From ABC to PhD
A theoretical and empirical analysis of education policy

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Preface

"Live as if you were to die tomorrow. Learn as if you were to live forever."

Mahatma Gandhi

The lecture "Investment in human capital" from Theodore Schulz to the American Economic Association in the year 1960 is considered to be the beginning of the economics of education (Johnes (1993)). In this regard the subject is quite new in the economics literature. The reason for the late research activities was the assumption of a given and constant labor force in a society until the 1950s. The introduction of the human capital theory changed this view and emphasized the role of education as an investment (Schultz (1961); Becker (1962, 1964)). By spending more time for education an individual can improve his/her productivity and hence the wage level. On the other hand investments in education are also associated with individual costs. In this context, opportunity costs represent the major cost factor since students cannot work during their school career.[1] Thereby education has the following characteristics in comparison to materialistic goods: The costs of education incur over a relatively long period of time, i.e. human capital accumulation is not only based on the financial resources, but also on time restrictions. Furthermore, the individual knowledge and skills do not lose in value over time like other goods. For instance, literacy and numeracy are always beneficial in life.

The demand for education was initially evaluated with regard to private returns (Psacharopoulos (1973, 1975)), which capture the benefit of individual investment decisions in education. According to human capital theory education enhances the individual productivity and thus earnings increase with educational attainment. The empirical study of Mincer (Mincer (1974)) shows a simple estimation model (known as the Mincerian earnings function) to identify the influence of educational attainment on the wage level. Thereby Mincer distinguishes the effect of pure education from the impact of post-school experience on individual income. However, the idea that wage differentials are caused by a different level of educational attainment can be explained by two other theoretical models, too: The signalling model (Spence (1973)) describes education not as an investment to increase the existing level of productivity, but to show the innate ability. Individuals with a high innate ability have less costs of education than individuals with a low innate ability and thus are willing to stay longer in the education system. The employers pay the individuals a higher wage level to compensate them for their higher investments in

[1] Beside this investment element of education we can also identify a consumer element of education. The acquisition of knowledge can be a pleasure which leads to a higher individual utility.

education. In this context, educational attainment is a proxy for the innate ability of an individual, since it does not enhance productivity, but rather reveals the existing productivity. The signalling model is a special case of the second theory, the so called screening model (Arrow (1973)). Firms usually organize several tasks which vary in difficulty and thus in required workers' productivity. Therefore, the allocation of workers according to their productivity is decisive for an efficient production. Again, the educational attainment serves as a proxy for the productivity of the prospective employees and helps the employers to find an optimal allocation of employees. According to the screening model the outcome of a firm increases due to the information on educational attainment, while the signalling model only explains the wage differentials. Hence the signalling model can be described as a special case of the screening model (firms organize only one task).[2]

The distinction between general and specific human capital is also an important aspect for firms' personnel policy (Becker (1962); Johnes (1993)). Thereby general human capital is defined as individual knowledge and skills which can be beneficial for all firms in the market. In contrast, firm-specific human capital is only useful for a single firm which implies that the worker is less productive in other firms. This explains why workers with highly specific skills are less likely to search for a new job, since the prospective employer offers lower earnings. On the other hand, specific human capital protects the worker to be laid off during an economic recession, since the current employer necessitates the firm-specific knowledge. Individuals need time to acquire the specific human capital which is associated with further costs for the employer. Since general human capital is portable, workers have more job opportunities in the market. In this case the individuals do not have to fear a lower wage offer when they search for a new job. The disadvantage of general human capital is the fact that employers can easily replace workers. The distinction between general and specific human capital is also helpful to explain why firms invest in training of their personnel.

Initially, the economics of eduction was seen as a topic of labor economics, and

[2]Finding empirical evidence for the human capital theory or the signalling/screening model is very difficult, since we observe a positive correlation between earnings and education in both cases. The early empirical study of Layard and Psacharopoulos (1974) tests the screening model in three ways and shows more evidence for the human capital theory, i.e. education improves individual knowledge and skills. This result is confirmed by Chevalier et al. (2004) who evaluate the response of students to a change in minimum school leaving age in the UK. For the Italian labor market Castagnetti et al. (2005) find evidence for the screening model. The authors compare the educational private returns of self-employed with employees. Overall, all authors point out to be careful with the interpretation of the estimated effects, since the empirical estimation strategy is problematic.

research activities focused on labor market phenomena. By including aspects of public finance and welfare economics the fields of interests expanded and the economics of education became a distinct sub-discipline (Johnes (1993)). In this context, the social returns to education were discussed,[3] for instance the positive effect of educational attainment on health behavior. A large body of empirical literature suggests that the age-specific rates of physical impairment, disability and mortality are negatively correlated with education (Ross and Wu (1995); Rogers et al. (1999); Lauderdale (2001); Mirowsky and Ross (2003)). Furthermore the relation between educational attainment and crime was analyzed both theoretically and empirically in several studies (Glaeser et al. (1996); Freeman (1999); Lochner (2004); Lochner and Moretti (2004); Machin et al. (2011)). As described above, educational attainment improves the wage offers and the labor market opportunities which implies a lower incentive for crime. Finally, education is seen as a crucial element for a vibrant democracy with participating citizens (Barro (1999); Glaeser et al. (2004); Glaeser and Ponzetto (2007); Papaioannou and Siourounis (2005)). Every society must decide about the optimal allocation of resources which is a complex issue. The educational attainment of citizens is beneficial for determining the best solution. All these effects describe positive externalities of education.

Beside external effects a further argument for state provision of education is the imperfect capital market. The reason for market failure is the uncertainty on both sides. On the one hand individuals cannot be sure whether their investments in education will be successful or not. Since the acquisition of knowledge needs time, it is difficult for individuals to foresee the future income. On the other hand the capital side cannot anticipate financial securities in the case of credit default, since individual human capital is not disposable like a materialistic good. These restrictions justify a redistributive state intervention in the education system.

Moreover the free access to education is a basic human right:

> *"Everyone has the right to education. Education shall be free, at least in the elementary and fundamental stages"*[4]

This Article of the Universal Declaration of Human Rights makes clear that education has a high priority in society and is not comparable with other goods. An efficient human capital accumulation is not the only goal which a government tries

[3]For a comparison of private and social returns of education see Psacharopoulos and Patrinos (2004).

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

to achieve. It is also important to guarantee equality of opportunities for all individuals, i.e. educational attainment depends only on individual effort and not on circumstances which cannot be influenced by the individual (Roemer (1993)).[5] According to equality of opportunity policy governmental intervention is successful when it decreases the influence of the socio-economic background, so that all individuals with the same amount of effort achieve the same educational attainment. The theory of equality of opportunities differs from the classical social choice theory, since it is not only based on outcome maximization and the distribution of outcome (welfarism). It also analyzes the correlation between individual effort and outcome. Education is a human right, but the welfarism approach does not capture the issue of civil rights (Sen (1979); Roemer (1998)). In addition, the theory of equality of opportunities differs from meritocracy, too. According to the meritocracy approach those individuals benefit who are most likely high productive measured by the outcome (regardless of their socio-economic background). Since the theory of equality of opportunities compensates for private living conditions, those individuals benefit who invest the most efforts. In general, a society must solve the conflict between an efficient outcome and fairness. Finding the solution to this conflict makes the economics of education one of the most interesting and exciting fields of research.

This dissertation provides new insights into four issues of education policy. In the first two chapters I analyze two different aspects of the primary and secondary school policy. The aim of chapter 1 is to set up a theoretical framework which helps us to understand why misallocation of students can be observed after the first tracking decision and to determine the decisive factors for the optimal timing of tracking. The preferred duration of secondary school is analyzed by a political economy model in chapter 2. With regard to the ongoing public debate about the reduction of secondary school length in Germany I examine the parental choice of teaching intensity which determines the duration of schooling. The second part of my dissertation focuses on empirical analyses of tertiary education. Thereby I evaluate both important duties of a university - teaching and research activities. Chapter 3 discusses the impact of tuition fees on students' teaching evaluation and thus on the perceived quality of teaching activities at the University of Munich. The

[5] In contrast, Dworkin (1981) argued for equalization of resources, since society is not responsible for individual "expensive taste". His approach was criticized by Arneson (1989) and Roemer (1993) and replaced by the idea of equality of opportunities. Thus not all individuals get the same resources to acquire knowledge and skills from the beginning, but the government compensates all individuals for their different circumstances.

last chapter delivers an insight into the relative efficiency of German universities and the impact of the Excellence Initiative (a performance-based funding program) on the competition between public universities.

As previously described, the economics of education started with the analysis of human capital. By using Mincerian earnings functions several studies try to measure the value of human capital. This empirical approach is based on estimating the difference in labor market outcome due to a different level of educational attainment. However, these studies neglect that individuals accumulate their human capital in an education system. Thus the human capital accumulation depends on the institutional setting of schools and the socio-economic background (Hanushek et al. (2011)). In this context, the latest international student achievement tests[6] created a new opportunity to measure human capital. Since these math, science and reading performance tests for students are standardized, cross-country analysis can identify the crucial determinants of an efficient human capital accumulation which guarantees equality of opportunities for all individuals.[7] The timing of tracking is an important institutional feature and the motivation for the first chapter in my dissertation.

The selection of students according to their innate ability generally covers tracking and streaming (Meier and Schütz (2008)). In both cases the education system pursues the goal to support each student according to his/her abilities and to use the advantage of a homogeneous students composition (tracking advantage). For this purpose, all students will be selected into different secondary school tracks after primary schooling. Decisive for this decision is the evaluation of students' skills, which is not only influenced by child's innate ability, but also by the individual socio-economic background. In our theoretical framework parents maximize their utility level over the choice of their financial effort for child's education. Therefore, it is possible that misallocation after the tracking decision occurs and decreases the tracking advantage. Misallocation is defined as assigning a low ability student to the high track (overachiever) and a high ability student to the low track (underachiever). The differences in family income cause misallocation after tracking which is a new contribution in the education literature. Previous theory approaches explain the

[6]The Programme for International Student Assessment (PISA) tests the achievements of 15-year-olds on a three-year cycle since 2000, the Trends in International Mathematics and Science Study (TIMSS) is specialized in testing the math and science performance of eighth-graders on a four-year cycle since 1995 and the Progress in International Reading Literacy Study (PIRLS) measures the reading capabilities of primary school students on a five-year cycle since 2001. Thus we are able to evaluate the human capital accumulation in primary and secondary school.

[7]For a general overview see Hanushek et al. (2011).

incorrect selection of students by an exogenous noise which influences students' human capital. Thus my theoretical framework relates to the latest empirical results which show the influence of the socio-economic background on the tracking decision (Hanushek and Wößmann (2006); Wößmann (2008); Schütz et al. (2008)). Furthermore I evaluate the consequences of an inefficient students composition for human capital accumulation and social welfare.

A second important institutional feature of the education system is the duration of secondary school which is analyzed in chapter 2 of the thesis. In comparison to other OECD countries the German graduates of the high secondary school (so called Gymnasium) are older than their counterparts from other education systems.[8] Hence most of the federal states reduced the secondary school length by one year to allow for an earlier access to the labor market. The authorities decided to keep the academic curriculum constant, in order to guarantee the same quality standard as before. As a consequence, the extent of afternoon classes due to a higher teaching intensity increased and hence school became more demanding. Furthermore a higher level of teaching intensity constrains students' leisure activities. Under the massive public criticism the decision process about the secondary school length was decentralized by several federal states in 2011, i.e. parents decide about the secondary school length for each school. In this context, I use a simple political economy model of school duration to analyze the voting behavior of parents who decide about the teaching intensity. The parents differ in two characteristics: family income and the child's innate ability. I can show that if the parents vote on the teaching intensity, families with a higher income and highly skilled children prefer a higher teaching intensity and so a shorter duration of schooling. Our theoretical implications are in line with empirical results in the literature (Heller (2008)) and contribute to the equality of opportunity debate. Since a faster graduation can be interpreted as a signal of human capital quality and hence improves the expected wage offer and job opportunities of an individual, our political economy model shows new and important implications for education policy.

The second part of my dissertation analyzes the efficiency of tertiary education from two perspectives. Before we can start to measure the performance of a decision making unit, we first have to determine which goals are pursued by the institution. In contrast to the primary and secondary schools, higher education institutions

[8] A survey of the OECD (2005) shows that German students are on average 19 years old at graduation, while, for instance, in the Netherlands graduation age is 17-18 years and 18 years in the US.

fulfill two duties, in particular teaching and research activities. Thus universities can be considered as multi-product firms (Johnes (1993)). Beside the organization of human capital accumulation, universities are responsible to generate new knowledge which basically differs from the function of primary and secondary education. However, the market for education is not comparable with other markets, especially in regard to market prices. The reason for this is the non-rivalness and non-excludability of basic research (Johnes (1993)). Without market prices it is quite challenging to identify the higher education institutions which are at the bottom line of performance. Therefore, the evaluation of universities' performance depends at first on the observed function (teaching or research activities), and secondly on the chosen measures for input and output factors.

In chapter 3 we examine the impact of introducing tuition fees on the students' teaching evaluation. Thereby we use the unique situation in German tertiary education which has been exclusively financed by public funds for nearly four decades. The introduction of tuition fees in the summer semester 2007 was controversially discussed between political parties and in public. Since the 16 federal state governments are responsible for the higher education system, not all universities charged tuition fees. However, the universities with tuition fees guarantee that the entire fund from students' private investments are only used to improve teaching activities, in order to ensure a large acceptance among students. A large body of literature (Cohen (1981); Kulik (2001); Perry et al. (2007)) is concerned with the validity of students' teaching evaluation and the important determinants of teaching quality perceived by students. For our purpose, we use a Difference in Difference approach and analyze students' teaching evaluation of the University of Munich (treatment group), which introduced tuition fees to the amount of 1000 Euro per year in the summer semester 2007. The students' teaching evaluation of the Humboldt University of Berlin is used as control group in our estimation model. During our observation period from 2004 to 2009 the Humboldt University of Berlin did not charge tuition fees. Our sample comprises 1.701 economics classes held by 491 instructors. Controlling for instructor and course fixed effects, we find that the introduction of tuition fees had a substantial positive impact on student evaluations of instructor effectiveness. The effect implies an improvement of up to one third of a grade. Our findings are interesting for the current political discussion in tertiary education policy, since the State of Bavaria abolished tuition fees again from winter semester 2013/2014.

Finally, I analyze the relative efficiency of German universities according to research activities. The introduction of the Excellence Initiative in 2006 was a novelty in German tertiary education and at the same time a remarkable change of previous policy. Since German universities are largely funded by taxes, the idea of supporting a small group of universities with additional financial resources and an elite status was rejected. The Excellence Initiative has the aim to improve international competitiveness of German universities with respect to research activities by performance based funding. To ensure competition between the universities the duration of financial support is limited and can only be extended by a new successful application. Our paper analyzes the impact of the Excellence Initiative on the competition between German universities by the use of two different approaches, the Data Envelopment Analysis and the Malmquist index. Our findings suggest that the reward decision was rather based on objective efficiency reasons than on political influence. Furthermore we show that the idea of competition between the universities is not harmed by the Excellence Initiative. Since it is not clear whether the Excellence Initiative will be continued after the year 2017, our analysis also has an important policy implication for the performance based funding of higher education institutions.

Overall, the present doctoral dissertation discusses several aspects of education policy. The derived results may help to understand certain issues of primary/secondary schools as well as higher education institutions, and to provide new insights for the efficiency and the equality of opportunities of the human capital accumulation.

Part I.

When is the right time to say goodbye? The influence of tracking on students composition and school success

1 Introduction

An education system with tracking intends to achieve the best possible school success for each student given the individual capabilities. Therefore, each schooling track is endowed with specially educated teachers, a separate funding and a particular academic curriculum. School authorities pursue the goal to achieve optimal learning conditions for a homogeneous composition of students within each school track according to the individual innate ability.

The aim of our paper is to set up a theoretical framework which helps us to understand why misallocation of students can be observed after the first tracking decision and to determine the decisive factors for the optimal timing of tracking. In our model, misallocation is defined as assigning a low ability student to the high secondary school track (overachiever) and a high ability student to the low track (underachiever). Thus it is a measure for students' homogeneity according to their innate ability in secondary school tracks. Parents derive utility from consumption and the entire child's human capital. Educational attainment does not only depend on students' innate ability but also on the parental support. Low ability students are able to be qualified for high secondary school if family income is high enough. Vice versa, high ability students with a not favorable financial endowment can fail the governmental requirements for a high school track. Students composition in secondary school determines the quality of human capital through the peer group effect, the difference between high and low ability students in class. Hence our analysis is focused on efficiency of tracking and the impact on equity of opportunities.

The first selection of students into different secondary school tracks usually takes place after six to nine years of primary schooling in OECD countries (Meier and Schütz (2008)). The tracking decision is largely influenced by ability achievement tests and evaluation of student's future prospects by teachers. Usually the secondary school is divided into two main tracks after primary school, a high school track for the most talented students with the aim to provide an academic education, while the low school track rather represents a vocational education. Some education systems, for instance in the USA, organize ability grouping of students not by tracking, but by streaming. In contrast to tracking, students are only allocated to different courses according to their capabilities within a school and are not forced to visit a different institution. Of course, both methods can lead to different results due to the change of the school environment. Although the difference between tracking and streaming is important for empirical analysis (Meier and Schütz (2008)), our theoretical approach is convenient for both types of ability grouping, since we focus on peer group effects and the problem of misallocation.

In this context, the timing of tracking is a controversial issue in policy debates. Dustmann (2004) shows for Germany that the wage level differs considerably between the three secondary school tracks.[1] In comparison to other OECD countries the duration of the German primary school is with four to six years relatively short. Initiated by the impressive success of Scandinavian countries in standardized PISA tests, some German states increased the duration of primary school.[2] Supporters of delayed tracking point out that an early selection of students leads to increasing influence of the family background on school success and hence to decreased social mobility (Bauer and Riphahn (2006); Wößmann (2008)). Furthermore the efficiency of early tracking is often criticized, especially in terms of students composition according to their innate ability.

Schnepf (2002) shows by the mean of the TIMSS 1995 data set that the performance of students from the three different secondary school tracks coincides. The international math and science study measures the capabilities of seventh grade students by standardized achievement tests. For the German case Schnepf (2002) shows that 36 percent of low school students *(Realschule*) do better than the lower performance quartile of high track students (*Gymnasium*). Even eight percent of *Hauptschule* students achieved more test scores than the lower performance quartile of the supposedly most skilled children in the education system.

Uhlig et al. (2009) use data from the German SOEP panel and analyze the birth cohorts of 1987/1988 and 1989/1990. These individuals had to perform a fluid intelligence test (Cattell (1987)) when they were 17 years old, in order to test their innate capabilities. The authors group 855 test persons according to their secondary school track and show the existence of similar performance profiles. Furthermore Uhlig et al. (2009) differ between students who perform better than the 50 percent threshold of *Gymnasium* students, the so called underachievers, and students who

[1] Some German states have additionally to the Gymnasium (high track) and the Realschule (low track) also a third school type: the Hauptschule. This lowest track is for low skilled students in order to ensure a practical schooling. However, due to a decreasing demand the Hauptschule is combined with the Realschule in many federal states and thus a shrinking factor in the German school system.

[2] For instance, in Berlin and Brandenburg ability grouping starts at the age of 12 instead of ten.

show a lower extent of intelligence than the median of the low school track, the so called overachievers. They estimate that about 30 percent of all German students visit the wrong secondary school track according to their innate abilities. More precisely 17 percent of all students are underachievers and 13 percent are overachievers. In summary, Uhlig et al. (2009) observe a large extent of misallocation after the first tracking decision. Of course, these findings are disastrous for an education system which is based on the advantage of a homogeneous students composition. The question is put why students can be misallocated.

Stern and Hardy (2004) show that only a small share of 12 to 26 percent of school success can be explained by the differences in intelligence tests. For instance, educational factors like the quality of teachers and student's family background play an important role for school career. It is obvious that the institutional structure of an education system reflects a major influence on equality of opportunities. Hanushek and Wößmann (2006) and Wößmann (2008) reveal with the PIRLS 2001 study and the data sets of PISA 2000 and 2003 that early tracking has a negative impact on equality of opportunities. The variable "amount of books at home" is taken as a measure for the influence of socio-economic background on school success for two reasons. On the one hand, books are expensive and so they are a proxy variable for family income, on the other hand, they are an indicator for the parental attitude to education. These results are supported by the analysis of Schütz et al. (2008) who use the same empirical method for both TIMSS data sets.

The chapter is structured as follows: In Section 2 we sum up the related literature on tracking and peer group effect. Our theoretical framework is presented in Section 3, while Section 4 focuses on the analysis of human capital accumulation and social welfare. Finally we conclude in Section 5.

2 Related literature

The basic idea of ability grouping is the use of a specialization advantage due to homogeneous classes within a school. Several studies examine the effect of peer groups on the school success of students who were selected to different tracks. A positive effect of a high quality peer group on achievement tests is shown by Summers and Wolfe (1977) and Henderson et al. (1978). By means of the mathematics test results of the National Education Longitudinal Study (NELS 1988) Argys et al. (1996) estimate a weak positive effect of detracking on low ability students, but also a negative effect on the school success of high ability students. The authors find an overall negative effect of delayed tracking and hence confirm the positive effect of homogeneous peer groups. In contrast, Hoffer (1992) and Betts and Shkolnik (2000) cannot find a positive effect of ability grouping on students' mean achievement in mathematics test scores. The reason is the unequal impact of tracking on students according to their capabilities. While low ability students show no improvements, students at the top of the ability distribution are able to achieve more test scores. The authors even estimate a negative effect of tracking on achievements of middle students. For our theoretical framework, we use the empirical finding that ability grouping is rather beneficial for high ability students than for low ability students.

The evaluation of tracking policy is not only a question of efficiency, but also of equality of educational opportunities. In this context, the empirical evidence seems to be clear. Ammermüller (2005) and Wößmann (2008) show with PIRLS and PISA data that early tracking increases the influence of socio-economic background and hence decreases social mobility of students. The authors rely on the proxy variable "books at home" which depicts both financial wealth and a positive attitude of parents towards education, to estimate the influence of family background. By analyzing the different timing of tracking in 26 cantons in Switzerland, Bauer and Riphahn (2006) show that the testing of students' innate ability is associated with noise, especially when students are quite young. Bauer and Riphahn (2006) use parental education as a proxy for the influence of family background on the probability to visit a college. Brunello and Chechi (2007) use a different outcome variable for evaluating early tracking, the wage level. Using European Community Household Panel the authors find an increased influence of family background. Thus we refer to these clear empirical results in our paper to analyze misallocation after first tracking decision and the influence of socio-economic background.

The aim of our paper is to set up a theoretical framework which helps us to understand why misallocation of students can be observed after the first tracking decision and to determine the decisive factors for the optimal timing of tracking. There is not much literature on this topic. Epple et al. (2002) evaluate the effects of ability grouping on school competition. The theoretical model compares either public schools with tracking and private schools with fees. The authors reveal that private schools have no need for implementing tracking, since these schools control their students composition by setting the appropriate tuition fees. Hence Epple et al. (2002) argue that in a competitive situation early tracking can increase welfare of public schools due to a higher number of skilled students who get attracted by the positive peer group. Moreover they predict that the winners of an education system with early tracking are students qualified for the high track, while students in the low track will lose due to a lower peer group effect. The study finds evidence that tracking leads to a correlation between parental income and child's ability in public schools. But Epple et al. (2002) do not respond to this disadvantage of early tracking in their analysis, because they focus on effects of competition between public and private schools. We add this dimension to our model, in order to evaluate the effect of early tracking on equality of opportunities.

The problematic issue of students' misallocation after the first tracking decision is pointed out by studies of Brunello et al. (2007) and **?**. Both papers are based on the same theoretical framework which assumes that parents and children share the same innate ability. The government is not able to observe student's ability but the achievement tests which are influenced by child's innate ability and an independent exogenous shock. This noise of selection becomes larger the earlier tracking takes place and is the reason for misallocation.

In contrast, parental income is perfectly uncorrelated with students' capabilities in our framework (Pedersen (2004); de Walque (2005)). If we allow for a positive correlation parents with more income will get more skilled children. This reduces misallocation, since parental income and child's innate ability are positively correlated, but misallocation still occurs. Secondly, we endogenize the reason for a sub-optimal students composition by considering parental investments for child's school success.

According to their utility function parents choose the optimal amount of investments for human capital accumulation. In our theoretical framework, misallocation does not rely on an exogenous shock like in previous studies, but is explained by heterogeneity in family income.

3 The model

3.1 Setup

We consider an economy with an exogenous number of families consisting of two parents and one child. Every family has a certain lifetime income $y \in [\underline{y}, \overline{y}]$, which is uniformly distributed with density function $f(y)$ and cumulative distribution $F(y)$. Each child has an innate ability level $a \in \{a_l, a_h\}$ with $a_l < a_h$. The education system is based on a primary school track visited by all students for a period of compulsory school time $\tau \in [0,1]$ which is normalized to one. Hence classes in primary school are heterogeneous regarding students' innate capabilities. The human capital accumulated in primary school by a child with ability a and family income y is calculated as follows:

$$H^p(\tau) \quad = \quad [a + e(y)]\tau \tag{I.1}$$

where e characterizes monetary efforts respectively investments of parents for the first stage of the education system which depends on family income.

While classes are heterogeneous in primary school, students composition in the secondary school track is much more homogeneous and hence influenced by a peer group effect. A student can either go for the period of time $(1-\tau)$ to the high school track (academic) or to the low school track (vocational). Human capital generated in the high school track is calculated as follows:

$$\begin{aligned} H^h &= H^p \gamma m_h (1-\tau) \\ &= [a + e(y)]\tau\gamma m_h (1-\tau) \end{aligned} \tag{I.2}$$

where m_h describes the tracking advantage of high secondary school which only lasts for period of time $(1-\tau)$. Classes in secondary school are more homogeneous in comparison to primary school, consequently teachers have better teaching conditions. Furthermore it is beneficial for students to learn in an adequate peer group (Summers and Wolfe (1977); Henderson et al. (1978); Argys et al. (1996)). The lowest level of m_h is limited to one, i.e. students accumulate human capital in the same way as in primary school (heterogeneous peer group). Accordingly the tracking advantage m_h equals one when no improvement with regard to heterogeneous primary school class occurs. The exogenous parameter γ captures the productivity advantage of high secondary school in relation to the low school track due to a higher share of high ability students. This productivity advantage is the reason why parents want to send their child to the academic school. Human capital accumulation in secondary school is based on the entire human capital after primary school H^p. Thus we assume that student's human capital which was built up in primary school is not getting lost after tracking. In addition, this setting implies that a high level of student's achievement at the first stage of education system leads to better academic results at the second stage. If H^p equals zero then there is also no human capital accumulation in the secondary school track.[3] Families take tracking advantage m_h as an exogenous parameter when they decide about their monetary efforts. In equilibrium it will depend on the extent of misallocation in secondary school, thus the difference between high and low ability students:[4]

$$m_h(n_h, n_l) \quad = \quad 1 + (n_h - n_l) \tag{I.3}$$

We denote the share of children with ability level a_h who are selected to the high school track by n_h, while n_l describes the share of students with ability level a_l who are qualified for the academic school. The larger the share n_h in comparison to n_l, the higher is the tracking advantage for all students of high secondary school due to an improved peer group. Hence tracking advantage increases with a lower share of low ability students who tend to be an encumbrance for high ability students with regard to learning progress (Meier and Schütz (2008)). In this context, the tracking advantage m_l occurs in the vocational school track and captures the difference between low and high ability students. Since low secondary school is exclusively for low ability students (vocational curriculum, trained teacher for low ability students), tracking advantage m_l increases with a higher share of low ability students $(1 - n_l)$:

$$\begin{aligned} m_l(n_h, n_l) &= 1 + [(1 - n_l) - (1 - n_h)] \\ &= 1 + (n_h - n_l) \\ &= m_h = m \end{aligned} \tag{I.4}$$

[3]Hence we assume that without the fundamental skills of literacy and numeracy which are learned in primary school, students are not able to build up human capital in the secondary school.

