a child with education costs x^h. This situation is described by the following transition matrix and Figure 2.3:

$$\begin{array}{c} \\ s^l \\ s^h \\ n^l \\ n^h \end{array} \begin{array}{c} \begin{array}{cccc} s^l & s^h & n^l & n^h \end{array} \\ \begin{pmatrix} p_{l\to l} & \beta p_{l\to h} & 0 & (1-\beta)p_{l\to h} \\ p_{h\to l} & \beta p_{h\to h} & 0 & (1-\beta)p_{h\to h} \\ \alpha p_{l\to l} & 0 & (1-\alpha)p_{l\to l} & p_{l\to h} \\ \alpha p_{h\to l} & 0 & (1-\alpha)p_{h\to l} & p_{h\to h} \end{pmatrix} \end{array}.$$

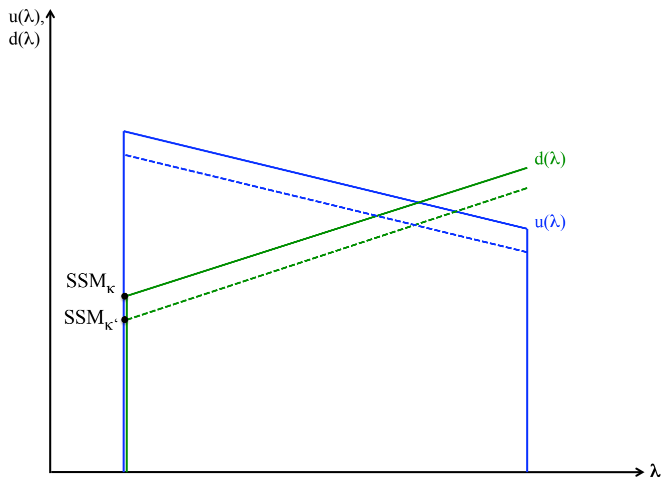

Figure 2.3: SSM of type II

Obviously, the situation of a type II SSM is unstable and is destroyed even by a small exogenous shock.

Type III: Parents of both occupation types invest in a child with education costs x^l and no one invests in a child with education costs x^h. This investment situation results in the following transition matrix and Figure 2.4:

$$\begin{array}{c} \\ s^l \\ s^h \\ n^l \\ n^h \end{array} \begin{array}{c} \begin{array}{cccc} s^l & s^h & n^l & n^h \end{array} \\ \begin{pmatrix} p_{l\to l} & 0 & 0 & p_{l\to h} \\ p_{h\to l} & 0 & 0 & p_{h\to h} \\ p_{l\to l} & 0 & 0 & p_{l\to h} \\ p_{h\to l} & 0 & 0 & p_{h\to h} \end{pmatrix} \end{array}.$$

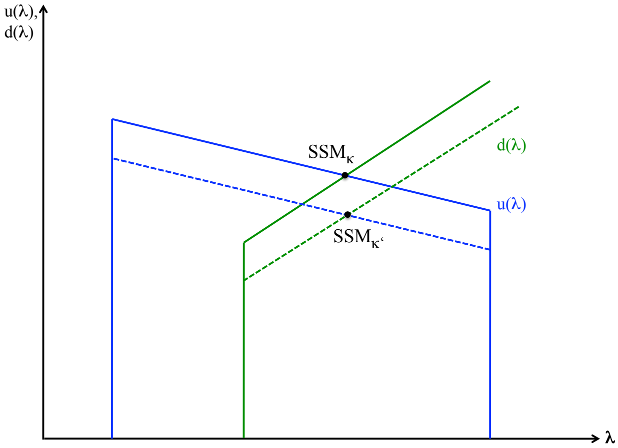

Figure 2.4: SSM of type III

Type IV: Skilled parents invest in a child with low education costs x^l while unskilled parents are indifferent with respect to this cost type. No parent invest in a child with high education costs x^h. This SSM implies the following transition matrix:

$$\begin{array}{c} \\ s^l \\ s^h \\ n^l \\ n^h \end{array} \begin{array}{c} \begin{array}{cccc} s^l & s^h & n^l & n^h \end{array} \\ \begin{pmatrix} p_{l\to l} & 0 & 0 & p_{l\to h} \\ p_{h\to l} & 0 & 0 & p_{h\to h} \\ \alpha p_{l\to l} & 0 & (1-\alpha)p_{l\to h} & p_{l\to h} \\ \alpha p_{h\to l} & 0 & (1-\alpha)p_{h\to h} & p_{h\to h} \end{pmatrix} \end{array}.$$

The situation of up- and downflows can be illustrated by Figure 2.5:

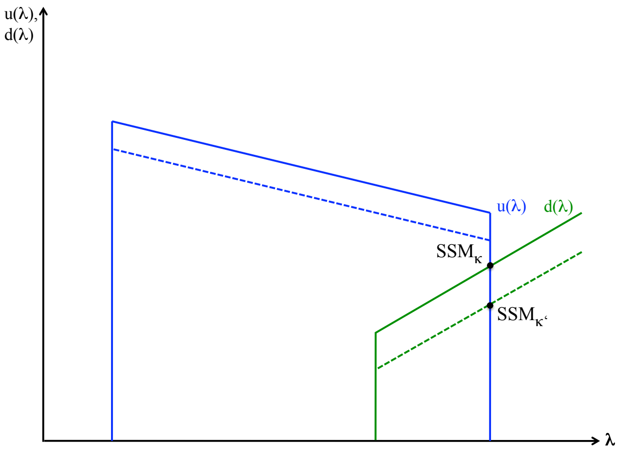

Figure 2.5: SSM opf type IV

Thus, for a SSM of type II, III or IV an increasing degree of dependence κ also - as for a SSM of type I - does not change the SSM or the level of inequality but reduces social mobility.

A final note on the aspect of efficiency: If an efficient situation is defined as a situation in which the education of a child only depends on its talent but not on the income of the parent only a SSM of type III represents an efficient situation. However, the focus of the model is not on efficiency but on inequality and social mobility.

3 Redistributive taxation vs. education subsidies: fostering equality and social mobility in an intergenerational model

Redistributive taxation and education subsidies are common policies intended to foster education attendance of poor children. However, this paper shows that in an intergenerational framework these policies can raise social mobility only in some investment situations but not in general. I also study the impact of both policies on the aggregate skill ratio and inequality. While redistributive taxation raises social mobility but never reduces inequality at the same time, education subsidies can, under some conditions, achieve both goals simultaneously. Unfortunately, these conditions necessarily require a population where the skill ratio is already quite high.

JEL: D91; H23; H24; I21; J24; J62; O15

3.1 Introduction

Educational decisions determine a great part of future income[1] and therefore potential inequality within and across generations. The wage gap, needed to induce investment, implies that it is easier for rich parents than for poor ones to invest in the education of their children. In this context, several policy interventions that foster investment incentives of the poor and therefore equalize the distribution of human capital are possible. The present paper analyzes the impact of two of them - redistributive taxation and education subsidies[2] - on the aggregate proportion of educated people as well as on social mobility and inequality.[3]

The paper is related to a great number of intergenerational models focusing on potential multiplicity of steady states (SS), inequality, and social mobility. This body of literature starts with Gary S. Becker. In a paper with Nigel Tomes he shows that there is a unique equilibrium which is characterized by social immobility and inequality (Becker and Tomes 1979). Here, wages of the skilled and unskilled are exogenous and not determined by the measures of both occupation types. Inequality in this model is mainly driven by luck. Some other papers, assuming endogenously determined wages and homogenous agents, find a continuum of SSs which mostly are also characterized by inequality and the absence of social mobility (Banerjee and Newman 1993; Galor and Zeira 1993; Freeman 1996; Mookherjee and Ray 2003).[4] In these models the equilibrium outcome is determined by initial conditions, i.e. there is great history dependence. But according to Maoz and Moav (1999), Mookherjee and Napel (2007), and Napel and Schneider (2007) these results are strongly connected to the assumption of homogeneous agents.[5] If children are heterogeneous with respect to their inherent talent it becomes possible that a poor parent invests in his highly talented child and also that a rich parent rejects investment in his low-talented child. Thus, steady states with social mobility (SSM) are fostered by heterogeneity. In Mookherjee and Napel (2007) steady states are characterized by inequality and social mobility. They are locally unique; and under some conditions global uniqueness is provided.

Although there are many intergenerational models of human capital investment, none of them investigates the impact of different policy interventions on the wage gap and the degree of social mobility. This paper tries to fill the gap.

In a basic overlapping generational model, where parents decide if their children that differ in talents get education or not, it can be shown that generally neither redistributive taxation

[1] One of the earliest studies that shows a positive effect of schooling on earning is by Mincer (1958). There is also evidence that the return to schooling has increased over the last decades (Blackburn and Neumark 1993).

[2] In the present context subsidies are transfer payments to the households that have to be invested in education.

[3] A higher degree of social mobility benefits intergenerational equity. Inequality within a generation is measured as the difference between skilled and unskilled wages.

[4] Galor and Zeira (1993) and Mookherjee and Ray (2003) find equal and unequal SSs.

[5] While Mookherjee and Napel (2007) assume that talent is independently and identically distributed Napel and Schneider (2007) show that the results are robust if the child's talent depends on the talent of the parent. Maoz and Moav (1999) focus on the qualitative features of the convergency process that leads to a steady state. They also find that redistributive policy has a negative effect on growth in developed economies but a positive effect in developing countries.

nor education subsidies can both decrease inequality and increase social mobility. Depending on the type of SSM, i.e. the equilibrium investment decisions of all parents without any public intervention, the impact of both policies on inequality and social mobility is analyzed. While redistributive taxation and subsidization have similar outcomes for some types of SSMs, they have different effects on the skill ratio for other types of SSMs. Under most circumstances there is a trade-off between the reduction of inequality and the increase of social mobility. However, the paper shows that in a situation where unskilled parents are indifferent in their investment decision for a child with low costs, education subsidies can reach both targets at the same time. Unfortunately, this result only holds for a population with a high initial aggregate skill ratio.

The paper is organized as follows. I present the basic intergenerational model without policy intervention in section 3.2. Section 3.3 studies the impact of redistributive taxation on the skill ratio as well as on inequality and social mobility. Section 3.4 does the same for education subsidies. Conclusions are discussed in section 3.5.

3.2 Model

Assume an overlapping generations model that involves a unit mass of families. At each point in time a family consists of a parent and a child. The parent can work as a skilled (s) or an unskilled (n) worker. The aggregate skill ratio of the population at time t is denoted by λ_t. Skilled work requires a costly education while unskilled work does not. Education costs depend on the talent[6] of the child and must be financed out of the parent's current income. For simplicity, I assume that there are only two possible types of talent, with corresponding education costs x^l for a highly talented child and x^h for a low-talented child respectively; the child's talent is private information of the parent. The fractions of both types of talent are exogenously given and fixed over time. The talent of a child depends on the talent of his parent in a Markovian way. Thus, for $i, j \in \{l, h\}$ the conditional probability $p_{i \to j}$ denotes the probability that a parent with education costs x^i has a child with education costs x^j.

The economy produces a single consumption good with a Cobb-Douglas production function $H = \lambda_t^{\gamma}(1-\lambda_t)^{1-\gamma}$ with $\gamma \in (0, 1)$. Wages are given by the marginal productivities. Thus, in equilibrium wages are

$$w_t^s \equiv \gamma(\frac{1-\lambda_t}{\lambda_t})^{1-\gamma} \tag{3.1}$$

and

$$w_t^n \equiv (1-\gamma)(\frac{\lambda_t}{1-\lambda_t})^{\gamma}. \tag{3.2}$$

[6] Here 'talent' should be perceived as 'potential to benefit from education' as, e.g. in De Fraja (2005).

Investment in education requires $w_t^s > w_t^n$ and therefore $\lambda_t < \gamma$ in equilibrium.
Parents' bequest motive is assumed to be altruistic. In particular, parents maximize

$$U(c_t, w_{t+1}^k) = \ln(w_t^k - Dx) + \delta \ln(w_{t+1}^k) \tag{3.3}$$

where $c_t \equiv w_t^k - Dx$ denotes the parent's own consumption, w_t^k and w_{t+1}^k with $k \in \{s, n\}$ are the incomes of the parent and the child respectively, x denotes the child's education costs and the parameter $\delta \in (0, 1)$ state the altruism motive. The binary variable D is 1 in the case of investment, and 0 otherwise. Thus, in the case of non-investment the parent can consume his whole income while his child only gets the lower wage of an unskilled worker. In the case of investment the parent can only consume his income minus education costs x, but the child's income is given by the skilled wage.
Given the utility function (3.3) the subjective benefit $B(\cdot)$ and the subjective costs $C^k(\cdot)$ from investment are

$$B(\lambda_{t+1}) \equiv \delta\Big(\ln w_{t+1}^s - \ln w_{t+1}^n\Big) \tag{3.4}$$

and

$$C^k(\lambda_t, x) \equiv \ln w_t^k - \ln(w_t^k - x). \tag{3.5}$$

The subjective benefit from investment is influenced by the skill ratio in the child's working period $t+1$ and is independent of the occupation type, whereas subjective costs depend on the skill ratio in the parent's working period t, on the occupation type of the parent and on the child's talent. It is clear that a parent invests (does not invest) in the education of his child with education costs x whenever the subjective benefit is higher (lower) than the subjective costs. If subjective benefit equals subjective costs skilled (unskilled) parents are assumed to invest with market clearing probability α (β).
Let us define $\hat{x}^k(\lambda)$, $k \in \{s, n\}$ as the critical costs function for the skilled and unskilled respectively, i.e.

$$\hat{x}^k(\lambda) \equiv \left(1 - \left(\frac{w^n(\lambda)}{w^s(\lambda)}\right)^{\delta}\right) w^k(\lambda). \tag{3.6}$$

Thus, $\hat{x}^k(\lambda)$ denotes - depending on the skill ratio - the education costs of a child that makes his parent with occupation k just indifferent in his investment decision. Depending on the aggregate skill ratio λ parents with occupation k invest (do not invest) in a child if his education costs are lower (higher) than $\hat{x}^k(\lambda)$. Figure 3.1 illustrates a situation where unskilled parents invest in a child with education costs x^l for $\lambda \in (\lambda_1, \lambda_3)$ and never invest in a child with education costs x^h. Analogously, skilled parents invest in the low cost type for $\lambda \in (0, \lambda_4)$ and in the high cost type for $\lambda \in (0, \lambda_2)$.

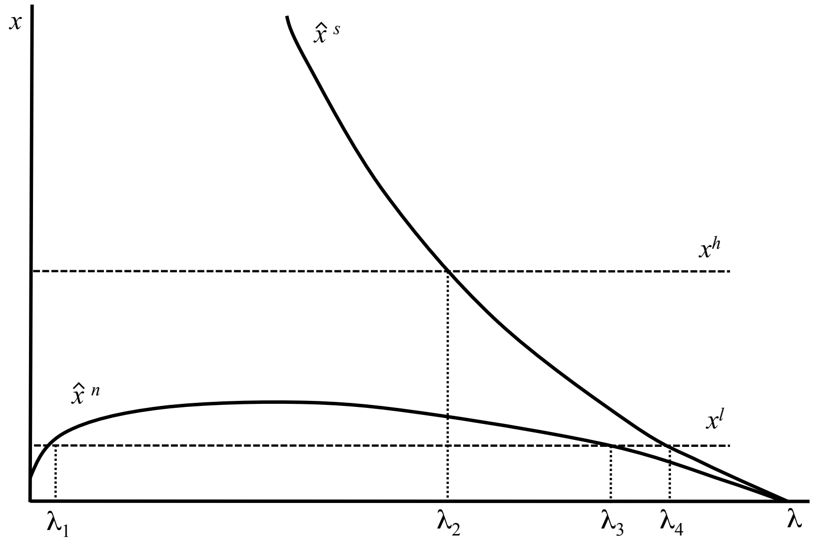

Figure 3.1: Critical costs functions of the skilled ($\hat{x}^s$) and unskilled ($\hat{x}^n$)

The situation of the population can be described by the occupation and cost distribution, which is denoted by

$$\pi(t) \equiv \{\pi_{s^l}(t), \pi_{s^h}(t), \pi_{n^l}(t), \pi_{n^h}(t)\} \tag{3.7}$$

where $\pi_{k^i}(t)$ is the fraction of agents with occupation $k \in \{s, n\}$ and education costs x^i, $i \in \{l, h\}$ at time t. Thus, the aggregate skill ratio of the population equals $\lambda_t = \pi_{s^l}(t) + \pi_{s^h}(t)$.
The dynamics of the model depends on the skilled fraction since it determines the investment decisions of the parents and therefore the transition matrix, which describes the evolution from state $\pi(t)$ to a new state $\pi(t+1)$. To make this clearer, e.g.

$$\pi(t) \cdot \begin{pmatrix} p_{l\to l} & \alpha \cdot p_{l\to h} & 0 & (1-\alpha) \cdot p_{l\to h} \\ p_{h\to l} & \alpha \cdot p_{h\to h} & 0 & (1-\alpha) \cdot p_{h\to h} \\ p_{l\to l} & 0 & 0 & p_{l\to h} \\ p_{h\to l} & 0 & 0 & p_{h\to h} \end{pmatrix} = \pi(t+1). \tag{3.8}$$

describes a situation where all parents at time t invest in a child with education costs x^l and skilled parents additionally are indifferent in the investment decision for a child with education costs x^h. Skilled parents invest in such a child with probability α. Summing up, the dynamic can be described by a time-heterogenous Markov chain.

Whenever the current skill ratio λ_t and the expectations about the next period λ^e_{t+1} induce a total skill ratio $\lambda_{t+1} = \lambda^e_{t+1}$ the sequence $\{\lambda_t\}_{t=0,1,2,...}$ describes a competitive equilibrium.

In my analysis I only focus on equilibria with stationary skill ratios (SS), i.e. $\lambda_t = \lambda_{t+1} \equiv \lambda^*$. In this case the transition matrix is stationary and the Markov chain becomes a homogeneous one. Since a situation without mobility is at odds with reality I restrict the analysis to steady states with mobility (SSM), i.e. equilibria with stationary skill ratios in which the number of unskilled investors is positive and equals the number of skilled non-investors.
Since investment of the unskilled - because of their wage disadvantage - always requires investment of the skilled, and investment in a child with education costs x^h always requires investment in a child with education costs x^l, there are four different types of SSMs that are summarized in Table 3.1. In the table *yes* denotes strict investment, *no* denotes strict non-investment and α (β) denotes that skilled (unskilled) parents are indifferent, and invest with market clearing probabilities.

	Type I	Type II	Type III	Type IV
Skilled invest in x^l-type	yes	yes	yes	yes
Unskilled invest in x^l-type	yes	β	yes	β
Skilled invest in x^h-type	α	α	no	no
Unskilled invest in x^h-type	no	no	no	no

Table 3.1: Four possible types of SSMs

Since a SSM of type II is unstable in the sense that it diminishes whenever there is a small change in the mobility flows I will not consider this type of SSM for the remaining analysis of the impact of policy interventions. The following analysis of the policy interventions is based on changes in the upward ($u(\cdot)$) and downward ($d(\cdot)$) social mobility flows. Both flows depend on the aggregate skill ratio and equal

$$u(\lambda) \equiv \{\beta(\pi_{n^l} p_{l\to l} + \pi_{n^h} p_{h\to l})\} \tag{3.9}$$

and

$$d(\lambda) \equiv \{(1-\alpha)(\pi_{s^l} p_{l\to h} + \pi_{s^h} p_{h\to h})\} \tag{3.10}$$

respectively. If the unskilled invest with strict preferences in the cost type x^l (see SSM types I and III) $\beta = 1$ holds; otherwise it is $\beta \in (0,1)$ (see SSM types IV). Analogously it is $\alpha = 0$ if the skilled strictly do not invest in the cost type x^h (see SSM types III and IV) and $\alpha \in (0,1)$ otherwise (see SSM types I). Although the RHS of equations (3.9) and (3.10) do not directly depend on the aggreate skill ratio λ they depend on the parameters α and β respectively that are determined by λ.

According to equation (3.9) the upflow is characterized by one upward jump and the corresponding downward jump. Between upward and downward jumps the flow strictly decreases. An increase in the aggregate skill ratio λ decreases the number of unskilled and therefore the upward flow. In contrast, the downflow by equation (3.10) is increasing in the aggregate skill ratio with one upward jump. It can easily be seen and is already mentioned in Mookherjee and Napel (2007) that there exists the possibility for a limited multiplicity of SSMs. More precisely, two SSMs can simultaneously occur in the present setup (e.g. see Figure 3.2).