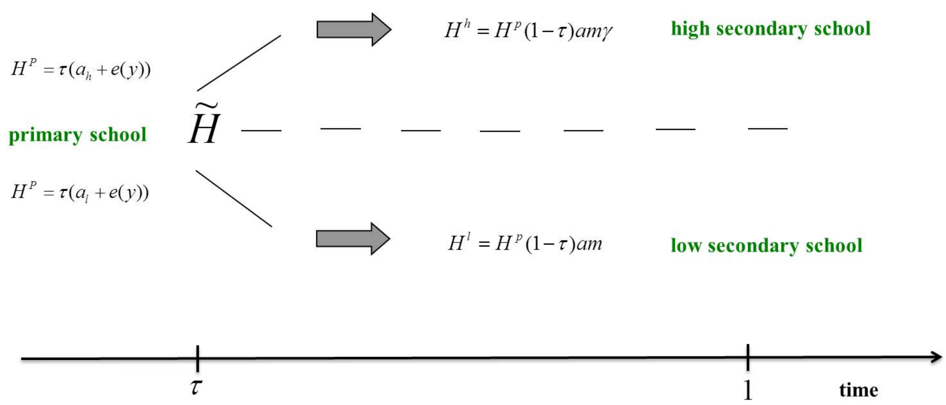
[4]In general, there are many ways to determine the tracking advantage, for instance as the ratio between high and low ability students or to use the average ability in a class. For our theoretical analysis, it is important to get clear results for a change in tracking advantage m_h with respect to the share of high and low ability students. This is guaranteed by the given difference in equation (I.3).

$$H^l = H^p m(1-\tau)$$
$$= [a+e(y)]\tau m(1-\tau) \quad \text{(I.5)}$$

Thus tracking advantage m is equal in both secondary school tracks. This means that improving students composition in high school track leads also to a better peer group in the low secondary school. The academic school becomes more productive than the low school track as soon as the share of high ability students is higher than the share of low ability students. Hence tracking advantage m of academic school track increases with an improved allocation of students after tracking. The institutional factor γ depicts the productivity advantage of high school track and the incentive for parents to send their child to the academic school.[5]

As you can see from human capital function (I.2), all students of the high school track benefit in the same way from the positive impact of the tracking advantage m. The positive peer group effect for students with a lower ability level in higher secondary school is a reason for this assumption. High ability students benefit from the higher share of students with the same innate ability and the improved learning conditions. Accordingly, all students benefit from tracking advantage m in low secondary school. Although it is the aim of authorities to select students into different secondary school tracks according to their innate capabilities, so that all children with a_h go to the academic and all children with a_l visit the vocational school, misallocation due to the influence of parental effort is possible.

Figure I.1.: Timing of tracking



[5] Dustmann (2004) shows that graduation at different secondary school tracks leads to significant wage differentials. These earnings differentials express the productivity dispersion due to different students composition.

Figure I.1 shows the education system at a glance. High and low ability students visit primary school and will be selected to different secondary school tracks after period of time τ. The government is not able to observe the innate ability of students but the test results which are influenced by innate ability and parental effort. In this way students build up their human capital H^p which is the base for the tracking decision. Students' human capital must exceed a threshold $\widetilde{H}$ to be qualified for the high school track, while all other students will be allocated to the low track. It is obvious that also low ability students can visit the academic school track, if family income is high enough to compensate student's low innate capability and to exceed $\widetilde{H}$. Vice versa a high ability child can fail qualification for high secondary school track due to a not favorable financial endowment of the parents.[6] These differences in family income are the explanation for misallocation in secondary school.

3.2 Timing of decision

In our education system with tracking, the government has two policy instruments. First authorities decide about primary school duration τ. The advantage of early tracking is the impact of m on human capital accumulation in secondary school track which lasts for (1-τ) (equation (I.2) and (I.5)). The problem of the government is the ignorance of child's innate ability. This is the reason for a compulsory primary school for all students at the beginning of school time in order to screen capabilities by achievement tests. However, human capital accumulation of students is not only based on innate ability but on parental effort, too. The influence of the socio-economic background is the reason for misjudgment of students' innate ability and hence for misallocation after tracking decision. The extent of misallocation determines the quality of the peer group in the secondary school track and consequently the tracking advantage (equation (I.3)). The government maximizes the aggregated utility of all families.

The second important policy instrument is the critical threshold of human capital $\widetilde{H}$ which a student has to pass for visiting the high school track. Accordingly, every student who has $H^p < \widetilde{H}$ visits the vocational school track. Rationally the government chooses a threshold $\widetilde{H}$ which guarantees that all students with innate ability a_h are selected to the academic school track, while students with a_l have to

[6] Thus the critical human capital $\widetilde{H}$ has to be at least as high as human capital of a high ability child without parental support in primary school (τa_h), otherwise all high ability students would be selected automatically to high secondary school.

visit the vocational track. Simultaneously the choice of $\widetilde{H}$ restricts the number of students who can visit the high secondary school track. This effect on the entire human capital accumulation has to be considered by the government, too.

After the essential variables of education system (τ and $\widetilde{H}$) are determined, parents choose their optimal effort for human capital accumulation of their child. Parents decide on effort according to their utility-function:

$$u = ln(y-\tau e)+\delta ln[\tau(a+e)+H^s], \text{ with } s \in \{l,h\} \tag{I.6}$$

where H^s represents total individual human capital built up in secondary school track (low or high track). Parental utility depends on parental consumption and child's entire human capital after compulsory school time weighted by parameter δ. One may interpret δ as a measure of parental altruism or status seeking. Parents can spend a part of their income e for primary education. Of course, this is associated with a lower consumption level.

At the last stage all students build up their individual human capital given their innate ability a, parental effort e and the two policy instruments (τ and $\widetilde{H}$).

In summary:

1. The government chooses timing of tracking τ and governmental requirements $\widetilde{H}$ by maximizing the aggregated utility of all families.

2. Parents choose their parental effort for child's education by maximizing their utility.

3. All students accumulate human capital given innate ability a, parental investment e and the two policy instruments (τ and $\widetilde{H}$).

We solve our model by backward induction.

3.3 Results

First students accumulate their human capital for a given level of innate ability a, parental effort e, duration of primary school τ and critical threshold $\widetilde{H}$.

Families maximize their utility with respect to parental effort e as follows:

$$\frac{\partial u}{\partial e} = -\frac{\tau}{y-\tau e}+\delta\frac{\tau+\frac{\partial H^S}{\partial e}}{\tau(a+e)+H^s} = 0 \tag{I.7}$$

For our theoretical framework it is important to distinguish between three cases: On the one hand financial parental effort has an impact on human capital accumulation in the secondary school track ($\frac{\partial H^S}{\partial e} > 0$). In this situation the child will be qualified either for academic or vocational school. In both cases further human capital accumulation depends on educational achievements in primary school and on parental effort. On the other hand human capital in the secondary school is not influenced by parental effort ($\frac{\partial H^S}{\partial e} = 0$), so children always get just enough parental support to be qualified for the academic school track. In this case parents ensure that their child will benefit from the productivity advantage of high school track γ and guarantee that their child pass the critical threshold ($H^p = \widetilde{H}$).

Parents maximize their utility with respect to parental effort e for the case that the child passes the critical human capital threshold $\widetilde{H}$ and visits the high school track. Thus we can insert H^h for H^s in equation (I.6). The optimal parental effort level can be written as follows:

$$e^h(\tau) \quad = \quad \frac{y\delta - a\tau}{(1+\delta)\tau} \tag{I.8}$$

$$e^h(\tau) \quad \geq \quad 0, \ if\, y \geq \frac{a\tau}{\delta} = \hat{y} \tag{I.9}$$

Secondly we can calculate the optimal effort for a student who will not be qualified for the academic school track and is selected to the low secondary school track. We insert H^l for H^s in equation (I.6):

$$e^l(\tau) \quad = \quad \frac{\delta y - a\tau}{(1+\delta)\tau} \tag{I.10}$$

$$e^l(\tau) \quad \geq \quad 0, \ if\, y \geq \frac{a\tau}{\delta} = \hat{y} \tag{I.11}$$

In both cases parental effort increases with δ ($\frac{\partial e^h(\tau)}{\partial \delta} > 0, \frac{\partial e^l(\tau)}{\partial \delta} > 0$), since the value of child's education is increasing. Obviously, parents spend more financial resources for education if family income increases ($\frac{\partial e^h(\tau)}{\partial y} > 0, \frac{\partial e^l(\tau)}{\partial y} > 0$) due to the decreasing marginal utility of income. Parental effort is higher for low skilled students ($\frac{\partial e^h(\tau)}{\partial a} < 0, \frac{\partial e^l(\tau)}{\partial a} < 0$). Thus parental support is rather a substitute for school resources than a complement (Houtenville and Conway (2007)). Students receive more financial resources when it is more required. With respect to τ (tracking decision) the derivatives of $e^h(\tau)$ and $e^l(\tau)$ are negative:

$$\frac{\partial e^h(\tau)}{\partial \tau} = \frac{\partial e^l(\tau)}{\partial \tau} = - \frac{y\delta}{(1+\delta)\tau^2} < 0 \tag{I.12}$$

This means that parents reduce their financial support for child's education if tracking decision is delayed. The earlier tracking takes place, the higher is the influence of family income in comparison to innate ability. Thus it is easier for a low ability child to be qualified for the academic school track when parents have enough financial resources. Hence the extent of misallocation in the secondary school track should decrease with τ, since a higher share of human capital is based on child's innate ability which is constant over time.

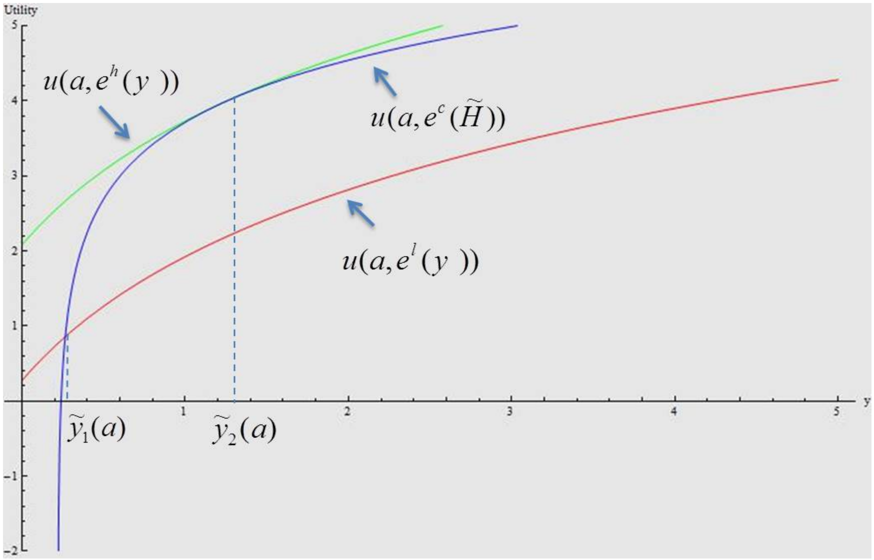
Finally we analyze the third case, i.e. parents spend just enough of their income to guarantee the critical threshold $\widetilde{H}$ and consequently the child visits the academic school track ($\frac{\partial H^S}{\partial e} = 0$). In this situation students always achieve a human capital, which is as high as the governmental requirements ($H^p(e^c) = \widetilde{H}$). Thus the critical effort level, which is necessary to accumulate $\widetilde{H}$, can be described as follows:

$$e^c(\tau) = \frac{\widetilde{H} - a\tau}{\tau} \tag{I.13}$$

It is obvious that $e^c(\tau)$ is independent of family income due to the restriction that in this special case parents always spend just the necessary amount of financial support to guarantee the qualification for the academic school track. The critical threshold $\widetilde{H}$ is mainly responsible for the determination of $e^c(\tau)$. With increasing governmental requirements $\widetilde{H}$ parental effort increases, too ($\frac{\partial e^c(\tau)}{\partial \widetilde{H}} > 0$). According to the previous results a delayed tracking decision leads to a decreasing parental support because of the stronger influence of child's innate ability.

In the next step we compare the different utility levels for all three cases. Our aim is to determine the critical income threshold $\widetilde{y}_1$ which guarantees a qualification for high secondary school track. Figure I.2 illustrates the three cases.

Figure I.2.: Comparison of the three possible utility levels



Own simulation with $\delta = 1$

The green curve depicts the utility level of parents as a function of family income for case one $u(a,e^h(\tau))$. Since a student visits the academic school track and benefit from the productivity advantage γ, the curve lies above the red one which represents utility for parents with a child who is selected to the vocational school track $u(a,e^l(\tau))$. In both situations parents can choose the optimal combination of private consumption and investments in child's education. In contrast, the blue line shows the utility level $u(a,e^c(\tau))$ of a family whose child attends high secondary school and gets just enough financial support for passing governmental requirements. In this case the utility level can even be negative, especially for low income families due to the relatively high marginal utility loss of consumption. Remember, in case three parents spend independently from own income just enough financial resources to ensure a qualification for high school track.

Furthermore Figure I.2 shows that the blue curve generates less utility for low income parents than case one or two. This is true until the blue and red curves intersect $(u(a,e^l(\tau)) = u(a,e^c(\tau)))$. From this critical income threshold it is worth to invest $e^c(\tau)$ for child's education instead of spending less effort and accepting the vocational track. Hence the point of intersection defines our critical income threshold $\widetilde{y}_1$ from which all students will visit high school track (for calculation we assume $\delta = 1$):

$$\widetilde{y}_1(a) \quad = \quad 2\widetilde{H} \cdot g(\tau,m,\gamma) - a\tau \qquad \text{(I.14)}$$

where $g(\tau, m, \gamma)$ describes the part of $\widetilde{y}_1(a)$ which is independent of $\widetilde{H}$ and child's innate ability (see Appendix A 2). Students with family income below $\widetilde{y}_1(a)$ are selected to the low secondary school, since parents benefit from a higher marginal utility of consumption in this case. Obviously the critical income threshold is dependent on the child's innate ability. Parents with a high ability child do not invest the same extent of effort for guaranteeing academic school track than parents with a low ability child. By using the implicit function theorem (see Appendix A 2) we are able to show that the critical threshold $\tilde{y}_1$ is decreasing with a ($\frac{\partial \tilde{y}_1}{\partial a} < 0$), thus we state:

$$\widetilde{y}_1(a_l) \quad > \quad \widetilde{y}_1(a_h) > 0 \tag{I.15}$$

which implies that students with a high innate ability do not require as much financial support to be qualified for the high school track as low ability students. However, low ability students with family income $y \in [\widetilde{y}_1(a_l), \overline{y}]$ are selected to the high secondary school. This confirms our theory that the differences in parental income respectively the heterogeneity in socio-economic background causes misallocation of students after the first tracking decision. The disadvantage of innate ability can be compensated by financial support of parents. Note again that in our model misallocation is defined as assigning a low ability student to the high secondary school track (overachiever) and a high ability student to the low track (underachiever).

Proposition 1: Since the government can only observe achievement tests which reflect both, innate ability and parental effort, low ability students with a family income of $y \in [\widetilde{y}_1(a_l), \overline{y}]$ and high ability students with $y \in [\widetilde{y}_1(a_h), \overline{y}]$ are selected to the academic school track. All other students have to visit the low school track.

We want to point out that without a critical income threshold $\widetilde{y}_1(a) > \underline{y}$ selection of students would not occur in our theoretical framework, since all students are able to visit the high school track. Therefore we have to assume two conditions for $\widetilde{y}_1(a)$ in order to observe tracking in our educational system. First parental utility $u(a, e^c(\tau))$ has to be smaller than $u(a, e^l(\tau))$ from the beginning of the family income distribution ($\underline{y}$):

$$u(a, e^c(\tau)) \mid_{y=\underline{y}} \quad < \quad u(a, e^l(\tau)) \mid_{y=\underline{y}} \tag{I.16}$$

Otherwise, low income parents generate more utility from spending just enough financial resources for high secondary school than for accepting the low school track. Again we cannot observe a selection of students. Moreover this could lead to an unrealistic scenario if both utility curves intersect with higher income. This means that low income parents invest just enough to send their child to high secondary school, while middle and high income families are better off with a child in the low track.

Secondly, the slope $\frac{\partial u(a,e^c(\tau))}{\partial y}$ (third case) has to be steeper from the minimum income $\underline{y}$ to the critical income threshold $\widetilde{y}_1(a)$ than the slope $\frac{\partial u(a,e^l(\tau))}{\partial y}$ (second case) to get an intersection point. Thus we assume the following condition:

$$\begin{aligned} \frac{\partial u(a,e^c(\tau))}{\partial \widetilde{y}_1} &> \frac{\partial u(a,e^l(\tau))}{\partial \widetilde{y}_1} \\ \frac{1}{\widetilde{y}_1 + a\tau - \widetilde{H}} &> \frac{1+\delta}{\widetilde{y}_1 + a\tau} \end{aligned} \tag{I.17}$$

Both conditions for $\widetilde{y}_1(a)$ depend on the governmental requirements $\widetilde{H}$. In our model tracking occurs if $\widetilde{H}$ is high enough, so that a certain share of students cannot reach the critical human capital for high school track. Thus equation (I.16) and (I.17) describe the necessary conditions for tracking. Otherwise high and low ability students stay together in secondary school and do not benefit from a tracking advantage.

Furthermore we calculate the change of $\widetilde{y}_1(a)$ with respect to governmental requirements $\widetilde{H}$ and tracking advantage m (see Appendix A 2):

$$\frac{\partial \widetilde{y}_1(a)}{\partial \widetilde{H}} > 0 \ \textit{and} \ \frac{\partial \widetilde{y}_1(a)}{\partial m} < 0 \tag{I.18}$$

With increasing governmental requirements parents have to spend more financial resources to pass the critical human capital and to guarantee the high school track for their child. As a consequence, less students get qualified to the academic school and the critical income threshold increases. Parents benefit more from investments in a child's education with increasing tracking advantage m, so that now families with lower income are willing to spend just enough to achieve $\widetilde{H}$ for their child.

Finally, we analyze the influence of the policy instrument τ on the critical income threshold $\widetilde{y}_1$. By using the implicit function theorem we evaluate the intersect of utility $u(a, \widetilde{y}_1, e^l(\widetilde{y}_1))$ (second case) and $u(a, \widetilde{y}_1, e^c(\widetilde{H}))$ (third case):

$$G = u(a, \widetilde{y}_1, e^l(\widetilde{y}_1)) - u(a, \widetilde{y}_1, e^c(\widetilde{H})) = 0 \tag{I.19}$$

$$\frac{d\tilde{y}_1}{d\tau} = -\frac{G_\tau}{G_{\tilde{y}_1}} \gtreqless 0 \text{ , } with\, G_{\tilde{y}_1} < 0 \tag{I.20}$$

$$\begin{aligned} G_\tau = \frac{\partial G}{\partial \tau} &= \frac{\partial u(a, \widetilde{y}_1, e^l(\widetilde{y}_1))}{\partial \tau} - \frac{\partial u(a, \widetilde{y}_1, e^c(\widetilde{H}))}{\partial \tau} \\ &= a\left[\frac{1}{\widetilde{y}_1 + a\tau} - \frac{1}{\widetilde{y}_1 + a\tau - \widetilde{H}}\right] \\ &\quad + \delta\left[\frac{a}{\widetilde{y}_1 + a\tau} - \frac{m}{1 + m(1-\tau)} + \frac{\gamma m}{1 + \gamma m(1-\tau)}\right] \gtreqless 0 \end{aligned} \tag{I.21}$$

The first term in equation (I.21) depicts the utility difference between case two and three which is caused by the change of parental consumption. In both cases the sign is positive, since parents reduce their financial support with increasing τ. Due to our condition for a relevant tracking in our educational system (equation (I.17)), the overall effect is negative, while the second part is positive (for $\gamma > 1$) which shows the change of a child's human capital with respect to the tracking decision. Since the critical human capital level $\widetilde{H}$ is independent of τ delayed tracking reduces human capital in the third case. For students in low secondary school we observe a trade off between the duration in primary and secondary school. The net effect is positive for tracking advantage $m \geq 1$ and $\gamma > 1$. Thus the influence of a marginal change of tracking decision τ on $\widetilde{y}_1(a)$ depends on both effects. With sufficiently high governmental requirements $\widetilde{H}$, the effect on parental consumption outweighs the effect on child's human capital. In this scenario, parents achieve more utility by investing just enough support for the high school track (case three), since delayed tracking leads to a higher decrease of financial support $e^c(\tau)$ and thus to more parental consumption. In contrast the effect on child's human capital outweighs the effect on parental consumption with a sufficiently high tracking advantage m. In this scenario delayed tracking decreases the quantitative effect of tracking advantage m and hence reduces the incentive for parents to send their child to high secondary school. This is the reason for an increasing $\widetilde{y}_1(a)$ and less students in the academic school.

Although the overall change of the critical income threshold $\widetilde{y}_1(a)$ with respect to tracking decision τ is not clear, we can see how the marginal change differs in child's innate ability:

$$|\frac{\partial \widetilde{y}_1(a_l)}{\partial \tau}| \quad < \quad |\frac{\partial \widetilde{y}_1(a_h)}{\partial \tau}|\,, \text{ for } \frac{\partial \widetilde{y}_1(a)}{\partial \tau} < 0 \tag{I.22}$$

$$|\frac{\partial \widetilde{y}_1(a_l)}{\partial \tau}| \quad > \quad |\frac{\partial \widetilde{y}_1(a_h)}{\partial \tau}|\,, \text{ for } \frac{\partial \widetilde{y}_1(a)}{\partial \tau} > 0 \tag{I.23}$$

Obviously high ability students benefit more respectively do not suffer as much as low ability students when tracking decision is delayed.

So far, we know that students with an income of at least $\widetilde{y}_1(a)$ are selected to high school track. Parents with an income $y \in [\widetilde{y}_1(a), \bar{y}]$ have enough financial resources to guarantee that their child pass governmental requirements $\widetilde{H}$. Thus students get the necessary parental effort $e^c(\widetilde{H})$ during their primary school time, while students with $e^l(y)$ are qualified for the low school track. Figure I.2 shows a second important family income threshold $\widetilde{y}_2$, which is the tangent of the green curve $u(a, e^h(y))$ and the blue curve $u(a, e^c(\widetilde{H}))$, since $\frac{\partial u(a, e^c(\tau))}{\partial \widetilde{y}_2} = \frac{\partial u(a, e^h(\tau))}{\partial \widetilde{y}_2}$:

$$\widetilde{y}_2(a) \quad = \quad \widetilde{H}(1+\frac{1}{\delta}) - a\tau \tag{I.24}$$

and

$$\frac{\partial \widetilde{y}_2(a)}{\partial a} < 0,\ \frac{\partial \widetilde{y}_2(a)}{\partial \widetilde{H}} \quad > \quad 0,\ \frac{\partial \widetilde{y}_2(a)}{\partial \tau} < 0 \tag{I.25}$$

From this parental income students receive parental investments $e^h(y)$ instead of $e^c(\widetilde{H})$ during their primary school time, since the marginal utility of consumption is so small that more parental effort is beneficial for utility.

3.4 Tracking advantage

In order to analyze the extent of misallocation at academic school track, we calculate the share of high ability students $n_h = \frac{\bar{y} - \tilde{y}_1(a_h)}{\bar{y}}$ and the share of low ability students $n_l = \frac{\bar{y} - \tilde{y}_1(a_l)}{\bar{y}}$ at the high school track. We can evaluate the change of tracking advantage m with respect to our policy instruments, the timing of tracking τ and the governmental requirements $\widetilde{H}$ (we use the implicit function theorem):

$$\begin{aligned} m(n_h, n_l) &= 1 + (n_h - n_l) \\ &= 1 + \frac{\bar{y} - \tilde{y}_1(a_h)}{\bar{y}} - \frac{\bar{y} - \tilde{y}_1(a_l)}{\bar{y}} \end{aligned} \tag{I.26}$$

$$R = \bar{y}m - 1 + \tilde{y}_1(m, \tau, a_h) - \tilde{y}_1(m, \tau, a_l) = 0 \tag{I.27}$$

$$\frac{dm}{d\tau} = -\frac{R_\tau}{R_m} \tag{I.28}$$

where

$$\begin{aligned} R_\tau &= \frac{\partial \widetilde{y}_1(m, \tau, a_h)}{\partial \tau} - \frac{\partial \widetilde{y}_1(m, \tau, a_l)}{\partial \tau} \\ &= a_l - a_h < 0 \end{aligned} \tag{I.29}$$

$$\begin{aligned} R_m &= \bar{y} + \frac{\partial \widetilde{y}_1(m, \tau, a_h)}{\partial m} - \frac{\partial \widetilde{y}_1(m, \tau, a_l)}{\partial m} \\ &= \bar{y} > 0 \end{aligned} \tag{I.30}$$

$$\frac{dm}{d\tau} = \frac{a_h - a_l}{\bar{y}} > 0 \tag{I.31}$$

Thus the tracking advantage increases with τ, while the extent depends on the difference between high and low ability students. Although the share of both high and low ability students increases respectively decreases with a delayed tracking decision (see equation (I.22) and (I.23)), the difference between high and low ability students improves in the academic school track due to the ability advantage of high ability children. Low ability children have less innate ability and need more parental support to compensate this disadvantage. Since the influence of parental effort decreases in comparison to innate ability for human capital accumulation with delayed tracking, low ability students have problems to reach the critical threshold for human capital $\widetilde{H}$.

In contrast, an increase of governmental requirements $\widetilde{H}$ does not influence tracking advantage m, since the derivative of $\tilde{y}_1(a)$ with respect to $\widetilde{H}$ is independent of child's innate ability:

$$\frac{\partial \widetilde{y}_1(a_l)}{\partial \widetilde{H}} = \frac{\partial \widetilde{y}_1(a_h)}{\partial \widetilde{H}} > 0 \tag{I.32}$$

$$R_{\widetilde{H}} = \frac{\partial \widetilde{y}_1(a_h)}{\partial \widetilde{H}} - \frac{\partial \widetilde{y}_1(a_l)}{\partial \widetilde{H}} = 0 \tag{I.33}$$

$$\frac{dm(n_h, n_l)}{d\widetilde{H}} = -\frac{R_{\widetilde{H}}}{R_m} = 0 \tag{I.34}$$

By determining the critical threshold for human capital $\widetilde{H}$ the government implicitly creates the size of the high secondary school in our model. Thus high ability students have no advantage in comparison to low ability students when $\widetilde{H}$ increases:

Proposition 2: With increasing τ the influence of parental effort decreases in comparison to child's innate ability in human capital accumulation. Due to the innate ability advantage of high ability students a delayed tracking decision increases the difference between high and low ability students and thus the tracking advantage m increases which is beneficial for both secondary school tracks. In contrast, governmental requirements $\widetilde{H}$ have no impact on the tracking advantage.

Overall, we analyze the necessary conditions for relevant tracking in our theoretical framework and the reasons for misallocation in an educational system with tracking. Furthermore our model shows how parents respond to delayed tracking decision and which institutional factors influence their utility. Government can increase the tracking advantage m by the choice of τ due to the improved homogeneity in secondary school classes. The choice of $\widetilde{H}$ determines the size of high secondary school in relation to the low school track. In the following section we analyze the optimal choice of τ and $\widetilde{H}$ if government maximizes social welfare.

4 Social Welfare

In the previous analysis we show how the government can influence the composition of students after primary school and reduce the extent of misallocation. Now we discuss the social welfare function in detail. Thereby we assume that a social planner maximizes utility of all families with respect to tracking decision τ and governmental requirements $\widetilde{H}$. Before we analyze the social welfare function, we first want to evaluate the development of human capital after the end of compulsory school $\bar{H}(a,\tau,\widetilde{H})$.

4.1 Human capital accumulation

For students with a given innate ability the accumulated human capital can be described as follows:

$$\begin{aligned} \bar{H}(a,\tau,\widetilde{H}) \;=\; & \int_{\underline{y}}^{\hat{y}} H^p(0)[1+m(1-\tau)] + \int_{\hat{y}}^{\widetilde{y}_1(a,\tau,\widetilde{H})} \underbrace{H^p(e^l(y))[1+m(1-\tau)]}_{\bar{H}_l} dy \\ & + \int_{\widetilde{y}_1(a,\tau,\widetilde{H})}^{\widetilde{y}_2(a,\tau,\widetilde{H})} \underbrace{H^p(e^c(\widetilde{H}))[1+\gamma m(1-\tau)]}_{\bar{H}_c} dy \\ & + \int_{\widetilde{y}_2(a,\tau,\widetilde{H})}^{\bar{y}} \underbrace{H^p(e^h(y))[1+\gamma m(1-\tau)]}_{\bar{H}_h} dy \end{aligned} \tag{I.35}$$

Parents with income $y \leq \hat{y}$ have not enough financial resources to support their child's education, hence these students cannot pass $\widetilde{H}$ and are selected to low secondary school. Human capital is integrated over family income, because only students with a given innate ability level and a family income of at least $\widetilde{y}_1(a)$ are qualified for high school track. We consider also the second critical income threshold $\widetilde{y}_2(a)$ which defines the transition of financial support $e^c(\widetilde{H})$ to $e^h(y)$. In secondary school students benefit from tracking advantage m due to a more homogeneous peer group. While the tracking advantage in vocational school is just m, students in the high school track have an additional productivity advantage ($\gamma > 1$). According to family income children receive different levels of parental efforts ($e^l(y)$, $e^c(\widetilde{H})$ or $e^h(y)$). Now we analyze the change of $\bar{H}(a,\tau,\widetilde{H})$ with respect to tracking decision

τ:

$$
\begin{aligned}
\frac{\partial \bar{H}(a,\tau,\widetilde{H})}{\partial \tau} &= \int_{\underline{y}}^{\hat{y}} \frac{\partial \bar{H}_l(0)}{\partial \tau} dy + \int_{\hat{y}}^{\widetilde{y}_1(a,\tau,\widetilde{H})} \frac{\partial \bar{H}_l}{\partial \tau} dy \\
&+ \int_{\widetilde{y}_1(a,\tau,\widetilde{H})}^{\widetilde{y}_2(a,\tau,\widetilde{H})} \widetilde{H} \left(\frac{\partial m}{\partial \tau} \gamma(1-\tau) - m\gamma \right) dy + \int_{\widetilde{y}_2(a,\tau,\widetilde{H})}^{\bar{y}} \frac{\partial \bar{H}_h}{\partial \tau} dy \\
&+ \frac{\partial \widetilde{y}_1}{\partial \tau} \left[\bar{H}_l(\widetilde{y}_1) - \bar{H}_c(\widetilde{H}) \right] + \frac{\partial \widetilde{y}_2}{\partial \tau} \left[\bar{H}_c(\widetilde{H}) - \bar{H}_h(\widetilde{y}_2) \right] \qquad \text{(I.36)}
\end{aligned}
$$

From equation (I.36) several effects are observable if we delay the timing of tracking τ. The change of human capital of students who visit either the low or high school track ($\frac{\partial \bar{H}_l}{\partial \tau}$ and $\frac{\partial \bar{H}_h}{\partial \tau}$) depends on the change of primary human capital and tracking advantage (see Appendix A 3.1). On the one hand m increases with τ due to the more efficient selection of students according to their innate capabilities. Hence the peer group improves in secondary school track which describes the qualitative effect of tracking advantage. On the other hand we also observe a quantitative effect. The longer the primary school lasts the shorter is the duration of secondary school track. Therefore, the period of time for m to be effective decreases. If the government sets $\tau = 0$, all students (high and low ability) visit the same school, since the government is not able to distinguish students' innate ability. In this case students composition is still heterogeneous and tracking advantage is equal to one. If government sets $\tau = 1$, students visit primary school for their whole compulsory school time. Accordingly students are not able to benefit from tracking advantage m, since the classes are still heterogeneous. At last we analyze the influence of τ on the critical income threshold $\widetilde{y}_1(a)$. We show in equation (I.20) and (I.21) that the influence of delayed tracking on critical income threshold depends on several institutional factors, for instance governmental requirements $\widetilde{H}$ and tracking advantage m ($\frac{\partial \widetilde{y}_1(a)}{\partial \tau} \gtreqless 0$). The effect on the second critical income threshold is clearly negative ($\frac{\partial \widetilde{y}_2(a)}{\partial \tau} = -a < 0$). Since the decrease of $\widetilde{y}_2(a)$ is larger for children with innate ability a_h, the share of high ability students who benefit from $e^h(y)$ instead of $e^c(\widetilde{H})$ increases with delayed tracking.

Beside the timing of tracking the government can also determine the critical threshold for human capital $\widetilde{H}$ which is required to be selected to the high secondary school track. Again we analyze the entire human capital for a given innate ability level (see Appendix A 3.2):

$$\frac{\partial \bar{H}(a,\tau,\widetilde{H})}{\partial \widetilde{H}} = \int_{\widetilde{y}_1(a,\tau,\widetilde{H})}^{\widetilde{y}_2(a,\tau,\widetilde{H})} 1+\gamma m(1-\tau)dy + \frac{\partial \widetilde{y}_1}{\partial \widetilde{H}}[\bar{H}_l(\widetilde{y}_1)-\bar{H}_c(\widetilde{y}_1)] + \frac{\partial \widetilde{y}_2}{\partial \widetilde{H}}[\bar{H}_c(\widetilde{y}_2)-\bar{H}_h(\widetilde{y}_2)] \quad \text{(I.37)}$$

Both critical income thresholds ($\widetilde{y}_1(a,\tau,\widetilde{H})$, $\widetilde{y}_2(a,\tau,\widetilde{H})$) increase with governmental requirements for high school track ($\frac{\partial \widetilde{y}_1}{\partial \widetilde{H}} > 0$, $\frac{\partial \widetilde{y}_2}{\partial \widetilde{H}} > 0$). An increased critical human capital $\widetilde{H}$ makes the qualification for the high secondary school more difficult. Consequently less students are selected to the academic school track. Since the tracking advantage is not influenced by $\widetilde{H}$ (equation (I.34)), the governmental requirements rather determine the size of both school tracks than improving students composition in secondary school.

4.2 Social welfare function

In the next step we analyze the problem of a social planner who maximizes the utility of all families. For this purpose it is not sufficient to evaluate only the entire human capital accumulation of children, but also parental consumption and financial support for their children. The utility for all families with a child in low school track and a given innate ability can be described as follows:

$$\begin{aligned} U^l &= \int_{\underline{y}}^{\hat{y}} u(a,0)dy + \int_{\hat{y}}^{\widetilde{y}_1(a,\tau,\widetilde{H})} u(a,e^l(y))dy \\ &= \int_{\underline{y}}^{\hat{y}} ln(y)+\delta ln(a\tau(1+m(1-\tau)))dy \\ &+ \int_{\hat{y}}^{\widetilde{y}_1(a,\tau,\widetilde{H})} ln(y-\tau e^l(y))+\delta ln(H^p(1+m(1-\tau)))dy \end{aligned} \quad \text{(I.38)}$$

Obviously we can distinguish parents who spend no financial resources ($y \leq \hat{y}$) and the three cases for positive parental investments. Hence the utility for parents with a child who receives just enough financial support to visit high school track is defined as follows:

$$\begin{aligned} U^c &= \int_{\widetilde{y}_1(a,\tau,\widetilde{H})}^{\widetilde{y}_2(a,\tau,\widetilde{H})} u(a, e^c(\widetilde{H}))dy \\ &= \int_{\widetilde{y}_1(a,\tau,\widetilde{H})}^{\widetilde{y}_2(a,\tau,\widetilde{H})} ln(y - \tau e^c(\widetilde{H})) + \delta ln(H^P(1 + m\gamma(1-\tau))) \end{aligned} \tag{I.39}$$

Analogously we calculate the utility of all families with a child who receives $e^h(y)$:

$$\begin{aligned} U^h &= \int_{\widetilde{y}_2(a,\tau,\widetilde{H})}^{\bar{y}} u(a, e^h(y))dy \\ &= \int_{\widetilde{y}_2(a,\tau,\widetilde{H})}^{\bar{y}} ln(y - \tau e^h(y)) + \delta ln(H^P(1 + m\gamma(1-\tau))) \end{aligned} \tag{I.40}$$

Hence the social planner maximizes the following social welfare function for a given level of child's innate ability level a:

$$W(a, y, m(n_h, n_l)) = U^l + U^c + U^h \tag{I.41}$$

From the perspective of maximizing social welfare of all families, the optimal education policy is given by:

$$(\tau^*, \widetilde{H}^*) = \underset{\tau,\widetilde{H}}{arg\,max}\, W(a, y, m(n_h, n_l)) \tag{I.42}$$

Analyzing the optimal choice of tracking decision we evaluate the derivative of the social welfare function with respect to τ:

$$\begin{aligned}\frac{\partial W}{\partial \tau} &= \int_{\underline{y}}^{\hat{y}} \underbrace{\frac{\partial u(a,0)}{\partial \tau}}_{+/-} dy + \frac{\partial \hat{y}}{\partial \tau} u(a,0) + \\ &+ \int_{\hat{y}}^{\widetilde{y}_1(a,\tau,\widetilde{H})} \underbrace{\frac{\partial u(a,e^l(y))}{\partial \tau}}_{+/-} dy + \frac{\partial \widetilde{y}_1}{\partial \tau} u(a,e^l(\widetilde{y}_1)) - \frac{\partial \hat{y}}{\partial \tau} u(a,0) \\ &+ \int_{\widetilde{y}_1(a,\tau,\widetilde{H})}^{\widetilde{y}_2(a,\tau,\widetilde{H})} \underbrace{\frac{\partial u(a,e^c(\widetilde{H}))}{\partial \tau}}_{+/-} dy + \frac{\partial \widetilde{y}_2}{\partial \tau} u(a,e^c(\widetilde{H}),\widetilde{y}_2) - \frac{\partial \widetilde{y}_1}{\partial \tau} u(a,e^c(\widetilde{H}),\widetilde{y}_1) \\ &+ \int_{\widetilde{y}_2(a,\tau,\widetilde{H})}^{\bar{y}} \underbrace{\frac{\partial u(a,e^h(y))}{\partial \tau}}_{+/-} dy - \frac{\partial \widetilde{y}_2}{\partial \tau} u(a,e^h(\widetilde{y}_2)) \end{aligned} \tag{I.43}$$

In order to show that the social planner prefers an interior solution in our model, we analyze the derivative of the social welfare function at the corner solution choices of tracking decision ($\tau \to 0$ and $\tau = 1$):[7]

$$\begin{aligned}\lim_{\tau \to 0} \frac{\partial W}{\partial \tau} &= \int_{\underline{y}}^{\widetilde{y}_1} \underbrace{\frac{\partial u(a,e^l(y))}{\partial \tau}}_{>0} dy + \int_{\widetilde{y}_1}^{\widetilde{y}_2} \underbrace{\frac{\partial u(a,e^c(\widetilde{H}))}{\partial \tau}}_{+/-} dy + \\ &+ \int_{\widetilde{y}_2}^{\bar{y}} \underbrace{\frac{\partial u(a,e^h(y))}{\partial \tau}}_{>0} dy \end{aligned} \tag{I.44}$$

where

$$\begin{aligned}\frac{\partial u(a,e^c(\widetilde{H}))}{\partial \tau} |_{\tau \to 0} &= \frac{a}{y-\widetilde{H}} + \frac{\delta\gamma}{(1+\gamma)}(\frac{\partial m}{\partial \tau} - 1) \\ &= \frac{a}{y-\widetilde{H}} + \frac{\delta\gamma}{(1+\gamma)}(\frac{a_h - a_l}{\bar{y}} - 1) \end{aligned} \tag{I.45}$$

Thus the sign depends on the governmental requirements and the marginal change of the tracking advantage with respect to τ which is smaller than one for a sufficiently high maximum income $\bar{y}$. By assuming $\frac{\partial u(a,e^c(\widetilde{H}))}{\partial \tau} |_{\tau \to 0} > 0$, the derivative

[7] Since our parental utility function is not defined for $\tau = 0$, we analyze the limit of the social welfare function.

of the social welfare function at $\tau \to 0$ is positive:

$$\lim_{\tau \to 0} \frac{\partial W}{\partial \tau} = \int_{\underline{y}}^{\widetilde{y}_1} \underbrace{\frac{\partial u(a, e^l(y))}{\partial \tau}}_{>0} dy + \int_{\widetilde{y}_1}^{\widetilde{y}_2} \underbrace{\frac{\partial u(a, e^c(\widetilde{H}))}{\partial \tau}}_{>0} dy + \\ + \int_{\widetilde{y}_2}^{\bar{y}} \underbrace{\frac{\partial u(a, e^h(y))}{\partial \tau}}_{>0} dy > 0 \tag{I.46}$$

and

$$\frac{\partial W}{\partial \tau}\Big|_{\tau=1} = \int_{\underline{y}}^{\hat{y}} \underbrace{\frac{\partial u(a, 0)}{\partial \tau}}_{=0} dy + \int_{\hat{y}}^{2\widetilde{H}-a} \underbrace{\frac{\partial u(a, e^l(y))}{\partial \tau}}_{<0} dy + \\ + \int_{2\widetilde{H}-a}^{\bar{y}} \underbrace{\frac{\partial u(a, e^h(y))}{\partial \tau}}_{<0} dy < 0 \tag{I.47}$$

The social planner chooses an interior solution for the timing of tracking τ (see Appendix A 4.1). This holds for the non-negative condition for parental effort ($y > \frac{a\tau}{\delta} = \hat{y}$) as well as for parents who cannot afford to support their child. Choosing $\tau = 0$ means that no child visits the primary school and therefore no child is able to accumulate human capital ($H^p = 0$). Hence no one is able to reach the critical human capital threshold $\widetilde{H}$ that qualifies for the high school track. Since in this case all students stay together, regardless of their innate ability, there is no tracking advantage ($m = 1$). In contrast, parents benefit from a high parental consumption, since we spend no financial support for child's education. However, visiting the primary school for the entire time period cannot be optimal, too. When all students stay together for $\tau = 1$, no selection of students according to their innate capabilities occurs. Again the peer group is heterogeneous and so no tracking advantage is observable ($m = 1$). Simultaneously parents have to support their child with investments for the entire compulsory school time. In both cases the social welfare can be increased by choosing a duration of primary school between zero and one ($\tau^* \in (0, 1)$).

Proposition 3: A social planner who maximizes the social welfare chooses an interior solution for the timing of tracking $\tau^* \in (0, 1)$. *In this context social welfare can be increased by delayed tracking if the current timing of tracking is too early* ($\tau < \tau^*$)*. If* τ *is higher than the optimal timing of tracking* τ^**, a shorter duration of primary school increases the social welfare.*

To determine the optimal choice of governmental requirements for high school track we evaluate the derivative of the social welfare with respect to $\widetilde{H}$:

$$\begin{aligned}\frac{\partial W}{\partial \widetilde{H}} &= \int_{\widetilde{y}_1}^{\widetilde{y}_2} \underbrace{\frac{\partial u(a,e^c(\widetilde{H}))}{\partial \widetilde{H}}}_{+/-} dy + \frac{\partial \widetilde{y}_1}{\partial \widetilde{H}}(u(a,e^l(\widetilde{y}_1)) - u(a,e^c(\widetilde{H}),\widetilde{y}_1)) + \\ &+ \frac{\partial \widetilde{y}_2}{\partial \widetilde{H}}(u(a,e^c(\widetilde{H}),\widetilde{y}_2) - u(a,e^h(\widetilde{y}_2))) \end{aligned} \tag{I.48}$$

Higher governmental requirements for the academic school track increase both income thresholds ($\frac{\partial \widetilde{y}_1}{\partial \widetilde{H}} > 0$, $\frac{\partial \widetilde{y}_2}{\partial \widetilde{H}} > 0$). Since the variable $\widetilde{H}$ is not included in human capital of students who visit the high respectively low school track, parental utility is not influenced by $\widetilde{H}$ ($\frac{\partial u(a,e^h(y))}{\partial \widetilde{H}} = \frac{\partial u(a,e^l(y))}{\partial \widetilde{H}} = 0$).

We evaluate the second derivative of the social welfare function (see Appendix A 4.2):

$$\begin{aligned}\frac{\partial^2 W}{\partial \widetilde{H}^2} &= \int_{\widetilde{y}_1}^{\widetilde{y}_2} \underbrace{\frac{\partial^2 u(a,e^c(\widetilde{H}))}{\partial \widetilde{H}^2}}_{<0} dy - 2\frac{\partial \widetilde{y}_1}{\partial \widetilde{H}} \underbrace{\left(\frac{\partial u(a,e^c(\widetilde{H}),\widetilde{y}_1)}{\partial \widetilde{H}}\right)}_{<0} + \\ &+ 2\frac{\partial \widetilde{y}_2}{\partial \widetilde{H}} \underbrace{\left(\frac{\partial u(a,e^c(\widetilde{H}),\widetilde{y}_2)}{\partial \widetilde{H}}\right)}_{=0} \gtreqless 0 \end{aligned} \tag{I.49}$$

since

$$\frac{\partial^2 u(a,e^c(\widetilde{H}))}{\partial \widetilde{H}^2} = -\frac{1}{(y + a\tau - \widetilde{H})^2} - \frac{\delta}{\widetilde{H}} < 0 \tag{I.50}$$

and

$$\frac{\partial u(a,e^c(\widetilde{H}),\widetilde{y}_1)}{\partial \widetilde{H}} < 0, \text{ for } y = \widetilde{y}_1 \tag{I.51}$$

Thus the sign of the second derivative of the social welfare function with respect to $\widetilde{H}$ is ambiguous.

The intuition for an interior solution for governmental requirements can be described as follows: With governmental requirements $\widetilde{H} = \widetilde{H}_{min}$ all students visit the high secondary school after the first tracking decision. Thus the peer group is still heterogeneous in class and no tracking advantage occurs ($m = 1$). Choosing the second corner solution $\widetilde{H} = \widetilde{H}_{max}$ leads to the other extreme. Now governmental requirements for high school track are too demanding for all students and thus everyone is selected to the low school track. Again the peer group is heterogeneous and no tracking advantage is observable ($m = 1$). An improvement of social welfare is in both cases possible by choosing a critical threshold of human capital between $\widetilde{H}_{min}$ and $\widetilde{H}_{max}$.

Note again that the tracking advantage m is not influenced by $\widetilde{H}$ (equation (I.34)). Thus the governmental requirements rather determine the size of both school tracks than improving students composition in secondary school. The high secondary school has a productivity advantage γ in comparison to the low secondary school.

5 Conclusion

The timing of the first tracking decision is one of the most important institutional factors in an education system. The duration of primary school does not only have an impact on the equality of educational opportunities, but also on the efficiency of students' selection. Thus our paper does not only aim to evaluate the aspect of fairness, but also to understand the inefficiency in an education system with tracking. The idea of tracking is to use the advantage of a peer group effect due to homogenous students composition. Uhlig et al. (2009) are able to show that almost every third German student visits the wrong secondary school track according to her or his innate ability which implies an inefficient selection of students. These empirical findings set the base of our theoretical framework which differs in two aspects from the previous literature (Epple et al. (2002); **?**).

First parental capabilities respectively family income is uncorrelated with child's innate ability (Pedersen (2004); de Walque (2005)), in order to have social mobility. Secondly we endogenize the reason for an inefficient students composition by implementing parental effort for students' human capital accumulation in our model. According to their utility function parents choose their optimal effort level for child's educational attainment. In contrast to our approach an exogenous shock parameter is often used in the literature. Thus we rely on the results of international empirical studies which reveal the strong influence of child's socio-economic background on school success.

At first our model explains the reasons for misallocation of students after the first tracking decision which is caused by the heterogeneity in family income. Thus a fraction of high ability students with a not favorable family background can be selected to the low school track (underachievers), while low ability students pass the governmental requirements and are allowed to visit the high secondary school due to the parental support (overachievers). The tracking advantage is a decreasing function of the inefficiency in students' selection. The higher the homogeneity of students composition in secondary school the higher the tracking advantage. Since the influence of parental support on child's human capital decreases with primary school length, the selection of students according to their innate ability improves with delayed tracking. As a consequence the tracking advantage increases which improves human capital accumulation in the secondary school.

Finally, we analyze the social welfare function with respect to our two policy instruments, the timing of first tracking decision and the governmental requirements for the high secondary school track. We are able to describe the necessary conditions for an interior solution for both policy instruments. Important for our analysis is the trade off between a qualitative (homogeneity of secondary school class) and quantitative (duration of secondary school) effect of the tracking advantage. Due to an improved selection of students according to their innate ability it is possible that high ability students gain from a delayed tracking decision, although this group has to stay for a longer term with low ability students in a school. Furthermore we point out that the choice of governmental requirements rather determines the size of the two different secondary school tracks than improving the students composition.

Appendix

A 1: Optimal parental effort level

Given the timing of tracking τ and the governmental requirements $\widetilde{H}$ the parents maximize their utility with respect to e^h:

First-order condition:

$$\frac{\partial u(a,e^h)}{\partial e^h} = -\frac{\tau}{c(y,e^h)} + \delta \frac{\tau(1+m\gamma(1-\tau))}{\bar{H}_h} = 0$$

while $\bar{H}_h$ captures the entire human capital for a student who visits the high secondary school.

Second-order condition:

$$\frac{\partial^2 u(a,e^h)}{\partial (e^h)^2} = -\frac{\tau^2}{(c(y,e^h))^2} - \delta \frac{(\tau(1+m\gamma(1-\tau)))^2}{\bar{H}_h^2} < 0$$

Hence

$$e^h(y) = \frac{\delta y - a\tau}{\tau(1+\delta)}$$

is the optimal parental effort for families whose child visits the high school track.

The optimal parental effort level $e^l(y)$ for families with children in the low school track can be calculated similarly (for $\gamma = 1$ and $\bar{H}_l$).

A 2: Marginal derivatives of the first critical income threshold

The first critical income threshold $\widetilde{y}_1$ is calculated by

$$u(a,y,e^l(y)) = u(a,y,e^c(\widetilde{H}))$$

Due to our concave utility function we achieve two intersection points, while only the first one is relevant for the analysis. The second intersection point has a higher value than the second critical income threshold $\widetilde{y}_2$ since this threshold is derived by the tangent of $u(a,y,e^c(\widetilde{H}))$ and $u(a,y,e^h(y))$. For the following calculation we assume $\delta = 1$:

$$\begin{aligned}\widetilde{y}_1(a,\tau,\widetilde{H}) &= \frac{2\widetilde{H}(-1+\gamma m(-1+\tau))}{-1+m(-1+\tau)} - a\tau + \\ &\quad \frac{2\widetilde{H}\sqrt{m(-1+\gamma)(-1+m\gamma(-1+\tau))(-1+\tau)}}{-1+m(-1+\tau)} \\ &= 2\widetilde{H}\cdot g(\tau,m,\gamma) - a\tau\end{aligned}$$

We can evaluate the following equation:

$$G = u(a,\widetilde{y}_1,e^l(y)) - u(a,\widetilde{y}_1,e^c(\widetilde{H})) = 0$$

Now we use the implicit function theorem for comparative statics:

$$\frac{d\widetilde{y}_1}{dx} = -\frac{G_x}{G_{\widetilde{y}_1}}\ , with x \in \{\tau,\widetilde{H},a,m\}$$

where

$$\begin{aligned}G_{\widetilde{y}_1} = \frac{\partial G}{\partial \widetilde{y}_1} &= \frac{\partial u(a,\widetilde{y}_1,e^l(y))}{\partial \widetilde{y}_1} - \frac{\partial u(a,\widetilde{y}_1,e^c(\widetilde{H}))}{\partial \widetilde{y}_1} \\ &= \frac{1+\delta}{\widetilde{y}_1 + a\tau} - \frac{1}{\widetilde{y}_1 + a\tau - \widetilde{H}} \leq 0\end{aligned}$$

$$\begin{aligned}G_a = \frac{\partial G}{\partial a} &= \frac{\partial u(a,\widetilde{y}_1,e^l(y))}{\partial a} - \frac{\partial u(a,\widetilde{y}_1,e^c(\widetilde{H}))}{\partial a} \\ &= \tau\left(\frac{1+\delta}{\widetilde{y}_1 + a\tau} - \frac{1}{\widetilde{y}_1 + a\tau - \widetilde{H}}\right) \leq 0\end{aligned}$$

$$\begin{aligned}G_m = \frac{\partial G}{\partial m} &= \frac{\partial u(a,\widetilde{y}_1,e^l(y))}{\partial m} - \frac{\partial u(a,\widetilde{y}_1,e^c(\widetilde{H}))}{\partial m} \\ &= \delta\frac{(-1+\gamma)(1-\tau)}{(-1+m(1-\tau))(-1+m\gamma(1-\tau))} < 0\end{aligned}$$

$$
\begin{aligned}
G_{\widetilde{H}} = \frac{\partial G}{\partial \widetilde{H}} &= \frac{\partial u(a,\widetilde{y}_1,e^l(y))}{\partial \widetilde{H}} - \frac{\partial u(a,\widetilde{y}_1,e^c(\widetilde{H}))}{\partial \widetilde{H}} \\
&= \frac{1}{\widetilde{y}_1 + a\tau - \widetilde{H}} - \frac{\delta}{\widetilde{H}} \\
&= \frac{\widetilde{H}(1+\delta) - \delta(\tilde{y} + a\tau)}{(\widetilde{y}_1 + a\tau - \widetilde{H})\widetilde{H}} > 0
\end{aligned}
$$

for

$$
\widetilde{y}_1 \;<\; \widetilde{H}\frac{(1+\delta)}{\delta} - a\tau = \widetilde{y}_2
$$

The second critical income threshold $\widetilde{y}_2$ is derived by the tangent of $u(a,y,e^c(\widetilde{H}))$ and $u(a,y,e^h(y))$:

$$
\frac{\partial u(a,e^c(\tau))}{\partial \widetilde{y}_2} \;=\; \frac{\partial u(a,e^h(\tau))}{\partial \widetilde{y}_2}
$$

Thus we calculate the following income threshold:

$$
\widetilde{y}_2(a,\tau,\widetilde{H}) \;=\; 2\widetilde{H} - a\tau
$$

A 3: Accumulated human capital

H^p is increasing with τ:

$$
\frac{\partial H^p(e^l(y),\tau)}{\partial \tau} = \frac{\partial H^p(e^h(y),\tau)}{\partial \tau} \;=\; a\frac{\delta}{1+\delta} > 0
$$

A 3.1 The change of human capital with respect to τ, for all four cases of parental effort ($e = 0$, $e^l(y)$, $e^h(y)$ and $e^c(\widetilde{H})$):

$$
\frac{\partial \bar{H}_l(0)}{\partial \tau} \;=\; a\left[1 + m(1-\tau) + \tau\left(\frac{\partial m}{\partial \tau}(1-\tau) - m\right)\right]
$$

$$
\frac{\partial \bar{H}_l(e^l)}{\partial \tau} \;=\; \frac{a\delta}{1+\delta}\left(1 + m(1-\tau)\right) + H^p(e^l)\left(\frac{\partial m}{\partial \tau}(1-\tau) - m\right)
$$

$$
\frac{\partial \bar{H}_h(e^h)}{\partial \tau} \;=\; \frac{a\delta}{1+\delta}\left(1 + m\gamma(1-\tau)\right) + H^p(e^h)\gamma\left(\frac{\partial m}{\partial \tau}(1-\tau) - m\right)
$$

$$\frac{\partial \bar{H}_c(\widetilde{H})}{\partial \tau} = \widetilde{H}\gamma\left(\frac{\partial m}{\partial \tau}(1-\tau)-m\right)$$

The overall sign of the derivatives depends on the change of human capital accumulated in primary school $\frac{\partial H^p}{\partial \tau}$, which is for the first three cases ($e=0$, $e^l(y)$ and $e^h(y)$) strictly positive. Since the timing of tracking τ does not influence $\widetilde{H}$, a change of H^p is not observable for the fourth case ($e^c(\widetilde{H})$). Additionally we consider the change of the tracking advantage with respect to primary school length ($\frac{\partial m}{\partial \tau} = \frac{a_h - a_l}{\bar{y}} > 0$) which shows the qualitative effect of the tracking advantage. Due to the decreasing time spent in secondary school we also observe a negative quantitative effect on human capital ($-m$).