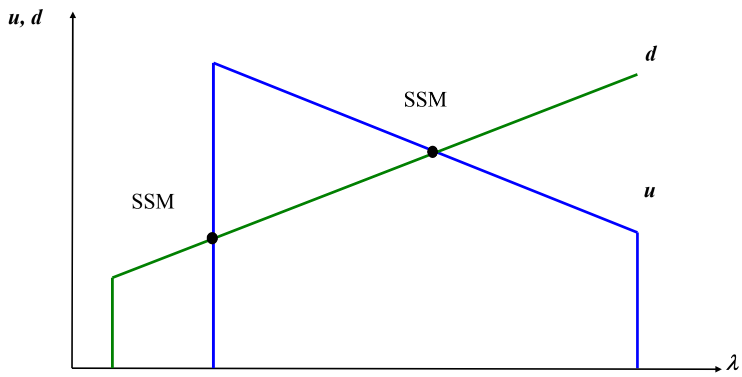

Figure 3.2: Mobility flows for a case with two SSMs

3.3 Redistributive taxation

In this section I analyze the effect of redistributive taxation on an existing SSM. Due to redistributive taxation the number and types of SSMs can change. To simplify matters I only focus on the marginal impact of redistributive taxation. Therefore, I introduce a tax rate that is marginally higher than zero. The main target of this analysis is to understand how the incentives of skilled and unskilled parents change and how these changes affect the skill ratio in the steady state, inequality and social mobility.

The introduction of a small tax rate τ results in post-tax wages

$$w^s_{\tau,t} \equiv w^s_\tau(\lambda_t) = (1-\tau)w^s_t + \tau\Big(\lambda_t w^s_t + (1-\lambda_t)w^n_t\Big) \tag{3.11}$$

and

$$w^n_{\tau,t} \equiv w^n_\tau(\lambda_t) = (1-\tau)w^n_t + \tau\Big(\lambda_t w^s_t + (1-\lambda_t)w^n_t\Big) \tag{3.12}$$

with w^s_t and w^n_t defined as in equations (3.1) and (3.2). Thus, redistributive taxation amounts to an unconditional transfer from the skilled to the unskilled. While this policy increases the wage of unskilled workers it decreases the wage of skilled workers. This directly gives Lemma 3.1.

Lemma **3.1** *Subjective benefit of investment (B_τ) is reduced by redistributive taxation. Subjective costs of investment are lowered for the unskilled (C^n_τ) but raised for the skilled (C^s_τ).*

Thus, for skilled parents investment incentives shrink due to increased costs and decreased benefit. However, for unskilled parents two counteracting effects appear. On the one hand investment becomes easier as a result of decreased costs (*cost effect*), on the other hand return on investment in human capital drops due to a lowered wage gap (*wage premium effect*). Let $\hat{\lambda} \in (0, \gamma)$ be defined as the solution of

$$w^n(\lambda) - \frac{w^n(\lambda)^{\delta+1}}{w^s(\lambda)^\delta} = w^n_\tau(\lambda) - \frac{w^n_\tau(\lambda)^{\delta+1}}{w^s_\tau(\lambda)^\delta}, \tag{3.13}$$

i.e. $\hat{\lambda}$ is the skill ratio at which the critical costs functions of the unskilled with and without redistributive taxation intersect.[7] At $\hat{\lambda}$ redistributive taxation has no influence on the investment incentives of the unskilled agents. Up to $\hat{\lambda}$ it raises investment incentives of the unskilled while for all $\lambda \in (\hat{\lambda}, \gamma)$ the reverse is true. The change in the critical costs function of the unskilled is illustrated in Figure 3.3.

The change in the investment incentives directly implies that the downflow weakly increases due to redistributive taxation. The upflow never decreases if the pre-tax SSM satisfies $\lambda^* \in (0, \hat{\lambda})$ but it never increases if $\lambda^* \in (\hat{\lambda}, \gamma)$ holds. Thus, the social mobility upflow can only be raised due to redistributive taxation if the population before the policy intervention is characterized by a low skill ratio. Proposition 3.1 summarizes the results for the change in the skill ratio.

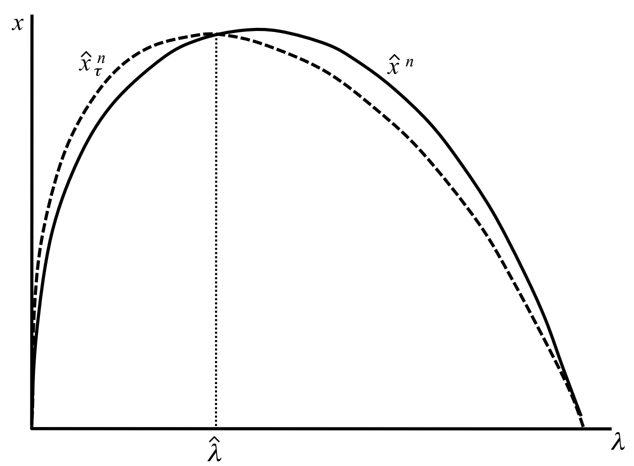

Figure 3.3: Critical costs function of the unskilled with and without redistributive taxation

[7] Existence and uniqueness of $\hat{\lambda}$ are equal to a single point of intersection of $C^n(\lambda) - C^n_\tau(\lambda)$ and $B(\lambda) - B_\tau(\lambda)$. While the difference in costs is a convex function in λ the difference in benefit has an S-shaped form, i.e. it is concave for $\lambda < \frac{1-2\gamma+2\tau\gamma}{2\tau}$ and convex otherwise. This directly flows from considering the second order derivative. Considering that at the lower bound of the investment interval the cost difference is higher than the difference in benefits and that both differences are zero at the end of the investment interval, i.e. at $\lambda = \gamma$, both functions intersect at a unique $\hat{\lambda}$.

PROPOSITION **3.1** *The aggregate skill ratio decreases due to redistributive taxation in the case of a type-I or type-IV SSM. It is unchanged in the case of a type-III SSM.*

Proof: The results for all cases are illustrated in Figure 3.4. While solid lines illustrate mobility flows without taxation dashed lines illustrate mobility flows with redistributive policy. Let λ^* denote the SSM before taxation while λ^*_τ is the stationary skill ratio after taxation. Focusing on a SSM of type I the investment incentives of the skilled are decreased by the policy while the investment incentives of the unskilled near the initial skill ratio λ^* are not influenced. This implies that the skilled start non-investment in at least some high-skilled children at $\lambda^*_\tau < \lambda^*$. Thus, the stationary skill ratio decreases. Note, that at the pre-tax SSM λ^* the downflow is higher than the upflow after introducing the policy. A SSM of type IV can appear at the lower bound of the interval where unskilled parents invest in a child with low costs, i.e. when $\lambda^* < \hat{\lambda}$ holds, or at the upper bound of this interval, i.e. when $\lambda^* > \hat{\lambda}$ holds. Redistributive taxation shifts this investment interval to the left. Therefore, $\lambda^*_\tau < \lambda^*$ holds, i.e. the stationary skill ratio is smaller with than without taxation. For a SSM of type III, i.e. a SSM where all agents have strict investment incentives, a small tax rate τ does not change investment incentives at the initial SSM λ^*. Therefore, stationary skill ratios before and after taxation are equal. $\square$

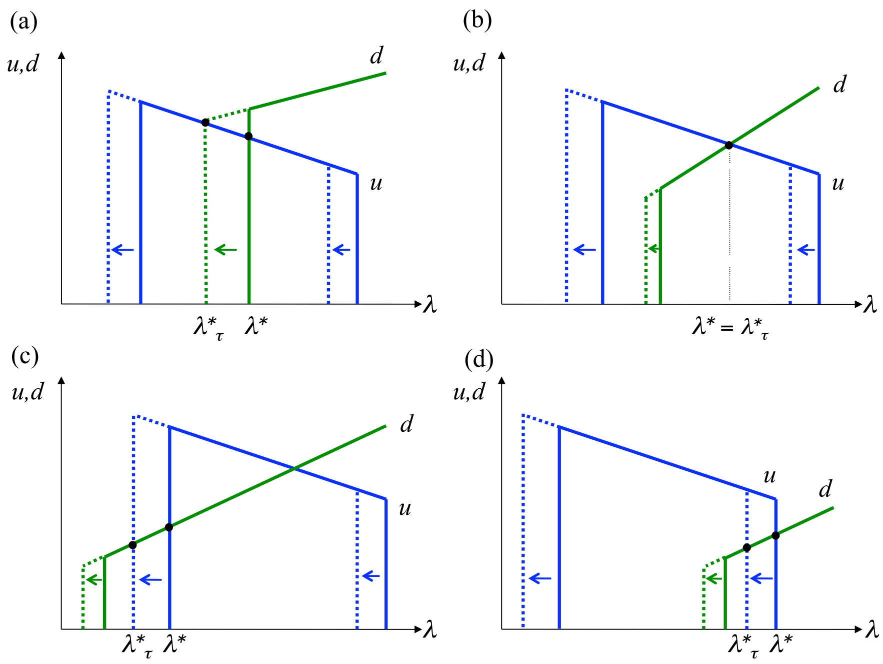

Figure 3.4: Change in skill ratio due to taxation for (a) SSM type I, (b) SSM type III, and (c) and (d) SSM type IV

Thus, redistributive taxation is not recommended as a policy targeting an increasing aggregate skill ratio. However, the change in the skill ratio is not only interesting for itself but also determines the change in inequality. Proposition 3.2 summarizes the impact of the tax on the level of inequality.

PROPOSITION **3.2** *A tax policy resulting in a constant or increased aggregate skill ratio reduces intragenerational inequality while a decreased skill ratio lowers and maybe overcompensates the direct tax effect and therefore can increase inequality.*

Proof: For an unchanged skill ratio redistributive taxation increases the wage of the unskilled and decreases the wage of the skilled. Thus, for an unchanged skill ratio inequality is reduced. I call this effect *direct tax effect.* Since an increased aggregate skill ratio ceteris paribus leads to a reduction of the wage gap, the *direct tax effect* is enhanced by an *indirect tax effect* if the aggregate skill ratio is increased. Analogously, the *direct tax effect* is weakened and may be overcompensated due to a decreased aggregate skill ratio.[8] □

Summing up, for a type-I or type-IV SSM, redistributive taxation may increase inequality while it is definitely reduced in case of a type-III SSM that is characterized by strict investment incentives of all agents.

The second point of interest is the change in social mobility due to redistributive taxation.

PROPOSITION **3.3** *Social mobility increases due to redistributive taxation if the SSM is of type I while it decreases if the SSM is of type IV. For a SSM of type III social mobility is not influenced by redistributive taxation.*

Proof: For a SSM of type I the skill ratio is decreased by redistributive taxation (see Prop. 3.1). This implies - since the upflow is strictly decreasing in the relevant range - increased upward mobility. Therefore, in the SSM, there must also be an increased downward mobility. For a SSM of type IV the skill ratio also increases due to redistributive taxation (see Prop. 3.1). However, the strictly decreasing downflow in this situation implies a reduction in the downard mobility, and therefore in the SSM also a decrease in the upward mobility. For a SSM of type III the skill ratio does not change due to redistributive taxation (see Prop. 3.1). Therefore upflow and downflow do not change at λ^*. The results for the different types of SSM can also be inferred by Figure 3.4. □

Summarizing, redistributive taxation is in general not a good policy to reduce inequality or to increase social mobility. However, it reduces inequality - for a constant level of social mobility - if the pre-tax SSM is of type III and it increases social mobility - with an ambiguous effect on inequality - if the SSM is of type I.

[8]The *indirect tax effect* that occurs due to a change in the aggregate skill ratio is already mentioned by Dur and Teulings (2001) and also plays a crucial role when Konrad and Spadaro (2006) show that not only low-talented but also highly talented agents may support redistribution.

3.4 Education subsidies

One may suspect that redistributive taxation is, in general, no good policy intervention because it amounts to an unconditional transfer. However, this section shows that education subsidies as a conditional transfer generally cannot decrease inequality and increase social mobility either. In the analysis the focus is again on the marginal effect of subsidization and therefore a subsidy rate θ that is marginally higher than zero is assumed. Otherwise the number and types of SSMs could change completely.

Assume that education subsidies are available to all parents that choose to acquire education, and that they are independent of the parent's occupation type. They are paid proportional to the education costs of the child and are financed by a flat rate tax levied on the general public (similar to Bovenberg and Jacobs (2005)). In equilibrium the aggregate amount of subsidy $\Theta(\lambda)$ for an exogenous and small subsidy rate θ is

$$\Theta(\lambda) = \theta\lambda(\rho_l x^l + \alpha\rho_h x^h) + \theta(1-\lambda)\beta\rho_l x^l, \tag{3.14}$$

where ρ_l and ρ_h denote the exogenous fractions of children with low and high education costs respectively. Considering a tax rate τ_{sub} the aggregate tax amount in equilibrium is $\tau_{\text{sub}}(\lambda w^s + (1-\lambda)w^n)$.[9] Thus, for a subsidy rate θ, that is exogenously fixed, the tax rate τ_{sub} is endogenously determined by the government's budget restriction as

$$\tau_{\text{sub}} \equiv \frac{\theta\lambda(\rho_l x^l + \alpha\rho_h x^h) + \theta(1-\lambda)\beta\rho_l x^l}{\lambda w^s + (1-\lambda)w^n}. \tag{3.15}$$

For the remaining analysis $\theta > \tau_{\text{sub}}$ is assumed to hold. This assumption is necessary to foster investment incentives of the agents[10] and can be guaranteed for at least a small exogenous subsidy rate.[11]

Considering the described policy intervention, equilibrium wages are

$$w^s_{\text{sub}} = (1-\tau_{\text{sub}})w^s \quad \text{and} \quad w^n_{\text{sub}} = (1-\tau_{\text{sub}})w^n \tag{3.16}$$

with w^s and w^n given as in equations (3.1) and (3.2). Replacing w^s and w^n in equations (3.4) and (3.5) by w^s_{sub} and w^n_{sub} gives subjective benefit and costs after subsidization.

Lemma **3.2** *The subjective benefit of investment (B_{sub}) does not change due to education subsidies. Subjective costs of the skilled (C^s_{sub}) and unskilled (C^n_{sub}) are reduced.*[12]

[9] All parameters that refer to the case of education subsidies are indexed with 'sub'.

[10] Subjective benefit is not influenced by the policy (see Lemma 3.2) and, easily checked again, only for $\tau_{\text{sub}} < \theta$ subjective costs are smaller with than without education subsidies.

[11] Considering equation (3.15), $\rho_l x^l + \alpha\rho_h x^h \big(< (\rho_l + \alpha\rho_h)x^h\big) < w^s$ and $\beta\rho_l x^l < w^n$ are sufficient conditions to assure $\tau_{\text{sub}} < \theta$. As $w^s \geq (1-\theta)x^h$ and $w^n \geq (1-\theta)x^l$ are necessary conditions for investment we can rewrite the sufficient conditions as $(1-\theta) \geq \rho_l + \alpha\rho_h$ and $(1-\theta) \geq \beta\rho_l$. As the second condition always holds if the first condition is fulfilled and the right-hand side of the first condition is smaller than 1 there exists a $\theta > 0$ so that the first condition and therefore $\theta > \tau_{sub}$ holds.

[12] The fact that subjective benefit is not influenced by subsidization depends on the special form of the utility

The lemma directly follows from the change in wages. Caused by the unchanged benefit and the reduced costs the investment incentives of all parents increase. Therefore, the upflow is never decreased due to the described policy while the downflow is never increased. The change in the mobility flows then gives Proposition 3.4.

PROPOSITION **3.4** *Education subsidies that are financed by a flat rate tax levied on the general public increase the aggregate skill ratio if the SSM is of type I and they do not change the skill ratio if the SSM is of type III. If the SSM is of type IV, then subsidization decreases the skill ratio in a low-skilled population, i.e. if* $\lambda^* < \hat{\lambda}$ *holds, but it increases the skill ratio in a high-skilled population, i.e. if* $\lambda^* > \hat{\lambda}$ *holds.*

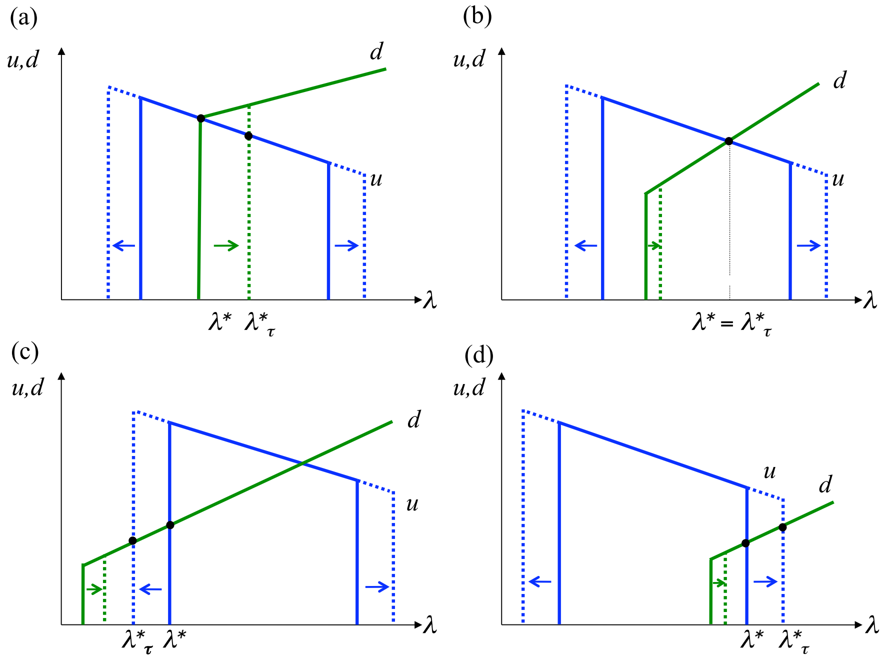

Figure 3.5: Change in skill ratio caused by education subsidies for (a) SSM type I, (b) SSM type III, and (c) and (d) SSM type IV

Proof: The changes in the upflows and downflows for all types of SSMs are illustrated in Figure 3.5. Again, solid lines represent the case without policy intervention while dashed lines are the social mobility flows with education subsidies. The skill ratio in a SSM of type I is determined by the indifference in the investment decision of skilled parents with respect to a child with high costs, i.e. an upward jump of the downward flow. With subsidization skilled parents are indifferent in their decision to invest in a low-talented child at a higher aggregate skill ratio than without policy intervention. Thus, the skill ratio increases due to subsidization. For a SSM of type III upflow and downflow do not change at λ^*. Thus, the skill ratio is not influenced. A

function. If the utility function is e.g. $u(c) = \frac{c^{1-\phi}}{1-\phi}$ subsidization causes an increase in the subjective benefit.

SSM of type IV is characterized by the indifference in the investment incentives of the unskilled. Since investment incentives of the unskilled are increased due to subsidization the skill ratio at which the upflow jumps from zero to a positive value is smaller with than without subsidization and the skill ratio at which the upflow jumps from a positive value to zero is higher with than without subsidization. Thus, if $\lambda^* < \hat{\lambda}$ holds education subsidies decrease the skill ratio while they increase the skill ratio if $\lambda^* > \hat{\lambda}$ holds. □

As wages w^s_{sub} and w^n_{sub} depend on the subsidy rate θ only via the taxation rate τ_{sub} education subsidies that are financed by a linear income tax affect inequality in the same way as redistributive taxation does. Thus, Proposition 3.2 also holds for education subsidies. Summarizing, education subsidies are an appropriate policy to reduce inequality under most circumstances, i.e. if the SSM is of type I, III or in a high-skilled population of type IV. However, if the population is characterized by a low aggregate skill ratio and the unskilled are indifferent in their investment decision with respect to the cost type x^l, the impact on the wage gap is ambiguous.

Focusing on the impact of education subsidies on social mobility one can obtain:

Proposition **3.5** *Social mobility decreases due to education subsidies if the SSM is of type I. It is not influenced if the SSM is of type III. If the SSM is of type IV social mobility is decreased by subsidization in a low-skilled population, i.e. if $\lambda^* < \hat{\lambda}$ holds, but it is increased in a high-skilled population, i.e. if $\lambda^* > \hat{\lambda}$ holds.*

Proof: All results are illustrated in Figure 3.5. The skill ratio in a SSM of type I is determined by the indifference in the investment decision of the skilled with respect to a child with high education costs. With education subsides skilled parents are indifferent in their investment decision for a low-talented child at a higher aggreagte skill ratio than without subsidies. This implies - since the upward mobility flow is strictly decreasing - a decrease in social mobility due to subsidization. For a SSM of type III investment incentives are not influenced by subsidization at λ^*. Thus, social mobility does not change due to the policy intervention. In a low-skilled population, the aggreagte skill ratio decreases for a SSM of type IV (see Proposition 3.4). This increase implies a reduction in the social mobility because the downflow increases in the aggregate skill ratio. In a high-skilled population, the aggregate skill ratio increases for a SSM of type IV (see Proposition 3.4). Therefore, the increasing downflow results in an increase of the social mobility. □

Thus, education subsidies increase social mobility only in a high-skilled population where the unskilled are indifferent in their investment decision with respect to a child with low education costs.

Comparing both types of policy intervention, redistributive taxation and education subsidies affect inequality and social mobility in the same way when the SSM is of type III or the SSM is of type IV and $\lambda^* < \hat{\lambda}$ holds but they have different effects in all other cases. Redistributive taxation can in no case simultaneously reduce inequality and increase social mobility. However, education subsidies can achieve this in a high-skilled population where the unskilled are indifferent in their investment decision having a child with cost type x^l.