A 3.2 The change of human capital with respect to $\widetilde{H}$

In the following three cases ($e=0$, $e^l(y)$ and $e^h(y)$) the human capital is independent of $\widetilde{H}$:

$$\frac{\partial \bar{H}_l(0)}{\partial \widetilde{H}} = \frac{\partial \bar{H}_l(e^l)}{\partial \widetilde{H}} = \frac{\partial \bar{H}_h(e^h)}{\partial \widetilde{H}} = 0$$

For the human capital with $e^c(\widetilde{H})$ we calculate the following derivative:

$$\frac{\partial \bar{H}_c(\widetilde{H})}{\partial \widetilde{H}} = 1 + m\gamma(1-\tau) > 0$$

A 4: Interior solution for social welfare function:

Critical income thresholds $\widetilde{y}_{1,2}(a,\tau,\widetilde{H})$, assuming $\delta = 1$:

$$\widetilde{y}_1(a,\tau,\widetilde{H}) = \frac{2\widetilde{H}(-1+\gamma m(-1+\tau))}{-1+m(-1+\tau)} - a\tau + \frac{2\widetilde{H}\sqrt{m(-1+\gamma)(-1+m\gamma(-1+\tau))(-1+\tau)}}{-1+m(-1+\tau)}$$

$$\widetilde{y}_2(a,\tau,\widetilde{H}) = 2\widetilde{H} - a\tau$$

For evaluating the social welfare function we calculate the income thresholds for

$\tau \to 0$ and $\tau = 1$:

$$\begin{aligned}\widetilde{y}_1(a,\tau,\widetilde{H})\mid_{\tau\to 0} &= \widetilde{H}(1+\gamma-\sqrt{\gamma^2-1})\\ \widetilde{y}_2(a,\tau,\widetilde{H})\mid_{\tau\to 0} &= 2\widetilde{H}\end{aligned}$$

$$\widetilde{y}_1(a,0,\widetilde{H}) \;<\; \widetilde{y}_2(a,0,\widetilde{H}),\ \text{for}\,\gamma>1$$

$$\begin{aligned}\tilde{y}_1(a,\tau,\widetilde{H})\mid_{\tau=1} &= 2\widetilde{H}-a\\ \tilde{y}_2(a,\tau,\widetilde{H})\mid_{\tau=1} &= 2\widetilde{H}-a\end{aligned}$$

$$\widetilde{y}_1(a,1,\widetilde{H}) \;=\; \widetilde{y}_2(a,1,\widetilde{H})$$

since all students visit the primary school for $\tau = 1$, the productivity advantage γ of the high school track cannot influence child's human capital, so that the utility functions $u(a,e^l(y))$ and $u(a,e^h(y))$ are the same at this point.

A 4.1 With respect to timing of tracking

Marginal change of parental consumption:

$$\frac{\partial c(e^l(y),\tau)}{\partial\tau}=\frac{\partial c(e^h(y),\tau)}{\partial\tau} \;=\; \frac{a}{1+\delta}>0$$

Child's human capital accumulated in primary school:

$$\begin{aligned}H^p(e^l(y),\tau) &= [a+e^l(y)]\tau\\ H^p(e^h(y),\tau) &= [a+e^h(y)]\tau\end{aligned}$$

for $\tau \to 0$ and $\tau = 1$:

$$\begin{aligned}H^p(e^l(y),\tau)\mid_{\tau\to 0} &= 0\\ H^p(e^h(y),\tau)\mid_{\tau\to 0} &= 0\\ H^p(e^l(y),\tau)\mid_{\tau=1} &= \frac{\delta(y+a)}{(1+\delta)}\\ H^p(e^h(y),\tau)\mid_{\tau=1} &= \frac{\delta(y+a)}{(1+\delta)}\end{aligned}$$

H^p is increasing with τ:

$$\frac{\partial H^p(e^l(y),\tau)}{\partial \tau} = \frac{\partial H^p(e^h(y),\tau)}{\partial \tau} = a\frac{\delta}{1+\delta} > 0$$

In the next step we evaluate the derivatives of parental utility function for all four cases of parental effort ($e = 0, e^l(y), e^h(y)$ and $e^c(\widetilde{H})$). Note that the tracking advantage $m = 1$ for $\tau \to 0$ and $\tau = 1$, since a selection of students according to their innate ability level does not occur. This means that the students composition is still heterogeneous.

- $e = 0$:

$$\frac{\partial u(a,0)}{\partial \tau} = \delta \frac{1}{\tau(1+m(1-\tau))}\left(1-\tau m + \frac{\partial m}{\partial \tau}(1-\tau)\right)$$

$$\frac{\partial u(a,0)}{\partial \tau}|_{\tau=1} = 0$$

- $e = e^l(y)$:

$$\begin{aligned}\frac{\partial u(a,e^l(y))}{\partial \tau} &= \frac{1}{c(e^l(y))}\frac{\partial c(e^l(y))}{\partial \tau} + \\ &\quad + \frac{\delta}{H^P}\left(\frac{\partial H^p}{\partial \tau}\right) + \\ &\quad + \frac{\delta}{(1+m(1-\tau))}\left(\frac{\partial m}{\partial \tau}(1-\tau) - m\right)\end{aligned}$$

$$\begin{aligned}\frac{\partial u(a,e^l(y))}{\partial \tau}|_{\tau\to 0} &= \frac{1}{c(e^l(y))}\frac{a}{1+\delta} + \frac{\delta}{2}\left(\frac{\partial m}{\partial \tau} - 1\right) + \\ &= +\underbrace{\frac{\delta}{H^P}\left(\frac{\partial H^p}{\partial \tau}\right)}_{\to\infty} \to \infty\end{aligned}$$

$$\begin{aligned}\frac{\partial u(a,e^l(y))}{\partial \tau}|_{\tau=1} &= \frac{a}{y+a} + \frac{1+\delta}{y+a}\left(-\frac{\delta y}{1+\delta}\right) \\ &= \frac{a-\delta y}{y+a} < 0, \text{ for } y > \frac{a}{\delta} = \hat{y}\end{aligned}$$

- $e = e^h(y)$:

$$\begin{aligned}\frac{\partial u(a,e^h(y))}{\partial\tau} &= \frac{1}{c(e^h(y))}\frac{\partial c(e^h(y))}{\partial\tau}+\\ &+\frac{\delta}{H^P}\left(\frac{\partial H^p}{\partial\tau}\right)+\\ &+\frac{\delta}{(1+m\gamma(1-\tau))}(\frac{\partial m}{\partial\tau}\gamma(1-\tau)-m\gamma)\end{aligned}$$

$$\begin{aligned}\frac{\partial u(a,e^h(y))}{\partial\tau}|_{\tau\to 0} &= \frac{1}{c(e^h(y))}\frac{a}{1+\delta}+\frac{\delta}{(1+\gamma)}\gamma(\frac{\partial m}{\partial\tau}-1)+\\ &= +\underbrace{\frac{\delta}{H^P}\left(\frac{\partial H^p}{\partial\tau}\right)}_{\to\infty}\to\infty\end{aligned}$$

$$\begin{aligned}\frac{\partial u(a,e^h(y))}{\partial\tau}|_{\tau=1} &= \frac{a}{y+a}+\frac{1+\delta}{y+a}\left(\frac{a\delta-a\delta\gamma-\gamma\delta y}{1+\delta}\right)\\ &= \frac{a(1+\delta(1-\gamma))-\gamma\delta y}{y+a}<0,\ \text{for}\ y>\frac{a(1+\delta(1-\gamma))}{\delta\gamma}\end{aligned}$$

which is true for $y > \frac{a}{\delta} = \hat{y}$, since $\gamma > 1$.

- $e = e^c(\widetilde{H})$:

$$\begin{aligned}\frac{\partial u(a,e^c(\widetilde{H}))}{\partial\tau} &= \frac{1}{c(e^c(\widetilde{H}))}\frac{\partial c(e^c(\widetilde{H}))}{\partial\tau}+\\ &+\frac{\delta}{(1+m\gamma(1-\tau))}(\frac{\partial m}{\partial\tau}\gamma(1-\tau)-m\gamma)\end{aligned}$$

A 4.2 With respect to governmental requirements

$$\begin{aligned}\frac{\partial u(a,e^c(\widetilde{H}))}{\partial\widetilde{H}} &= \frac{1}{c(e^c(\widetilde{H}))}\frac{\partial c(e^c(\widetilde{H}))}{\partial\widetilde{H}}+\frac{\delta}{\widetilde{H}}\\ &= -\frac{1}{y+\tau a-\widetilde{H}}+\frac{\delta}{\widetilde{H}}\end{aligned}$$

which is smaller than zero for

$$y \;<\; \widetilde{H}\frac{(1+\delta)}{\delta}-a\tau=\widetilde{y}_2$$

Part II.

The discovery of slowness: Why does the preferred duration of secondary school differ?

1 Introduction

Every society has to determine the academic curriculum and the duration of schooling in an education system. Thereby the extent of academic curriculum defines primarily the quality of graduation and thus the human capital accumulation. The duration of secondary and tertiary school determines on the one hand the point in time students can enter the labor market and on the other hand how much time students have for the academic requirements. The duration of a school track depends on the level of teaching intensity, the ratio of academic content per unit of instructional time. Especially in countries with a course system in the secondary school track the timing of graduation is quite heterogeneous, for instance in Finland or USA.[1] In this context, a higher teaching intensity leads to a reduced school length, but makes the education system more demanding. Since students have to spend a higher share of their time for learning and consequently receive a decreased benefit of leisure, the efforts for graduation increase.

To examine the preferred duration of schooling we construct a political economy model of the teaching intensity, the ratio of academic content per unit of instructional time. We assume that the academic curriculum is held constant, thus parental choice of teaching intensity determines the duration of schooling. Households differ in income as well as in child's innate ability. By analyzing the political preferences of parents we show that a majority voting equilibrium exists and that the preferred teaching intensity is higher for households with more financial resources and children with a high innate ability.

One of the most striking and discussed educational reforms in Germany is the reduction of time spent in high secondary school (*Gymnasium*) from nine (so called G9) to eight years (G8). The main intention of this policy is the extension of working life due to a faster access to the labor market, to provide the social security systems with higher financial resources. Due to the federal structure of the education system the 16 state governments decide on the duration of secondary school track in Germany. After several considerations in the Kultusministerkonferenz (KMK)[2]

[1] In Finland, one of the most successful countries in the international PISA studies (OECD (2010)), students in the final stage of their secondary school graduation can choose between a duration of two till four years. The duration of this final stage depends on the number of courses which a student can pass in a year.

[2] Voluntary and independent council of all state minister of education with the aim to coordinate the education policy.

almost all states agreed to reduce the length of Gymnasium from nine to eight years in 2003, while the quantity of the academic curriculum was kept constant. This should ensure that the quality of high secondary school degree is unaffected by the reform.

This policy change in the German education system is the base for our simple political economy model of the choice of teaching intensity with endogenous parental investments in students' human capital. Each household generates utility from consumption and the child's human capital which depends on several factors. Beside the positive influence of innate ability and parental investments, students also have to deal with their efforts due to a certain teaching intensity. If the ratio of academic content per unit of instructional time increases school becomes more demanding for students and thus they put more effort into graduation. Simultaneously opportunities for leisure activities shrink which can be interpreted as an additional burden for students. Due to the assumption that academic curriculum is kept constant, parents can influence with their choice of teaching intensity the overall duration of secondary school time. Time spent in secondary school track has an impact on parental consumption, since parental financial support is only paid in this period.

We show in our analysis that the choice of teaching intensity is monotonically increasing in household income and child's innate ability. Since political preferences are single-peaked, a majority voting equilibrium exists and is defined by the decision of the median household. Thus our model can explain why an observable demand for a diverging duration of secondary school occurs, once the decision is decentralized.

There is only a short literature which is related to the analysis of duration of secondary school. A few empirical studies estimate the effect of reducing secondary school length on academic achievements (Büttner and Thomsen (2011); Pischke (2007)). A recent study from Büttner and Thomsen (2011) uses the introduction of G8 in the German state of Saxon-Anhalt as a natural experiment. Their results are in line with the previous literature which estimate significantly negative effects for achievement tests in mathematics and foreign language, while the extent of the effects differs by gender. In our theoretical framework we do not focus on academic performance, but rather on the political decision making process which determines the duration of secondary school. For our purpose, the quasi-experimental design of Heller (2008) is helpful. In 1992 several cohorts of students got the opportunity to visit the high secondary school not for nine but for eight years as part of a pilot project to support talented children in the state of Baden-Württemberg. Both G8 and

G9 classes were implemented within the same participating schools and the decision was made by the parents alone to which class a student is selected. Heller (2008) finds out that in every examined cohort of G8 students the socioeconomic status (parental income level and educational attainment) is more favorable in comparison to G9 students. In addition, we observe the trend of increasing demand for private lessons after reducing secondary school's length due to a more demanding school. In this context, students with a favorable family background will benefit, since high-income households are more able to afford additional support.

The chapter is organized as follows: After a short description of the reduction of secondary school time in Germany in Section 2, we introduce the model setup in Section 3, Section 4 characterizes the political equilibrium and describes the implications. Section 5 summarizes our results.

2 Educational reform and descriptive analysis

2.1 Reduction of secondary school length in Germany

As described before the reduction of secondary school length by one year (G8) is subject of public debate and controversially discussed in all political parties. After the German reunification the KMK decided that the sum of 265 lessons per week is the minimum level of academic curriculum in high secondary school. Hence the average number of lessons per week varies from 27 to 33 at the G9. By implementing the G8 the average number of lessons per week rises up to 36, an increase of 10 to 20 percent of teaching intensity. Because of the fact that students have to accept more afternoon lessons than in G9, time for leisure activities declines. Furthermore some school subjects, e.g. the second foreign language, are brought forward by one year which makes the school even more demanding for students. Accordingly the demand for private lessons increased after the introduction of G8 in Germany (FiBS Consulting (2010)). A survey of the parents association in the state of Saarland[3] which reduced secondary school duration by one year show that students of a G8 class perceive school as more demanding as students from a G9 class. Furthermore G8 students often suffer from health problems.[4]

With the exception of Rhineland Palatinate all other state governments supported the reform. But controversial debates are still going on. In 2011 the state of Schleswig-Holstein passed a bill that enabled the governing body of a school to switch back from G8 to G9 if parents and students agree. Also a combined solution is possible, i.e. students can opt for G8 or G9 within the same school. From 100 high secondary schools in Schleswig-Holstein about 16 percent decided to switch back from G8 to G9, or to implement a combined solution respectively. Baden-Württemberg and North Rhine-Westphalia, the most populous state of Germany,

[3] In this survey 755 students of a G8 and 965 students of a G9 school were interviewed in the year 2008. While a share of 13.7 percent of G9 students use private lessons to improve their academic achievements, the share is with 22.3 percent significantly higher among G9 students (LEV der Gymnasien (2008)).

[4] The statement "I often have a headache or nausea caused by classwork" was significantly often affirmed by G8 students than by students who have one year more time for graduation (LEV der Gymnasien (2008)).

introduced similar pilot projects in 2011. Since these are pilot projects, only 10 percent of all high secondary schools were allowed to participate. This limit was easily achieved in both states which makes the demand for a longer duration of secondary school obvious.

In summary, we can point out that reducing the duration of secondary school track led to an increase of teaching intensity in order to keep the quality constant. Hence students are forced to increase their efforts to achieve the academic requirements for graduation.

2.2 Descriptive analysis

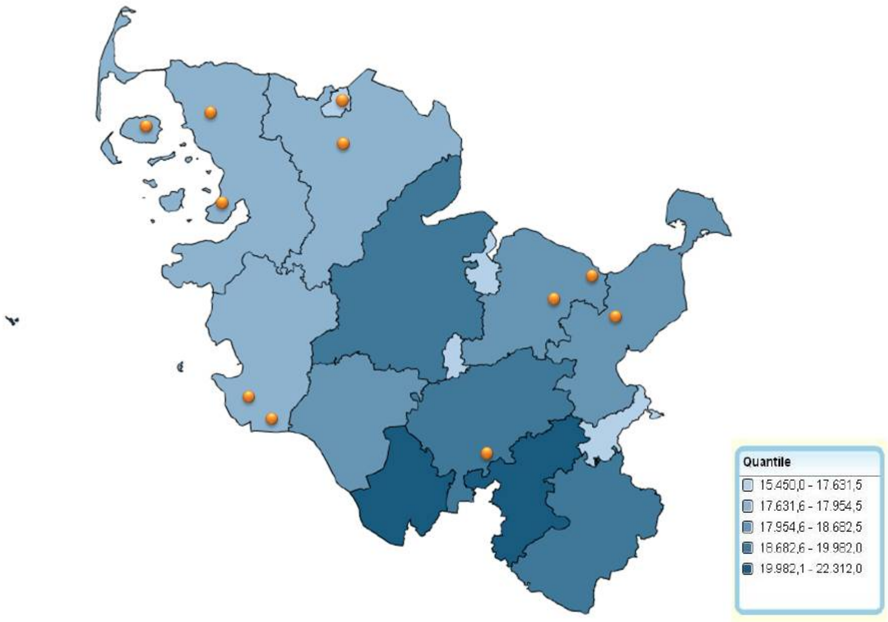
The state of Schleswig Holstein was the first one which decentralized the decision about high secondary school duration. Figure II.1 shows all eleven secondary schools which completely switched from G8 to G9 and kept academic curriculum constant. Schleswig-Holstein has eleven districts and four separate urban districts which differ in population and economic strength.[5] With the exception of Segeberg[6] the top five districts with the highest average after tax income per household have no secondary school which switched from G8 to G9. All other G9 schools are in districts which have a lower average after tax income per household in comparison to the state level (18.620 Euro).[7] The descriptive analysis suggests a positive relation between family income and the choice of secondary school duration.

[5]Ascending with after tax income of each resident in the year 2009: Flensburg, Kiel, Neumünster, Lübeck, Nordfriesland, Dithmarschen, Schleswig-Flensburg, Steinburg, Plön, Ostholstein, Rendsburg-Eckernförde, Segeberg, Herzogtum Lauenburg, Pinneberg and Stormarn.

[6]The district Segeberg has nine high secondary schools (Gymnasium) and only one decided to increase the duration from eight to nine years. This school is one of four high secondary schools in Norderstedt which has an average pre tax income of each resident similiar to the district level.

[7]The urban district Flensburg has the lowest average after tax income per household of all districts.

Figure II.1.: G9 Schools in the state of Schleswig-Holstein



Note: The dots denote the schools which chose to switch from G8 to G9. Schleswig-Holstein has eleven districts which differ in population and economic strength. In this graph the districts are marked with a darker color which has a higher after tax income of each household in the year 2009 (in Euro). The average after tax income per household is 18.620 Euro.

In our theoretical model families do not only differ in income, but in child's innate ability, too. In reality it is quite hard to measure the innate capability level of students, since all academic achievement results are influenced by random circumstances. An analysis of Stern and Hardy (2004) shows that only a small share of 12 to 26 percent of school success can be explained by differences in intelligence tests. For instance, the quality of teachers and students' socio-economic background play a decisive role for the school career. Hence we analyze an index for students' innate ability. The Bertelsmann Foundation generates a measure for the so called "learning to know" ability of individuals which is observed during the school. For this proxy variable Schoof et al. (2011) use data of both undergraduates and graduates. Beside the results of the latest PISA tests in math/science and reading capabilities in German/English (PIRLS) the authors add information on the share of class repeater, students without graduation and successful graduation to their measure "learning to know" (Schoof et al. (2011), p. 27-28). Again with the exception of the districts

Segeberg[8] and Plön (together three of eleven schools) all schools which switched from eight to nine years of secondary school are in districts with an average score in "learning to know" below the equivalent state level score (see Table II.1). The authors cannot provide any data on city level, thus we are not able to compare the various cities with G9 schools with the district level. Nevertheless, the descriptive analysis suggests a positive relation between child's capabilities and the choice of secondary school duration.

Table II.1.: Districts and cities in Schleswig-Holstein according to their "learning to know" score

District/City	Average score in "learning to know"	G9/G8 schools
Storman	39,04	0/9
Segeberg	38,08	1/9
Lübeck	36,5	0/7
Pinneberg	36,13	0/11
Neumünster	36,09	0/4
Plön	35,6	2/4
Rendburg-Eckernförde	35,43	0/8
State of Schleswig-Holstein	**35,08**	**11/100**
Kiel	34,95	0/12
Herzogtum Lauenburg	34,66	0/5
Ostholstein	34,64	1/7
Steinburg	33,64	0/4
Schleswig-Flensburg	33,2	1/4
Dithmarschen	31,44	2/6
Nordfriesland	31,01	3/6
Flensburg	28,26	1/4

[8] The district Segeberg has nine secondary schools (Gymnasium) and only one decided to increase the duration from eight to nine years. This school is one of four high secondary schools in Norderstedt which has an average pre tax income of each resident similiar to the district level.

3 Theoretical framework

3.1 Model setup

We consider a simplified economy with an exogenous number of families consisting of one parent and one child. Every parent works and has the opportunity to earn income $y \in [y_{min}, y_{max}]$, which is uniformly distributed with density function $f(y)$ and cumulative distribution $F(y)$. Family lifetime is normalized to one and each child visits a school with teaching intensity $\psi \in [S, \psi_{max}]$.[9] This ratio of academic content per unit of instructional time characterizes school's difficulty and is determined by majority voting. A high level of teaching intensity means that a large share of unit of time has to be spent for institutional education, so that a smaller share is left for leisure activities. Parameter $\tau \in [0,1]$ describes the entire duration of compulsory schooling, while the remaining time is used for working. Students have to complete an academic syllabus $S \in [0, S_{max}]$ for graduation which is comparable to the sum of lessons per week in reality. This given academic syllabus is a multiplicative relation between the entire time spent at the educational institution τ and teaching intensity ψ, so we define:

$$S = \tau\psi \tag{II.1}$$

$$\tau = \frac{S}{\psi} \tag{II.2}$$

The longer the duration of schooling τ the more academic content S can be taught. Hence through the choice of teaching intensity ψ parents influence the duration of school, since S is held constant. The academic syllabus can also be interpreted as a quality standard of education, since it determines how much a student learns at school. The accumulated human capital for a child is defined as follows:

$$h(a, e, \psi) \tag{II.3}$$

[9] Theoretically teaching intensity ψ can go to infinity, so that the period of time spent in education system could approximately go to zero for a given level of syllabus S ($\lim_{\psi\to\infty} \tau = \frac{S}{\psi} \to 0$). Due to time restriction and students' receptiveness for education we assume that teaching intensity is restricted to a maximum level ψ_{max}, so that students will visit school ($\tau > 0$).

Each student has an innate ability $a \in [a_{min}, a_{max}]$ which is uniformly distributed and completely independent of parental financial resources ($h_a \equiv \frac{\partial h}{\partial a} > 0$). The parameter e characterizes monetary efforts of parents for child's education during compulsory schooling. This factor depicts socio-economic background of a student and has a positive impact on human capital accumulation ($h_e \equiv \frac{\partial h}{\partial e} > 0, h_{ee} \leq 0$). Teaching intensity ψ has a negative impact on human capital, since the entire academic curriculum S is kept constant and consequently each student has to handle with a more demanding school and with a higher level of stress ($h_\psi \equiv \frac{\partial h}{\partial \psi} < 0$).

After graduation students have access to the labor market for a period of time $(1-\tau)$ and earn a wage which is equal to human capital $h(a,e,\psi)$. Thus consumption of a child can be written as follows:

$$\begin{aligned} c^c &= h(1-\tau) \\ &= h(1-\frac{S}{\psi}) \end{aligned} \tag{II.4}$$

From equation (II.4) two effects on child's consumption with respect to teaching intensity are observable. With a higher ψ duration of school decreases, if S is held constant, and thus the period of time for working increases. In contrast, an increasing teaching intensity leads to a more demanding school which is associated with higher efforts ($h_\psi < 0$). Human capital h decreases and as a consequence child's consumption. As soon as children are working they get no parental support and during compulsory school students are not working and earn no income.

Furthermore parent's consumption is defined as follows:

$$\begin{aligned} c^p &= y - e\tau \\ &= y - e\frac{S}{\psi} \end{aligned} \tag{II.5}$$

Parental support for child's education reduces consumption during child's school attendance and increases student's human capital (see equation (II.3)). If a student leaves school and enters labor market, the parent can invest the complete remaining time to generate income. It is obvious that lifetime parental consumption depends on duration of compulsory school. Thus the choice of teaching intensity has not only an impact on human capital accumulation, but on parent's consumption, too.

3.2 Timing of decisions

Firstly, parents vote on teaching intensity and hence ψ^* is a majority voting outcome. In our simplified education system the academic syllabus S is kept constant and accordingly the quality of graduation. By choosing the teaching intensity ψ the total time spent in school τ is determined. Parents' advantage of a shorter duration of school is the increased time for working without any financial support for students' education. In addition, the child is able to get a job earlier and to earn income. However, a higher teaching intensity reduces human capital accumulation due to a more demanding school.

Secondly, parents have to choose their optimal effort level for child's human capital accumulation, given the teaching intensity ψ for the school. Parents decide on efforts according to their utility-function:

$$\begin{aligned} \max_e U(c^p, c^c) &= u(c^p) + \delta v(c^c) \\ &= u(y - \tau e) \\ &\quad + \delta v(h(1-\tau)) \text{ , with } \tau = \frac{S}{\psi} \end{aligned} \tag{II.6}$$

where $u(\cdot)$ and $v(\cdot)$ are increasing concave functions of parental consumption respectively child's consumption ($u' > 0$, $v' > 0$ and $u'' < 0$, $v'' < 0$). Parental utility is weighted by parameter δ for child's consumption. One can interpret δ also as a measure of parental altruism or status seeking. Hence the utility function can be seen as the total family consumption which parents maximize.

At the last stage all students build up their individual human capital given their innate ability a, parental investments e and teaching intensity ψ.

In summary:

1. Parents vote on teaching intensity ψ.
2. Parents choose their parental effort for child's education by maximizing their utility.
3. All students accumulate human capital given innate ability a, parental investments e and teaching intensity ψ.

We solve our model by backward induction.

3.3 Parental investments

First of all students accumulate their human capital for a given level of parental support e and teaching intensity ψ.

Afterwards parents maximize their utility over e for a given teaching intensity. The first order condition can be written as follows:

$$\begin{aligned} \frac{\partial U(c^p, c^c)}{\partial e} &= u^{'} c^p_e + \delta v^{'} c^c_h h_e \\ &= -u^{'} \frac{S}{\psi} + \delta v^{'} (1 - \frac{S}{\psi}) h_e = 0 \end{aligned} \tag{II.7}$$

Increasing financial support in child's education reduces parental consumption by the duration of school, while child's consumption increases due to a higher human capital. For a period of time $(1-\tau)$ a child is able to generate income.