3.5 Concluding remarks

This paper shows that neither redistributive taxation nor education subsidies are always a recommended policy to help poor children become educated when parents decide on the education of their children and wages are endogenous. The impact of both policy interventions on the aggregate skill ratio as well as on inequality and social mobility depends on the initial investment decisions of all parents. Under some circumstances both policies can definitely reduce inequality and under other circumstances increase social mobility. However, only education subsidies can ensure both at the same time for at least one situation. Unfortunately, this situation requires that the population without policy intervention is already characterized by a high skill ratio. Thus one can say that the simultaneous improvement of intra- and intergenerational equity can only be reached in developed countries. Finally, although both policies should increase social mobility I provide conditions for both analyzed interventions under which social mobility is reduced due to public provision. Only when the government is aware of the specific situation can it implement the 'right' policy to raise the number of poor children that get educated. However, in a low-skilled population where unskilled parents are indifferent with respect to an investment in a child with low education costs neither redistributive taxation nor education subsidies yield an increase in social mobility.

Note that, in the present model a child's future wage depends only on the education decision of its parents but not on the inherent talent of the child. Thus, this model does not consider a possible positive effect in aggregate productivity or growth if the most talented agents get educated (see e.g. Hassler and Rodríguez Mora (1998) and De Fraja (2002) for models that consider this effect). Additionally, the influence of the analyzed policies on social welfare could be an interesting starting point for further research. Such an approach seems to be complicated because even the special forms of the utility and production functions considered above do not allow to quantify the exact change in the skill ratio but at most to determine the direction of change.

4 Science and teaching: two-dimensional signalling in the academic job market

Post-docs signal their ability to do science and teaching in trying to get a tenure giving universities the possibility of separating highly talented agents from the low talented ones. However, separating becomes even more important in a two-dimensional signalling case. This attracts notice to time constraints. Under weak conditions separating equilibria do not exist if time constraints are binding. The existing equilibria are more costly but without additional information compared to the one-dimensional case. Considering this, the efficiency of the current two-dimensional academic job market signalling can be improved by switching to a one-dimensional one.

JEL: I23; D82; J41

4.1 Introduction

From the 19th century on the Germans know the concept of the unity of research and teaching. This idea of Wilhelm von Humboldt has influenced especially the German higher education system and is still present today. On the other hand post-docs and professors often rail against the double burden of such a system. These conflicting argumentations in mind economists study the optimal design of the university system (e.g. Del Rey 2001, De Fraja and Valbonesi 2008 or Gautier and Wauthy 2007) as well as their optimal labor contract behavior (Walckiers 2008). In line with the second part of literature the present paper analyzes the possibility of separating highly productive agents from the low-productive ones in a model where post-docs can signal their ability to do science and teaching to get a tenure.

Arguing in line with a job market signaling model it is necessary to mention the work of Michael Spence. Spence as the father of signaling models shows that education can be an efficient signal to correct asymmetric information in the job market. It's due to him that we know about the existence of signaling equilibria (Spence 1973; Spence 1974).[1] In contrast to Spence who mainly deals with the existence of equilibria, Cho and Kreps (1987) rank equilibria. They implement an intuitve criterion to eliminate equilibria that are build on unplausible out-of-equilibrium beliefs. This stronger equilibrium concept will be the basic equilibrium concept of the present paper.

Up to here all concepts work in a one-dimensional world. Thus, agents send a one-dimensional signal. Since future professors produce a two-dimensional output consisting of science and teaching a multi-dimensional set up is needed. Unfortunately, papers on multi-dimensional signaling are rare. One of the first is by Rochet and Quinzii (1985). This paper analyzes in a formal way the difference between the one- and multi-dimensional signaling set up. Assuming a separable cost structure they give necessary conditions for the existence of a separating equilbrium. In the same kind of model Engers (1987) focuses on pareto-dominant separating equilibria. Armstrong and Rochet (1999) simplify conditions that are necessary to ensure a separating equilibrium by assuming a discrete type distribution. This is also an assumption in my model. A current paper by Kim (2007) is of interest as well because it analyzes time binding constraints in a two-dimensional job market signaling model.

The aim of this paper is to analyze separating equilibria in a two-dimensional signaling model that describes the academic job market. Post-docs that differ in their ability to do research and teaching can signal both talents to get a tenure. As one result separating equilibria in the two-dimensional case can vanish with time binding constraints. This always happens if teaching (science) productivity of the highly talented is higher than the science (teaching) productivity of the low-talented. Nevertheless, implying the concept of partially separating equilibria it can be shown that under weak conditions there is at least one partially separating equilibrium. More precisely, agents that are highly productive in both outputs send the same signal as the type that is highly talented with respect to the output that is more preferred by the universities.

[1] While Spence's first paper focuses on the general existence of signaling equilibria the second paper highlights the different market forms.

What is important for policy implications is that the signaling effort in the partially separating equilibrium - although it is smaller than in the two-dimensional separating equilibrium - is higher than in the one-dimensional separating equilibrium. This is of interest if signaling only has an effect on costs but not on productivity as it is the case in Spence (1973) and also in the present model. Thus, if time constraints are binding in the academic job market it is more efficient to let post-docs only signal their talent of the activity that is more preferred by the universities. Under time binding constraints universities can only distinguish highly productive from low-productive types in one dimension just like in the one-dimensional case. Having this in mind there is no argument for the two-dimensional signaling process that is currently observed in reality. It just implies additional costs. Only weak conditions concerning the ranking of the productivity parameters are necessary to make a separating equilibrium under time binding constraints impossible in the two-dimensional case. Thus, agents that are highly-talented in both outputs cannot be identified by universities.
The remaining paper is structured as follows: Section 4.2 sets the basic model. The existence of equilibria is analyzed in section 4.3. While section 4.3.1 focuses on the one-dimensional case that goes in line with Spence (1973), section 4.3.2 extends the analysis to the two-dimensional case. In this part the analysis also distinguishes between a situation where time constraints are not binding resulting in a unique separating equilibrium which is most efficient for the universities, and a situation where time constraints are binding which may lead to the vanishing of the separating equilibrium. In the second case the existence of partially separating equilibria where some types of agents can be separated while others play the same stratgey is analyzed. Section 4.4 concludes.

4.2 The model

Assume a competitive academic job market with a unit mass of academics. Each university post-doc produces science and teaching which requires specific unobservable abilities.[2] Academics as well as other laborers vary in their abilities. There are four types $ij \in \{HH, HL, LH, LL\}$ of future professors.[3] While i denotes research productivity j describes the teaching productivity. Both productivities can be high (H) or low (L). Future professors can signal both abilities: Science s_{ij} and teaching t_{ij}, $i, j \in \{H, L\}$. As in Spence (1973) signals do not have any influence on productivity. Agents use the signals to influence the universities' beliefs on their abilities. Thus, the pre-tenure research and teaching output works as a signal for post-tenure productivities. However, there is a time binding constraint $s_{ij} + t_{ij} = \bar{l}$. Signaling effort cannot be higher than the available time and therefore is limited. The agents' ij cost function depending on his type is assumed as:

$$c_{ij}(s_{ij}, t_{ij}) = \frac{s_{ij}}{\theta_i^s} + \frac{t_{ij}}{\theta_j^t}, \tag{4.1}$$

[2]In the remaining paper 'research', 'science' and publishing' are synonymously used.
[3]This notation follows Walckiers (2008).

where θ_i^s and θ_j^t, $i,j \in \{H,L\}$, are the productivities of science and teaching respectively. Clearly, $\theta_H^k > \theta_L^k, k \in \{s,t\}$ holds. For simplicity I also assume $\theta_L^k \geq 1$, $k \in \{s,t\}$. Implicitly I assume that the research (teaching) productivity is independent of the ability to teach (research). The fraction of type ij agents in the population is denoted by α_{ij}. The distribution of the types is common knowledge.
Universities compete for prospective professors. However, they face asymmetric information and can only form beliefs on the agents' abilities via signals.
The profit of a university is $\pi((\theta_i^s, \theta_j^t), w) = \theta_i^s + \theta_j^t - w$, where w is the wage paid to the agent. The competition of the academic job market implies that universities make a profit of zero and therefore wages are given by productivities. Thus, the equilibrium wage offered by the universities is w^*

$$w^* \equiv E[\alpha_{ij}(\theta_i^s + \theta_j^t)] \tag{4.2}$$

where E is the expectation operator.

Although pre-tenure publishing and teaching do not influence the productivity universities can condition wage offers on the pre-tenure science and teaching output. The optimal decision of a prospective professor of type ij is

$$\max_{s_{ij},t_{ij}} U_{ij} = E[w_{ij} - (\frac{s_{ij}}{\theta_i^s} + \frac{t_{ij}}{\theta_j^t})]. \tag{4.3}$$

subject to $s_{ij} + t_{ij} \leq \bar{l}$.
Section 4.3 will analyze equilibria of this signaling model.

4.3 Signaling in the academic job market

First the focus is on signaling equilibria when universities are only interested in science (section 4.3.1). This analysis goes in line with the signaling model of Spence (1973). Afterwards section 4.3.2 analyzes a two-dimensional signaling model where agents signal on science and teaching. In both cases the main question is if there are separating equilibria where signaling can help to improve inefficient results caused by asymmetric information. Therefore, pooling equilibria are only analyzed in the margin.

Under incomplete information there is need for a definition of a perfect Bayesian equilibrium.

Definition **4.1** *Perfect Bayesian Equilibrium (PBE): A PBE is a set that consists of a signal* (s_{ij}^*, t_{ij}^*) *for each type of agent* $ij \in \{HH, HL, LH, LL\}$ *and a wage offer* $w_{ij}(s_{ij}^*, t_{ij}^*)$ *used by the universities. For each signal* (s_{ij}^*, t_{ij}^*) *the universities make zero profits given the belief* $\mu(ij|(s_{ij}, t_{ij}))$ *which types could have sent* (s_{ij}, t_{ij})*. Each type* ij *maximizes his utility by choosing* (s_{ij}^*, t_{ij}^*) *given the wage offer* w_{ij} *of the university.*

The university's belief must be consistent with Bayes' rule and with the agent's strategy: $\mu(ij|(s_{ij}, t_{ij})) = \frac{\alpha_{ij}}{\sum_{ij} \alpha_{ij}}$.

Therefore, one can distinguish between a separating equlibrium and a pooling equilibrium. In the first case all types send different signals, i.e. $(s^*_{ij}, t^*_{ij}) \neq (s^*_{i'j'}, t^*_{i',j'})$ if $ij \neq i'j'$. In the second case the signal is identical for all types, i.e. (s^*_{ij}, t^*_{ij}), $\forall\ i, j \in \{H, L\}$. In contrast to a model set up with two different types of agents that is normally used, in the present model there is also the posibility for an equilibrium in which some but not all agents send the same signal. Such a perfect Bayesian equilibrium will be called a partially separating equilibrium.

4.3.1 One-dimensional signaling

Let us assume for the moment universities are only interested in science and not in teaching. In this case there is no value of teaching and therefore no agent sends a teaching signal. Thus, type HH and HL can be interpreted as one type denoted by H. The same applies to LH and LL. This low-productive type is denoted by L.[4] Then the fraction of the high-productive type is $\alpha_H \equiv \alpha_{HH} + \alpha_{HL}$ and the fraction of agents with low productivity is $\alpha_L \equiv \alpha_{LH} + \alpha_{LL}$. Under complete information the highly productive type would earn a wage of θ^s_H while the type with low productivity gets $\theta^s_L < \theta^s_H$. Since pre-tenure publishing only implies a cost effect but no effect on productivity both types do not publish anything under complete information. Under incomplete information one can distinguish between a pooling and a separating equilibrium. However, the partially separating equilibrium is irrelevant in the case of two different types of agents.

PROPOSITION **4.1** *Given a two type signaling game where future professors can have high or low productivity of publishing (θ^s_H or θ^s_L) and the universities' wage offer $w(s)$ depends on the research signal s there is the unique separating equilibrium*

$$s^*_H = \theta^s_L(\theta^s_H - \theta^s_L),\ \ s^*_L = 0$$

$$w(s^*_H) = \theta^s_H,\ \ w(s^*_L) = \theta^s_L$$

$$\mu(H|s \geq s^*_H) = 1,\ \ \mu(L|s < s^*_H) = 1.$$

The detailed proof of Proposition 4.1 can be found in appendix A page 53. The motivation behind the result is as follows: In a separating equilibrium there is no incentive for the type with low productivity to invest in publishing because this has just a cost effect but no impact on his publishing productivity. Therefore, an agent with high productivity must publish exactly the amount that ensures type L does not mimic him. However, it is possible that the time

[4] Clearly, in this two type case the cost and wage structure satifies the well known Spence-Mirrlees *single crossing property* condition, i.e. the two-types' $w - s_i$–indifference curves with $i \in \{H, L\}$ have only one point of intersection.

constraint is binding, i.e. $s_H^* > \bar{l}$. Then the agent with the high productivity cannot publish enough to prevent mimicing of the low-productive type.

In addition there is also a unique pooling equilibrium where nobody signals.[5] This is a standard result whenever signals do not have an effect on productivity. In this case nobody has an incentive to invest in signaling playing $s^* = 0$. Note, if the time constraint is binding, only the pooling equilibrium persists. However, this paper focuses on efficient separating equilibria.

Of course, all results persists if universities are solely interested in teaching. In this case just replace s by t in the previous analysis and redefine $\alpha_H \equiv \alpha_{HH} + \alpha_{LH}$ and $\alpha_L \equiv \alpha_{HL} + \alpha_{LL}$ respectively.

4.3.2 Two-dimensional signaling

A higher load of teaching (and also administrative work) reduces publication output since time to teach cannot be used to do research (Mitchell and Rebne 1995). Although teaching can enhance research (Becker and Kennedy 2005), there is no general evidence that good researchers are also good teachers. In contrast economists prefer doing reseach to teaching (Allgood and Walstad 2005). Since results of the interdependency of science and teaching are unclear I do not make any additional assumptions on the distribution of the four types of agents.[6] Nevertheless note, if both talents are substitutes (complements) α_{HL} and α_{LH} are high (small) while α_{HH} and α_{LL} are small (high).[7]

In subsection 4.3.1 we have already seen that the time constraint can have an important influence on the existence of PBE. In the one-dimensional case time constraints can lead to a situation where only the pooling equilibrium exists. Now, under two-dimensional signaling I show that the separating equilibrium is even more likely to be destroyed by time constraints. However, with two dimensions there is the possibility of partially separating equilibria. First, I analyze the separating equilbrium in the two-dimensional case. Then I show that under some conditions (more precisely, if Assumption 4.1 holds) time constraints make a separating equilibrium imposssible. Nevertheless, if agents send a two-dimensional signal there is always at least one partially separating equilibrium. In this equilibrium type HH sends the same signal like the type that is highly talented with respect to the output that is more preferred by the universities.

[5] For the explicit notation of the pooling PBE and for the proof of its existence see appendix A page 53.

[6] Although there is no clear evidence that research and teaching are complements from the individual perspective both act complementary on the university level. For a meta-analysis on this topic see Hattie and Marsh (1996).

[7] Gottlieb and Keith (1997) find in their study that the connection between research and teaching is not just substitutive or complementary but more complex. In detail they show that research can positively affect teaching but attributes of teaching negatively impact research.

Time constraint not binding

Proposition **4.2** *If agents signal science and teaching ability via (s_{ij}, t_{ij}), universities offer wages $w(s_{ij}, t_{ij})$ and the time constraint is not binding, i.e. $s^*_{ij} + t^*_{ij} \leq \bar{l}$, there is a separating equilibrium*

$$s^*_{ij} = \begin{cases} \theta^s_L(\theta^s_H - \theta^s_L), & i = H \\ 0, & i = L \end{cases} \quad \text{and} \quad t^*_{ij} = \begin{cases} \theta^t_L(\theta^t_H - \theta^t_L), & j = H \\ 0, & j = L \end{cases}$$

$$w(s^*_{ij}, t^*_{ij}) = \theta^s_i + \theta^t_j, \;\; \forall i, j \in \{H, L\}$$

$$\mu(i, j = H | k_{ij} \geq \theta^k_L(\theta^k_H - \theta^k_L)) = 1 \text{ and } \mu(i, j = L | k_{ij} < \theta^k_L(\theta^k_H - \theta^k_L)) = 1$$

where $k \in \{s, t\}$.

The detailed proof of Proposition 4.2 is given in appendix B page 54. The basic idea is to derive conditions under which type ij has no incentive to mimic type $i'j'$ for all $i, i', j, j' \in \{H, L\}$. Although these conditions are fulfilled by a continuum of signal combinations (s_{ij}, t_{ij}), there is only a unique signal for each type that maximizes utility. Caused by additive linearity of costs and productivities the signals in the two-dimensional PBE equal in each of the two components the signals arising in the one-dimensional case.

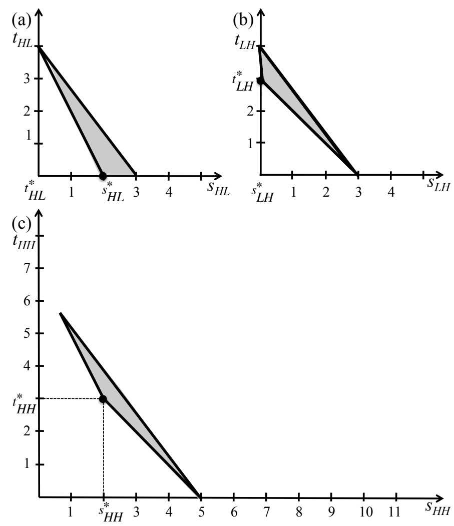

Figure 4.1: (a) Incentive compatibility constraint that prevents type HL from mimicing LL and vice versa, (b) Incentive compatibility constraint that prevents type LH from mimicing LL and vice versa, (c) Incentive compatibility constraint that prevents type HH from mimicing HL or LH and vice versa.

To illustrate the decisions Figure 4.1 shows the incentive compatibility constraints of the different types of agents.[8] The grey triangle in part (a) of the figure shows all combinations that prevent HL from mimicing LL and vice versa. The cost minimal combination that fulfills these incentive compatibility conditions is $(s^*_{HL}, 0)$. Analogously, part (b) of the figure gives the incentive compatibility constraints that prevent LH from mimicing LL and vice versa. Here, $(0, t^*_{LH})$ is optimal strategy for type LH. The grey triangle in part (c) consists of all strategies that prevent HH from mimicing LH and HL and vice versa. The optimal strategy of type HH is then (s^*_{HH}, t^*_{HH}) which is in both components equal to the separating strategy of the high-talented type in the one-dimensional case.

The same argumentation as in the one-dimensional case leads to a pooling PBE where nobody signals, i.e. all agents' strategy is $(s^*, t^*) = (0, 0)$.[9] There is also the possibility for partially separating PBEs in the present case. However, universities are interested in the real type of the agent. So, the most efficient situation is the separating one. I pay more attention to the partially separating PBEs in the next subsection where time constraints play a crucial role.

Time constraint binding

Now, I try to answer the question: What happens if time constraints are binding, i.e. if type HH cannot play his strategy of the separating equilibrium of Proposition 4.2. More formally, $s^*_{HH} + t^*_{HH} > \bar{l}$ holds. For simplicity I assume that $\theta^k_L(\theta^k_H - \theta^k_L) \leq \bar{l}$, $k \in \{s, t\}$, holds. This guarantees that the equilibria of the one-dimensional case exist. If this is not fulfilled only the pooling equilibrium remains.

As a key mechanism of a separating equilibrium the highly talented agent separates himself by signaling so much that there is no incentive of the low-talented agent to mimic him. This is possible because of the difference in costs. However, if there are not only one but two signals the signaling effort increases[10] and may become too high to be realized in the time given.

Before discussing the main result of this section I make an assumption about the ranking of the productivity parameters that is crucial for the remaining analysis.

Assumption **4.1** *The ranking of the productivity parameters fulfills*

$$\theta^s_H \geq \theta^t_L$$

and

$$\theta^t_H \geq \theta^s_L.$$

By defintion $\theta^k_H > \theta^k_L$, $k \in \{s, t\}$ always holds. So, for both activities the highly talented agent is more productive than the agent with low productivity. However, nothing is known

[8] The figure refers to the parameter setting $\theta^s_L = 2$, $\theta^s_H = 3$, $\theta^t_L = 3$ and $\theta^t_H = 4$.

[9] For the detailed proof see appendix B page 58.

[10] In the present model the signaling effort in the two-dimensional case is exactly the sum of the two one-dimensional signaling models where the agent signals on teaching or science. However, this result is driven by the additive structure of productivity and costs.

about the ranking of the productivity parameters comparing both activities. Assumption 4.1 requires that agents that are highly productive doing one activity are more productive than agents doing the other activity with low talent. Or, the other way round, Assumption 4.1 is violated if the universities' benefit from one output is so high that producing this output by a low-productive agent is better than producing the other output by a high-productive one.

PROPOSITION **4.3** *If agents signal their abilities to do science (s_{ij}) and to teach(t_{ij}), universities offer wages $w(s_{ij}, t_{ij})$, the time constraint is binding, i.e. if in Proposition 4.2 $s^*_{HH} + t^*_{HH} > \bar{l}$, and Assumption 4.1 holds, there is no separating equilibrium.*
If Assumption 4.1 does not hold, the separating equilibrium from Proposition 4.2 is destroyed but there is again the possibility of separating the four types in equilibrium.

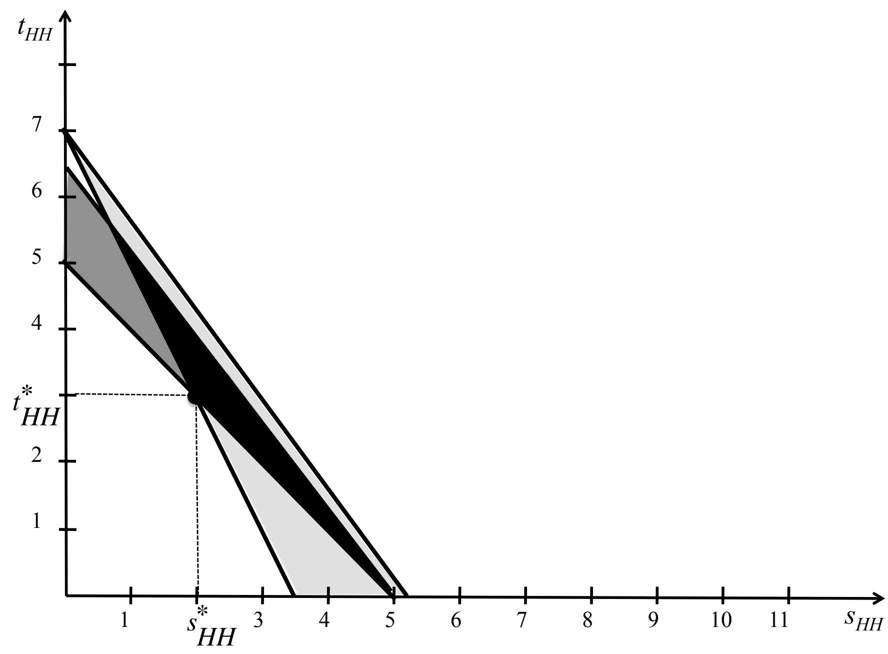

Figure 4.2: Incentive compatibility constraints for type HH when Assumption 4.1 holds.

For an illustration of the situation where Assumption 4.1 holds see Figure 4.2.[11] The figure describes the incentive compatibility constraints of type HH. All strategies in the light-grey triangle prevent HH from mimicing LH and vice versa. The dark-grey triangle consists of all s-t-combinations that prevent HH from mimicing HL and vice versa. The black triangle therefore gives all strategies that fulfills both conditions. The strategy (s^*_{HH}, t^*_{HH}) is the equilibrium strategy. The key idea here is as follows: Because of the pure cost effect of signaling HH realizes a cost minimal combination that is tangent to the black triangle at its lower bound.

[11]The figure refers to parameter setting $\theta^s_L = 2$, $\theta^s_H = \theta^t_L = 3$ and $\theta^t_H = 4$.

The lower bound of the light-grey triangle has a slope of $-(\theta^t_H/\theta^s_L)$. The lower bound of the dark-grey triangle has a slope of $-(\theta^t_L/\theta^s_H)$. Since the slope of HH's cost function is $-(\theta^t_H/\theta^s_H)$ and therefore meets the condition $-(\theta^t_H/\theta^s_L) < -(\theta^t_H/\theta^s_H) < -(\theta^t_L/\theta^s_H)$ strategy (s^*_{HH}, t^*_{HH}) becomes the cost minimal strategy that fulfills both incentive compatibility constraints. However, if (s^*_{HH}, t^*_{HH}) is the equilibrium strategy of type HH and time constraints are binding there is no strategy that lies south-west of (s^*_{HH}, t^*_{HH}) - which is necessary to meet the time constraint - and is located in the black triangle - which is necessary to fulfill the incentive compatibility constraints of type HH. So, if Assumption 4.1 holds there is no spearating PBE.
Figure 4.3 shows a situation in which Assumption 4.1 does not hold.[12] The grey area describes all strategies of HH that fulfill both incentive compatibility constraints. Contrary to Figure 4.2 a decrease in the available time from $\bar{l}_1$ to $\bar{l}_2$ shifts the separating PBE from HH_1 to HH_2. Thus there is still the possibility of separating the different types of agents.

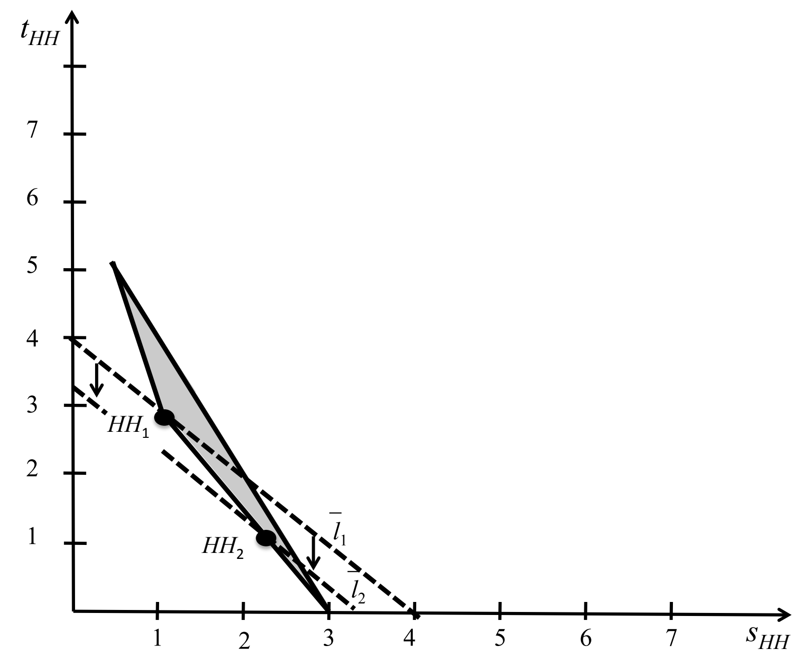

Figure 4.3: Incentive compatibility constraints for type HH when Assumption 4.1 is not fulfilled.

PROPOSITION 4.4 *If agents signal their abilities to do science (s_{ij}) and teaching (t_{ij}) and universities offer a wage $w(s_{ij}, t_{ij})$ equal to the expected productivity there are two partially separating equilibria.*

[12]The figure referes to the parameter setting $\theta^s_L = 1$, $\theta^s_H = 2$, $\theta^t_L = 3$ and $\theta^t_H = 4$.

If $\theta^s_L\theta^t_H \geq \theta^s_H\theta^t_L$ *holds there is a partially PBE where strategies of the prospective professors are:*

$$(s^*_{LL}, t^*_{LL}) = (0,0), \quad (s^*_{HL}, t^*_{HL}) = (\theta^s_L(\theta^s_H - \theta^s_L), 0) \quad \text{and}$$

$$(s^*_{(LH,HH)}, t^*_{(LH,HH)}) = (0, \theta^t_L C1_{(LH,HH)})$$

with $C1_{(LH,HH)} \equiv \frac{\alpha_{HH}}{\alpha_{LH}+\alpha_{HH}}\theta^s_H - (1 - \frac{\alpha_{LH}}{\alpha_{LH}+\alpha_{HH}})\theta^s_L + \theta^t_H - \theta^t_L$.

If $\theta^s_H\theta^t_L \geq \theta^s_L\theta^t_H$ *holds there is a partially separating PBE where strategies of the prospective professors are:*

$$(s^*_{LL}, t^*_{LL}) = (0,0), \quad (s^*_{LH}, t^*_{LH}) = (0, \theta^t_L(\theta^t_H - \theta^t_L)) \quad \text{and}$$

$$(s^*_{(HL,HH)}, t^*_{(HL,HH)}) = (\theta^s_L C1_{(HL,HH)}, 0)$$

with $C1_{(HL,HH)} = \theta^s_H - \theta^s_L + \frac{\alpha_{HH}}{\alpha_{HL}+\alpha_{HH}}\theta^t_H - (1 - \frac{\alpha_{HL}}{\alpha_{HL}+\alpha_{HH}})\theta^t_L$.

Because of a clear arrangement Proposition 4.4 only denotes strategies of the prospective professors.[13] The wage setting of the universities for the separated types is equal to the wage setting of Proposition 4.2. The pooled types are paid by average productivities. Thus in the first partially separating PBE it is $w_{(LH,HH)} = \frac{\alpha_{LH}}{\alpha_{LH}+\alpha_{HH}}\theta^s_L + \frac{\alpha_{HH}}{\alpha_{LH}+\alpha_{HH}}\theta^s_H + \theta^t_H$ and in the second partially separating equilibrium it is $w_{(HL,HH)} = \theta^s_H + \frac{\alpha_{HL}}{\alpha_{HL}+\alpha_{HH}}\theta^t_L + \frac{\alpha_{HH}}{\alpha_{HL}+\alpha_{HH}}\theta^t_H$.
The detailed proof can be found in the appendix C page 60. In the first partially separating PBE universities can distinguish between LL, HL and (LH, HH), i.e. they cannot separate type LH from HH. In the second partially separating PBE universities can separate LL from LH and (HL, HH) but not types HL and HH. The key arrangement of the proof of the first partially separating PBE (and analogously of the second one) is as follows: Type LL does not signal because of the pure cost effect. Type HL playes his strategy from the one-dimensional case to prevent LL from mimicing. Then the incentive compatibility constraints of (LH, HH) not to mimic LL or HL and vice versa are calculated. This results in the equilibrium strategy for (LH, HH).
To illustrate the necessary condition of the existence of the first partially separating PBE $(LL, HL, (LH, HH))$, i.e. to illustrate the necessity of $\theta^s_L\theta^t_H \geq \theta^s_H\theta^t_L$, look at Figure 4.4.[14]
In part (a) of Figure 4.4 it is $\theta^s_L\theta^t_H \geq \theta^s_H\theta^t_L$ and both minimal cost functions of the pooled types, i.e. c_{LH} and c_{HH}, are tangent to the black area that consists of all strategies which meet the incentive compatibility constraints at point (LH, HH).[15] This s-t-combination is the strategy

[13] Proposition 4.4 only describes two partially separating equilibria. There is also the possibility of other partially separating equilibria, e.g. of $((LL, LH), HL, HH)$. Nevertheless, universities try to identify the highly productive agents. Thus the partially separating PBEs of Proposition 4.4 are the one of interest.

[14] Clearly, an analogous argumentation holds for condition $\theta^s_H\theta^t_L \geq \theta^s_L\theta^t_H$ and the second partially separating PBE.

[15] Part (a) of the figure refers to parameter values $\theta^s_L = \theta^t_L = 1$, $\theta^s_H = 2$ and $\theta^t_H = 3$. More precisely, optimal strategies should be labeled $(s^*_{(LH,HH)}, t^*_{(LH,HH)})$. However, caused by clarification I label the strategy with the type.

LH and HH play in the first partially separating equilibrium. In part (b) it is $\theta_L^s \theta_H^t < \theta_H^s \theta_L^t$.[16] Thus, the cost function of HH, i.e. c_{HH}, runs 'too flat'. The minimal cost function of type HH is tangent to the black area where the incentive compatibility constraints are fulfilled at point HH. Since the minimal cost function of type LH is tangent to the black array at point LH there is no pooling equilibrium strategy for both types and so no partially separating PBE.

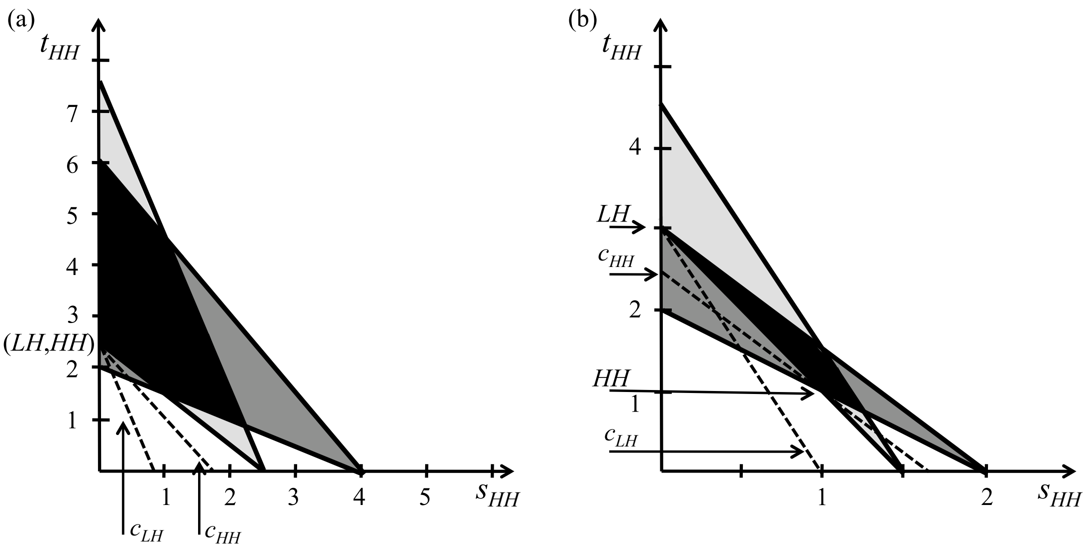

Figure 4.4: Incentive compatibility constraints for (LH, HH) in the first partially separating PBE (a) when $\theta_L^s \theta_H^t \geq \theta_H^s \theta_L^t$ holds and (b) if this condition is not fulfilled

As a first result one can see that both partially separating PBE can only co-exist if $\theta_H^s \theta_L^t = \theta_L^s \theta_H^t$ holds. One example for such a situation is the symmetric case, where low (high) productivity of science equals low (high) productivity of teaching, i.e. $\theta_H^s = \theta_H^t$ and $\theta_L^s = \theta_L^t$. Thus, universities do not have a clear preference for the one or the other output. Assuming that the highly productive agents are the critical ones and therefore normalizing the productivities of the low-talented to one, i.e. $\theta_L^s = \theta_L^t = 1$, the first partially separating PBE only exists if teaching productivity of the highly talented is higher than his research productivity. Analogously, if the contrary appraisement holds the second partially separating PBE appears. In general an agent that is good in teaching and science pooles with the type that is highly talented in the output that is more prefered by the universities. This strengthens the argument of Becker (1975, 1979) that the professors' research and teaching output positively react on an increase in pecuniary

[16]Part (b) of Figure 4.4 refers to $\theta_L^s = 1$, $\theta_H^s = \theta_L^t = 2$ and $\theta_H^t = 3$.

returns.
Secondly, it is clear that without time constraints always at least one of the partially PBEs exists. However, in this case they are less interesting because the separating PBE is more efficient.
Thirdly, Proposition 4.4 shows that if the time constraint is too strong there is even no possibility for a partially separating equilibrium but only for the pooling one. Thus, in both partially separating equilibria the time constraint is relaxed compared to the separating case but not removed. More precisely, the time investment of type HH in the first partially separating equilibrium is $\theta_L^t C1_{(LH,HH)} = \theta_L^t \frac{\alpha_{HH}}{\alpha_{LH}+\alpha_{HH}}(\theta_H^s - \theta_L^s) + \theta_L^t(\theta_H^t - \theta_L^t)$. This is clearly higher than the investment in the one-dimensional case, i.e. $\theta_L^t(\theta_H^t - \theta_L^t)$.[17] So, time constraints can still be binding. They are weakend to the two-dimensional separating equilibrium where time input is $\theta_L^s(\theta_H^s - \theta_L^s) + \theta_L^t(\theta_H^t - \theta_L^t)$ if and only if $\alpha_{HH}/(\alpha_{LH} + \alpha_{HH}) < \theta_L^s/\theta_L^t$. This is always fulfilled if $\theta_L^s \geq \theta_L^t$ and therefore especially in the case where low productivities are normalised to one. By the same argumentation time constraints of the second partially PBE is weaker than in the two-dimensional separating PBE if and only if $\alpha_{HH}/(\alpha_{HL} + \alpha_{HH}) < \theta_L^t/\theta_L^s$ holds. A sufficient condition for this purpose is $\theta_L^t \geq \theta_L^s$.

4.4 Conclusion

The output of post-docs and professors consists, besides the administrative one not treated here, of science and teaching. In general universities are interested in both outputs and assign a tenure contract only to those post-docs that are highly talented in both activities. However, since talent is a private information a job market signaling model à la Spence arises. Post-docs signal their ability of science and teaching to get a tenure.
As Spence (1973) has shown in the one-dimensional case signaling can separate highly talented and low-talented agents also in the two-dimensional case. So it solves the inefficiency problem of asymmetric information. Unfortunately, the highly productive agents need a signaling effort to separate themselves from the low-productive types and this effort increases in the two-dimensional case. Considering this, time constraints attract attention.
If time constraints are binding and the science (teaching) productivity of the high-talented is higher than the teaching (science) productivity of the type with low talent a separating equilibrium cannot exist in the two-dimensional case. The required assumption is quite weak as it just says that universities should not prefer one output over the other regardless wether the first is created by a high- or low-productive person.
In addition the paper shows that even if the separating equilibrium is destroyed by time constraints there is always at least one partially separating equilibrium where some types can be separated while others pool on the same strategy. More precisely, if the university prefers science to teaching a partially separating equilibrium exists where universities can separate types

[17] One cannot be sure that this one-dimensional equilibrium implies the stronger time constraint, i.e. that $\theta_L^t(\theta_H^t - \theta_L^t) > \theta_H^s(\theta_H^s - \theta_L^s)$ holds. Nevertheless, this is true if the high-productive agents are of most interest and low productivities are normalized to one.

with high and low research productivity. However, they do not know if an agent with high research productivity is also highly talented in teaching. This is the same result as in the one-dimensional case. Regrettably, the signaling effort that only implies a pure cost effect is higher in the two-dimensional partially separating equilibrium than in the one-dimensional separating one. Corresponding to real life, the two-dimensional signaling system that is currently used in academic admission processes is inefficient if time constraints are binding. In such a situation universities cannot identify both talents of the post-doc but only one. The identifiable talent is the one they value more. Then universities can ease requirements on post-docs and can let them - without loosing information - just signal on science or teaching.

Appendix

Part A: One-dimensional case

Proof of Proposition 4.1:

Separating equilibrium:

Since pre-tenure publishing implies costs but has no effect on productivity there is no incentive for a L-type to invest in publishing in a separating equilibrium. Therefore, it is $s_L^* = 0$.

In addition any equilibrium must satisfy two incentive compatibility conditions: On the one hand type H must not have an incentive to mimic the L-type, i.e.

$$\begin{aligned} w(s_H) - c_H(s_H) &\geq w(s_L) - c_H(s_L) \\ \Leftrightarrow \theta_H^s - \frac{s_H}{\theta_H^s} &\geq \theta_L^s - \frac{s_L}{\theta_H^s}. \end{aligned} \tag{4.4}$$

On the other hand the L-type must not have an incentive to mimic the H-type, i.e.

$$\begin{aligned} w(s_L) - c_L(s_L) &\geq w(s_H) - c_L(s_H) \\ \Leftrightarrow \theta_L^s - \frac{s_L}{\theta_L^s} &\geq \theta_H^s - \frac{s_H}{\theta_L^s}. \end{aligned} \tag{4.5}$$

Taking into account that the equilibrium strategy of the L-type is to publish nothing, i.e. $s_L^* = 0$, inequation (4.4) results in $s_H \leq \theta_H^s(\theta_H^s - \theta_L^s)$. Analogously, solving inequation (4.5) by s_H I get $s_H \geq \theta_L^s(\theta_H^s - \theta_L^s)$. Both incentive compatibility conditions together imply that $\theta_L^s(\theta_H^s - \theta_L^s) \leq s_H \leq \theta_H^s(\theta_H^s - \theta_L^s)$ is a necessary condition of a separating equilibrium.

Since the universities never pay a wage higher than θ_H^s only the lower bound of the interval, i.e. $s_H^* = \theta_L^s(\theta_H^s - \theta_L^s)$, maximizes utility of type H.