To achieve an interior solution for the optimal parental effort, the second derivative of parental utility function has to be negative:

$$\frac{\partial^2 U(c^p, c^c)}{\partial e^2} = u^{''} (\frac{S}{\psi})^2 + \delta (1 - \frac{S}{\psi}) [v^{''} (1 - \frac{S}{\psi}) (h_e)^2 + v^{'} h_{ee}] < 0 \tag{II.8}$$

which depends on the second derivative of human capital with respect to parental effort (h_{ee}), since the other parts of equation (II.8) are strictly negative. By assuming constant or decreasing marginal returns ($h_{ee} \leq 0$), we achieve an interior solution for parental effort. This assumption is quite feasible, since human capital accumulation is based on innate capabilities which are limited (Kuehn and Landeras (2012)).

In the next step we want to analyze how optimal parental effort reacts on a change of family income, child's innate ability and teaching intensity. For our purpose we define equation (II.7) as $R(e^*) = 0$, thus we can use the implicit function theorem:

$$R(e^*) = -u^{'} \frac{S}{\psi} + \delta v^{'} (1 - \frac{S}{\psi}) h_e = 0 \tag{II.9}$$

$$\frac{de^*}{dx} = -\frac{R_x}{R_e}, \text{ where } x \in \{y, a, \psi\} \tag{II.10}$$

Firstly, we analyze the impact of parental income on parental investments in child's education:

$$R_y = -\frac{S}{\psi} u'' c_y^p > 0 \tag{II.11}$$

so we can state:

$$\frac{de^*}{dy} = -\frac{R_y}{R_e} > 0 \tag{II.12}$$

Parents invest more financial resources for human capital if family income increases ($\frac{\partial e^*}{\partial y} > 0$), because of decreasing marginal utility of income.

Furthermore we can analyze the influence of child's innate ability on parental effort:

$$R_a = \delta(1-\frac{S}{\psi})[v'' c_h^c h_a h_e + v' h_{ea}] \gtreqless 0 \tag{II.13}$$

so we can state:

$$\frac{de^*}{da} = -\frac{R_a}{R_e} \gtreqless 0 \tag{II.14}$$

where the overall sign effect depends on the sum in the bracket of equation (II.13). The first part is strictly negative, while the derivative h_{ea} is positive (Kuehn and Landeras (2012)). We can assume that given a certain level of parental investments, students with a higher innate ability level benefit more from these ($h_{ea} > 0$). In his empirical analysis Wößmann (2008) compares the influence of socio-economic background on students' TIMSS performance[10] in the US and 17 Western European countries. Measured by the performance distribution of the students and quantile regressions the author shows that for the majority of observed school systems the extent of family background increases with the innate ability of the child,[11] e.g. in England the effect of family background is more than double so high for the 90^{th} percentile than for the 10^{th} percentile.[12]

Finally we are interested in the impact of teaching intensity on parental invest-

[10] In this analysis the standardized math respectively science test results are used of the year 1995.

[11] Only the Netherlands, Flemish Belgium and Denmark show a different pattern.

[12] These differences vary from country to country, e.g. in Switzerland the appropriate increase is only about 10 percent.

ments in child's education:

$$R_\psi = \frac{S}{\psi^2}\left[u^{'} - u^{''} e \frac{S}{\psi}\right] + \delta \left[v^{''} (c_h^c)^2 h_\psi h_e + v^{'} \left(h_e c_{h\psi}^c + h_{e\psi} c_h^c\right)\right] \gtreqless 0 \quad \text{(II.15)}$$

so we can state:

$$\frac{de^*}{d\psi} = -\frac{R_\psi}{R_e} \gtreqless 0 \quad \text{(II.16)}$$

The first part of the derivative concerning the effect on parental consumption is positive, since duration of parental support decreases with teaching intensity. In contrast, the second part is not so clear, which depicts the effect on child's consumption. On the one hand an increase of ψ has a negative effect on human capital accumulation ($h_\psi < 0$), on the other hand the period of time for working increases and so child's consumption. Additionally, the sign of $h_{e\psi}$ is ambiguous which we discuss in the following section.

3.4 Human capital and teaching intensity

For our purpose, we have to define an explicit human capital function and utility function, to analyze parental choice of teaching intensity ψ and a majority voting equilibrium. The empirical evidence shows that family efforts appear to be rather a substitute than a complement for school resources (Houtenville and Conway (2007)). Parents increase financial support for education if their children need more help to establish human capital.[13] It seems convincing that parents increase financial efforts with increasing teaching intensity to support their children in school. Hence we determine the following human capital function:

$$h(a, e, \psi) = (ae - b\psi^2)S \quad \text{(II.17)}$$

This human capital function fulfills our main assumptions ($h_a > 0$, $h_e > 0$, $h_\psi < 0$). In our analysis the human capital of a student depends not only on innate ability, but also on socio-economic background. Following the equality of opportunity

[13] A clear majority of parents (79 percent) still prefer a longer duration of secondary school in Germany (**?**). This poll indicates that parents evaluate the reduction of secondary school duration rather as a disadvantage than a successful policy change in the education system. Thus it is more likely that parents increase their financial support for child's education.

literature (Roemer (1998); Schütz et al. (2008)) this means that child's education is also influenced by exogenous circumstances, e.g. parents' educational attainment or income.[14] We assume that child's innate ability has to be supported by the parents, to be effective for human capital.[15] Being in school means to make efforts for graduation. In this context b describes an exogenous weight parameter which depicts the influence of teaching intensity ψ on student's human capital accumulation. We can interpret b as an institutional factor for the education system. A high level of b means that students are influenced to a great extent by teaching intensity ψ, while a lower b stands for a smaller relevance for human capital accumulation. While student's human capital is increasing with innate ability, it is decreasing with teaching intensity. Hence our human capital function describes the consequences of a more demanding school due to an increased teaching intensity.

By using the following parental utility function we can calculate the optimal parental effort level:

$$\begin{aligned} \max_e U(c^p, c^c) &= ln(c^p) + \delta ln(c^c) \\ &= ln(y - \tau e) \\ &\quad + \delta ln(h(1-\tau)) \text{ , with } \tau = \frac{S}{\psi} \end{aligned} \tag{II.18}$$

and

$$e^*(a, y, \psi) = \frac{\psi(ay\delta + Sb\psi)}{Sa(1+\delta)} \tag{II.19}$$

Apparently, the marginal utility of the child's consumption is decreasing with child's innate ability, so that parental support is decreasing if the student is more talented ($\frac{\partial e^*}{\partial a} < 0$). Analyzing the impact of the exogenous institutional parameter b ($\frac{\partial e^*}{\partial b} > 0$) and teaching intensity ($\frac{\partial e^*}{\partial \psi} > 0$) on financial efforts shows that a more demanding school increases parental support. In our theoretical framework financial resources spent by parents increase if students need more help to accumulate their human capital. Furthermore we get a convex relationship between parental financial

[14] The extent of inequality in opportunities is up to the institutional setting of the education system. For example the importance of preschool education and a de-tracked secondary school is pointed out by several studies (**?**Schnepf (2002); Schütz et al. (2008); Uhlig et al. (2009); Hanushek and Wößmann (2006)).

[15] In this context an additive relation between child's ability a and parental effort e is also possible. The advantage of the multiplicative relation is the avoidance of corner solutions with respect to parental support (hence $e^* > 0$).

support and teaching intensity ($\frac{\partial^2 e^*}{\partial \psi^2} > 0$) due to the decreasing influence of socio-economic background, for instance if the extent of afternoon classes increases. Thus parents have to increase their educational investments disproportionately as soon as school becomes more demanding for students.

One kind of parental financial support could be the purchase of private lessons, in order to help the own child to achieve educational goals. The market for additional private lessons is quite developed in Germany[16] and a recent analysis shows that the demand for private lessons depends on socio-economic background (Dohmen et al. (2008)). Obviously the introduction of G8 led to a more demanding school for students which parents try to compensate by additional financial resources. Hence the results of our theoretical framework are in line with empirical studies.

Proposition 1: Parents try to compensate rising educational requirements with additional financial resources ($\frac{\partial e^*}{\partial \psi} > 0$). *Parental support for child's graduation decreases with respect to student's innate ability level* ($\frac{\partial e^*}{\partial a} < 0$) *and increases with parental income* ($\frac{\partial e^*}{\partial y} > 0$) .

Proof: see Appendix A 1

Finally, each parent decides on the desired teaching intensity ψ given the optimal choice of parental effort e^*:

$$\begin{aligned} \frac{\partial U(c^p(e^*), c^c(e^*))}{\partial \psi} &= \frac{1}{c^p}\frac{\partial c^p}{\partial \psi} + \delta \frac{1}{c^c}\frac{\partial c^c}{\partial \psi} \\ &= -\frac{1}{c^p}\frac{Sb}{a(1+\delta)} \\ &\quad + \delta \frac{1}{c^c}\frac{\delta(ay - 2Sb\psi)}{1+\delta} = 0 \end{aligned} \quad \text{(II.20)}$$

Concerning teaching intensity parents face the following trade-off: On the one hand an increasing ψ reduces time spent in school and hence parental financial support for child's education is invested for a shorter duration. As a consequence parental consumption increases. On the other hand school becomes more demanding and student's effort increases with negative outcome on human capital accumulation. Simultaneously parents increase their efforts for child's education in order to compensate the more demanding school.

[16] Due to unsatisfying data base Dohmen et al. (2008) estimate the market volume of professional private lesson to be about 1 billion Euro. This corresponds to a share of 20 percent of total private expenditures for secondary and tertiary education in Germany (Klemm (2005)).

The second order condition shows concavity:

$$\frac{\partial^2 U(c^p,c^c)}{\partial \psi^2} = -\frac{1}{(c^p)^2}\left(\frac{\partial c^p}{\partial \psi}\right)^2 + \frac{1}{c^p}\frac{\partial^2 c^p}{\partial \psi^2} + \delta[-\frac{1}{(c^c)^2}\left(\frac{\partial c^c}{\partial \psi}\right)^2 + \frac{1}{c^c}\frac{\partial^2 c^c}{\partial \psi^2}] < 0 \qquad \text{(II.21)}$$

since $\frac{\partial^2 c^p}{\partial \psi^2} = 0$ and $\frac{\partial^2 c^c}{\partial \psi^2} < 0$ (see Appendix A 3). Parents face also a trade-off regarding child's consumption. An increasing teaching intensity ψ reduces the duration in school and increases the period of time in labor market. Nevertheless, the rise of student's effort decreases human capital and consequently future wage level decreases. Hence we calculate the expression for the optimal choice of the teaching intensity ψ:

$$\psi^*(a,y) = \frac{ay\delta + S^2 b(1+\delta)}{Sb(1+2\delta)} \qquad \text{(II.22)}$$

The desired teaching intensity $\psi^*(a,y)$ is monotonically increasing in parental income and child's innate ability:

$$\frac{\partial \psi^*}{\partial y} = \frac{a\delta}{Sb(1+\delta)} > 0 \qquad \text{(II.23)}$$

and

$$\frac{\partial \psi^*}{\partial a} = \frac{y\delta}{Sb(1+\delta)} > 0 \qquad \text{(II.24)}$$

Proposition 2: Given their optimal financial support for child's education, parents' desired teaching intensity ψ^* is a monotonically increasing function of parental income and child's innate ability.

4 Political economy analysis

4.1 Policy preferences

After analyzing parental decision on financial support for child's education we characterize in the next step the political decision process. In this section we discuss the general conditions for a majority voting equilibrium with regard to the parental utility function. Households differ in income y as well as in child's innate ability a and vote on the optimal teaching intensity $\bar{\psi}^*$ at the first stage. In our simplified education system the duration of compulsory school τ is determined by the entire academic syllabus S and the teaching intensity ψ. Since academic curriculum is kept constant, parents determine by voting on teaching intensity the duration of compulsory school. Again we want to point out that the focus of our political economy model is not the quality of the education system, but parents' choice of the optimal teaching intensity.

Now we want to evaluate how teaching intensity ψ changes with respect to family income y. Therefore we build the total differentiation of equation (II.20) with respect to ψ and y which can be written as follows:

$$\frac{d\psi}{dy} = -\frac{\frac{\partial^2 U}{\partial\psi\partial y}}{\frac{\partial^2 U}{\partial\psi^2}} > 0 \tag{II.25}$$

The following lemma is proved in the Appendix A 4:

Lemma 1:

$$\begin{aligned}\frac{\partial^2 U(c^p(e^*),c^c(e^*))}{\partial\psi\partial y} &= -\frac{1}{(c^p)^2}\frac{\partial c^p}{\partial y}\frac{\partial c^p}{\partial\psi}+\frac{1}{c^p}\frac{\partial^2 c^p}{\partial\psi\partial y} \\ &\quad +\delta\left(-\frac{1}{(c^c)^2}\frac{\partial c^c}{\partial y}\frac{\partial c^c}{\partial\psi}+\frac{1}{c^c}\frac{\partial^2 c^c}{\partial\psi\partial y}\right) > 0\end{aligned} \tag{II.26}$$

Hence in our case the choice of teaching intensity ψ is monotonically increasing in parental income y. We can state that preferences of households are single crossing (Gans and Smart (1996)) and the median income $\bar{y}$ household is decisive for a given innate ability a. With increasing family income parental consumption increases as well as child's human capital due to a greater financial support. In this context, households with a higher family income can easier deal with a higher level of teaching intensity.

Proposition 3: For a given innate ability a the preferred teaching intensity $\bar{\psi}^*$ *is the one which is also chosen by the median income* $\bar{y}$ *household. The teaching intensity is monotonically increasing in parental income.*

In our framework families differ not only in income y, but also in child's innate ability a. Now we analyze how teaching intensity reacts if child's capability changes. Again we use the total differentiation of (20) with respect to ψ and a which can be written as follows:

$$\frac{d\psi}{da} = -\frac{\frac{\partial^2 U}{\partial\psi\partial a}}{\frac{\partial^2 U}{\partial\psi^2}} > 0 \tag{II.27}$$

The following lemma is proved in the Appendix A 5:

Lemma 2:

$$\begin{aligned}\frac{\partial^2 U(c^p(e^*), c^c(e^*))}{\partial\psi\partial a} &= -\frac{1}{(c^p)^2}\frac{\partial c^p}{\partial a}\frac{\partial c^p}{\partial\psi} + \frac{1}{c^p}\frac{\partial^2 c^p}{\partial\psi\partial a} \\ &+\delta\left(-\frac{1}{(c^c)^2}\frac{\partial c^c}{\partial a}\frac{\partial c^c}{\partial\psi} + \frac{1}{c^c}\frac{\partial^2 c^c}{\partial\psi\partial a}\right) \geq 0 \end{aligned} \tag{II.28}$$

According to parental income teaching intensity ψ is monotonically increasing in child's innate ability a. Household's preferences are single crossing (Gans and Smart (1996)) and the family with the median of child's capability $\bar{a}$ is decisive for a given income. Again with increasing student's innate ability parental consumption increases due to decreasing financial support for student's education. Simultaneously student's human capital increases as the marginal increase of a weights more than the loss of financial resources. Hence parents can easier cope with a higher level of teaching intensity ψ.

Proposition 4: For a given family income y the preferred teaching intensity $\bar{\psi}^*$ *is the one which is also chosen by the median innate ability* $\bar{a}$ *household. Teaching intensity* ψ *is monotonically increasing in a.*

4.2 Political equilibrium

So far we analyzed how parents choose their financial efforts e for child's education and how the preferred teaching intensity ψ responds to a marginal change in parental income y or child's innate ability a. In both cases we find that the ratio of curriculum content per unit of instructional time ψ is monotonically increasing in y and a, so preferences of parents are single crossing. Since households not only differ in one characteristic we need single-peaked preferences[17] of voters to define a voting equilibrium (Gradstein et al. (2005)). From equation (II.21) we can see that for all parental income and student's ability levels the second order condition is negative which ensures concavity and so single-peaked preferences. Thus a majority voting equilibrium exists and the preferred teaching intensity is the one which is also preferred by the median household (Gradstein et al. (2005)).

In our simple model families differ in parental income and child's capability, thus the preferred teaching intensity ψ^* depends on y and a:

$$\psi^*(a,y) \quad = \quad \frac{ay\delta + S^2b(1+\delta)}{Sb(1+2\delta)} \tag{II.29}$$

A marginal increase in parental income as well as in child's innate ability leads to a higher level of teaching intensity. Thus we can determine a line in a parental income-child's ability plane for a given teaching intensity $\bar{\psi}^*$ which is preferred by the median household (see Figure II.2):

$$\bar{a}(y) \quad = \quad \frac{Sb[\bar{\psi}^*(1+2\delta) - S(1+\delta)]}{y\delta} \tag{II.30}$$

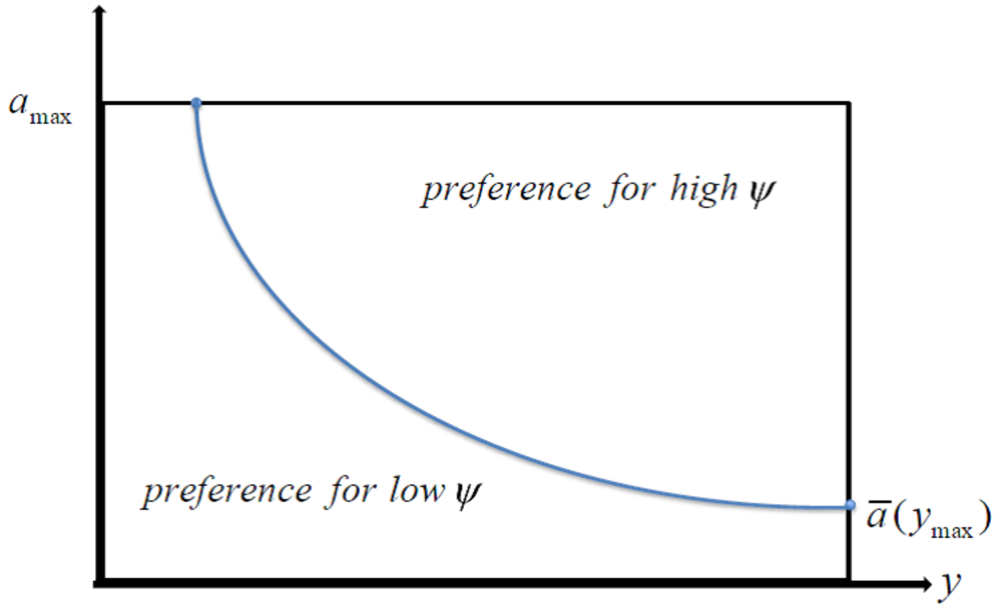
where every point on this line shows us a combination of y and a which represents a median household, i.e. for every income level we get the corresponding $\bar{a}_1(y)$ for a median household.

Since we know that the curve $\bar{a}(y)$ divides the parental income-child's ability plane into two equal parts, we can calculate the following relation (Hartung et al. (2005)):

$$\frac{1}{2} \quad = \quad \frac{1}{a_{max} \cdot y_{max}} \cdot \int_{y_{min}}^{y_{max}} \bar{a}(y)dy \tag{II.31}$$

[17] In contrast to the single crossing property single peaked preferences impose restrictions on the shape of individual preferences. In the case of single peaked preferences the voters are ranked according to their individually preferred policies, while voters with single crossing preferences can be ranked according to their individual types.

Figure II.2.: Determining the majority voting equilibrium of teaching intensity



which determines teaching intensity $\bar{\psi}^*$ which is preferred by the median household:

$$\bar{\psi}^* = \frac{a_{max}\delta + 2S^2 by_{max}(1+\delta)ln(\frac{y_{max}}{y_{min}})}{2Sby_{max}(1+2\delta)ln(\frac{y_{max}}{y_{min}})} \tag{II.32}$$

Figure II.2 shows that households with a relatively high parental income and children with a higher innate ability tend to vote for higher level of teaching intensity ψ than families with less income and children with a lower innate ability. Between these two groups the line represents all median households with a y-a combination who are decisive for the preferred teaching intensity $\bar{\psi}^*$. Consequently the time spent in school τ decreases with higher parental income and student's capability in equilibrium. Again we want to point out that the quality of graduation S is kept constant, so that a shorter school duration does not lead per se to a lower human capital accumulation.

Following this result our simple political economy model can explain why diverging duration of secondary school can be observed when the decision making process is decentralized.

Proposition 5: By characterizing the majority voting equilibrium we can show that parents' preferences are single-peaked and hence the preferred teaching in-

tensity $\bar{\Psi}^*$ is the one which is also preferred by median household. Families with a more favorable socio-economic background and children with a higher innate ability vote for a relatively high teaching intensity and thus prefer a shorter school duration.

The diverging duration of secondary school could also play an important role for equity of opportunities of graduates on the labor market. If employers interpret the time spent for a high school degree as a signal for quality of future employees, students with a more favorable family background will benefit due to the reduced duration of secondary school. Since academic syllabus is kept constant and independent of teaching intensity, students with more parental support are able to achieve graduation faster than students with the same innate ability but less family income. In this context, a decentralized decision making process with regard to teaching intensity increases the correlation between employment and family background and thus decreases social mobility in a society. This aspect has to be considered in the discussion about secondary school length.

5 Conclusion

Educational reforms are always associated with intense controversies, since policy changes are often far-reaching. Also the reduction of time spent in highest secondary school track (*Gymnasium*) in almost every German federal state was critically discussed just from the beginning. A clear consequence of the introduction of G8 was an increasing teaching intensity in order to keep academic curriculum constant. The amount of afternoon classes increased and some difficult subjects, for instance the second foreign language, was brought forward. Due to the higher ratio of curriculum content per unit of instructional time students' effort increased. Furthermore the concrete implementation was criticized, because not every school seemed properly prepared for the reform. Hence some state governments decided to decentralize the decision about secondary school duration by parental voting.

The aim of this paper is to characterize the majority voting equilibrium. We introduce a political economy model with households who differ in both parental income and child's innate ability. Therefore, we endogenize parental investment in child's human capital and implement students' effort into human capital accumulation which are increasing with teaching intensity.

First, we can show that financial support for child's education increases if teaching intensity increases, according to the empirical evidence that family financial support appears to be a substitute for school resources (Houtenville and Conway (2007)). A higher level of teaching intensity increases student's effort which parents try to compensate by financial resources. In addition, family support decreases with increasing level of child's innate ability.

Secondly, we analyze the influence of parental income as well as child's innate ability on preferred teaching intensity. In both cases we can show that preferences are single crossing, i.e. preferred teaching intensity is monotonically increasing in both household's characteristics.

Finally, we describe the majority voting equilibrium. Since parental preferences are single-peaked the preferred teaching intensity is the one which is also preferred by median household. In this context, families with a favorable socio-economic background and children with a higher innate ability tend to vote for a higher teaching intensity and to favor a reduced secondary school length. Hence we can observe that the preferred duration of secondary school diverges if the decision making process is decentralized and determined by parents.

Our theoretical model is also a contribution to the equality of opportunity literature (Roemer (1998); Schütz et al. (2008)), since the human capital accumulation depends on parental financial resources. Households with more income can afford more private support and therefore their children can deal with a more demanding school. This result is in line with the empirical analysis of Heller (2008) and can be the base for educational implications. One advantage of a shorter duration of school is the early access to the labor market. In addition a faster graduation could be a signal for student's productivity which improves the employment opportunities. Due to the positive correlation between preferred teaching intensity and family income, students from a favorable socio-economic background are able to graduate faster. Thus social mobility decreases in the labor market if parents vote on the teaching intensity of secondary school.

Appendix

A 1: Optimal parental investments

Given a teaching intensity ψ the parents maximize their utility with respect to e (parental effort).

First-order condition:

$$\frac{\partial U(c^p,c)}{\partial e} = \frac{1}{c^p}(-\tau)+\delta\frac{1}{c}\tau(1-\tau)=0$$

Second-order condition:

$$\begin{aligned}\frac{\partial^2 U(c^p,c)}{\partial e^2} &= \tau\frac{1}{(c^p)^2}\frac{\partial c^p}{\partial e}-\tau(1-\tau)\frac{1}{(c)^2}\frac{\partial c}{\partial e}\\ &= -\tau^2\frac{1}{(c^p)^2}-\tau^2(1-\tau)^2\frac{1}{(c)^2}<0\end{aligned}$$

Hence

$$e^* = \frac{\psi(ay\delta+Sb\psi)}{Sa(1+\delta)}$$

is the optimal parental investment level.