However, if $s_H^* > \bar{l}$ the separating equilibrium vanishes. Having the optimal decision of the agents in mind universities belief that they focus on an agent of type H whenever $s \geq s_H^*$ and that they focus on an agent with type L whenever $s < s_H^*$. □

Pooling equilibrium:

The pooling equilbrium in the one-dimensional case is

$$s^* = s_H = s_L = 0$$

$$w(s^*) = \alpha_H \theta_H^s + \alpha_L \theta_L^s$$

$$\mu(H|s \leq \alpha_H(\theta_L^s(\theta_H^s - \theta_L^s))) = \alpha_H, \; \mu(L|s \leq \alpha_H \theta_L^s(\theta_H^s - \theta_L^s)) = \alpha_L$$

$$\mu(L|s > \alpha_H(\theta_L^s(\theta_H^s - \theta_L^s))) = 1$$

if the time constraint is not binding, i.e. $s_i^* \leq \bar{l}, i \in \{H, L\}$. The argumentation is as follows: In every pooling equilibrium agents send identical signals, i.e. $s_H^* = s_L^* = s^*$. Since universities cannot distinguish between both types they set a unique wage that equals average valuation of the universities, i.e.

$$w(s) = \alpha_H \theta_H^s + \alpha_L \theta_L^s. \tag{4.6}$$

In a pooling equilibrium both types must not get lower utility than without signaling getting θ_L^s, i.e.

$$\begin{aligned} \theta_L^s &\leq w(s) - c_H(s) \\ \Leftrightarrow \theta_L^s &\leq \alpha_H \theta_H^s + \alpha_L \theta_L^s - \frac{s}{\theta_H^s} \end{aligned} \tag{4.7}$$

and

$$\begin{aligned} \theta_L^s &\leq w(s) - c_L(s) \\ \Leftrightarrow \theta_L^s &\leq \alpha_H \theta_H^s + \alpha_L \theta_L^s - \frac{s}{\theta_L^s}. \end{aligned} \tag{4.8}$$

With $\theta_H^s > \theta_L^s$ only condition (4.8) becomes critical. It implies that in every pooling equilibrium

$$\begin{aligned} \theta_L^s &\leq \alpha_H \theta_H^s + \alpha_L \theta_L^s - \frac{s}{\theta_L^s} \\ \Leftrightarrow s &\leq \theta_L^s \big(\alpha_H \theta_H^s - \underbrace{(1 - \alpha_L)}_{=\alpha_H} \theta_L^s \big) \\ \Leftrightarrow s &\leq \alpha_H \theta_L^s (\theta_H^s - \theta_L^s) \end{aligned} \tag{4.9}$$

must hold. However, since publishing only implies a cost effect both types prefer the $s_H^* = s_L^* = s^* = 0$. This is a pooling perfect Bayesian equilibrium and in addition always satisfies the time constraint $s^* \leq \bar{l}$. □

Part B: Two-dimensional case without time constraints

Proof of Proposition 4.2:

In a separating PBE universities pay an agent ij a wage equal to his productivity. Thus, $w(s_{ij}^*, t_{ij}^*) = \theta_i^s + \theta_j^t$ holds.

This directly gives $(s_{LL}^*, t_{LL}^*) = (0, 0)$ as equilibrium signal of type LL. In a next step, signals of types HL and LH must meet the incentive compatibility constraints so that both types have no incentive to mimic LL and vice versa. This automatically prevents HH from mimicing LL. Type HL does not mimic LL if

$$\begin{aligned} w(s_{LL}^*, t_{LL}^*) - c_{HL}(s_{LL}^*, t_{LL}^*) &\leq w(s_{HL}, t_{HL}) - c_{HL}(s_{HL}, t_{HL}) \\ \Leftrightarrow \theta_L^s + \theta_L^t &\leq \theta_H^s + \theta_L^t - \frac{s_{HL}}{\theta_H^s} - \frac{t_{HL}}{\theta_L^t} \end{aligned}$$

$$\Leftrightarrow \frac{1}{\theta_H^s} s_{HL} + \frac{1}{\theta_L^t} t_{HL} \quad \leq \quad \theta_H^s - \theta_L^s$$

holds.
Analogously, LL does not mimic HL whenever

$$\begin{aligned} w(s_{LL}^*, t_{LL}^*) - c_{LL}(s_{LL}^*, t_{LL}^*) &\geq w(s_{HL}, t_{HL}) - c_{LL}(s_{HL}, t_{HL}) \\ \Leftrightarrow \theta_L^s + \theta_L^t &\geq \theta_H^s + \theta_L^t - \frac{s_{HL}}{\theta_L^s} - \frac{t_{HL}}{\theta_L^t} \\ \Leftrightarrow \frac{1}{\theta_L^s} s_{HL} + \frac{1}{\theta_L^t} t_{HL} &\geq \theta_H^s - \theta_L^s \end{aligned}$$

holds. Therefore the incentive compatibility constraint that prevents HL from mimicing LL and vice versa is

$$\frac{1}{\theta_H^s} s_{HL} + \frac{1}{\theta_L^t} t_{HL} \leq \theta_H^s - \theta_L^s \leq \frac{1}{\theta_L^s} s_{HL} + \frac{1}{\theta_L^t} t_{HL}.$$

A signal that maximizes utility of type HL must lie on the lower bound which can be rewritten as

$$s_{HL} = \theta_L^s(\theta_H^s - \theta_L^s) - \frac{\theta_L^s}{\theta_L^t} t_{HL}.$$

Type HL will now choose the signal that fulfills this condition and minimizes costs. Since costs are (taking the last equation into account)

$$\begin{aligned} c_{HL}(s_{HL}, t_{HL}) &= \frac{s_{HL}}{\theta_H^s} + \frac{t_{HL}}{\theta_L^t} \\ &= \frac{\theta_L^s(\theta_H^s - \theta_L^s)}{\theta_H^s} - \frac{\theta_L^s}{\theta_H^s \theta_L^t} t_{HL} + \frac{1}{\theta_L^t} t_{HL} \\ &= \frac{\theta_L^s(\theta_H^s - \theta_L^s)}{\theta_H^s} + \underbrace{(1 - \frac{\theta_L^s}{\theta_H^s}) \frac{1}{\theta_L^t}}_{>0} t_{HL} \end{aligned}$$

the minimal cost combination is $t_{HL}^* = 0$ and therefore $s_{HL}^* = \theta_L^s(\theta_H^s - \theta_L^s)$. Type HL's strategy in the separating PBE is (s_{HL}^*, t_{HL}^*).

In the same way type LH does not mimic type LL if

$$\begin{aligned} w(s_{LL}^*, t_{LL}^*) - c_{LH}(s_{LL}^*, t_{LL}^*) &\leq w(s_{LH}, t_{LH}) - c_{LH}(s_{LH}, t_{LH}) \\ \Leftrightarrow \theta_L^s + \theta_L^t &\leq \theta_L^s + \theta_H^t - \frac{s_{LH}}{\theta_L^s} - \frac{t_{LH}}{\theta_H^t} \\ \Leftrightarrow \frac{1}{\theta_L^s} s_{LH} + \frac{1}{\theta_H^t} t_{LH} &\leq \theta_H^t - \theta_L^t \end{aligned}$$

holds.
Type LL does not mimic type LH if

$$w(s_{LL}^*, t_{LL}^*) - c_{LL}(s_{LL}^*, t_{LL}^*) \geq w(s_{LH}, t_{LH}) - c_{LL}(s_{LH}, t_{LH})$$

$$\begin{aligned}\Leftrightarrow \theta_L^s + \theta_L^t &\geq \theta_L^s + \theta_H^t - \frac{s_{LH}}{\theta_L^s} - \frac{t_{LH}}{\theta_L^t}\\ \Leftrightarrow \frac{1}{\theta_L^s} s_{LH} + \frac{1}{\theta_L^t} t_{LH} &\geq \theta_H^t - \theta_L^t\end{aligned}$$

is fulfilled. Taking both conditions together type LH has no incentive to mimic type LL and vice versa if

$$\frac{1}{\theta_L^s} s_{LH} + \frac{1}{\theta_H^t} t_{LH} \leq \theta_H^t - \theta_L^t \leq \frac{1}{\theta_L^s} s_{LH} + \frac{1}{\theta_L^t} t_{LH}$$

holds. Again LH chooses a signal on the lower bound given by the second part of the condition. Thus it is

$$t_{LH} = \theta_L^t(\theta_H^t - \theta_L^t) - \frac{\theta_L^t}{\theta_L^s} s_{LH}.$$

This in mind costs of type HL are given by

$$\begin{aligned}c_{LH}(s_{LH}, t_{LH}) &= \frac{s_{LH}}{\theta_L^s} + \frac{t_{LH}}{\theta_H^t}\\ &= \frac{\theta_L^t(\theta_H^t - \theta_L^t)}{\theta_H^t} + \frac{1}{\theta_L^s} s_{LH} - \frac{\theta_L^t}{\theta_L^s \theta_H^t} s_{LH}\\ &= \underbrace{(1 - \frac{\theta_L^t}{\theta_H^t})\frac{1}{\theta_L^s}}_{>0} s_{LH} + \frac{\theta_L^t(\theta_H^t - \theta_L^t)}{\theta_H^t}.\end{aligned}$$

To minimize costs and therefore maximize utility given the wage $\theta_L^s + \theta_H^t$ type LH plays in equilibrium $s_{LH}^* = 0$ and $t_{LH}^* = \theta_L^t(\theta_H^t - \theta_L^t)$.

With (s_{HL}^*, t_{HL}^*) and (s_{LH}^*, t_{LH}^*) type HL has no incentive to mimic type LH and vice versa because

$$\begin{aligned}w(s_{LH}^*, t_{LH}^*) - c_{HL}(s_{LH}^*, t_{LH}^*) &\leq w(s_{HL}^*, t_{HL}^*) - c_{HL}(s_{HL}^*, t_{HL}^*)\\ \Leftrightarrow \theta_L^s + \theta_H^t - \frac{\theta_L^t(\theta_H^t - \theta_L^t)}{\theta_L^t} &\leq \theta_H^s + \theta_L^t - \frac{\theta_L^s(\theta_H^s - \theta_L^s)}{\theta_H^s}\\ \Leftrightarrow 0 &\leq (\theta_H^s - \theta_L^s)^2\end{aligned}$$

and

$$\begin{aligned}w(s_{HL}^*, t_{HL}^*) - c_{LH}(s_{HL}^*, t_{HL}^*) &\leq w(s_{LH}^*, t_{LH}^*) - c_{LH}(s_{LH}^*, t_{LH}^*)\\ \Leftrightarrow \theta_H^s + \theta_L^t - \frac{\theta_L^s(\theta_H^s - \theta_L^s)}{\theta_L^s} &\leq \theta_L^s + \theta_H^t - \frac{\theta_L^t(\theta_H^t - \theta_L^t)}{\theta_H^t}\\ \Leftrightarrow 0 &\leq (\theta_H^t - \theta_L^t)^2\end{aligned}$$

are always fulfilled.

In a last step one has to make sure that HH does neither mimic HL nor LH and vice versa.

Type HH does not mimic HL whenever

$$\begin{aligned} w(s^*_{HL}, t^*_{HL}) - c_{HH}(s^*_{HL}, t^*_{HL}) &\leq w(s_{HH}, t_{HH}) - c_{HH}(s_{HH}, t_{HH}) \\ \Leftrightarrow \theta^s_H + \theta^s_L - \frac{\theta^s_L(\theta^s_H - \theta^s_L)}{\theta^s_H} &\leq \theta^s_H + \theta^t_H - \frac{s_{HH}}{\theta^s_H} - \frac{t_{HH}}{\theta^t_H} \\ \Leftrightarrow s_{HH} + \frac{\theta^s_H}{\theta^t_H} t_{HH} &\leq \theta^s_H(\theta^t_H - \theta^t_L) + \theta^s_L(\theta^s_H - \theta^s_L) \end{aligned}$$

holds.

Analogously, type HL has no incentive to mimic HH if

$$\begin{aligned} w(s_{HH}, t_{HH}) - c_{HL}(s_{HH}, t_{HH}) &\leq w(s^*_{HL}, t^*_{HL}) - c_{HL}(s^*_{HL}, t^*_{HL}) \\ \Leftrightarrow \theta^s_H + \theta^t_H - \frac{s_{HH}}{\theta^s_H} - \frac{t_{HH}}{\theta^t_L} &\leq \theta^s_H + \theta^t_L - \frac{\theta^s_L(\theta^s_H - \theta^s_L)}{\theta^s_H} \\ \Leftrightarrow s_{HH} + \frac{\theta^s_H}{\theta^t_L} t_{HH} &\geq \theta^s_H(\theta^t_H - \theta^t_L) + \theta^s_L(\theta^s_H - \theta^s_L) \end{aligned}$$

is fulfilled. Both conditions together are the incentive compatibility condition that prevents HH from mimicing HL and vice versa. Because of the pure cost effect of signaling the lower bound of the second condition, i.e.

$$\begin{aligned} s_{HH} + \frac{\theta^s_H}{\theta^t_L} t_{HH} &= \theta^s_H(\theta^t_H - \theta^t_L) + \theta^s_L(\theta^s_H - \theta^s_L) \\ \Leftrightarrow s_{HH} &= \theta^s_H(\theta^t_H - \theta^t_L) + \theta^s_L(\theta^s_H - \theta^s_L) - \frac{\theta^s_H}{\theta^t_L} t_{HH} \end{aligned} \tag{4.10}$$

is a necassary condition for a separating PBE. However additionally, type HH does not have an incentive to mimic type LH and vice versa. Therefore,

$$\begin{aligned} w(s^*_{LH}, t^*_{LH}) - c_{HH}(s^*_{LH}, t^*_{LH}) &\leq w(s_{HH}, t_{HH}) - c_{HH}(s_{HH}, t_{HH}) \\ \Leftrightarrow \theta^s_L + \theta^t_H - \frac{\theta^t_L(\theta^t_H - \theta^t_L)}{\theta^t_H} &\leq \theta^s_H + \theta^t_H - \frac{s_{HH}}{\theta^s_H} - \frac{t_{HH}}{\theta^t_H} \\ \Leftrightarrow \frac{\theta^t_H}{\theta^s_H} s_{HH} + t_{HH} &\leq \theta^t_H(\theta^s_H - \theta^s_L) + \theta^t_L(\theta^t_H - \theta^t_L) \end{aligned}$$

and

$$\begin{aligned} w(s_{HH}, t_{HH}) - c_{LH}(s_{HH}, t_{HH}) &\leq w(s^*_{LH}, t^*_{LH}) - c_{LH}(s^*_{LH}, t^*_{LH}) \\ \Leftrightarrow \theta^s_H + \theta^t_H - \frac{s_{HH}}{\theta^s_L} - \frac{t_{HH}}{\theta^t_H} &\leq \theta^s_L + \theta^t_H - \frac{\theta^t_L(\theta^t_H - \theta^t_L)}{\theta^t_H} \\ \Leftrightarrow \frac{\theta^t_H}{\theta^s_L} s_{HH} + t_{HH} &\geq \theta^t_H(\theta^s_H - \theta^s_L) + \theta^t_L(\theta^t_H - \theta^t_L) \end{aligned}$$

must hold. Both condtions together are the incentive compatibility constraint that prevent HH from mimicing LH and vice versa. Cause of the pure cost effect of signaling the lower bound of the second condition, i.e.

$$\begin{aligned}\frac{\theta_H^t}{\theta_L^s}s_{HH}+t_{HH} &= \theta_H^t(\theta_H^s-\theta_L^s)+\theta_L^t(\theta_H^t-\theta_L^t)\\ \Leftrightarrow s_{HH} &= \theta_L^s(\theta_H^s-\theta_L^s)+\frac{(\theta_H^t-\theta_L^t)\theta_L^s\theta_L^t}{\theta_H^t}-\frac{\theta_L^s}{\theta_H^t}t_{HH} \qquad (4.11)\end{aligned}$$

is a necessary condition for a PBE. In a separating PBE type HH is neither mimicing HL nor LH. Thus, conditions (4.10) and (4.11) must hold. Both linear functions describe the lower bound of the area that fulfills both incentive compatibility constraints. Because of the pure cost effect of signaling the optimal strategy is element of this lower bound. To make sure that the optimal startegy is unique the slope of this lower bound must be unequal to the slope of the cost function of HH.[18] The cost function of type HH is $c_{HH}(s_{HH},t_{HH})=(s_{HH}/\theta_H^s)+(t_{HH}/\theta_H^t)$. So, the slope of this function in a s-t-area is $-(\theta_H^t/\theta_H^s)$. As the slope of equation (4.10) in such an area is $-(\theta_L^t/\theta_H^s)$ and the slope of equation (4.11) is $-(\theta_H^t/\theta_L^s)$ there is a unique optimal strategy of HH that is given by the point of intersection of the linear combinations (4.10) and (4.11). Calculating this point of intersection leads to

$$\begin{aligned}\theta_H^s(\theta_H^t-\theta_L^t)+\theta_L^s(\theta_H^s-\theta_L^s)-\frac{\theta_H^s}{\theta_L^t}t_{HH} &= \theta_L^s(\theta_H^s-\theta_L^s)+\frac{(\theta_H^t-\theta_L^t)\theta_L^s\theta_L^t}{\theta_H^t}-\frac{\theta_L^s}{\theta_H^t}t_{HH}\\ \Leftrightarrow \theta_H^s\theta_H^t(\theta_H^t-\theta_L^t)-\theta_L^s\theta_L^t(\theta_H^t-\theta_L^t) &= \frac{\theta_H^s\theta_H^t-\theta_L^s\theta_L^t}{\theta_L^t}t_{HH}\\ \Leftrightarrow (\theta_H^s\theta_H^t-\theta_L^s\theta_L^t)(\theta_H^t-\theta_L^t) &= \frac{\theta_H^s\theta_H^t-\theta_L^s\theta_L^t}{\theta_L^t}t_{HH}\\ \Leftrightarrow t_{HH}^* &= \theta_L^t(\theta_H^t-\theta_L^t).\end{aligned}$$

Inserting this in equation (4.10) gives the first part of the equilibrium signal $s^*=\theta_L^s(\theta_H^s-\theta_L^s)$.
□

The pooling PBE in the two-dimensional case:
The pooling PBE in the two dimensiona case is

$$(s^*,t^*)\equiv(s_{ij}^*,t_{ij}^*)=(0,0)\quad\forall i,j\in\{H,L\}$$

$$w(s^*,t^*)=\sum_{ij}\alpha_{ij}(\theta_i^s+\theta_j^t)$$

$$\mu\Big(ij|(s,t)=\big(I\cdot(\alpha_{HH}+\alpha_{HL})\theta_L^s(\theta_H^s-\theta_L^s)),J\cdot(\alpha_{HH}+\alpha_{LH})\theta_L^t(\theta_H^t-\theta_L^t)\big)\Big)=\alpha_{ij}$$

where $I=1$ if $i=H$ and 0 otherwise and $J=1$ if $j=H$ and 0 otherwise.

The proof of this result is as follows:

[18]If this condition is not fulfilled the minimal cost combination would be tangent to the area that fulfilles the incentive compatibility constraints on a whole section represented by a part of the linear function (4.10) or (4.11) and not to a unique point.

Universities' wage setting seeing the pooled signal (s^*, t^*) is

$$w(s^*, t^*) = \sum_{ij} \alpha_{ij}(\theta_i^s + \theta_j^t).$$

Since each agent ij can always get the lowest wage $\theta_L^s + \theta_L^t$, utility with the pooled signal must be higher than this reward, i.e.

$$\begin{aligned}
\theta_L^s + \theta_L^t &\leq w(s,t) - c_{ij}(s,t) \\
\Leftrightarrow \theta_L^s + \theta_L^t &\leq \sum_{ij} \alpha_{ij}(\theta_i^s + \theta_j^t) - \frac{s}{\theta_i^s} - \frac{t}{\theta_j^t} \\
\Leftrightarrow \frac{s}{\theta_i^s} + \frac{t}{\theta_j^t} &\leq (\alpha_{LL} + \alpha_{LH} - 1)\theta_L^s + (\alpha_{HH} + \alpha_{HL})\theta_H^s + (\alpha_{LL} + \alpha_{HL} - 1)\theta_L^t \\
&\quad + (\alpha_{HH} + \alpha_{LH})\theta_H^t \\
\Leftrightarrow \frac{s}{\theta_i^s} + \frac{t}{\theta_j^t} &\leq -(\alpha_{HH} + \alpha_{HL})\theta_L^s + (\alpha_{HH} + \alpha_{HL})\theta_H^s - (\alpha_{HH} + \alpha_{LH})\theta_L^t \\
&\quad + (\alpha_{HH} + \alpha_{LH})\theta_H^t \\
\Leftrightarrow \frac{s}{\theta_i^s} + \frac{t}{\theta_j^t} &\leq (\alpha_{HH} + \alpha_{HL})(\theta_H^s - \theta_L^s) + (\alpha_{HH} + \alpha_{LH})(\theta_H^t - \theta_L^t) \\
\Leftrightarrow t &\leq (\alpha_{HH} + \alpha_{HL})(\theta_H^s - \theta_L^s)\theta_j^t + (\alpha_{HH} + \alpha_{LH})(\theta_H^t - \theta_L^t)\theta_j^t - \frac{\theta_j^t}{\theta_i^s} s.
\end{aligned}$$

This is just a linear equation in s. Clearly type LL is the restricting type. Thus every linear combination of (s,t) for which

$$\frac{s}{\theta_L^s} + \frac{t}{\theta_L^t} \leq (\alpha_{HH} + \alpha_{HL})(\theta_H^s - \theta_L^s) + (\alpha_{HH} + \alpha_{LH})(\theta_H^t - \theta_L^t)$$

holds meets the incentive compatibility constraints. However, the pure cost effect of signaling makes $(s^*, t^*) = (0,0)$ the unique pooling PBE.

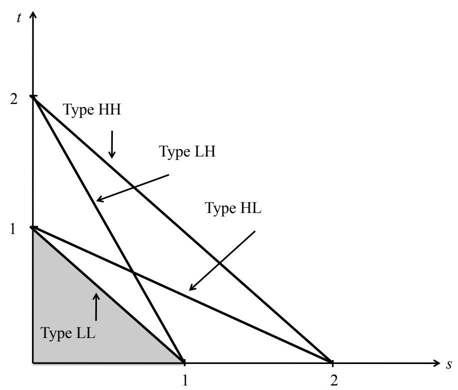

Figure 4.5: Incentive compatibility constraint of type LL in a pooling PBE of two dimensions

The incentive conditions that prevent agents from breaking out of the pooling PBE are illustrated in Figure 4.5. It refers to the symmetric case with $\theta_H^s = \theta_H^t = 2$, $\theta_L^s = \theta_L^t = 1$ and $\alpha_{ij} = \frac{1}{4}\, \forall i, j \in \{H, L\}$. The grey area describes all combinations that prevent LL - and therefore also the other types - from breaking out of the pooling PBE. However, only $(s^* = 0, t^* = 0)$ implies minimum costs and therefore is PBE. □

Part C: Two-dimensional case with time constraints

Proof of Proposition 4.4:
The sequence of the proof of the partially separating PBE $(LL, HL, (LH, HH))$ is as follows: First of all the proof focuses on the optimal strategy for HL that prevents him from mimicing LL. Secondly, the incentive compability constraint that prevents LL from mimicing (LH, HH) and vice versa are analyzed. Thirdly, the proof focuses on the incentive compatibility constraint that prevents HL from mimicing (LH, HH) and vice versa. Step two and three together result in an optimal strategy for (LH, HH).

In a PBE where LL is separated he has no icentive to signal. Thus, $(s^*_{LL}, t^*_{LL}) = (0, 0)$. Then refering to the first step HL signals $(s^*_{HL}, t^*_{HL}) = (\theta_L^s(\theta_H^s - \theta_L^s), 0)$ to prevent LL from mimicing him. This strategy directly results from the separating PBE.

To make sure that in a second step LL does not mimic (LH, HH)

$$\begin{aligned}
w_{LL} - c_{LL}(s^*_{LL}, t^*_{LL}) &\geq w_{(LH,HH)} - c_{LL}(s_{(LH,HH)}, t^*_{(LH,HH)}) \\
\Leftrightarrow \theta_L^s + \theta_L^t &\geq \frac{\alpha_{LH}}{\alpha_{LH} + \alpha_{HH}}\theta_L^s + \frac{\alpha_{HH}}{\alpha_{LH} + \alpha_{HH}}\theta_H^s + \theta_H^t \\
&\quad - \frac{s_{(LH,HH)}}{\theta_L^s} - \frac{t_{(LH,HH)}}{\theta_L^t} \\
\Leftrightarrow \frac{s_{(LH,HH)}}{\theta_L^s} + \frac{t_{(LH,HH)}}{\theta_L^t} &\geq \underbrace{\frac{\alpha_{HH}}{\alpha_{LH} + \alpha_{HH}}\theta_H^s - (1 - \frac{\alpha_{LH}}{\alpha_{LH} + \alpha_{HH}})\theta_L^s + \theta_H^t - \theta_L^t}_{\equiv C1_{(LH,HH)}}.
\end{aligned} \tag{4.12}$$

must hold.
Analogously, LH and therefore (LH, HH) does not mimic LL if

$$\begin{aligned}
w_{LL} - c_{LH}(s^*_{LL}, t^*_{LL}) &\leq w_{(LH,HH)} - c_{LH}(s_{(LH,HH),t_{LH,HH}}) \\
\Leftrightarrow \theta_L^s + \theta_L^t &\leq \frac{\alpha_{LH}}{\alpha_{LH} + \alpha_{HH}}\theta_L^s + \frac{\alpha_{HH}}{\alpha_{LH} + \alpha_{HH}}\theta_H^s + \theta_H^t \\
&\quad - \frac{s_{(LH,HH)}}{\theta_L^s} - \frac{t_{(LH,HH)}}{\theta_H^t}
\end{aligned}$$

$$\Leftrightarrow \frac{s_{(LH,HH)}}{\theta^s_L} + \frac{t_{(LH,HH)}}{\theta^t_H} \leq \underbrace{\frac{\alpha_{HH}}{\alpha_{LH}+\alpha_{HH}}\theta^s_H - (1-\frac{\alpha_{LH}}{\alpha_{LH}+\alpha_{HH}})\theta^s_L + \theta^t_H - \theta^t_L}_{=C1_{(LH,HH)}}.$$

is fulfilled. Since signals cannot be negative a necessary condition for the existence of the partially separating PBE is $C1_{(LH,HH)} > 0$. I will come to this later on.
To prevent HL from mimicing (LH, HH) (third step) the following condition must hold:

$$\begin{aligned}
w_{HL} - c_{HL}(s^*_{HL}, t^*_{HL}) &\geq w_{(LH,HH)} - c_{HL}(s_{(LH,HH)}, t_{(LH,HH)}) \\
\Leftrightarrow \theta^s_H + \theta^t_L - \frac{\theta^s_L(\theta^s_H - \theta^s_L)}{\theta^s_H} &\geq \frac{\alpha_{LH}}{\alpha_{LH}+\alpha_{HH}}\theta^s_L + \frac{\alpha_{HH}}{\alpha_{LH}+\alpha_{HH}}\theta^s_H + \theta^t_H \\
&\quad -\frac{s_{(LH,HH)}}{\theta^s_H} - \frac{t_{(LH,HH)}}{\theta^t_L} \\
\Leftrightarrow \frac{s_{(LH,HH)}}{\theta^s_H} + \frac{t_{(LH,HH)}}{\theta^t_L} \geq &
\end{aligned}$$

$$\underbrace{-(1-\frac{\alpha_{HH}}{\alpha_{LH}+\alpha_{HH}})\theta^s_H + (1+\frac{\alpha_{LH}}{\alpha_{LH}+\alpha_{HH}})\theta^s_L + \theta^t_H - \theta^t_L - \frac{(\theta^s_L)^2}{\theta^s_H}}_{\equiv C2_{(LH,HH)}} \qquad (4.13)$$

Analogously, to prevent HH and therefore (LH, HH) from mimicing HL

$$\begin{aligned}
w_{HL} - c_{HH}(s^*_{HL}, t^*_{HL}) &\leq w_{(LH,HH)} - c_{HH}(s_{(LH,HH)}, t_{(LH,HH)}) \\
\Leftrightarrow \theta^s_H + \theta^t_L - \frac{\theta^s_L(\theta^s_H - \theta^s_L)}{\theta^s_H} &\leq \frac{\alpha_{LH}}{\alpha_{LH}+\alpha_{HH}}\theta^s_L + \frac{\alpha_{HH}}{\alpha_{LH}+\alpha_{HH}}\theta^s_H + \theta^t_H \\
&\quad -\frac{s_{(LH,HH)}}{\theta^s_H} - \frac{t_{(LH,HH)}}{\theta^t_H} \\
\Leftrightarrow \frac{s_{LH,HH}}{\theta^s_H} + \frac{t_{(LH,HH)}}{\theta^t_H} &\leq
\end{aligned}$$

$$\underbrace{-(1-\frac{\alpha_{HH}}{\alpha_{LH}+\alpha_{HH}})\theta^s_H + (1+\frac{\alpha_{LH}}{\alpha_{LH}+\alpha_{HH}})\theta^s_L + \theta^t_H - \theta^t_L - \frac{(\theta^s_L)^2}{\theta^s_H}}_{=C2_{(LH,HH)}}$$

must hold. A necessary condition for the existence of the partially separating PBE is again that $C2_{(LH,HH)} > 0$ is fulfilled. This condition is even stronger than $C1_{(LH,HH)}$ from above because

$$\begin{aligned}
C2_{(LH,HH)} - C1_{(LH,HH)} &= -\theta^s_H + 2\theta^s_L - \frac{(\theta^s_L)^2}{\theta^s_H} \\
&= \frac{-(\theta^s_H)^2 + 2\theta^s_H\theta^s_L - (\theta^s_L)^2}{\theta^s_H} \\
&= -\frac{(\theta^s_H - \theta^s_L)^2}{\theta^s_H} < 0
\end{aligned}$$

holds. Although $C2_{(LH,HH)} < C1_{(LH,HH)}$ is fulfilled one cannot directly see if equation (4.12) or equation (4.13) is the stronger condition because of the different LHS. If you compare both conditions you find out that the relationship depends on the exact parameter values. However, I show that the optimal - cost minimal - behavior for type LH and HH is the same regardless whether boundary equation (4.12) or equation (4.13) is the stronger condition.

Thus assume that equation (4.12) is stronger than equation (4.13) then $t_{(LH,HH)} = \theta^t_L C1_{(LH,HH)} - \frac{\theta^t_L}{\theta^s_L} s_{(LH,HH)}$ holds. This in mind costs of LH are

$$\frac{s_{(LH,HH)}}{\theta^s_L} + \frac{t_{(LH,HH)}}{\theta^t_H} = \frac{1}{\theta^s_L} \underbrace{(1 - \frac{\theta^t_L}{\theta^t_H})}_{>0} s_{(LH,HH)} + \frac{\theta^t_L}{\theta^t_H} C1_{(LH,HH)}.$$

Since costs increase in $s_{(LH,HH)}$ the optimal strategy of LH is $s_{(LH,HH)} = 0$. Analogously, costs of HH are

$$\frac{s_{(LH,HH)}}{\theta^s_H} + \frac{t_{(LH,HH)}}{\theta^t_H} = (\frac{1}{\theta^s_H} - \frac{\theta^t_L}{\theta^s_L \theta^t_H}) + \frac{\theta^t_L}{\theta^t_H} C1_{(LH,HH)}.$$

If $\frac{1}{\theta^s_H} - \frac{\theta^t_L}{\theta^s_L \theta^t_H} \leq 0$ holds the optimal strategy is to maximize $s_{(LH,HH)}$. However, then the partially separating PBE is destroyed. Type LH and HH do not pool on the same strategy. Therefore $\frac{1}{\theta^s_H} - \frac{\theta^t_L}{\theta^s_L \theta^t_H} \geq 0$ must hold to ensure the described PBE. If condition (4.12) is the stronger one $\theta^s_L \theta^t_H \geq \theta^s_H \theta^t_L$ becomes a necessary condition of the partially separating PBE.

Now assume that instead of equation (4.12) equation (4.13) is the stronger condition then $t_{(LH,HH)} = \theta^t_L C2_{(LH,HH)} - \frac{\theta^t_L}{\theta^s_H} s_{(LH,HH)}$ holds and costs of type LH are

$$\begin{aligned} \frac{s_{(LH,HH)}}{\theta^s_L} + \frac{t_{(LH,HH)}}{\theta^t_H} &= (\frac{1}{\theta^s_L} - \frac{\theta^t_L}{\theta^s_H \theta^t_H}) s_{(LH,HH)} + \frac{\theta^t_L}{\theta^t_H} C2_{(LH,HH)} \\ &= \underbrace{(\frac{\theta^s_H \theta^t_H - \theta^s_L \theta^t_L}{\theta^s_H \theta^t_L \theta^t_H})}_{>0} s_{(LH,HH)} + \frac{\theta^t_L}{\theta^t_H} C2_{(LH,HH)}. \end{aligned}$$

Again it is optimal for type LH to play $s_{(LH,HH)} = 0$. Analogously, costs of type HH are

$$\frac{s_{(LH,HH)}}{\theta^s_H} + \frac{t_{(LH,HH)}}{\theta^t_H} = \frac{1}{\theta^s_H}(1 - \frac{\theta^t_L}{\theta^t_H}) s_{(LH,HH)} + \frac{\theta^t_L}{\theta^t_H} C2_{(LH,HH)}.$$

As costs increase in $s_{(LH,HH)}$ type HH sets $s_{(LH,HH)} = 0$.

Summarizing, under both assumptions $s^*_{(LH,HH)} = 0$ is an optimal strategy for both pooling types. This reduces condition (4.12) to $t_{(LH,HH)} = \theta^t_L C1_{LH,HH}$ and condition (4.13) to $t_{(LH,HH)} = \theta^t_L C2_{(LH,HH)}$. With $C1_{(LH,HH)} > C2_{(LH,HH)}$ from the above condition (4.12) becomes the crucial condition for the existence of the partially separating PBE. The equilibrium strategy of (LH, HH) is $(s^*_{(LH,HH)}, t^*_{(LH,HH)}) = (0, \theta^t_L C1_{(LH,HH)})$. A necessary condition for the existence of the equilibrium is $\theta^s_L\theta^t_H > \theta^s_H\theta^t_L$.

Finally, the proof of the second partially PBE, i.e. of $(LL, LH, (HL, HH))$ is analogous and is therefore not specified here. $\square$

5 The interaction of publications and appointments – new evidence on academic economists in Germany*

with Klaus Beckmann

Using a new panel dataset comprising publication and appointment data for 889 German academic economists over a quarter of a century, we confirm the familiar hypothesis that publications are important for professorial appointments, but find only a small negative effect of appointments on subsequent research productivity. In fact, a simple theoretical model leads us to hypothesize that no such effect exists for top researchers which is confirmed by our estimation results. We also provide some evidence of the effects of the fundamental reform of economics in Germany and of affirmative action procedures.

JEL: I23;I20

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5.1 Motivation

Most economists would agree, even though a few might silently deplore, that the key aspects of a career in economics can be succinctly summarized by the classic quip 'publish or perish'. According to this view, no other consideration, be it the quality of teaching or effort put into some other dimension of scholarly work, will outweigh the weighted number of refereed journal publications in the collective eye of a tenure commission. On the other hand, there is a widespread suspicion that professors, once they have obtained tenure, like to cut themselves some slack.[1] Of course, these two observations might be connected: if you subject young researchers to a rat race, you had better make the prize compelling if you need to compete with other options young people have over their life cycle.

The economics of education is rife with empirical papers on research productivity and career paths in economics. One part of the literature on academic career focuses on the effect of publishing on academic salaries. A clearly visible result of these papers is a significant and positive impact of publications on the academics' earnings (Diamond 1986; Grimes and Register 1997).

Beyond this there is a second stream of literature focusing on the changes in publications over the academic life cycle. As early as 1979, Cole showed that the performance of academic scientists fluctuates over the life cycle. More concretely, Levin and Stephan (1991) find for several non-economic research fields that scientists become less productive as they age. Hamermesh and Oster (1998) confirm this for the economic research field.

In contrast to many other labor markets, the market for academics is characterized by the existence of tenure contracts. Although this assures the possibility to produce new, creative, non-popular research output, it also may lower the *ex post* incentives to publish. Therefore, some authors focus on the question if tenure negatively influences the publication output. As a main result of this literature publication decreases after tenure but the decline in productivity sets in very slowly (Goodwin and Sauer 1995; Hutchinson and Zivney 1995). Particularly the top researches show little tendency for a decline in publication productivity (Goodwin and Sauer 1995).

Although most of the literature focuses on the US or the UK market, there are also a few papers analysing the situation in Germany. In line with the behavior of academics in the US and in the UK German economists tend to publish most in the years before tenure while there is a post-tenure drop in the publications (Backes-Gellner and Schlinghoff 2004; Rauber and Ursprung 2008). Rauber and Ursprung (2008) also find evidence for a cohort effect. Thus, there seems to be an institutional change in the market for German academics over the last decades.

In this paper we analyze the effect of publication on the probability to get an appointment as well as the reversed effect of an appointment on subsequent publication behavior for German economists. Contrary to the existing literature we do not cull our data from curriculis vitae but

[1] See McKenzie (1996) for a summary of popular arguments against tenure, as well as a forceful opposing view.

from two officious journals– 'Das unabhängige Hochschulmagazin' and 'Forschung und Lehre' – that regularly list new appointments for the academic market. Thus, we use a new panel data set comprising publication and appointment data for almost 900 German economists over a quarter of a century (from 1981 to 2006).[2] Beyond providing a testing ground for general hypotheses on careers in economics, this period is interesting because it is roughly cut in half by a major informal reform of economics in Germany, which brought the practice of economics (or lack thereof) more in line with the Anglo-American mainstream. These decades also saw a growing sensitivity to gender issues, which prompted a number of reforms in public service hiring procedures in Germany (and, by extension, in German universities).

A main conclusion from our research is that while we can confirm the overwhelming importance of research productivity for being offered an appointment, we find little evidence of a disincentive effect of tenure on research productivity. Possible explanations for this include the fact that additional (post-appointment) efforts can still elicit further job offers, which are the major source of pay raises – either from the new or, by re-negotiation, from the old employer – in Germany.

The next section 5.2 sets out a simple theoretical model of the choice of publication effort in an academic career (sub-section 5.2.1), which we then distil into a couple of hypotheses (sub-section 5.2.2). The data set is described in section 5.3, while section 5.4 presents the estimation technique, tabulates the major results, and provides a short discussion. Section 5.5 concludes.

5.2 Theory and hypotheses

There is a considerable number of plausible hypotheses concerning career paths of economists milling about in the economics of education literature, and we will address the most important ones in our empirical research (see sub-section 5.2.2). However, our main focus remains on the common tenet that tenure provides a job security that will reduce post-tenure incentives to publish. Put somewhat differently, if you pay younger researchers less than their marginal value product, you have to pay older ones in excess of theirs if you want to keep the career as a whole competitive. Risk considerations and the specificity of researchers' human capital may also enter the picture (McKenzie 1996), but we will ignore them throughout the remainder of the paper.

5.2.1 A simple model

In fact, we can illustrate the 'folk wisdom' cited above with a very simple two-period model. The first period represents the PhD, post-doc and assistant professor phases of an American's career,[3] with tenure (the German version being *Verbeamtung*) being granted at the start of the second. Denote the individual's publication output at time t as f_t and let $\mathrm{MC}_t = cf_t$ reflect the

[2] We also have publication data for 2007, but refrain from using this as the collection is likely incomplete.

[3] For her German colleague, the first phase would end with the first award of a non-expiring contract, which is typically the first professorial appointment.

researcher's opportunity cost of research, such as not being able to play *Warcraft* or cutting back on teaching activities. In Germany, where remuneration for teaching is basically lump-sum with a minimum teaching requirement, the relevant trade-off will in fact be one between research and spare time unless intrinsic motivation for teaching intervenes. If there were a representative researcher and all parameters were known, the obvious solution would be for the authorities to set a per-publication wage equal to the marginal product.

But suppose that researchers can be a continuum of types, the individual type being private information. Specifically, we follow Walckiers (2008) in allowing the marginal cost c of producing papers to vary, but instead of considering a limited number of types, we use a continuous distribution: let c be uniform i.i.d. over the interval $[\underline{c}, \overline{c}]$, and assume $\underline{c} > 0$ for technical reasons. Let the university offer contracts which specify a base wage $\overline{w}_t$ and an output based wage $w_t f_t$ for $t = 1, 2$ (we can safely let $\overline{w}_1 = 0$ for the remainder of the discussion as this is already sunk when researchers decide about f_1).

We also allow for *intrinsic* motivation to publish ν_t. Let $v_t = \nu_t + w_t$ denote an individual's overall per-unit reward for publishing f_t. For simplicity, we assume the v_is to be same for all types, such that all individual heterogeneity in preferences stems from a different slope c of the marginal cost function. In Germany, per-unit financial rewards for academics below the professorial level are nil, $w_1 = 0$, and while the recent change to the professorial 'W' scale has introduced an incentive element into the remuneration of professors, w_2 remains effectively very low, and was close to zero for most of the time covered by our panel data set. What *financial* incentives there are for publishing must therefore arise through appointments and promotions (with a higher base salary $\overline{w}_2$), viz. the mechanism we intend to model.

In addition to wages, universities set a threshold level of publications f^* in such a way that only researchers whose first-period output exceeds this level will be kept on (Coupé et al. 2003). The remainder will fail to obtain a professorial appointment and drop out, receiving reservation utility u_0.

Now consider researchers' incentives. The obvious interior optimum for both periods *taken separately* would be to produce $f_t^* = \frac{v_t}{c}$. There are two main cases to consider:

1. $f_1^* = \frac{v_1}{c} \geq f^*$ ('stars'). These are researchers whose marginal cost of research is so low that they exceed the threshold without really trying.

2. $f_1^* = \frac{v_1}{c} < f^*$. These researchers fail to meet the criteria for appointment unless they publish more than they would in an interior solution. Doing so is a good idea as long as the producer's surplus in $t = 2$ exceeds the first-period loss. This former is

$$\overline{w}_2 + \int_0^{\frac{v_2}{c}} v_2 - cf \mathrm{d}f - u_0$$

while the latter is given by

$$\int_{\frac{v_1}{c}}^{f^*} cf - v_1 \mathrm{d}f$$

Computing the above integrals and normalizing the outside option u_0 to zero, we obtain the following two sub-cases:

a) $\frac{v_1}{f^*} < c \leq \frac{\overline{w}_2+v_1f^*+\sqrt{f^{*2}v_2^2+2f^*\overline{w}_2v_1+\overline{w}_2^2}}{f^{*2}}$ ('hopefuls'). Hopefuls are researchers who stretch themselves to meet the appointment criteria in order to enjoy the second-period surplus of being a professor. It is evident that for equal wages $v_1 = v_2$, hopefuls will publish less after appointment. Generally speaking, their publication output will drop relative to a colleague publishing f^* before appointment in an interior solution – after all, their investment has to pay off some time.[4]

b) $\frac{\overline{w}_2+v_1f^*+\sqrt{f^{*2}v_2^2+2f^*\overline{w}_2v_1+\overline{w}_2^2}}{f^{*2}} < c \leq \overline{c}$ ('losts'). Losts have no incentive to meet the quantity standard of research output in order to become a professor; they drop out after getting their PhD and move into other sectors, such as industry or consulting, presumably using their degree as an additional academic qualification for access to high-paying jobs.