A 2: Marginal derivatives of the optimal parental investment e^*

a) With respect to teaching intensity ψ

$$\frac{\partial e^*}{\partial \psi} = \frac{ay\delta+2Sb\psi}{Sa(1+\delta)}>0$$

thus parental investments in child's education increases with teaching intensity. Parents have to rise their educational investments disproportionately as the school becomes more demanding for the students.

$$\frac{\partial^2 e^*}{\partial \psi^2} = \frac{2b}{a(1+\delta)}>0$$

b) With respect to the innate ability level a

$$\frac{\partial e^*}{\partial a} =- \frac{b\psi^2}{a^2(1+\delta)}<0$$

c) With respect to income y

$$\frac{\partial e^*}{\partial y} = \frac{\delta\psi}{S(1+\delta)} > 0$$

d) With respect to b

$$\frac{\partial e^*}{\partial b} = \frac{\psi^2}{a(1+\delta)} > 0$$

A 3: Single-peaked preferences of the parents (voters)

In order to show that a majority voting equilibrium exists, we have to prove the concavity of the parents' utility function:

$$\frac{\partial^2 U(c^p(e^*),c^c(e^*))}{\partial\psi^2} = \underbrace{-\frac{1}{(c^p)^2}\left(\frac{\partial c^p}{\partial\psi}\right)^2}_{<0} + \underbrace{\frac{1}{c^p}\frac{\partial^2 c^p}{\partial\psi^2}}_{=0} + \\ + \underbrace{-\frac{\delta}{(c^c)^2}\left(\frac{\partial c^c}{\partial\psi}\right)^2}_{<0} + \underbrace{\frac{\delta}{c^c}\frac{\partial^2 c^c}{\partial\psi^2}}_{<0} < 0$$

Therefore we analyze the following second-order conditions:

a) Parental consumption

$$c^p(e^*) = y - \tau e^*$$

with

$$\tau = \frac{S}{\psi},\ \frac{\partial\tau}{\partial\psi} \equiv \tau' = -\frac{S}{\psi^2} < 0,\ \frac{\partial^2\tau}{\partial\psi^2} \equiv \tau'' = \frac{S}{\psi^3} > 0$$

and

$$\frac{\partial c^p(e^*)}{\partial\psi} = -\tau' e^* - \frac{\partial e^*}{\partial\psi}\tau = -\frac{Sb}{a(1+\delta)} < 0$$

On the one hand we can see from the derivative that the parental consumption decreases with ψ. On the other hand $\frac{\partial c^p(e^*)}{\partial \psi}$ is independent of the teaching intensity ψ, so we can state:

$$\frac{\partial^2 c^p(e^*)}{\partial \psi^2} = 0$$

b) Child's consumption

$$\begin{aligned}
c^c(e^*) &= h(e^*)(1-\tau) \\
&= [ae^* - b\psi^2]S(1-\frac{S}{\psi}) \\
&= \left(\frac{\delta\psi(ay - Sb\psi)}{1+\delta}\right)S(1-\frac{S}{\psi})
\end{aligned}$$

with

$$\begin{aligned}
\frac{\partial h(e^*)}{\partial \psi} &= S\left[(a\frac{\partial e^*}{\partial \psi} - 2b\psi)(1-\frac{S}{\psi}) + \frac{S}{\psi^2}(ae^* - b\psi^2)\right] \\
&= \frac{\delta(ay - 2Sb\psi)}{1+\delta}
\end{aligned}$$

so we can state:

$$\frac{\partial^2 h(e^*)}{\partial \psi^2} = -\frac{\delta}{1+\delta}2Sb < 0$$

Derivative of child's consumption with respect to ψ :

$$\begin{aligned}
\frac{\partial c^c(e^*)}{\partial \psi} &= \frac{\partial h(e^*)}{\partial \psi}(1-\tau) - \tau' h(e^*) \\
&= \frac{\delta(ay + Sb(S - 2\psi))}{1+\delta}
\end{aligned}$$

and

$$\begin{aligned}
\frac{\partial^2 c^c(e^*)}{\partial \psi^2} &= \frac{\partial^2 h(e^*)}{\partial \psi^2}(1-\tau) - 2\tau' \frac{\partial h(e^*)}{\partial \psi} - \tau'' h(e^*) \\
&= -\frac{\delta}{1+\delta}2Sb < 0
\end{aligned}$$

A 4, Proof of Lemma 1: Single-crossing of teaching intensity with respect to y
We want to show the following relation:

$$\frac{d\psi}{dy} = -\frac{\frac{\partial^2 U}{\partial \psi \partial y}}{\frac{\partial^2 U}{\partial \psi^2}} > 0$$

with

$$\begin{aligned}\frac{\partial c^p(e^*)}{\partial \psi} &= \tau' e^* - \frac{\partial e^*}{\partial \psi}\tau \\ &= -\frac{Sb}{a(1+\delta)} < 0\end{aligned}$$

and

$$\begin{aligned}\frac{\partial c^c(e^*)}{\partial \psi} &= \frac{\partial h(e^*)}{\partial \psi}(1-\tau) - \tau' h(e^*) \\ &= \frac{\delta(ay + Sb(S-2\psi))}{(1+\delta)}\end{aligned}$$

Since we already know that $\frac{\partial^2 U}{\partial \psi^2} < 0$, $\frac{\partial^2 U}{\partial \psi \partial y} > 0$ has to be proved:

$$\begin{aligned}\frac{\partial U(c^p(e^*), c^c(e^*))}{\partial \psi} &= \frac{1}{c^p}\frac{\partial c^p}{\partial \psi} + \delta \frac{1}{c^c}\frac{\partial c^c}{\partial \psi} \\ &= -\frac{1}{c^p}\frac{Sb}{a(1+\delta)} \\ &\quad + \delta \frac{1}{c^c}\frac{\delta(ay + Sb(S-2\psi))}{(1+\delta)}\end{aligned}$$

So we can evaluate the derivative with respect to parental income y:

$$\frac{\partial^2 U(c^p(e^*), c^c(e^*))}{\partial \psi \partial y} = -\frac{1}{(c^p)^2}\frac{\partial c^p}{\partial y}\frac{\partial c^p}{\partial \psi} + \delta \frac{1}{c^c}\frac{\partial c^c}{\partial \psi \partial y} - \delta \frac{1}{(c^c)^2}\frac{\partial c^c}{\partial y}\frac{\partial c^c}{\partial \psi}$$

with

$$\frac{\partial c^p}{\partial y} = \frac{1}{1+\delta} > 0$$

$$\frac{\partial c^c}{\partial y} = \frac{a\delta(\psi - S)}{1+\delta} \geq 0 \text{ , for } \psi \geq S$$

$$\frac{\partial c^c}{\partial \psi \partial y} = \frac{a\delta}{1+\delta} > 0$$

so we get the following term:

$$\frac{\partial^2 U(c^p(e^*), c^c(e^*))}{\partial \psi \partial y} = \frac{Sba(1+\delta)}{(ay - Sb\psi)^2} > 0$$

A 5, Proof 5 of Lemma 2: Single-crossing of teaching intensity with respect to a

We want to show the following relation:

$$\frac{d\psi}{da} = -\frac{\frac{\partial^2 U}{\partial \psi \partial a}}{\frac{\partial^2 U}{\partial \psi^2}} > 0$$

Since we already know that $\frac{\partial^2 U}{\partial \psi^2} < 0$, $\frac{\partial^2 U}{\partial \psi \partial a} > 0$ has to be proved:

$$\begin{aligned}\frac{\partial U(c^p(e^*), c^c(e^*))}{\partial \psi} &= \frac{1}{c^p}\frac{\partial c^p}{\partial \psi} + \delta \frac{1}{c^c}\frac{\partial c^c}{\partial \psi} \\ &= -\frac{1}{c^p}\frac{Sb}{a(1+\delta)} \\ &\quad + \delta \frac{1}{c^c}\frac{\delta(ay + Sb(S - 2\psi))}{(1+\delta)}\end{aligned}$$

So we can evaluate the derivative with respect to innate ability level a

$$\begin{aligned}\frac{\partial^2 U(c^p(e^*), c^c(e^*))}{\partial \psi \partial a} = &-\frac{1}{(c^p)^2}\frac{\partial c^p}{\partial a}\frac{\partial c^p}{\partial \psi} + \frac{1}{c^p}\frac{\partial c^p}{\partial \psi \partial a} \\ &+ \delta \frac{1}{c^c}\frac{\partial c^c}{\partial \psi \partial a} + (-\delta \frac{1}{(c^c)^2}\frac{\partial c^c}{\partial a}\frac{\partial c^c}{\partial \psi})\end{aligned}$$

with

$$\frac{\partial c^p}{\partial a} = \frac{Sb\psi}{a^2(1+\delta)} > 0$$

$$\frac{\partial c^c}{\partial a} = \frac{y\delta(\psi - S)}{1+\delta} \geq 0 \text{ , for } \psi \geq S$$

$$\frac{\partial c^c}{\partial \psi \partial a} = \frac{y\delta}{1+\delta} > 0$$

so we get the following term:

$$\frac{\partial^2 U(c^p(e^*), c^c(e^*))}{\partial \psi \partial a} = \frac{Sby(1+\delta)}{(ay - Sb\psi)^2} > 0$$

Part III.

It’s payback time: The impact of tuition fees on students’ teaching evaluation

1 Introduction

The policy of university funding is decisive for quantity and quality of teaching activities. Although some European countries offer an almost cost-free higher education, most tertiary education systems are financed by a combination of tax based funding and private tuition fees (EURYDICE (2011)). In this context, students' private investments for visiting a university is an ongoing debate in public policy. The latest discussion about removing the cap on tuition fees in Britain and the intense protests led by students' organizations in 2011 show the importance of this controversial issue.[1] To achieve acceptance for tuition fees supporters point out that the additional financial resources are used for improving universities' teaching quality. Therefore students benefit from their private investments. However, by paying tuition fees students increase their expectations of teaching quality due to the higher financial burden, so that they are more seen as consumers by higher education institutions.

Thus, it is important for universities to analyze students' perception of course quality and to respond to critics. The organization of teaching activities is a fundamental duty of tertiary education. By using students' teaching evaluation the teaching staff get an impression of perceived quality of lectures and tutorials. In this context, students' evaluation offers the chance for an improved supply of universities' teaching activities and for an increased acceptance for tuition fees.

The aim of our paper is to analyze the impact of tuition fees on students' teaching evaluation and hence on the perceived quality of teaching activities. We use the partial introduction of tuition fees in Germany to estimate the causal effect on teaching evaluation by means of a Difference in Difference (DiD) approach. The introduction of tuition fees in the summer semester 2007 was controversially discussed between political parties and in public, since the German tertiary education system had been free of any financial burden for students for almost 40 years. So far universities were not allowed to charge tuition fees for their Bachelor and Master programs.[2] Several state governments (Baden-Württemberg, Bavaria, Hamburg,

[1]Finally the British government allowed universities to charge annual tuition fees up to 9000 pounds. The previous cap was 3290 pounds.

[2]The so called *Hochschulrahmengesetz* by the federal government regulates the general institutional setting for public universities in Germany. Nevertheless, the education policy is mainly determined by the state governments, so that national regulations can only be interpreted as

Hesse, North Rhine-Westphalia, Saarland and Lower Saxony) implemented annual tuition fees of up to a maximum amount of 1000 Euro to receive additional financial resources.[3] Hereby the universities guarantee that the entire fund from tuition fees are only used to improve teaching activities, in order to ensure a large acceptance among students.[4]

"We have used these funds to improve services for students by, for instance, extending library opening hours, giving more tutorials and improving facilities in medical education." (Prof. Bernd Huber, President of the University of Munich (LMU))[5]

On the one hand we have evaluation data from the economics department of the University of Munich which introduced tuition fees of up to 1000 Euro per year for the first time in four decades in the summer semester 2007.[6] On the other hand we use students' teaching evaluation from the economics department of the Humboldt University Berlin which does not charge tuition fees in the observation period. Students from both universities have to finance administrative costs amounting to 100 Euro per year. Our panel data set (winter semester 2004/05 till winter semester 2008/09) comprises information on under- and postgraduate courses, class size and the number of tutorials provided by the responsible chairs. Furthermore we know the instructor of the evaluated course, so that we can control for instructor fixed effects.

Beside the use of students' teaching evaluation for an improved supply of lectures and tutorials, the teaching quality perceived by students is also important for the instructor. The results of students' evaluation can affect the promotion and tenure decision of universities and thus influence instructors' future academic career. Especially when the feedback of students is published, teaching effectiveness and social

guidelines for tertiary education policy. In the year 2005 the German Constitutional Court decided that a ban on tuition fees by the federal administration is illegitimate.

[3] Before tuition fees were introduced students had to finance administration costs amounting to 100 Euro per year which were kept. Hence students now have to spend eleven times as much as before to visit a higher education institution.

[4] To ensure that the fund from tuition fees is only spent for teaching activities, a committee was founded which controls universities' expenditures. Half of the members are students' representatives. Consequently it is possible for students to control the contribution of tuition fees.

[5] Interview with Times Higher Education, 01.12.2011:
www.timeshighereducation.co.uk/418257.article (13.06.2013)

[6] Tuition fees existed before for students who either studied more than one Bachelor respectively Master program or needed more semesters for graduation than approved.

skills of the instructor are revealed. Students' choice of courses and respectively of the instructor can depend on evaluation results. Thus teaching evaluation can be the base for the distribution of the department's budget.

The remainder of the chapter is structured as follows: The next section gives a short overview of the discussion about teaching evaluation. Section 3 briefly describes the data set and depicts the estimation method. Section 4 shows and interprets our findings and Section 5 concludes.

2 Teaching evaluations

Students' teaching evaluation in tertiary education systems is a very common practice in many countries. Seldin (1993) shows the immense expansion of students' evaluation in the USA for the last decades. In 1973 only 29 percent of all US universities used a teaching evaluation system, twenty years later almost 86 percent of all tertiary education institutions implemented students' teaching evaluation. The same trend is observable in other Anglo-Saxon oriented universities (Kulik (2001)).

There is a widespread literature about the sense or nonsense of students' teaching evaluation (Kulik (2001)). The core question in these studies is always whether students' feedback reveals teaching quality or reports other instructor characteristics. The aim of every students' evaluation practice is the measure of teaching effectiveness. Like Kulik (2001) tellingly summarizes:

"If ratings are valid, students will give good ratings to effective teachers and poor ratings to ineffective ones" (p.10)

But which kind of measurement is the best for this purpose? Evaluation by teaching experts and alumni surveys are often used as alternatives to students' teaching evaluation. However, there is evidence that both alternatives have their drawbacks in comparison to students' teaching evaluation (Scriven (1983)). In addition, several studies show a positive correlation between students' evaluation and students' academic achievements (Costin et al. (1971); Cohen (1981); Perry et al. (2007)). The meta-analysis of Cohen (1981) was the first published on this topic and covers data from forty-one studies which include information of 68 university courses. The findings suggest that the correlation between teaching evaluation and students' achievements is moderate to high.

Due to the relevance of teaching evaluation we find a large literature concerning the important determinants. First, the focus is on instructor characteristics. Marsh (1987) is able to show that instructor characteristics are more influential than the subject taught by the instructor. The same conclusion is made by Aigner and Thum (1986), who estimate that 67 percent of the variation in instructors' teaching performance was explained by instructor-specific variables, for instance enthusiasm and interaction abilities. But which characteristics are most appreciated by students? Several studies show that teaching skills like the ability to organize a course and to communicate with students are most valued (Nelson and Lynch (1984); DeCanio (1986); Boex (2000); Gokcekus (2000)). It is important to note, that students distinguish between instructor's teaching effectiveness and instructor's pure entertainment skills (Costin et al. (1971); Marsh and Ware (1982); McKeachie (1978)). Overall, students give higher evaluation scores for instructors who are able to deliver the academic curriculum in a competent and enjoyable manner. An instructor's charisma has a considerable impact on students' feedback (Shevlin et al. (2000)), but this does not mean that teaching effectiveness is less regarded. An instructor with a strong personality is self-confident and hence it is easier for him/her to teach a group of students. Some studies also estimate the influence of instructor's beauty on students' evaluation (Hamermesh and Parker (2005); Süssmuth (2006)) and conclude a small but significant positive effect. Accordingly we use instructor fixed effects to control for these factors in our DiD approach.

Secondly, there are several studies which examine the importance of student-specific characteristics, for instance students' grade expectations (Aigner and Thum (1986); Isely and Singh (2005)). It seems that students give higher evaluation scores to instructors who guarantee favorable grades. In this context it is important to know whether the grades of a course are made before or after the instructor is evaluated by the students. In our case students' teaching evaluation is organized three to four weeks before the final exam for the course is taken place and six to seven weeks before the results of the exam are published. Thus for students from the University of Munich and the Humboldt University of Berlin it is quite hard to anticipate instructors' grading policy at the date of teaching evaluation. Furthermore, there is no strong evidence for an effect of gender or students' capabilities on teaching evaluation (Seldin (1993)).

Finally, we examine subject-specific characteristics which have an impact on students' evaluation. Many studies analyze the class size effect on perceived teaching quality. While Williams and Ory (1992) and Ting (2000) can not find an influence of class size on students' feedback, Bedard and Kuhn (2008) and Mandel and Süssmuth (2011) find an effect of class size. Controlling for both instructor and course fixed effects, they find evidence for a large, highly significant and nonlinear negative class size effect on teaching evaluation. Hence Mandel and Süssmuth (2011) assume for classes with more than 20 students that an instructor hardly knows students' names by heart and consequently the course loses its familiar character. Further subject-specific characteristics like the time of day or time of year in which the course was held are not significant (Liaw and Goh (2003)). Due to our evaluation data set we are able to include class size information and control for course fixed effects.

Overall, it is important to point out that there are several effects which can influence students' teaching evaluation. Some of these instructor-, student- and course-specific factors are explained above. In reality it is hard to distinguish between instructor's pure charisma and his or her teaching abilities. Do students give better grades to instructors because they are likable or due to the fact that they learn a lot? Furthermore, some instructor characteristics can be associated with teaching effectiveness. Nevertheless, it seems to be clear that the perceived quality of offered lectures and tutorials plays a decisive role for students' satisfaction, especially when students have to pay tuition fees and can be seen as consumers (Clayson and Haley (2005)). Thus students' teaching evaluations are an important instrument for universities to measure students' perception of teaching quality.

3 Data and method

3.1 Student evaluation data

Our panel data set includes nearly all economics classes offered at the University of Munich (Ludwig-Maximilians University, henceforth: LMU) and the Humboldt University of Berlin (henceforth: HUB) from the winter semester 2004/05 to the winter semester 2008/09.[7] During this 8 semester period, 1.701 economics classes in 395 different courses were offered by 491 instructors. Our data set comprises information on class size, the semester, the level of the class (lower and upper division), the instructor and the average evaluation score. Summary statistics for our variables are reported in Table III.1.

Table III.1.: Summary statistics (2004-2009)

Variables	University of Munich (LMU)	Humboldt University of Berlin (HUB)
Total number of classes	913	788
Instructors	264	227
Courses	172	223
Average number of tutorials	2.38	0.70
Average class size	47.32	51.39
Share of upper division	73.6 %	71.1 %
Share of lectures	36.9 %	62.5 %

The academic studies of a diploma degree takes four to five years and is divided into a lower (three to four semesters) and an upper division part (five to six semesters). Students of both universities have to pass all basic courses in the lower division part to visit the advanced classes of the upper division part. Thus we can assume that these courses differ in their level of difficulty. According to this our data set includes 71.1 percent of upper division courses of the LMU and 73.6 percent of the HUB. The share of 36.9 percent of the entire supply of LMU courses are lectures which are usually organized and held by the chair holders. In contrast, the Humboldt University of Berlin shows a higher share of lectures of 62.5 percent

[7] Disclosure of an instructor's evaluation result is not mandatory. However, the resulting attrition is less than 2 percent. Subsamples of this data set are also used and described in Süssmuth (2006) and Mandel and Süssmuth (2011).

due to the lower number of offered tutorials. The reason for the smaller supply of tutorials is probably the smaller total number of students visiting the HUB, since the difference in average class size is not very high. Tutorials are usually held by research assistants.

In accordance with the Bologna Process the economics department of the LMU started to offer the existing German Diploma degree as well as the Bachelor/Master degree in the year 2000. This first reform step generally corresponded to a separation of the Diploma program into two parts, since nearly the same courses with the same grading scheme were offered. A complete switch to the Bachelor and Master degrees with a Europe-wide comparable credit point system was implemented in 2008. The management department of the LMU changed their academic studies in a similar way in 2006. The Humboldt University of Berlin introduced a comparable Bachelor and Master program in the winter semester 2004/05 and stopped to provide the previous Diploma degree in the summer semester 2007. Nevertheless, the separation between lower and upper division courses with lectures and tutorials is still observable for both universities during our observation period.

The evaluation data are published and made available in the form of student evaluation scores aggregated to class means:

$$E_{j,i,c,t} = \frac{1}{R_{j,i,c,t}} \sum_{k=1}^{R_{j,i,c,t}} e_{i,c,t,k} \qquad \text{(III.1)}$$

where e denotes individual student evaluation scores, E is the average class evaluation score, R is the number of evaluation responses,[8] t denotes the semester (t = 2004/2005,..., 2008/2009), c denotes different courses, $i = 1,..., I$ denotes the instructor and j reflects the University of Munich respectively the Humboldt University of Berlin.

The evaluation sheet of the LMU separates between an overall rating for the course[9] and for the instructor. Amongst other categories, students can evaluate the instructor's teaching skills, competence and motivation. Similar to the U.S. practice (Hamermesh and Parker (2005); Bedard and Kuhn (2008)) the rating forms at the LMU include: "Overall, my personal impression is that the instructor was excellent

[8]The number of responses R might differ from class size or enrollment, due to absenteeism on the day that evaluations are administrated. At the LMU and the HUB this is usually the case three to four weeks before the semester ends.

[9]For instance, students can evaluate the structure of the course and the coordination between lecture and tutorial.

(1); very good (2); satisfactory (3); unsatisfactory (4); very unsatisfactory (5).”[10] The evaluation sheet of the HUB only has one overall impression rating which follows the same five rating levels as the LMU evaluation sheet. Accordingly students can rate the course and the instructor with regard to different characteristics, for instance the structure of the course, the instructor’s teaching ability and competence. Since these sub-questions are focused on instructor’s teaching capabilities, the HUB overall evaluation score is comparable with the LMU overall instructor rating. For interpretive ease, we reverse and transform the average class evaluation scores E to lie in the interval $[0,1]$, by using $\widetilde{E}_{j,i,c,t} = \frac{1}{4} \mid E_{j,i,c,t} - 5 \mid$. Thus $\widetilde{E}_{j,i,c,t} = 0$ denotes the poorest and $\widetilde{E}_{j,i,c,t} = 1$ the best instructional performance.

Figure III.1.: Average evaluation score

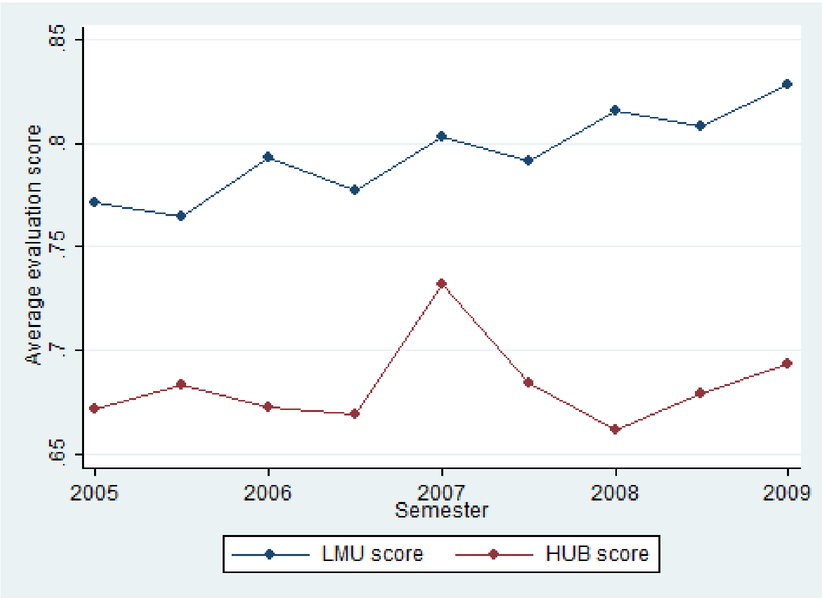


Figure III.1 illustrates that the average evaluation score is higher at the University of Munich (0.79) than at the Humboldt University of Berlin (0.68) for the observation period. Both universities show improved students’ teaching evaluation at the end of the period in comparison to the winter semester 2004/05. Furthermore the average evaluation score of the University of Munich follows the trend that the instructors’ mean score is higher in winter semesters than in summer semesters. The reason for this could be the supply of courses which differs from semester to semester or the students composition.[11] Therefore we control for semester dummies

[10] We only have information on mean evaluation scores. Data on medians and intra-class standard deviations are not available.

[11] German students usually begin their academic studies in winter semester.

in our Difference in Difference approach.

The introduction of tuition fees in the summer semester 2007 was the subject of public debate and quite controversially discussed by the political parties, since the German tertiary education system had been free of any financial burden for students for almost 40 years. In order to ensure a large students acceptance, the University of Munich guaranteed that the total budget from tuition fees is only used to improve teaching activities. For this purpose, a committee was founded which controls the expenditure planning at the University of Munich. Half of the members are students' representatives. Thus it is possible for LMU students to influence the use of tuition fees. The following changes were initiated to improve the learning conditions: A new central information and service office for all concerns regarding the Bachelor and Master program as well as administrative questions was set up at the economics and management department. Moreover, the supply of lecture notes for almost all courses was expanded. The correction duration of exams was reduced by additional research assistants.[12] However, the main part of the tuition fees was spent on additional teaching supply, through additional tutorials and lectures held by guest professors.

Figure III.2.: Average class size

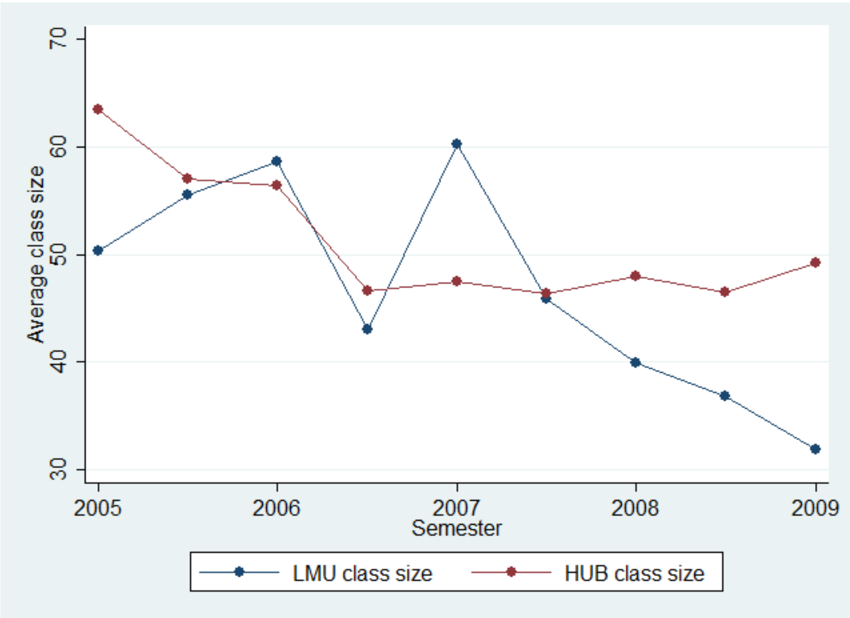


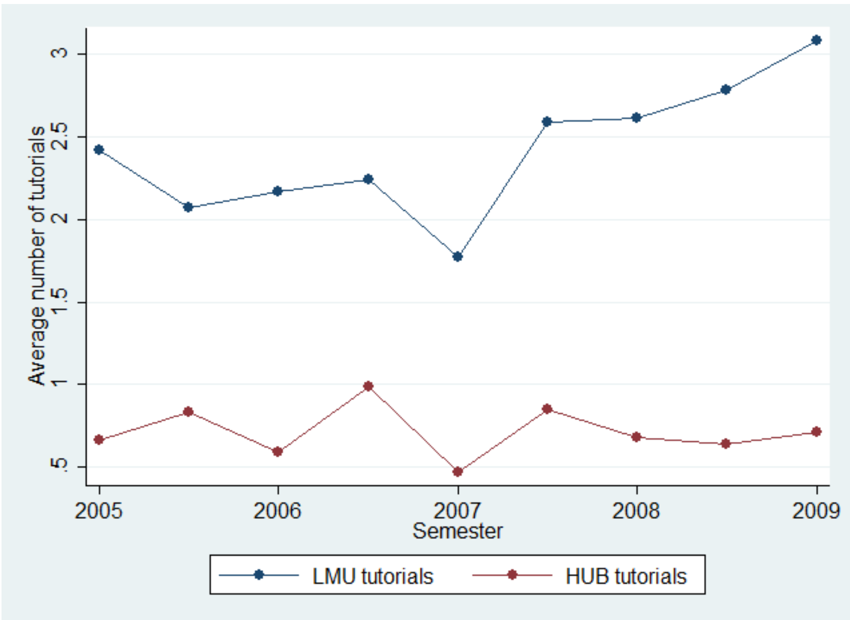
Figure III.2 shows that the average class size was quite similar before tuition fees

[12]Furthermore the University of Munich offered presentation techniques courses for all instructors to support the teaching abilities. These courses are optional and financed by tuition fees.

were introduced by the University of Munich. After the summer semester 2007 the average class size of LMU courses decreased and diverged from the average class size of HUB courses (Figure III.2). Obviously, the increased supply of courses led to an increased instructor-students ratio. The relevance of the class size for instructors' evaluation scores is evident (Mandel and Süssmuth (2011)) and is included in our DiD approach.

Figure III.3 illustrates the change of average number of tutorials over the observation period. Note that tutorials are usually held by research assistants and offered to exercise the lecture's notes by problem sets. These exercise questions are often the base for the final exam of the course and thus important for students. While the average number of tutorials stayed almost constant at the Humboldt University of Berlin after the summer semester 2007, the University of Munich increased the supply of tutorials. Again, this growth in average number of tutorials suggest that the additional financial resources from tuition fees were invested to improve the instructor-students ratio.

Figure III.3.: Average number of tutorials



In both universities student research assistants at the chair of the students' dean (StudiendekanIn) organize the evaluation of all courses which are offered in the respective semester. The results are discussed in detail by the council of the faculty and published by the economics students' representative body. Thus all members of the faculty and all students have access to the instructors' mean score. Besides

E, the published evaluation summary contains information on the number of participants in the class, the title of the class, and the instructor. These information are important, because it allows us to estimate instructor fixed effects models that control for time-invariant instructor heterogeneity and course fixed effects models that control for course-specific heterogeneity.

In summary, the descriptive analysis suggests that the additional financial resources from tuition fees were invested to improve students' learning conditions by different channels. Both, institutional factors and the entire supply of teaching activities were influenced by the new policy. With our student evaluation data set we estimate whether these reforms had an impact on teaching quality perceived by students.

3.2 Difference in Difference approach

To identify the unbiased effect of introducing tuition fees on students' teaching evaluation we use a DiD approach with instructor and course fixed effects. Starting from the summer semester 2007 (begin of the treatment: introduction of tuition fees) all courses of the University of Munich are included as the treatment group in our estimation. Since the Humboldt University of Berlin did not charge tuition fees in this period, we use these courses as our control group. By the mean of fixed effects we consider the following endogeneity problems: Instructors' characteristics could be a reason for biased estimations. For instance, the University of Munich could try to increase the perceived teaching quality by selecting instructors, who are more able to hold a course or are more popular with students than other instructors. Hence we control for instructors' ability to teach and to interact with students which is important for the average evaluation score. Furthermore our panel data set includes information about the offered courses in each semester. It is obvious that 395 courses differ in some kind, e.g. in difficulty and average students' interest. In this context, our estimated treatment effect could be biased if the supply of courses changed after the introduction of tuition fees. By using a fixed effects model we are able to control for such endogeneity issues.