This simple model is sufficient to illustrate the relationship between post-appointment (post-tenure), pre-appointment wages and admission standards, providing the underpinnings for typical 'folk' hypotheses about the publishing behavior of professors over the life cycle. It also puts the relevant trade-offs into sharp relief: For instance, increasing $\overline{w}_2$ has clearly no effect on second-period research, but grows the class of hopefuls in the first period (stars are not motivated in this manner, though, as they treat higher base salaries as a windfall that they will get anyway), leading to more research overall. Higher performance pay (ν_2) will boost research efforts in both periods, but again all of the first-period gain will come from an increasing number of hopefuls all publishing at the minimum f^*.

As a special case, consider what would happen if academic economists were neither financially nor intrinsically motivated to publish, i.e. $v_1 = v_2 = 0$. There would be no 'stars' at all in this scenario, but there would still be a number of 'hopefuls' taking up a professorial career and all producing the minimum research output to enable them to do so. Second-period publication activity, however, would be zero for all types, professors opting for teaching, *Warcraft*, or the golf course instead.

5.2.2 Hypotheses

In this sub-section, we summarize the hypotheses we will test in the main part of the paper. Let us begin with the main 'folk wisdom' hypotheses illustrated formally in the preceding sub-section. Most importantly, our model suggests a bifurcation in the post-appointment behavior of researchers that is not present in the existing empirical literature: While the output of hopefuls drops as they move from a corner solution to the interior, *ceteris paribus*, stars will

[4]We have implicitly assumed that the university is committed to its announced policy. For everyone bunched at f^* is clearly a hopeful, information which the administration might be tempted to exploit *ex post*. Also note that we do not state that the announced policy is in any way optimal – we have no need to analyze optimal policies in the present paper.

continue publishing at a higher rate. Put rather differently, a variation in f^* will have no effect on infra-marginal stars. The above model therefore implies:

(H1:) In general, publication output drops after (a) tenure and (b) any subsequent job offer.

The remaining task is to deal with the 'stars'. Of course, this begs the question of how we measure 'stardom' in our empirical data. One approach, which we are going to follow below, relies on *multiple* appointments, suggesting that stars are professors who are able to switch universities (or re-negotiate with their existing employer) based on their performance. An alternative would be to consider a percentile of the publication distribution, say the top-ranking 25 % of researchers. As this would appear rather *ad hoc*, we settle on the first version, leading us to

(H2:) Professors receiving two or more job offers in different years are less likely, other things being equal, to exhibit a negative effect of appointments on subsequent publication output.

Finally, there is an important though incontroversial assumption that we have built into the model, rather than deriving it. Stating this as a hypothesis, we have:

(H3:) Research output in the recent past (measured by a moving average of ComLi publication points) is positively associated with the probability of obtaining an appointment in any given year.

In addition, we also want to test a couple of ancillary hypotheses that do not follow from the model, but correspond to widely held beliefs. First, formal rules for hiring at German universities place increasing emphasis on equal opportunity issues, a practice which is apparently based on the popular (e.g. Kahn 1993)

(H4:) There is a gender bias against women in the university recruitment process.

We might also want to consider a variant of this hypothesis stating that gender bias *used to be* present, but has been eroded since the implementation of reforms *(H4a)*.

Finally, a large number of studies confirm an age, or cohort, effect on publications (Levin and Stephan 1991; Hamermesh and Oster 1998). We need to capture this also, if only to control for experience effects on publication output as well as on the likelihood of employment. We summarize this in

(H5:) After completion of the post-doc phase, annual publication output decreases with years of experience, albeit at a declining rate. On the other hand, the likelihood of promotion increases with age at a declining rate.

5.3 Data

We are now in a position to confront the data. For the purposes of this study, we have assembled a new panel data set consisting, for the one part, of the standard *Verein für Socialpolitik* panel on the publications of German economists (Rauber and Ursprung 2008), and on appointment data from two officious journals of the German higher education community ('Das unabhängige Hochschulmagazin' and 'Forschung und Lehre'). Amongst other things, these journals publicize offers of professorial appointment ('Rufe'), rejected offers as well as completed appointments.

We use these data to compute a dummy variable that takes on the value 1 if an individual received, declined, or accepted at least one *Ruf* in a given year.[5]

There is also some information concerning the award of *Habilitation* – the old Germanic way qualifying for a professorial position – and the pay grade of the various appointments. The latter is, however, fairly incomplete, and we refrain from using this information in the present paper.

Publication output is measured using the Combes and Linnemer (2003) ('ComLi') weights for journal quality. We do not weight articles for length, and we follow the standard procedure of assigning each author $\frac{1}{n}^{\text{th}}$ of an article's score if there are $n-1$ co-authors. Books, book chapters as well as journal articles appearing in journals not listed in *Econlit* are not considered as a form of research output at all, as is standard in the literature.

We also have information on the year individuals received their PhDs, which allows us to construct our 'years of experience' variable (German young economists spend more time working as research assistants than their American counterparts do, but we exclude this time from consideration for want of data), on individuals' gender, as well as on affiliation.

Table 5.1: Descriptive statistics for individuals (over the entire careers since PhD)

	μ	σ	min	max
Overall publications (ComLi)	1.42	2.33	0	19.49
Annual avg. ComLi Score	0.143	0.181	0	1.394
Action years	0.550	0.969	0	5
Year of PhD	1990	11.4	1958	2007
Gender (1=fem)	0.112	0.316		
N	889			

Table 5.1 gives simple descriptive statistics (per individual) for the main variables in our analysis. As we can see, only one in nine economists in the panel is female. We also note the rather large spread in publications: While the average German economist has published, over her entire career up to 2007, the equivalent of one JPE article and a half, the standard deviation is almost twice the mean. In fact, 265 – almost one third – of the economists in the panel *have not published a single article* counting towards the ComLi score.

It is interesting to look at the publication output over time. Figure 5.1 on page 72 displays a sequence of box plots, one for each year, from 1980 to 2006, where years are plotted on the

[5]Note that our data set does not include *all* 'actions' that may have occurred. Some may neither have been announced to the two officious journals nor been captured by the journals' own research. However, the German Wissenschaftsrat (2005) provides summary statistics on the number of appointments in Germany for the period from 1997 to 2003. Over these six years, there were a total of 93 completed appointments in the fields of Economics and Business Administration. For comparison, the subset of our data set for the same time period contains 95 records where a job was made (leading to rejection or completion of appointment), and this is for all German-speaking countries and for Economics only. This suggests that we have captured a substantial share of the appointment proceedings over time.

abscissa. Note that up to the early 1990s, outliers dominate the picture. It is not until 1987 that the box containing the middle 50 % of the distribution makes an appearance at all; and even for second half of the period of time covered in our panel, the confidence interval of ComLi scores still includes zero.

All the same, Figure 5.1 indicates that the three decades in our data set differ; an increasing prevalence of ComLi-ranked publications – or, to phrase it negatively, an increasing relevance of American-style 'publish or perish' modes of research to the detriment of the previous book-centric mode – is clearly visible. This is consistent with impromptu evidence and our personal experience with the German economics community: something happened in the early 90s to change the face of economics in Germany, for better or worse. We consequently need to take care to account for this heterogeneity in the following analyses.

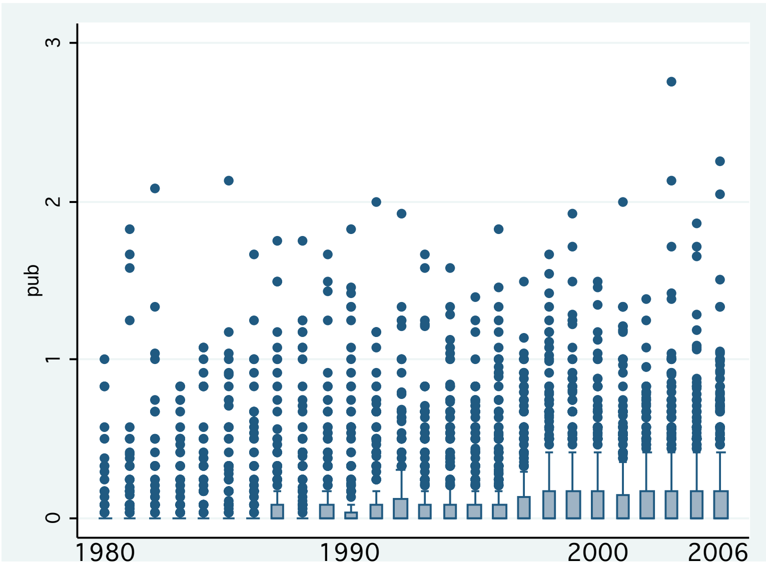

Figure 5.1: Distribution of publication activity over time in Germany, 1980-2006

5.4 Results

5.4.1 Effects of publication activity on appointments

Addressing (H3) first, if publishing increases the probability of getting an appointment, we estimate the effect of publishing on the dummy *action* that is 1 whenever there is at least one job offer (whether leading to an appointment or to re-negotiations with the present employer) at time t and 0 otherwise. Since we believe that the decision of the committee of appointment is affected by the average publication behavior of the candidate we measure publishing by the 5-year ($f_{i,(t-5,t-1)}$) respectively 3-year-average ($f_{i,(t-3,t-1)}$) Combes-Linnemer index before the appointment. To account for the fact that the action variable $a_{i,t}$ is a binary, we fit the following panel probit model:

$$\Phi^{-1}[P(a_{i,t} = 1)] = \beta_0 + \beta_1 f_{i,(t-k,t-1)} + \beta_2 s_i + \beta_3 y_{i,t} + \beta_4 y_{i,t}^2 + \beta_5 \delta_t + \epsilon_{i,t} \tag{5.1}$$

for $k = 3, 5$, where s_i is a sex dummy (1 = female) and $y_{i,t}$ describes work experience of individual i at time t measured as years since obtaining a PhD. In line with Mincer (1974) we also control for $y_{i,t}^2$ believing that the marginal effect of experience is not constant. δ_t is a year dummy accounting for time fixed effects. The results of our regressions are given in Table 5.2.

As in Germany university professors in general retire at the age of 65, we only include observations where the individual has less than 30 years' work experience.[6]

Table 5.2: Probit estimates for appointment

	(I)	
ComLi5	1.4158***	
(5-yr avg.)	(10.07)	
ComLi3		1.2195***
(3-yr avg.)		(10.10)
Female	-0.1310	-0.1416
	(-1.05)	(-1.13)
Yrs since	0.16714***	0.1767***
PhD	(10.63)	(11.19)
$(\text{Yrs})^2$	-0.0062***	0.1767***
	(-10.51)	(-10.97)
N	10624	10624

(z-statistics in parentheses), */**/*** significant at 10/5/1 percent levels, respectively. In the cause of clarity we do not list time fixed effects.

As the results in Table 5.2 illustrate, there is a highly significant influence of publications on getting appointed. More precisely, one AER article on average over 5 years (3 years) increases the probability of an appointment by 58.61% (54.94%). Interestingly, we do not find a female discrimination in the models (I) that refer to the whole sample. So, we can reject (H4). Focusing (H5), the results show a positive but decreasing effect of experience on the probability of getting an appointment. Using the 3-year average instead of the 5-year average always decreases the regression coefficient.

[6] In fact, there are several reasons for excluding older individuals from our data set. For instance, regulations in *some* German *Länder* stipulate the no-one over a certain age – typically 53 to 55 years – can be appointed as tenured professor; this removes the main mechanism in our model underlying hypotheses 1 through 3. The average graduation age of German PhDs in the early 1980s exceeded 30, while the mandatory retirement age for tenured professors was 65 (although there was an option to stay on until age 67). Faced with this mess, we decided to use a cut-off of 30 years, although we also report estimations for a cut-off of 20 years of experience.

To capture possible cohort effects as mentioned by Rauber and Ursprung (2008), we also run the regression for a work experience smaller than 20 years and for a work experience between 20 and 30 years (model (II) Table 5.3).

Table 5.3: Probit estimates for appointments referring to cohort, time and star effects

	(II)		(III)		(IV)
	<20 yrs	20<yrs<30	t<1995	t≥1995	min 2 appts.
ComLi3	1.1350***	1.1377***	0.9985***	1.3658***	0.5071***
(3-yr avg.)	(9.28)	(2.85)	(5.06)	(9.12)	(3.57)
Female	-0.1912	0.1554	-0.5390*	-0.0503	-0.0413
	(-1.45)	(0.51)	(-1.70)	(-0.38)	(-0.18)
Yrs since PhD	0.2769***	0.1742	0.0303***	0.1670***	0.2071***
	(10.26)	(0.37)	(6.26)	(8.36)	(8.95)
$(\text{Yrs})^2$	-0.0119***	-0.0058	0.0012***	-0.0062***	-0.0080***
	(-9.42)	(-0.59)	(-5.45)	(-8.58)	(-9.47)
N	8508	2116	4047	6577	2392

(z-statistics in parentheses), */**/*** significant at 10/5/1 percent levels, respectively. In the cause of clarity we do not list time fixed effects.

Model (II) in Table 5.3 shows that publications significantly influence the probability of getting appointed for all stages of the academic career. Nevertheless, experience only matters for earlier stages of the academic career but not later on. Since appointments after more than 20 years of experience often are second or third appointments we can conclude: While experience importantly influences the first-appointment it is not so important for additional appointments.

As the descriptive analysis in section 5.3 shows average publication output increases over time. Therefore, we also split our data set and run regressions for years before and after 1995 (see models (III)). In line with the basic models (I) there is a highly significant effect of publications and experience on the action dummy. However, now the regression discover a significant female discrimination in the early years of our data set. Before 1995 we can not reject hypothesis (H4). So, efforts against female discrimination in the last years seem to act.

Finally, in model (IV) we analyze the group of academic 'stars'. Stars are researchers who get more than one appointment in our data set. For this group of researchers the effect of publications on appointments is signficant but much smaller than for the whole group of academic economists. Thus, we can not reject hypothesis (H5).

The above model (5.1) assumes that tenure boards, or professorial selection committees, look at research output in the years preceding the application. The main idea is that they would consider successes in the distant past uninformative if the candidate had not been able to keep up to this record. However, departments might be tempted to 'buy' a candidate's long publication list in order to improve their own standing, if only on paper. In that case, it is the *overall* number of ranked publications that counts. As the correlation with our experience measure y is significant (at the 1 % level), however, we need to drop the Mincer terms from our model due to possible multicollinearity. We have therefore also estimated the following model

$$\Phi^{-1}[P(a_{i,t} = 1)] = \beta_0 + \beta_1 \sum_{j=1981}^{t} f_{i,j} + \beta_2 s_i + \beta_3 \delta_t + \epsilon_{i,t} \quad (5.2)$$

Note that we lack data on publications prior to 1981, and therefore were only be able to include individuals who received their PhD during the time span of our sample. The results turned out to be consistent with what we had found previously: Publications have a significant positive impact on the probability of being appointed, and the significant gender bias against women that is present in the first half of our sample fails to be significant overall.

5.4.2 Post-appointment publishing

We now turn to the effects that appointments have on research productivity. The basic panel model we estimate in this sub-section is

$$f_{i,(t+j,t+k)} = \beta_0 + \beta_1 a_{i,t} + \beta_2 s_i + \beta_3 y_{i,t} + \beta_4 y_{i,t}^2 + \mu_t + \epsilon_{i,t} \quad (5.3)$$

where $f_{i,(t+j,t+k)}$ is a moving average of Combes-Linnemer publication measures (weighted for co-authorships, but not for article length) over a period ranging from j years after the appointment at time t to k years after, s_i is a sex dummy (1 = female), $y_{i,t}$ is years of post-doc experience at time of appointment t, and μ_t is the standard random effects term. The inclusion of the square of experience reflects the typical Mincer-type considerations, but with a twist: Hypothesis H5 holds that research output decreases with age, but at a decelerating rate (see sub-section 5.2.2).

For our data, a random effects model is clearly more appropriate. A Hausman test also did not reject this approach in favour of a fixed effects one. We consequently estimated a random effects version of (5.3) to control for unobserved heterogeneity. Table 5.4 displays the results.

The second column in Table 5.4 represents the baseline, giving the results for $p_{i,(t+1,t+6)}$. There is, in fact, a significant negative effect of appointment on average productivity. The coefficient, however, appears rather small, corresponding to about one-twentieth of an article in the *German Economic Review* (or a hundredth of an article in the *Journal of Political Economy*) per annum. To put it in perspective, though, note that the average annual ComLi score for individuals in our sample, computed over the entire time horizon, is 0.0872 – which means that the coefficient amounts to an estimated 8.37 % reduction on average. While there appears to be some disincentive associated with obtaining an appointment, the size of this effect is open to debate.

The coefficients on s_i and $y_{i,t}$ are highly significant and negative, the coefficient on $y_{i,t}^2$ is positive and significant at the 1% level, suggesting that hypothesis H5 holds: Output declines as researchers grow older, albeit at a diminishing rate. This result is in line with previous findings by Backes-Gellner and Schlinghoff (2004). We also find that female researchers tend to publish less.

Table 5.4: Estimation results for post-appointment productivity

	Average annual publications (ComLi)			
	5 years	5 years, lagged	5 years, lagged, before 1995	5 years, lagged, 2 or more appts
Appt. dummy	-0.0087**	-0.0073*	-0.0022	0.00059
	(-2.08)	(-1.73)	(-0.45)	(-0.09)
Female	-0.548***	-0.0606***	-0.0484	-0.040
	(-3.43)	(-3.31)	(-1.51)	(-0.41)
Yrs since PhD	-0.0053***	-0.0083***	-0.0040***	-0.0161***
	(-13.37)	(-20)	(-6.05)	(-14.44)
(Yrs since PhD)^2	8.6×10^{-5}***	1.8×10^{-4}***	8.9×10^{-5}***	3.8×10^{-4}***
	(6.34)	(12.55)	(3.34)	(10.03)
ρ	0.700	0.742	0.854	0.708
N	10824	10824	4247	2258

(z-statistics in parentheses), */**/*** significant at 10/5/1 percent levels, respectively. In the cause of clarity we do not list time fixed effects.

This baseline, however, is open to one criticism: Newly appointed (tenured) professors face high demands on their time budget to set up their curriculum, to get organized on administrative issues, moving house, and (at least in Germany) to set up their own small outfit (for example, hiring and training assistants). It is likely that this burden diminishes as time progresses in the new job. Therefore, column 3 in table 5.4 shows the results for a model with $p_{i,(t+3,t+8)}$ as dependent variable; that is, we lag the moving average by an additional two years, leaving out the first two years immediately following the new appointment. The negative coefficient on the appointment dummy grows even smaller and now barely escapes being insignificant. The disincentive effect of an appointment, therefore, almost disappears when we look farther into the future. Also note that the coefficient of the female dummy shrinks to about one tenth, which is consistent with a story that set-up costs in a professorial job are higher for females than for males.

The fourth column shows what happens if we restrict the analysis to the first half of the panel, which loosely corresponds to the time before economics in Germany began to model itself on the Anglo-American example. Only the experience variables remain, and both the appointment and sex dummies become insignificant (and their coefficients even smaller). While we would not place too much reliance on the second non-result – owing to the small number of female appointees in the first half of our sample –, the first is consistent with the hypothesis that extrinsic incentives of the kind modelled in sub-section 5.2.1 did not become operative until after the reform.

Finally, in the model represented in the fifth column, we take up the distinction between ‘stars’ and (ex-) ‘hopefuls’ outlined in the model. If we restrict the estimation to those individuals who received at least two appointments in distinct periods of time,[7] the coefficient on the appointment dummy becomes very small and statistically indistinguishable from zero. For this group, we cannot reject the null that there is no effect of an appointment on subsequent research activity, which corresponds to hypothesis (H3) outlined in sub-section 5.2.2.

5.5 Conclusion

Economists are increasingly interested in analyzing their own labor market. Most of the research focuses on the popular beliefs that tenure decreases the productivity of academics and also that there is a discrimination against women.

Our paper contributes to this literature by analyzing the interplay of publications and appointments for German economists. Although there are a lot of studies on the academic market in the USA and the UK only few things are known about the situation in Germany (Backes-Gellner and Schlinghoff 2004; Rauber and Ursprung 2008). In contrast to previous studies, we do not use appointment data from CVs but data that are regularly published in two German magazines. By doing this we address a selection bias.

The results confirm a positive effect of publication activity on the probability to get an appointment. This effect increases by-and-by. So, we find evidence that publication becomes more and more important to get an appointment. Interestingly, we do not find discrimination against women for our whole data including the years 1981-2006 but for the sub-sample including the years 1981-1995. Thus, we find some evidence that the anti-discrimination efforts in Germany take effect.

Focusing on the effect of tenure on the publication behavior our results support a negative, but small, effect of tenure on publications for the whole time spread. However, before 1995 there is no significant decline in publications after tenure. This could mean that in early years publication behavior was stronger driven by an intrinsic motivation than today. Nevertheless, there is hope because top researchers do not show such a behavior. There publications do not significantly drop after tenure.