Since the influence of tuition fees on average evaluation score can differ during the observation period, we consider the following fixed effects model (following

Acemoglu et al. (2011)):

$$\begin{aligned}\widetilde{E}_{j,i,c,t} &= \alpha+\alpha_{ji}+\alpha_{jc}+d_t+ \\ &+\sum_{\tau\in T^{pre}}\beta_\tau\times d_\tau\times I_j+ \\ &+\sum_{\tau\in T^{post}}\beta_\tau\times d_\tau\times I_j+\delta X_{j,i,c,t}+u_{j,i,c,t} \qquad \text{(III.2)}\end{aligned}$$

where $\alpha_{j,i}$ and $\alpha_{j,c}$ are vectors of instructor i respectively course c fixed effects for university j. Matrix X contains several course characteristics: level of class (lower or upper division), a dummy identifying whether the class is a lecture or a tutorial, the average class size and the total number of tutorials which were offered in combination with the lecture. In addition, we include semester dummies d_t to control for potential differences between winter and summer semesters and to identify a time trend. Our treatment variable I_j is one for every LMU course and zero for every HUB course. To estimate the treatment effect we include interaction terms between our treatment group I_j and a set of pre-treatment semester dummies T^{pre} as well as post-treatment semester dummies T^{post}. Thus we can evaluate the pre-trends of both universities with regard to our dependent variable average evaluation score $\widetilde{E}$ as well as post-tuition fees effects on perceived teaching quality ($\sum_{\tau\in T}\beta_\tau\times d_\tau\times I_j$ denotes the separate interaction effects for each semester). We expect the pre-treatment coefficients $\sum_{\tau\in T^{pre}}\beta_\tau$ to not be significantly different from zero and simultaneously the post-treatment coefficients $\sum_{\tau\in T^{post}}\beta_\tau$ to be significant and positive if the introduction of tuition fees led to improved students' teaching evaluation. Finally, α represents a constant and u denotes the usual error term.

We test our results for robustness by estimating a general DiD model of the following form:

$$\begin{aligned}\widetilde{E}_{j,i,c,t} &= \alpha+\alpha_{ji}+\alpha_{jc}+d_t+ \\ &+F+I_j+\beta(F\times I_j)+\delta X_{j,i,c,t}+u_{j,i,c,t} \qquad \text{(III.3)}\end{aligned}$$

where the dummy variable F equals one for all semesters after the introduction of tuition fees (from summer semester 2007). For identifying the influence of tuition fees on the average teaching evaluation we are particularly interested in the coefficient β which measures the treatment effect in our model. All other included variables are the same as described above.

Overall, we want to point out the advantages of our DiD approach: By comparing the average evaluation scores of two economics departments (treatment group: LMU and control group: HUB) before and after the introduction of tuition fees we are able to identify the unbiased effect on teaching quality perceived by students. Furthermore, we include instructor fixed effects to purge the treatment effect of any bias caused by time invariant instructors' heterogeneity. Individual characteristics, for example the ability to teach, to organize a course and to interact with students differ among the 491 observed instructors in our panel data set. Therefore we control for a non-random assignment of instructors after the introduction of tuition fees. Accordingly we also include fixed effects for the supply of courses in each semester to control for a potential selection bias.

4 Findings and interpretation

4.1 Findings

In total we run three estimation models to identify the effect of introducing tuition fees on students' teaching evaluation (Table III.2).

Table III.2.: Students' teaching evaluation

	OLS (1)	I-FE (2)	I-C-FE (3)
Constant	0.724***(0.016)	0.791*** (0.022)	0.805*** (0.025)
LMU×SS 05 (pre)	-0.020 (0.027)	-0.004 (0.020)	0.043 (0.027)
LMU×WS 05/06 (pre)	0.021 (0.023)	0.017 (0.019)	0.016 (0.019)
LMU×SS 06 (pre)	0.006 (0.024)	0.012 (0.021)	0.063**(0.028)
LMU×WS 06/07 (pre)	-0.026 (0.028)	-0.023 (0.026)	-0.020 (0.027)
LMU×SS 07 (post)	0.006 (0.024)	0.028 (0.024)	0.053*(0.027)
LMU×WS 07/08 (post)	0.049** (0.022)	0.081*** (0.021)	0.077*** (0.025)
LMU×SS 08 (post)	0.022 (0.023)	0.064** (0.026)	0.075** (0.034)
LMU×WS 08/09 (post)	0.023 (0.021)	0.046* (0.026)	0.043* (0.025)
Number of observations	1701	1511	1115
R^2	0.225	0.143	0.146
p-value for joint significance before SS 07	0.393	0.376	0.106
p-value for joint significance after WS 06/07	0.218	0.001	0.015

Standard errors in parentheses, p-value: *=0.10, **=0.05, ***=0.01

Dependent variable: Average evaluation score

Notes: All regressions have full set of semester dummies and all course characteristics X as described in the previous section. We run the regression with robust standard errors clustered by the instructor respectively course.

The first column shows the pooled cross-section regression (OLS) which includes all 1701 courses of our panel data set. By controlling for instructor fixed effects (I-FE, column 2) our sample size decreases, since instructors who held only one course during the observation period are excluded. The last regression also controls for course fixed effects (I-C-FE, column 3) which reduces sample size again. Now all courses are excluded which were held by a single instructor from winter semester 2004/05 to winter semester 2008/09 (Mandel and Süssmuth (2011)).[13]

[13] In our full panel data set we have 53.6 percent courses of the LMU and 46.4 percent HUB courses. The reduced sample of the I-C-FE model shows a similar ratio: 55.2 percent LMU courses and 44.8 percent HUB courses.

According to Acemoglu et al. (2011) we estimate interaction terms for the treatment group LMU and for each semester in our three specifications. Thereby the set T^{pre} denotes summer semester 2005 to winter semester 2006/07 (for the regression we omit the winter semester 2004/05), while T^{post} represents the period from summer semester 2007 to winter semester 2008/09. Analyzing the simple OLS regression (column 1), we can see that the sign of the pre-treatment dummies varies. However, all estimated coefficients $\hat{\beta}_{T^{pre}}$ are not only insignificant, but also confirm the hypothesis that they are not significantly different from zero. This is also the case for all post-treatment dummies $\hat{\beta}_{T^{post}}$ with a p-value of the F-test for joint significance of 0.218, although $\hat{\beta}_{WS07/08}$ is positive and significant. In column 2 we evaluate the instructor fixed effects model which shows, that all pre-treatment dummies are insignificant and can have a negative or positive sign. Similar to the OLS regression the estimated coefficients $\hat{\beta}_{T^{pre}}$ are not significantly different from zero. In contrast, our post-treatment dummies are all positive and significant after the summer semester 2007. Furthermore, the estimated coefficients $\hat{\beta}_{T^{post}}$ are significantly different from zero (p-value of the F-test for joint significance of 0.001). These results indicate that the introduction of tuition fees had a positive influence on students' teaching evaluation, although the effect is with $\hat{\beta}_{WS07/08} = 0.081$ and $\hat{\beta}_{WS08/09} = 0.046$ decreasing during the period. In our last estimation model in column 3 we additionally control for course fixed effects. Again, we see that not all estimated coefficients $\hat{\beta}_{T^{pre}}$ are positive and we can confirm the hypothesis that all pre-treatment dummies are not significantly different from zero. The coefficients of our interaction terms $\hat{\beta}_{T^{post}}$ are again all positive and significant. According to the I-FE estimation (column 2) the post-treatment dummies are significantly different from zero (p-value of the F-test for joint significance of 0.015) and qualitatively similar. Keeping in mind that the five distinct grades of the evaluation score was transformed to the close interval [0,1], the move from one full grade to another amounts 0.25. Thus the estimated coefficient $\hat{\beta}_{WS07/08} = 0.077$ implies an improvement of LMU's average evaluation score of up to one-third of a full grade in winter semester 2007/08. In terms of size it mostly outweighs all other estimated coefficients in the three regressions (see Table III.3).

To sum up, these results suggest that the aim of tuition fees was achieved at the University of Munich, to increase the teaching quality perceived by students.

Table III.3.: Students' teaching evaluation, remaining coefficients

	OLS (1)	I-FE (2)	I-C-FE (3)
Class size	-0.001***(0.000)	-0.001***(0.000)	-0.001***(0.000)
Class size^2	0.004*** (0.001)	0.005*** (0.001)	0.004*** (0.001)
Class size^3	-0.004*** (0.001)	-0.005*** (0.001)	-0.004** (0.001)
Upper division	0.003 (0.007)	0.003 (0.013)	-0.027 (0.017)
Lecture	-0.028*** (0.008)	-0.024 (0.018)	-0.032 (0.020)
Number of tutorials	-0.001 (0.001)	0.001 (0.003)	0.009 (0.007)
SS 05	0.014 (0.020)	0.002 (0.015)	-0.045** (0.022)
WS 05/06	0.001 (0.017)	-0.002 (0.014)	-0.004 (0.012)
SS 06	-0.005 (0.017)	-0.004 (0.014)	-0.063*** (0.023)
WS 06/07	0.058** (0.024)	0.049** (0.023)	0.043* (0.024)
SS 07	0.011 (0.018)	0.003 (0.019)	-0.048** (0.024)
WS 07/08	-0.010 (0.016)	-0.025 (0.017)	-0.034* (0.019)
SS 08	0.007 (0.017)	-0.006 (0.022)	-0.050* (0.029)
WS 08/09	0.023 (0.015)	0.033 (0.021)	0.023 (0.019)
Number of observations	1701	1511	1115

Standard errors in parentheses, p-value: *=0.10, **=0.05, ***=0.01

Dependent variable: Average evaluation score

Table III.3 shows the estimated coefficients of the remaining control variables. As expected the class size effect is negative and highly significant in all specifications (Mandel and Süssmuth (2011)). Tutorials are usually held by research assistants and offered to exercise the lecture's notes by problem sets. These exercise questions are often the base for the final exam of the course. Nevertheless, the number of tutorials is insignificant in all three estimation models and thus we cannot observe a positive impact on average evaluation scores. We can also not find any difference in students' teaching evaluation for an upper division course. A highly significant negative effect of the lecture dummy is only observable for the simple OLS regression, while by controlling for instructor and course fixed effects (column 2 and 3) the estimated coefficients are still negative but insignificant. In column 1 and 2 we see that the semester dummies are insignificant with the exception of the winter semester 2006/07. In our estimation model with instructor and course fixed effects almost all semester dummies are significant and mostly negative.

Finally, we estimate the general DiD model from equation (III.3) to test our results for robustness. Again, we run a simple OLS regression, an instructor fixed effects model and an estimation model controlling for instructor and course fixed effects. In all specifications the estimated coefficient for the treatment effect is positive and highly significant. This result confirms the positive influence of tuition fees on students' teaching evaluation.

Table III.4.: Students' teaching evaluation, general DiD model

	OLS (1)	I-FE (2)	I-C-FE (3)
Constant	0.751***(0.017)	0.792*** (0.022)	0.804*** (0.026)
$F \times I_j$ (Treatment effect)	0.031**(0.011)	0.054***(0.013)	0.038***(0.014)
F	-0.001 (0.013)	-0.010 (0.015)	-0.037** (0.016)
I_j	0.087*** (0.009)	-	-
Class size	-0.001***(0.000)	-0.001***(0.000)	-0.001***(0.000)
Class size^2	0.004*** (0.001)	0.005*** (0.001)	0.004*** (0.001)
Class size^3	-0.004*** (0.001)	-0.005*** (0.001)	-0.004** (0.001)
Upper division	0.002 (0.007)	-0.003 (0.013)	-0.018 (0.021)
Lecture	-0.028*** (0.008)	-0.024 (0.018)	-0.034* (0.020)
Number of tutorials	-0.001 (0.001)	0.001 (0.003)	0.007 (0.007)
SS 05 (pre)	-0.004 (0.013)	-0.000 (0.009)	-0.017 (0.012)
WS 05/06 (pre)	0.011 (0.011)	0.005 (0.019)	0.002 (0.009)
SS 06 (pre)	-0.001 (0.012)	0.001 (0.010)	-0.029**(0.013)
WS 06/07 (pre)	0.042** (0.013)	0.038*** (0.013)	0.036** (0.015)
WS 07/08 (post)	0.001 (0.011)	-0.000 (0.011)	0.020 (0.014)
SS 08 (post)	0.004 (0.011)	0.008 (0.012)	0.008 (0.013)
WS 08/09 (post)	0.021 (0.011)	0.038*** (0.012)	0.062*** (0.014)
Number of observations	1701	1511	1115
R^2	0.222	0.143	0.131

Standard errors in parentheses, p-value: *=0.10, **=0.05, ***=0.01

Dependent variable: Average evaluation score

Notes: We run the regression with robust standard errors clustered by the instructor respectively course.

4.2 Interpretation

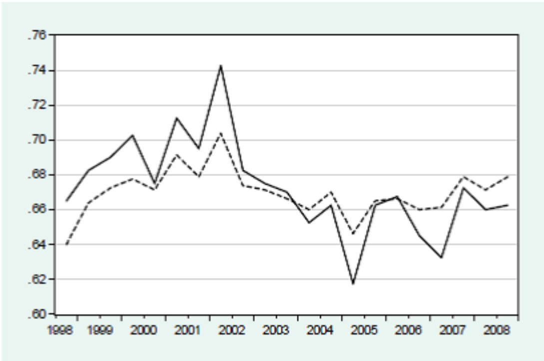
Although we are convinced that our estimation strategy has its advantages for identifying the causal effect of tuition fees on average evaluation scores, there are also some limitations.

The improvement of instructors' evaluation scores after the introduction of tuition fees could be explained in several ways. Clayson and Haley (2005) analyze the student's role as a consumer, especially when tuition fees have to be paid for tertiary education.

"Research is extensive in showing that students evaluate instructors based on what they want from the class." (Clayson and Haley (2005), p. 3).

Of course, one expectation refers to the final exam of the course and the grading. The interaction between higher grade expectations and higher instructor's evaluation score is shown by Isely and Singh (2005). In this context, instructors could assume that students impute a higher quality level to the course, since they have to pay tuition fees. Consequently students are more demanding and critical than before. These increased expectations could be compensated by the instructor's grading policy. We can rule out that our findings of a structural break in instructional evaluations after the introduction of tuition fees is driven by such a behavior (Figure III.4). The average final grades of the LMU management and economics department are tested to be stationary over our period of observation.[14] Hence we can not observe any kind of instructor's leniency with respect to students' achievements in course.

Figure III.4.: Mean final examination grades, fall 1998 to summer 2009



Solid line – average final grades economics programs

Dashed line – including management studies programs (weighted average)

KPSS test statistic (solid line): 0.365; fails to reject null of stationarity at 5 and 1% level

KPSS test statistic (dashed line): 0.115; fails to reject stationarity at 10, 5, and 1% level

Note: For interpretive ease, we reverse and transform the mean final examination grades to lie in the interval $[0,1]$.

The influence of students' grade expectations on teaching evaluations and instructors' effectiveness, is controversially discussed in the literature (Clayson and Haley (2005); Isely and Singh (2005)). Some empirical studies show that factors which define the quality of a course, e.g. the instructor's teaching ability and motivation, are much more important than the grade expectations (Hill et al. (2003); Gruber et al. (2010)).

Another explanation for improved students' teaching evaluation could be a different composition of students due to a change of mobility induced by tuition fees.

[14]Unfortunately we do not have the final examination grades of the Humboldt University of Berlin.

Again it is important to know that in Germany the education policy is mainly determined by the 16 state governments. Not all federal states introduced tuition fees.[15] Dwenger et al. (2012) use this "natural experiment" character to compare students mobility in a state with tuition fees (treatment group) with a state which do not charge tuition fees (control group). The authors can only observe a small significant decrease in university applicants for states with tuition fees (smaller than 2 percentage points). Since the Difference-in-Difference approach is based on the assumption that the control group is unaffected by the introduction of tuition fees, Dwenger et al. (2012) point out that

> "... our estimation yields an upper bound of the true effect on the treated individuals." (Dwenger et al. (2012), p. 7)

In contrast to these findings, Baier and Helbig (2011) analyze high school graduates' intention to study.[16] The authors cannot find a significant negative effect. Hence, their results do not suggest an increase in students mobility due to tuition fees in Germany. Beside the estimation of potential effects on students mobility, it is also crucial to analyze the impact of tuition fees on students' motivation. Are students even attracted by universities which charge tuition fees due to higher quality expectations? Students could expect a higher teaching quality due to the increased budget of the university. Every German higher education institution with tuition fees points out that the additional financial resources are only used to improve the teaching activities. A representative survey of the Federal Ministry of Education among high school graduates (Heine et al. (2008)) finds that only 1-2 percent of respondents see tuition fees as a signal of quality. Hence we see less evidence that the introduction of tuition fees was seen as a high quality signal by the students.

Overall, a change in students mobility due to tuition fees is quite unlikely. Moreover a potential discouraging effect should also be smaller for the University of Munich, since in the summer semester 2007 and winter semester 2007/2008 the tuition fees were only set at 300 Euro, instead of the allowed amount of 500 Euro per semester. Hence our estimations suggest that the higher instructors' evaluation scores are caused by the improved teaching activities. A student satisfaction survey

[15] The following states did not introduce tuition fees: Mecklenburg-Western Pomerania, Rhineland-Palatinate, Schleswig-Holstein, Bremen, Brandenburg, Saxony, Saxony-Anhalt, and Thuringia.

[16] Baier and Helbig (2011) make clear that they do not use real university application numbers, but the intention to study. They defend their dependent variable as a convincing proxy variable since the numbers of positive studying intentions and real university applications fit to 95 percent.

among LMU management students (Schwaiger and Schloderer (2009)) indicates an improved teaching quality perceived by the students. By comparing the years 2007 and 2009, the students' responses show an increase in interaction between students and instructors. This result is statistically significant for seminars and tutorials offered by the LMU economics department. In addition, the students appreciated the increased supply of lecture notes and decreased time of exam correction. Since teaching techniques courses for all instructors and the increased supply of course materials were financed by tuition fees, these changes could be a reason for the higher evaluation scores after the summer semester 2007.

5 Conclusion

The introduction of tuition fees was controversially discussed in Germany, especially regarding the question of equality of opportunities.[17] The implementation of tuition fees could lead to a relevant barrier for students from an unfavorable socio-economic background. Educational attainment would not only depend on individual achievements, but also on individual financial resources. Supporters of tuition fees see the opportunity for improved teaching activities due to an increased budget. Hence universities committed to invest the total budget from tuition fees in teaching activities. Furthermore students' representatives can directly control and decide about the use of the additional resources.

In this context, it is very important for a university to evaluate the success of tuition fees, especially in terms of improved teaching evaluations. Our paper analyzes the impact of tuition fees on students' teaching evaluation at the University of Munich (LMU) by using a DiD approach. The panel data set comprises the evaluation data of the management and economics departments of the University of Munich (treatment) and the Humboldt University of Berlin (control group). Furthermore, we are able to include both instructor and course fixed effects. Since the instructors differ in their characteristics, e.g teaching ability and motivation, our estimated coefficients could be biased due to a potential selection after tuition fees were introduced. It is also obvious that courses differ in difficulty and students' interest. Hence our fixed effects models help us purge our estimates of these types of bias.

But the introduction of tuition fees was not the only fundamental change in tertiary education during this period. In line with the Bologna Process the Bachelor and Master degree were implemented and replaced the previous Diploma degree. This change in graduation regularities was complemented by the new European Credit Transfer System, which makes students' achievements more comparable throughout Europe. By including semester dummies (from winter semester 2004/05 to winter semester 2008/09) we can control for these factors.

Controlling for instructor and course fixed effects we find a significant positive impact of tuition fees on students' teaching evaluation. The effect implies an improvement of up to one third a grade and thus an increase in teaching quality per-

[17] Several exceptions of paying tuition fees are made for different groups, e.g. students with children or less income. In addition to mitigate a possible discouraging effect of tuition fees the federal government offers student credits at reduced rates of interest.

ceived by students. Although our approach has several advantages, due to the existing data we cannot control for a potential change in students composition. Nevertheless, empirical surveys find no convincing evidence for a significant change in students mobility caused by tuition fees. In addition, we cannot confirm a change in grade policy after the introduction of tuition fees.

An improvement of the instructors' evaluation scores is a necessary condition for the University of Munich to be competitive with other universities, but it is not sufficient. Our results just provide evidence that the teaching activities improved in comparison to the Humboldt University of Berlin. However, we are not able to evaluate the teaching activities in comparison to all other universities (with or without tuition fees). For this purpose, it is necessary to introduce a standardized evaluation method for all universities. With the published instructors' evaluations scores students would get a better insight into the various teaching activities. Thus students have more information for their choice of university due to a higher transparency. This increased comparability strengthens the idea of students as customers, which is particularly convenient for students who pay tuition fees.

Finally, standardized students' teaching evaluation would help analyze how sustainable the effect of tuition fees on perceived teaching quality is. As described above, the charging of tuition fees was criticized from the beginning. The State of Bavaria abolished tuition fees again from winter semester 2013/2014. Of course, some positive changes are long-lasting, for instance instructors' improved teaching skills and the supply of lecture notes. However, the increased supply of courses and the improved instructor-students ratio (class size) depend on the financial resources.

Part IV.

Playing in the Champions League: The impact of the Excellence Initiative on competition between German universities

1 Introduction

In 1999 the European countries decided to aim convergence in higher education system. For this purpose, they initiated the Bologna Process with the goal to increase student mobility in Europe and to enhance the quality and comparability of higher education institutions. Therefore the European universities implemented the Bachelor and Master degree. As a consequence of this far-reaching reform competition for the best students increased and the efficiency of universities was discussed in public.

To improve the international competitiveness of German universities with respect to their research activities the German Federal Ministry of Education and Research introduced the Excellence Initiative in 2006, a nationwide program to reward the most efficient and productive universities in Germany. Every public university was allowed to apply for the excellence status and to benefit from additional financial resources. For the first round of the Excellence Initiative (2006/07-2012) the budget was set to 1.9 billion Euro for three funding lines: new graduate schools for post graduates (PhD students), the creation of interdisciplinary research clusters and the conceptual design of universities (so called *Zukunftskonzept*). Especially the last funding line is very important, since universities which are funded by this line are entitled to be called "Elite University". In Germany, most universities are publicly financed[1] and hence no university was officially characterized as an elite institution. Thus the Excellence Initiative adds the performance based funding to the previous universities' budget which is a novelty in German higher education policy.

One core element of the Excellence Initiative is the idea of competition and this for two reasons. On the one hand responsible authorities wanted to avoid the impression that certain universities are only supported due to political influence:

"In today's meeting there was unanimous consensus that the criterion of scientific excellence is key in both funding rounds and that decisions won't be made on the basis of preferred regions." (Annette Schavan, former Federal Minister of

[1] While over 110 universities are under the administrative and financial control of 16 German states, about 13 institutions are privately funded and state-approved. In Germany the administrative and financial responsibility for the entire education policy belongs to federal states. Hence the major share of financial resources is contributed by local governments (about 90 percent), while the remaining part is financed by the federal government.

Education and Research)[2]

On the other hand the public program should give an incentive for continuing improvements by a competitive setting. For this purpose, the Excellence Initiative has several application rounds which are evaluated by an independent expert council:

"This kind of competition set free a lot of new forces within the universities." (Margret Wintermantel, former President of the German Rectors' Conference)[3]

Consequently the prestigious status of an "Elite University" and the additional financial resources can be lost again and assigned to universities which were not supported before. However, the decision making process of the program was criticized since the results of the expert council are hard to verify. Furthermore it was doubted whether universities without financial support in the first round are really able to catch up and to get the excellence status in the next round.

In this context, our paper analyzes whether the decisions of the expert council was justified and the impact of the Excellence Initiative on the competition between German universities. Our panel data set (2001-2010) includes both information about output (amount of research grants, number of post graduates) and input variables (current expenditures, research and technical staff) of 70 public universities. Nine of these universities were entitled to be called "Elite University"[4] in the years 2006 and 2007 and were supported by additional financial resources. For our purpose, we use two different approaches. With the help of Data Envelopment Analysis (DEA) we evaluate the relative efficiency of German universities before the Excellence Initiative started to check the expert council decision. We find that seven of nine chosen "Elite Universities" are in fact on the efficient frontier line and thus more efficient than other higher education institutions with respect to research activities. In the next step we estimate the Malmquist index to analyze the change of total factor productivity of each university before (2001-2005) and after the introduction of the Excellence Initiative (2006-2010). The results suggest that competition between German universities is still balanced, although a certain group of universities benefited from additional financial support.

[2] Press release "Success for Baden-Württemberg in Germany's excellence initiative" of Bio Pro (16.10.2006): www.bio-pro.de/magazin/umfeld/archiv_2006/ (13.06.2013)

[3] The Chronicle of Higher Education, "Germany Pursues Excellence Over Egalitarianism" (02.07.2010): chronicle.texterity.com/chronicle/20100702a?pg=21#pg21 (13.06.2013)

[4] In the first round three universities (University of Karlsruhe, University of Munich (LMU) and Technical University of Munich (TUM)) were chosen and one year later six universities were added (RWTH Aachen University, Free University of Berlin (FU Berlin), University of Freiburg, University of Göttingen, Heidelberg University and University of Konstanz).

The chapter is organized as follows: In the next step we describe the Excellence Initiative in Germany and give an overview of the empirical literature. Our panel data set and a first descriptive analysis is presented in Section 2. The two different approaches of the DEA and the Malmquist index are shown in Section 3 and 4. Finally, the essential results of the paper are summed up in Section 5.

1.1 The Excellence Initiative in Germany

In the year 2005 the federal government and the 16 state governments[5] came to an agreement about a publicly funded program for high-class research activities in German universities. The main aim of this program is the improvement of public universities' international competitiveness and the support of research staff.[6] Thus the budget of 1.9 billion Euro[7] is allocated to three different funding lines: About 40 graduate schools are promoted with an entire amount of 40 million Euro per year to guarantee a high quality standard of post-graduate education. In addition, the program supports interdisciplinary research networks, the so called clusters of excellence. The total fund of 195 Million Euro per year is invested in both a more intensive cooperation between different departments and different non-university research institutions, for instance industry companies. The last funding line of the Excellence Initiative is the most important aspect for universities to achieve the prestigious status of an "Elite University". The board of the university has to prepare an institutional strategy to expand high-class research activities which are competitive with international standards (so called *Zukunftskonzept*). The last funding line has a budget of 210 Million Euro per year.

The selection process for the Excellence Initiative and the distribution of the financial resources were organized by the German Research Foundation (DFG) and the German Council of Science and Humanities (*Wissenschaftsrat*). For this purpose, a two-stage application procedure (first stage: draft proposal, second stage:

[5]The main share of 75 percent of the funding is provided by federal government.

[6]Beside research activities universities are also responsible to manage various teaching activities, but the focus of the Excellence Initiative is clear on improving the research branch. The reason for this selective promotion is the federal constitution in Germany which does not allow an influence of federal government on teaching activities. In this case only state governments are authorized, i.e. even a cooperation is not allowed.

[7]In comparison to total public expenditures for higher education institutions the budget of the Excellence Initiative is below one percent (Statistisches Bundesamt (2011)). Nevertheless, the public promotion is still remarkable for a single university. For instance, 24 percent of total research grants of the University of Munich are financed by the funding lines of the Excellence Initiative (**?**).

full application) was implemented which is organized by an independent council of 26 experts. The applications were evaluated according to several criteria, e.g. outstanding research quality, university's attractiveness for foreign post graduates, previously provided research activities, experience with research grants and a convincing organization. It is important to know that at least one successful application for a graduate school as well as a cluster of excellence were necessary to get also support from the third funding line (*Zukunftskonzept*). As already explained above, this last funding line was combined with the elite status and of course additional financial support. Nevertheless, the acceptance of only one funding line, whether a graduate school or a cluster of excellence, was also possible.