Summing up, institutional changes in the labor market for academics in Germany have markedly reduced discrimination against female postdoctoral academics. However, the number of female researchers is still proportionally low. As an additional result we find an increasing importance of publications on the probability to get an appointment. Our simple model predicts that the increasing efforts in the time period before tenure reduces publication activities afterwards. This is also confirmed by the data.

[7] See above for a discussion of why we roll multiple job offers in a single year into a single ‘action’.

6 Lessons learnt

After reading the Intro and the four articles presented here, it should be clear that the discipline of educational economics is very broadly dimensioned and highly prominent too as there are a couple of Nobel-prize winners among its scholars. And it goes without saying that education is a key factor of development, especially if a country is comparably poor in natural resources as it is the case with Germany. But education is not only linked to productivity but has some social implications of its own: education is a source of success within a society and missing education an origin of social deprivation. The ups-and-downs in social status within a society (social mobility) are, therefore, mainly driven by education, and they result in changing images of the distribution of income and wealth (inequality) which, then, at least partly is an indirect effect of education. Education *and* social mobility *and* inequality are the theme of the first two articles presented here, but thats only one aspect among a variety of others in educational economics.

One such other aspect has to do with the institution we live and work in: the universities. It's needless to say that university education follows different rules but there is something schools and universities have in common: the quality of the teaching personel, and there should be a high correlation between the quality of teaching und the quality of education. What differentiates universities from schools is that good teaching should be complemented by good research according to the classic concept of 'Einheit von Forschung und Lehre', however this principle is realized in the current system or not. The point is that to guarantee good teaching and research, the university is in the same dilemma as any other employer: it has to face the problem of asymmetric information but on the other hand applicants for a university career have developed techniques to signal their abilities relevant for the universities so that the problem can be mitigated to some extent. This theme is elaborated in the second part of the articles, and it is corrobated by an empirical analysis of the role of publications in application procedures in Germany. As to be expected, publications play a decisive role for appointments as a university professor at least during the last 15 years but for older professors and their second or third 'Ruf' other criteria seem to be valid experience seems to be the main factor here which cannot be substituted for.

Going into the details and the transmission of skills between generations for the last time, it is rather astonishing that former studies have regularly assumed children to be homogeneous with respect to their talents which is totally at odds with the reality of more or less 'feudal' societies. In such cases, the poor will not invest in their children but the rich will do so that there won't be any social mobility. Changing that assumption to randomly distributed talents there will be upward and downward social mobility, and the aggregate skill level of the population can change over time. In the paper with Stefan Napel we skipped this assumption too and postulated a more 'feudal' world where the ability of a child depends on the abilities of its parents. At the end, our model proves that a high degree of dependence reduces social mobility but does not affect the aggregate skill level and inequality. This follows from our long-term equilibrium approach where upward and downward mobility are equal, and the social mobility in equilibrium only depends on the fraction of highly talented children which is assumed to be fixed over time. Due to these constraints policy recommendations are clear-cut: It's always good to weaken the social dependence of parent's and children's abilities because social mobility will be strengthened but inequality cannot be tackled this way.

Consequently, it should be asked if there are any instruments to raise social mobility and to reduce inequality at the same time. Discussing redistributive taxation the change in net-wages will ceteris paribus lower inequality because of the reduced wage-gap, and the poor will start to invest in their children at a lower aggregate skill level but the rich will obstain from that to a certain extent; thus, social mobility can be increased. Since the effect on the aggregate skill level is ambigious because investment of the poor is strengthend while investment of the rich is reduced, the paper discusses both possible cases in detail. Finding an increase in the aggregate skill level the labor market effect always strengthens the redistributive effect and inequality is reduced. Unfortunately, it can be increased by an *indirect tax effect* if we focus on a situation where the overall skill level is reduced by taxation. Educational subsidies (financed via a tax levied on the general public) as the second political instrument reduce education costs and triggers investments of rich and poor parents. Analyzing four different initial investment situations where poor/rich parents invest, do not invest or are just indifferent in their investment decision, in three out of this four cases the aggregate skill level will grow. However, there is one initial investment situation where the aggregate skill level is reduced. This exceptional case appears when unskilled parents are indifferent in their investment decision having a highly talented child. The corresponding skill level that leads to this situation and therefore the degree of equality are decreased by education subsidies because reduced costs make it possible that unskilled can invest at a lower aggregate skill level. Since the case appears when the skill level is just so high that unskilled start thinking about investment, the situation is characterized by a low aggregate skill level that is typical for developing countries.

Switching to the second theme of this dissertation, the university and its labor market, the initial focus is on the academic appointment system. In general, universities prefer professors that are good in research *and* teaching. Therefore, since talents are private information, applicants have to signal their research and teaching abilities distinguishing them from their competitors, and the universities have to interpret these two-dimensional signal. Since the literature on multi-dimensional signaling is very restricted, the paper had to go new ways by analyzing separating equilibria. In a first step, serving as a benchmark, such an equilibrium in considered where universities are only interested in science *or* teaching; in a second step separating equilibria are analyzed if future professors signal their abilities to do research *and* teaching. If future professors would have unlimited time to prepare themselves (teach *and* publish to signal abilities) for their first application at a university, the two-dimensional equilibrium would consist of both parts of the two one-dimensional cases: in publications as well as teaching high quality post-docs would separate themselves from low-talented competitors. But if time is restricted (as it really is) and since a day has 24 hours only, a complete separation would be illusionary so that, at the end, they will play the same strategy as future professors that are only highly productive in one of both activities. Then, universities face a dilemma: They can identify good researchers and good teachers but cannot assess the other qualification at a time leading to the fact that not all types of post-docs can be discerned. Since the information content of the current two-dimensional signaling will be reduced in practice to one-dimensional signaling, the current appointment system is obviously inefficient. If time constraint exclude the possibility of competitors to qualify in research *and* teaching and to separate themselves from the other types, universities are well advised to choose only the one criterion they value most. The universities will not lose any information, but future professors can save much time and costs.

The last article in this row sheds some light on the publication policy of real or potential professors to test for the typical behavior of civil servants: only to do whats absolutely necessary. Together with Klaus Beckmann an unique data-set for Germany of academic appointments ('Rufe') was developed, and the result is contrary to the civil-servant hypothesis: the mere descriptive statistics show that although there is a high variance in the publication behavior of German academic economists, the average publication output grew remarkably from 1995 to 2006. Furthermore, regression analysis reveals clear evidence of a positive effect of the number of publications on the probability to get an appointment at a university, increasing considerably from 1980 to 2006. This effect is smaller for older professors implying that at that age publication output is not so important as experience to get a second or third appointment. However, there is a small but significant drop of average publication output after an appointment which means, due to German regulations, after becoming a civil servant; that does not hold, however, for professors with more than one appointment during his/her career, maybe due to high intrinsic motivation or a numerous staff. Interestingly, the average drop in publications after an appointment was smaller before 1995 than in recent years; growing administrative challenges or rising pretensions of students may be the reasons. Finally, discrimination against women clearly belongs to the past: after 1995 such an effect cannot be recognized any more.

It is to be hoped that these explorations into two fields of the economics of education have been able to arouse the interest of the non-specialist for this challenging field of research, and that the specialist will have found something worthwhile to remember. Anyway, it should have become clear how important an increasing knowledge in this field can be for a positive development of a society which surely goes beyond pure economics.

Bibliography

Allgood, Sam and Wiliam B. Walstad (2005). Views of teaching and research in economics and other disciplines. *American Economic Review Papers and Proceedings 95*(2), 177–183.

Arai, Kazuhiro (1998). The economics of education: An analysis of college-going behavior. Springer, Tokyo et al.

Arcidiacono, P. (2005). Affirmative action in higher education: How do admission and financial aid rules affect future earnings? *Econometrica 73*(5), 1477–1524.

Aristotele. Politics (with an English transition by H. Rackham). Loeb Classical Library, Harvard University Press, Cambridge et al., 1998.

Armstrong, Mark and Jean-Charles Rochet (1999). Multi-dimensional screening: A user's guide. *European Economic Review 43*, 959–979.

Backes-Gellner, Uschi and Axel Schlinghoff (2004). Careers, incentives, and publication patterns of US and German (business) economists. http : //papers.ssrn.com/sol3/papers.cfm?abstract_id = 616822.

Banerjee, A. and A. Newman (1993). Occupational choice and the process of development. *Journal of Political Economy 101*(2), 274–298.

Becker, Gary S. (1964). Human Capital: A theoretical and empirical analysis, with special reference to education. Columbia University Press, New York et al.

Becker, G. and N. Tomes (1979). An equilibrium theory of the distribution of income and intergenerational mobility. *Journal of Political Economy 87*(6), 1153–1189.

Becker, William E. (1975). The university professor as a utility maximizer and producer of learning, research, and income. *Journal of Human Resources 10*(1), 107—115.

Becker, William E. (1979). Professorial behavior given a stochastic reward structure. *The American Economic Review 69*(5), 1010–1017.

Becker, William E. and Peter E. Kennedy (2005). Does teaching enhance research in economics? *American Economic Review Papers and Proceedings 95*(2), 172–176.

Bils, Mark and Peter J. Klenow (2000). Does schooling cause growth? *American Economic Review 90*(5), 1160—1183.

Blackburn, M. and D. Neumark (1993). Omitted-ability bias and the increase in the return to schooling. *Journal of Labor Economics 11*(3), 521–544.

Blanden, Jo, Alissa Goodman, Paul Gregg and Stephen Machin (2004). Changes in intergenerational mobility in Britain. In: Corak, Miles (Ed.). Generational income mobility in North America and Europe, Cambridge University Press, Cambridge.

Bouchard, T. and M. McGue (1981). Familial studies of intelligence: A review. *Science 212*(29 May), 1055–1059.

Bovenberg, A. and B. Jacobs (2005). Redistribution and education subsidies are Siamese twins. *Journal of Public Economics 89*(11-12), 2005–2035.

Bowles, Samuel, Herbert Gintis and Melissa Osborne Groves (Ed.) (2008). Unequal chances: Family background and economic success. Princeton University Press, Princeton NJ.

Card, David (1999). The causal effect of education on earnings. In: Ashenfelter, Orley and David Card (Ed.). Handbook Labor Economics, vol. 3A, ch. 30, 1801–1863, Elsevier, Amsterdam et al.

Carneiro, Pedro, Costas Meghir and Matthias Parey (2007). Maternal education, home environments and the development of children and adolescents. Working Paper of the Institute for Fiscal Studies, University College London, no. W07/15.

Chan, J. and E. Eyster (2003). Does banning affirmative action lower college student quality? *American Economic Review 93*(3), 858–872.

Cho, In-Koo and David M. Kreps (1987). Signaling games and stable equilibria. *The Quarterly Journal of Economics 102*(2), 179–221.

Ciccone, Antonio and Elias Papaioannou (2009). Human capital, the structure of production, and growth. *Review of Economic and Statistics 91*(1), 66—82.

Cohen, Daniel and Marcelo Soto (2007). Growth and human capital: good data, good results. *Journal of Economic Growth 12*, 51–76.

Cole, Stephen (1979). Age and scientific performance. *Journal of Sociology 84*(4), 958–977.

Combes, Pierre-Philippe and Laurent Linnemer (2003). Where are the economists who publish? Pubication concentration and rankings in Europe based on cumulative publications. *Journal of the European Economic Association 1*(6), 1250–1308.

Couch, K. A. and O. F. Morand (2005). Inequality, mobility, and the transmission of ability. *Journal of Macroeconomics 27*(2), 365–377.

Coupé, Tom, Valérie Smeets and Frédéric Warzynski (2003). Incentives in economic departments: Testing tournaments? Working Paper, Dept. of Economics, Aarhus School of Business 03-25, $http://www.hha.dk/nat/wper/03-25_vasfwa.pdf$.

Cutler, David M. and Adriana Lleras-Muney (2006). Education and health: Evaluating theories and evidence. NBER Working Paper, no. 12352 .

Dee, Thomas S. (2004). Are there civic returns to education? *Journal of Public Economics 88*(9-10), 1697—1720.

De Fraja, G. (2002). The design of optimal education policies. *Review of Economic Studies 69*(239), 437–466.

De Fraja, G. (2005). Reverse discrimination and efficiency in education. *International Economic Review 46*(3), 1009–1031.

De Fraja, Gianni and Paola Valbonesi (2008). The design of the university system. CEPR Discussion Paper no. 7038.

Del Rey, Elena (2001). Teaching versus research: A model of state university competition. *Journal of Urban Economics 49*, 356–373.

Devlin, B., M. Daniels, and K. Roeder (1997). The heritability of IQ. *Nature 388*(31 July), 468–471.

Diamond, Arthur M. Jr. (1986). What is a citation worth? *Journal of Human Resources 21*(Spring), 200–215.

Di Tella, Rafael, Robert J. MacCulloch and Andrew J. Oswald (2003). The macroeconomics of happiness. *Review of Economics and Statistics 85*(4), 809–827.

Donne, John. The major works. Carey, John (Ed.). Oxford University Press, Oxford et al., 2008.

Doyle, Orla, Colm Harmon and Ian Walker (2007). The impact of parental income and education on child health: Further evidence for England. Warwick Economic Research Papers, no. 788.

Dur, R. and C. Teulings (2001). Education and efficient redistribution. CESifo Working Paper, no. 592.

Engers, Maxim (1987). Signalling with many signals. *Econometrica 55*(3), 663–674.

Freeman, S. (1996). Equilibrium income inequality among identical agents. *Journal of Political Economy 104*(4), 1047–1064.

Galor, O. and J. Zeira (1993). Income distribution and macroeconomics. *Review of Economic Studies 60*(1), 35–52.

Gautier, Axel and Xavier Wauthy (2007). Teaching versus research: The role of internal financing rules in multi-department univeristies. *European Economic Review 51*, 273–295.

Glaeser, Edward L., Giacomo A. M. Ponzetto and Andrei Shleifer (2007). Why does democracy need education? *Journal of Economic Growth 12*(2), 77–99.

Goodwin, Thomas H. and Raymond D. Sauer (1995). Life cycle productivity in academic research: Evidence from cumulative publication histories of academic economists. *Southern Economic Journal 61*, 728–1743.

Gottlieb, Esther E. and Bruce Keith (1997). The academic research-teaching nexus in eight advanced-industrialized countries. *Higher Education 34*, 397–420.

Greenaway, David and Michelle Haynes (2004). Funding higher education. In: Jones, Geraint and Jill Johnes (Ed.). International Handbook on the Economics of Education, ch. 8, 298–328, Edward Elgar Publishing Ltd, Cheltenham.

Grimes, Paul W. and Charles A. Register (1997). Career publications and academic job rank: Evidence from the class of 1968. *Journal of Economic Education Winter*, 82–92.

Hamermesh, Daniel S. and Sharon M. Oster (1998). Aging and productivity among economists. *The Review of Economics and Statistics 80*(1), 154–156.

Hanushek, Eric A. (1986). The economics of schooling: Production and efficiency in public schools. *Journal of Economic Literature 24*, 1141—1177.

Hassler, J. and J. Rodríguez Mora (1998). IQ, social mobility and growth. *C.E.P.R. Discussion Papers 1827*.

Hattie, John and H. W. Marsh (1996). The relationship between research and teaching: A meta-analysis. *Review of Educational Research 66*(4), 507–542.

Helliwell, John F. (2003). How's life? Combining individual and national variables to explain subjective well-being. *Economic Modelling 20*(2), 331—360.

Humboldt, Wilhelm von (1767-1835). Bildung und Sprache. Fourth edition. Ferdinand Schöningh, Paderborn, 1985.

Hutchinson, Bruce E. and Terry L. Zivney (1995). The publication profile of economists. *Journal of Economic Education Winter*, 59–79.

Jäntti, M., K. Røed, R. Naylor, A. Bjöerklund, B. Bratsberg, O. Raaum, E. Österbacka, and T. Eriksson (2006). American exceptionalism in a new light: A comparison of intergenerational earnings mobility in the Nordic Countries, the United Kingdom and the United States. IZA Discussion Paper 1938, Bonn. [ftp://repec.iza.org/RePEc/Discussionpaper/dp1938.pdf].

Kahn, Shulamit (1993). Gender differences in academic career paths of economists. *The American Economic Review 83*(2), 52–56.

Kim, Jeong-Yoo (2007). Multidimensional signaling in the labor market. *Manchester School 75*(1), 64–87.

Konrad, K. and A. Spadaro (2006). Education, redistributive taxation and confidence. *Journal of Public Economics 90*(1-2), 171–188.

Krueger, Dirk and Krishna B. Kumar (2004). Skill-specific rather than general eudcation: A reason for US-Europe growth differences? *Journal of Economic Growth 9*(2), 167—207.

Levin, Sharon G. and Paula E. Stephan (1991). Research productivity over the life cycle: Evidnece for academic scientists. *The American Economic Review 81*(1), 114–132.

Lindelow, Magnus (2006). Health as a family matter: Do intra-household education externalities matter for maternal and child health? *Journal of Development Studies 44*(4), 562—585.

Ljungqvist, L. (1993). Economic underdevelopment – The case of a missing market for human capital. *Journal of Development Economics 40*(2), 219–239.

Lochner, Lance and Enrico Moretti (2004). The effect of education on crime: Evidence form prison inmates, arrests, and self-reports. *American Economic Review 94*(1), 155—189.

Locke, John (1693). Some thoughts concerning education. John W. Yolton and Jean S. Yolton (Edt.), Clarendon Press, Oxford, 1989.

Loury, G. C. (1981). Intergenerational transfers and the distribution of earnings. *Econometrica 49*(4), 843–867.

Maoz, Y. and O. Moav (1999). Intergenerational mobility and the process of development. *Economic Journal 109*(458), 677–697.

Mazumder, B. (2005). Fortunate sons: New estimates of intergenerational mobility in the United States using social security earnings data. *Review of Economics and Statistics 87*(2), 235–255.

McKenzie, Richard B. (1996). In defense of academic tenure. *Journal of Institutional and Theoretical Economics June*, 325–341.

Mincer, J. (1958). Investment in human capital and personal income distribution. *Journal of Political Economy 66*(4), 281–302.

Mincer, Jacob (1974). Schooling, experience, and earnings. Columbia University Press, New York et al.

Mitch, David (2004). School finance. In: Jones, Geraint and Jill Johnes (Ed.). International Handbook on the Economics of Education, ch. 7, 260–297, Edward Elgar Publishing Ltd, Cheltenham.

Mitchell, John E. and Douglas S. Rebne (1995). Nonlinear effects of teaching and consulting on academic research productivity. *Socio-Economic Planning Sciences 29*(1), 47–57.

Mookherjee, D. and S. Napel (2007). Intergenerational mobility and macroeconomic history dependence. *Journal of Economic Theory 137*(1), 49–78.

Mookherjee, D. and D. Ray (2003). Persistent inequality. *Review of Economic Studies 70*(2), 369–393.

Napel, S. and A. Schneider (2008). Intergenerational talent transmission, inequality, and social mobility. *Economics Letters 99*(2), 405–409.

Nelson, Richard R. and Edmund S. (1966). Investment in humans, technological diffusion, and economic growth. *American Economic Review 56*(2), 69–75.

OECD (2009). Education at a glance 2008: OECD indicators. Organisation for Economic Co-operation and Development, Paris et.

Piketty, T. (1995). Social mobility and redistributive politics. *Quarterly Journal of Economics 60*(3), 551–584.

Plato. The Republic, Books I-V (with an English transition by Paul Shorey). Loeb Classical Library, Harvard University Press ,Cambridge et al., 1999.

Psacharopoulos, George (1994). Returns to investment in education: A global update. *World Development 22*(9), 1325—1343.

Rauber, Michael and Heinrich W. Ursprung (2008). Life cycle and cohort productivity in economic research: The case of Germany. *German Economic Review 9*(4), 431–456.

Rochet, Jean-Charles and Martine Qunizii (1985). Multidimensional signalling. *Journal of Mathematical Economics 14*, 261–284.

Schultz, Theodore W. (1963). The economic value of education. Columbia University Press, New York et al.

Schultz, Theodore W. (1975). The value of the ability to deal with disequilibria. *Journal of Economic Literature 13*(3), 827—846.

Silles, Mary A.(2009). The causal effect of educationon health: Evidence from the United Kingdom. *Economics of Education Review 28*(1), 122—128.

Smith, Adam (1776). The works of Adam Smith. Vol. II - The nature and causes of the wealth of nations. Otto Zeller, Aalen, 1963.

Spence, Michael (1973). Job markt signalling. *The Quarterly Journal of Economics 87*(3), 355–374.

Spence, Michael (1974). Competitive and optimal responses to signals: An analysis of efficiency and distribution. *Journal of Economic Theory 7*, 296–332.

Walckiers, Alexis (2008). Multi-dimensional contracts with task-specific productivity: an application to universities. *International Tax and Public Finance 15*, 165–198.

Wissenschaftsrat (2005). Empfehlungen zur Ausgestaltung von Berufungsverfahren. *Drucksache 6709-05* .