After the first stage a total number of 36 universities were asked to send a full application. In the second stage 10 public universities were selected for the funding line *Zukunftskonzept* and finally three got the status of an "Elite University" - the University of Karlsruhe, the University of Munich and the Technical University of Munich. One year later six universities were added to this funding line - RWTH Aachen University, Free University of Berlin, University of Freiburg, University of Heidelberg, University of Göttingen and the University of Konstanz.[8]

One core element of the Excellence Initiative is the limited duration of financial support. After the first round (2006/07-2012) all public universities are again allowed to apply for financial support in the second round of the Excellence Initiative (2012-2017). Of course, this means that previously accepted funding lines can lose their status. Thus it is also possible that the nine "Elite Universities" lose their prestigious status. This application procedure should provide an incentive for a continuing improvement of research activities in Germany.

1.2 Empirical strategy

A large number of empirical studies analyzes the efficiency of universities and the determinants of a successful human capital accumulation in tertiary education by using the Data Envelopment Analysis (DEA).

Several studies analyze the efficiency of economics departments, like Johnes and Johnes (1995) for British and Cokgezen (2009) for Turkish universities. In contrast, Beasley (1997) examines the relative efficiency of chemistry and physics depart-

[8]In total 39 graduate schools and 37 clusters of excellence from 28 universities were announced. As described before some of these graduate schools and clusters of excellence belong to the nine "Elite Universities".

ments in Britain. Of course, various papers estimate the efficiency of an entire university within a country (Avkiran (2001); Carrington et al. (2005); Warning (2004); Johnes (2006)). All these empirical studies have in common to use information on expenditures and personnel for the DEA. The first comparison of universities' relative efficiency between different countries was made by Joumady and Ris (2005) who examine universities' technical efficiency of eight European countries. The authors add data of interviews with graduates to their study to analyze efficiency of teaching activities with respect to the needs of working graduates. Further cross-national studies were made by Agasisti and Johnes (2009) and Agasisti and Perez-Esparrells (2010) who use the amount of research grants as an output factor for higher education institutions. For our analysis we also include research grants as an output variable, since the Excellence Initiative only supports research activities.

For German higher education institutions we can refer to two studies with different approaches. On the one hand Warning (2004) uses DEA to examine relative efficiency of 73 publicly funded universities in 1998. By including information about expenditures (technical/research staff, remaining costs) and numbers of publications (differentiated between Science Citation Index (SCI) and Social Science Citation Index (SSCI)) the author analyzes differences between teaching versus research and social versus natural sciences. Warning (2004) concludes that the German universities differ in efficiency and that the relative efficiency depends on universities' characteristics and structural factors. Our estimation approach also controls for the influence of universities' characteristics and structural factors, for instance the economic power of the region. On the other hand Kempkes and Pohl (2010) examine relative efficiency of German universities with a panel data set (1998-2003) which is more convenient for volatile data.[9] Thus the authors are able to estimate the change of total factor productivity over the period of time by using the Malmquist index. The study focus on the question whether the East German universities are catching up on teaching and research activities in comparison to their West German counterparts. In contrast, our paper analyzes the competition between German universities with respect to the Excellence Initiative. Hence we include the number of post graduates instead of the number of under graduates as an output variable, since the support of PhD students is part of the Excellence Initiative. In addition, we use the Malmquist index to evaluate the impact of the public reward program on the competition between German universities.

[9] For instance research grants, number of publications and graduates are volatile data.

2 Data and descriptive analysis

Our paper is focused on the relative efficiency of German universities and the influence of the Excellence Initiative on tertiary education system. Hence we include all relevant publicly financed universities which were allowed to apply for the governmental support. In this context private universities and universities of applied science (the so called *Fachhochschule*) are not taken into account since these institutions are excluded from the public program.

The panel data set includes information on 70 German universities with multiple input and output variables, provided by the Federal Statistic Office of Germany. For estimating the relative efficiency of universities we have to determine our output and input variables. Since the Excellence Initiative is clearly focused on research activities, we include the number of post graduates as a proxy variable for the quality of post graduation.[10] Furthermore we determine the amount of research grants[11] as the second important output variable in our data set. Research grants are seen as a proxy variable for quality of previous research projects and thus as a kind of a market price for research (Johnes (1997); Koshal and Koshal (1999)). In addition it reflects the ability to organize research activities with other institutions.[12] As described before each application of a university for the Excellence Initiative benefited from the experience of previous research grants.

Higher education institutions use several input factors. Firstly, we consider technical and research staff as input variables. Besides, current expenditures are an additional input (Kempkes and Pohl (2010)).[13] In our panel data set all monetary variables are deflated to the base year 2005 using the government consumption deflator (Sachverständigenrat (2011)).

Before we analyze the relative efficiency of German universities, we describe

[10] Accordingly it is prevalent to use the number of graduates as a proxy variable for teaching activities in the empirical literature (Stevens (2005); Kempkes and Pohl (2010)). Since many exams are organized decentralized by universities and not centralized, it is not feasible to compare exam results for evaluating the teaching quality of an entire university.

[11] Due to the data set we cannot tell for what purpose the research grants were spent.

[12] The number of publications is also a proxy variable for research activities in empirical studies (Warning (2004)). Unfortunately, we do not have a general index for all universities. Furthermore not all faculties measure their research quality by the number of publications.

[13] Other expenditures are defined as follows: Total expenditures minus entire wage spending. We exclude wage spending, since wage level can differ from state to state. In Germany the tertiary education is completely organized by state governments.

by means of some basic data the general situation of the publicly financed tertiary education system from 2001 to 2005, i.e. one year before the Excellence Initiative started.

Table IV.1.: Ratios of outputs and inputs in federal states (2001-2005)

Federal state	$\frac{Expenditures^{a)}}{Graduates}$	$\frac{Research\,staff}{Graduates}$	$\frac{Research\,grants^{a)}}{Research\,staff}$
Baden-Württemberg (W[b)])	57.34	1.57	20.83
Bavaria (W)	42.88	1.18	15.11
Berlin (E)	62.01	1.28	21.28
Brandenburg (E)	24.22	1.30	15.95
Bremen (W)	30.47	1.30	32.47
Hamburg (W)	45.28	1.36	18.88
Hesse (W)	45.64	1.22	17.76
Mecklenburg-West Pomerania (E)	91.56	1.77	11.93
Lower Saxony (W)	32.13	1.16	14.71
North Rhine-Westphalia (W)	54.78	1.13	16.88
Rhineland-Palatinate (W)	27.80	0.92	15.60
Saarland (W)	74.69	1.85	11.50
Saxony (E)	45.40	1.51	20.12
Saxony-Anhalt (E)	123.81	2.09	14.51
Schleswig-Holstein (W)	90.67	1.00	24.09
Thuringia (E)	42.49	1.44	15.14
AverageØ	49.62	1.30	17.23
Universities in West Germany	46.48	1.23	17.23
Universities in East Germany	60.21	1.54	17.22

a) measured in 1000 Euro with the base year 2005.

b) W: West Germany, E: East Germany

Source: Federal Statistical Office of Germany; own calculations

Table IV.1 shows average expenditures of 49.620 Euro per graduate,[14] but these expenditures differ to some extent significantly from state to state. For instance, the average expenditures per graduate in the East German federal states Mecklenburg-West Pomerania and Saxony-Anhalt are more than double and three times as high as in the West German federal state Bavaria. For the German context it is interesting that average expenditures are lower in West Germany than in East Germany. The reason for this difference could be a catching-up process of the East German universities after the German reunification (Kempkes and Pohl (2010)).

Beside financial resources university's research staff is an important input. Again the ratio between research staff and graduates differs from state to state and is lower

[14]The number of graduates is determined according to the final exam results of the last visited university.

in West Germany. Finally, we evaluate research grants per employee (only research staff) which was on average 17.230 Euro from 2001 to 2005. The extent of research grants varies from state to state, but in this case the differences between East and West Germany are not substantial.

Table IV.2.: Ratios of outputs and inputs for different faculty compositions (2001-2005)

Federal State	$\frac{Expenditures^{a)}}{Graduates}$	$\frac{Research staff}{Graduates}$	$\frac{Research grants^{a)}}{Research staff}$
With engineering faculty	51.94	1.46	20.52
With medical faculty	78.65	1.43	18.08
With engineering and medical faculty	86.58	1.63	19.59
Later "Elite Universities"	64.70	1.42	22.65
AverageØ	49.62	1.30	17.23

a) measured in 1000 Euro with the base year 2005.

Source: Federal Statistical Office of Germany; own calculations

Table IV.2 shows that faculty composition of a university influences expenditures per graduate. Higher education institutions with a medical and/or an engineering faculty have considerably higher costs. In addition faculty composition influences the acquisition of additional financial resources. Universities with an engineering faculty have about 3.200 Euro and institutions with a medical department about 2.400 Euro more than the average amount of research grants per research staff. In this context we analyze universities which were later supported by the third funding line and accordingly got the status of an "Elite University". Interestingly, these universities already obtained significantly higher research grants than the average before the Excellence Initiative started. This indicates an relative advantage of these nine universities with regard to research activities. However, to evaluate the universities' efficiency we also have to consider the invested input factors. Thus we check the decisions of the expert council by a Data Envelopment Analysis in the following section.

3 Data Envelopment Analysis

One advantage of DEA is the non-parametric approach which analyzes the ratio between weighted inputs and outputs[15] of a decision making unit, in our case public universities in Germany. Instead of assuming a particular production respectively cost function, this method calculates an efficient frontier line given a set of input and output factors. Hence it is possible to show which institutions are in comparison to this frontier inefficient. Furthermore DEA is able to include multiple output and/or input factors (see Table IV.3).

Table IV.3.: Output and input variables

Variable	Description of variable
Outputs	
Post graduates	Number of graduates with PhD degree
Research grants	Amount of research grants
Inputs	
Technical staff	Number of technical employees
Research staff	Number of research employees minus post graduates
Current expenditure	Financial means

3.1 Model specification

Every decision making unit (dmu) whose production is based on a combination of multiple input and output factors is prone to inefficiencies within a market (Barrow and Wagstaff (1989)). In order to analyze such relative disadvantages of participating institutions the Data Envelopment Analysis (DEA) calculates relative efficiency scores for each dmu. Thereby the relative efficiency of a dmu is associated with its productivity, i.e. the ratio of produced outputs to invested inputs (Farrel (1957)). The productivity of a dmu is generally based on two parts: On the one hand technical efficiency exhibits dmu's capability to produce the maximum level of output with a given set of inputs, on the other hand the optimal combination of input and

[15]Note that the weights are not given, but are based on linear programming with respect to the restriction that the calculated efficiency score lies between zero and one.

output factors given the respective prices is reflected by dmu's allocative efficiency. The basic idea of DEA is to estimate an efficient frontier line[16] given the output-input ratios of decision making units and to analyze the position of each decision making unit in comparison to the efficient frontier line. This approach has the advantage that a parametric model with certain assumptions is not required.[17] In general, the DEA approach can be input or output oriented. In our case of estimating relative efficiencies of publicly financed universities it is convincing to assume the output oriented version of DEA. Higher education institutions have a given level of financial resources allocated by state governments and try to optimize their teaching and research activities. DEA calculates relative efficiency by the ratios of output y_{rj} to input x_{ij} of university j weighted by endogenous parameters for each university. According to Charnes et al. (1978) the weight parameters are calculated in a way which favors the university in relation to the other universities. The university-specific weight parameter λ_j is a result of linear programming which uses the input and output information to compute a relative efficiency score e_k. Universities with an efficient output-input ratio lie on the efficient frontier line and have a score of one, while inefficient institutions lie below this frontier line and have a score between zero and one. By calculating an output-input ratio of a hypothetical efficient reference university for each relative inefficient university, the relative inefficiency can be computed in comparison to the hypothetical institution on the frontier line.

Efficiency score e_k of a university k is calculated on the following conditions (Kempkes and Pohl (2010)):

$$\max_{e,\lambda} \quad e_k \tag{IV.1}$$

$$s.t. \sum_{j=1}^{n} y_{rj}\lambda_j \quad \geq \quad e_k y_{rk} \quad (r = 1,2,...,s) \tag{IV.2}$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j \quad \leq \quad x_{ik} \quad (i = 1,2,...,m) \tag{IV.3}$$

[16]For the output oriented case the efficient frontier line is comparable with the product-possibility curve, known from microeconomic theory. It is important to know that this approach estimates relative efficiency, but not absolute efficiency. Thus the efficient decision making units rather lie on a best practice production frontier than on the absolute optimal production frontier.

[17]The DEA assumes the convexity axiom, which implies for the input and output sets decreasing marginal rate of substitution.

$$\sum_{j=1}^{n} \lambda_j = 1 \ \ (j = 1, ..., n) \tag{IV.4}$$

$$\lambda_j \geq 0 \tag{IV.5}$$

$$y_{rj}, x_{ij} \geq 0 \tag{IV.6}$$

$$e_k \in [0,1] \tag{IV.7}$$

Thereby, equation (IV.2) and (IV.3) describe the necessary conditions for an efficient production. On the one hand it guarantees that the hypothetical reference university has at least the same output and on the other hand uses at most as many inputs as the observed university. Since the higher education institutions in our data set differ in size, we cannot assume constant returns to scale, i.e. it is not likely that every university operates on the optimal scale. Thus we assume variable returns to scale which leads to condition (4). Additionally the endogenous weight parameter has to be positive, as well as output and input factors. The last condition restricts the efficiency score between values of zero and one, so that an inefficient university has to increase its output by the factor $\frac{1}{e_k}$ to be on the efficient frontier line.

3.2 Results of DEA

As explained above we use university's current expenditures and personnel (research[18] and technical staff) as input variables for the DEA, while output is displayed by research grants and the number of post graduates (see Table IV.3). We analyze relative efficiency scores of the year 2006, the start of first round of the Excellence Initiative in Germany.[19]

All together 17 West German and 3 East German universities[20] show an relative efficient output-input ratio. Thereby the size of universities measured by total number of students plays obviously no role for relative efficiency. Both smallest institutions (University of Vechta and Clausthal University of Technology) are on the efficient frontier, simultaneously both largest universities (University of Cologne

[18]Since post graduates are used as an output variable, we subtract this number from the entire research staff.

[19]Note again that six of the nine elite universities were selected in 2007, while the University of Munich, the Technical University of Munich and the University of Karlsruhe were already rewarded in 2006. Nevertheless, these three universities are also on the efficient frontier in the year 2005.

[20]The Free University of Berlin was founded in West Berlin in 1948, while the Humboldt University of Berlin is located in East Berlin. We treat Berlin as an East German state in our data set.

and University of Munich) show an efficient score of one.

Interestingly seven of nine chosen “Elite Universities” are on the efficient frontier line of Data Envelopment Analysis (see Table IV.4). University of Göttingen is with an efficient score of 0.98 very close to the frontier line, while the University of Konstanz (0.86) is not so efficient in the ranking (average efficiency score: 0.828). Thus we can say that our efficiency measure for German universities is quite convincing with regard to reward decisions of the Excellence Initiative.

Table IV.4.: Universities on the efficient frontier in the year 2006

University	Students	East/West
U Cologne	45568	W
U Munich	44174	W
U Hamburg	39001	W
U Mainz	34252	W
FU Berlin	31637	E
TU Aachen	30013	W
HU Berlin	28895	E
U Heidelberg	25941	W
TU Munich	21904	W
U Kiel	21627	W
U Freiburg	21252	W
U Marburg	18482	W
U Bremen	18161	W
U Karslruhe	17975	W
U Trier	13513	W
U Mannheim	11246	W
U Frankfurt (Oder)	4953	E
TU Freiberg	4461	W
U Vechta	3496	W
TU Clausthal	2922	W

DEA ignores universities’ faculty composition as well as the impact of structural factors on the relative efficiency. To estimate these effects we calculate the efficiency scores for each university for each year (2001-2010) and then we regress these efficiency scores on structural factors:

$$\begin{aligned} e_{jt} &= \alpha + \alpha_1 t + \alpha_2 GDP_j + \beta X_{jt} + \gamma elite + \\ &\quad + \omega_1 ENG_{jt} + \omega_2 MED_{jt} + \omega_3 ENG_{jt} \times MED_{jt} + u_{jt} \end{aligned} \quad \text{(IV.8)}$$

while e_{jt} represents relative efficiency score for university j in the year t of the observation period (2001-2010). To control for universities' faculty composition we include dummies for institutions with an engineering department ENG_{jt} or a medical department MED_{jt} and an interaction term $ENG_{jt} \times MED_{jt}$. It is conceivable that an engineering and a medical department affect our output and input variables. For instance, medical departments could have above-average research grants in comparison to social science departments. Also the number of post graduates could diverge. Furthermore we include information on the economic power of university's location GDP_j in our regression,[21] in order to observe potential spillover effects between the institution and the region. These secondary effects could affect the intensity of cooperation between higher education institutions and non-academic organizations, or the average wage level. We use GDP per capita as proxy variable for economic power of the region. Moreover we control for university's characteristics X_{jt} which could have a non negligible impact on university's application for the Excellence Initiative. Since the expert council evaluates each application in consideration of international standards, the share of foreign students at a university could be a proxy for attractiveness and international reputation (Stevens (2005)). A larger number of high-class research publications improves the reputation of a university and hence more students from other countries are attracted and are willing to study. At the same time university's costs could increase due to the integration of students from other countries. Accordingly a university could be forced to increase their efficiency to avoid additional expenditures. Moreover we use the share of personnel costs in relation to total costs as a proxy for quality of employees. The reason for a higher share of wage expenditures could be a higher wage level due to a better qualified staff. We include also the dummy variable $elite$ which is equal to one if the university was supported by the third funding line in the respective year. Thus we try to identify the influence of being an elite university on the relative efficiency. Finally, our regression has a constant α and a linear time trend t which can be an indicator for a technological change.

Beside an OLS regression we also run a Tobit regression, because the relative efficiency scores e_{jt} lie between zero and one (right-censored).[22] Furthermore we estimate a fixed effects model to control for time invariant omitted variables. Un-

[21] We use the data provided by the Federal Ministry of Transport, Building and Urban Development which includes the relevant information for 434 regional authorities in Germany from the year 2009 (BBR (2011)). Unfortunately, some larger cities are combined with their surrounding areas, so that the GDP per capita is generally downwards biased.

[22] The ratio between universities' output and input factors cannot be negative, but higher than one. Due to the university-specific weight parameters the relative efficiency scores are restricted to one.

fortunately, a parametric conditional fixed effects model for a Tobit regression does not exist,[23] so that we are only able to compare the fixed effects estimation with a random effects model. However, by using the Hausman test we show that the coefficients of the random effects model are not the same as the estimates of the fixed effects model. Hence we prefer the results of the fixed effects estimation (Table IV.5, column 4).

Table IV.5.: Regression analysis of structural factors on relative efficiency

	OLS (1)	Tobit (2)	RE (3)	FE (4)
Constant	-15.876***	-18.764***	-19.321***	-19.114***
	(5.335)	(6.706)	(5.181)	(5.249)
Elite	0.140***	0.222***	0.006	-0.011
	(0.018)	(0.042)	(0.018)	(0.018)
Time	0.007***	0.009***	0.009***	0.009***
	(0.002)	(0.003)	(0.002)	(0.002)
Wage share	0.730***	0.886***	0.681***	0.676***
	(0.120)	(0.153)	(0.176)	(0.188)
Foreign students share	1.255***	1.955***	0.732***	0.290
	(0.107)	(0.215)	(0.199)	(0.218)
Economic power	-0.000	-0.000	0.000	-
	(0.000)	(0.000)	(0.001)	-
Engineering faculty	0.001	-0.021	0.023	-
	(0.018)	(0.026)	(0.043)	-
Medical faculty	0.066***	0.069**	-0.052	-
	(0.025)	(0.032)	(0.075)	-
Interaction term faculty	-0.048*	-0.029	-0.052	-
	(0.027)	(0.037)	(0.075)	-
Number of observations	697	697	697	697
R^2	0.239	0.628	0.203	0.090

Standard errors in parentheses, p-value: *=0.10, **=0.05, ***=0.01

Hausman test, H_0: Difference in coefficients is not systematic, Prob>chi2 = 0.0000

Our variable for the linear time trend is in all specifications positive and significant which indicates a positive technical change over the observation period. The proxy variable for economic power (GDP per capita) is insignificant in all specifications. Thus it seems that the economic power of university's region and consequently the proximity to financially strong organizations do not lead to positive/negative spillover effects. Apparently, the local terms are not so important for research activities in times of decreasing transaction costs due to improved and

[23]Unconditional fixed effects with in combination with a Tobit regression leads to biased results.

cost-efficient communication systems.

To control for faculty composition we include dummy variables for an engineering respectively medical department. The dummy variable for an engineering department is in all specifications insignificant. In contrast, the influence of a medical department is in simple OLS as well as simple Tobit regressions (column 1 and 2) positive and highly significant which suggests that relative efficiency increases. However, we cannot confirm this result for the random effects model (column 3). The estimated coefficients for the interaction term between an engineering and medical department is negative, but only significant for the OLS regression.

The dummy variable for an elite university is positive and significant for the simple OLS and Tobit regression. This would mean that the financial support of the third funding line of the Excellence Initiative improved the relative efficiency of the universities. However, our estimation models controlling for random respectively fixed effects (column 3 and 4) lead to insignificant coefficients.

Finally, we analyze both university-specific variables. On the one hand the share of wage expenditures in relation to total expenditures is in all estimations positive and highly significant. Thus it seems that a high quality staff improves the relative efficiency. On the other hand the share of foreign students is with the exception of the fixed effects model (column 4) in all specifications positive and highly significant. We prefer the results of the fixed effect model due the Hausman test. Hence our proxy for university's attractiveness seems to have no significant influence on universities' efficiency score.

Overall, our results seem to dispel concerns that the decisions of the expert council were rather based on political influence than on efficiency reasons. These concerns are discussed, since representatives of the federal government as well as the 16 state governments are part of the decision-making process. Furthermore we estimate the influence of universities' characteristics on relative efficiency scores. We cannot find a significant negative effect of an engineering and/or medical department, neither can we confirm a positive spillover effect caused by universities' region. However, our proxy variable for the quality of universities' employees is positive and significant. Thus a highly qualified staff increases the relative efficiency of a university. Our results of the random and fixed effects model do not confirm a positive influence of the third funding line on universities' relative efficiency during the observation period. In order to gain a deeper insight into the influence of the Excellence Initiative on the competition between German universities, we estimate the Malmquist index in the following section.

4 The Malmquist index

One aim of this paper is also to analyze a potential change in competition between German universities induced by the Excellence Initiative. The aspect of competition is a core element of the Excellence Initiative, since the guaranteed duration of financial support is limited to five years and can only be extended by a new application (first round: 2006/2007-2012, second round: 2012-2017). In this context, the question is raised whether the advantage of being rewarded in first round is so large that the remaining universities cannot apply successfully for second round of Excellence Initiative. In the following section we use the Malmquist index to evaluate the impact of the Excellence Initiative on the competition between German universities.

4.1 Model specification

With the efficiency scores for every university we can determine relative efficiency of each institution in a certain year. Furthermore we can estimate potential changes of total factor productivity by the Malmquist index m (Malmquist (1953)), since we have output and input vectors of several years (y_t, x_t). For this purpose we calculate the distance of output-input ratios between the observed university and hypothetical reference university for each year t in a particular period. We also take into account that the efficient frontier line can change in every year due to a technological change. Thus we are able to measure the distance functions between two years (d_t, d_{t+1}) and by computing the geometric mean[24] we can identify changes of total factor productivity (Caves et al. (1982); Fare et al. (1989)). Accordingly a Malmquist index $m = 1$ means that we cannot observe a change in total factor productivity of the university over the period, while $m > 1$ implies an increase.

The Malmquist index is based on the following formula (Kempkes and Pohl (2010)):

$$m(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\frac{d_t(y_{t+1}, x_{t+1})}{d_t(y_t, x_t)} \frac{d_{t+1}(y_{t+1}, x_{t+1})}{d_{t+1}(y_t, x_t)} \right]^{\frac{1}{2}} \qquad \text{(IV.9)}$$

It is important to understand that a change in total factor productivity can be caused by two main reasons: First of all efficiency of the higher education institu-

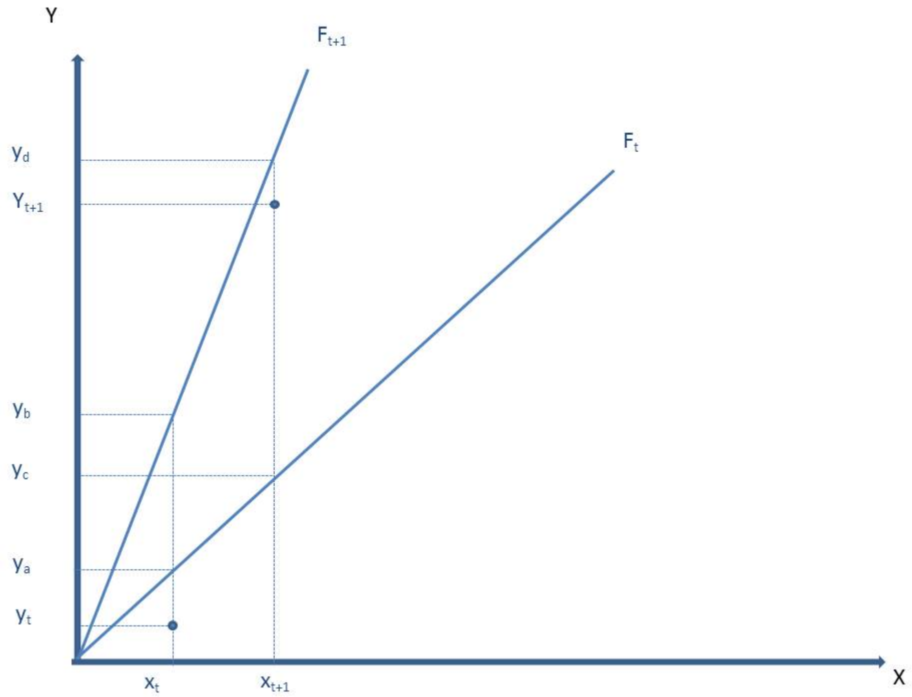
[24]By using the geometric mean we do not have to choose a base year for our calculations.

tion itself can change over time, for instance by an improved production function. The second explanation could be a change of the efficient frontier line due to a technology change. By decomposing the Malmquist index both reasons can be identified:

$$m(y_{t+1}, x_{t+1}, y_t, x_t) = \frac{d_{t+1}(y_{t+1}, x_{t+1})}{d_t(y_t, x_t)} \times \left[\frac{d_t(y_t, x_t)}{d(y_{t+1}, x_{t+1})} \frac{d_t(y_{t+1}, x_{t+1})}{d_{t+1}(y, x)} \right]^{\frac{1}{2}} \quad \text{(IV.10)}$$

The first term of formula (IV.10) expresses the technical efficiency change of a single university and the product in brackets measures the technology change.

Figure IV.1.: Illustration of technical efficiency change and technology change



For simplification we assume constant return to scale for the production frontier F and a single input x and single output y factor. We analyze two periods t and $t+1$.

The decomposition of the Malmquist index can be interpreted as follows: The technical efficiency change depicts with a value of greater than one the "catching-up process" to the frontier, i.e. the university is more able to achieve the maximum output given a set of input (see Figure IV.1):

$$Technical\,efficiency\,change \quad = \quad \frac{y_{t+1}/y_d}{y_t/y_a} \tag{IV.11}$$

The technology change reflects a move of the best practice production frontier:

$$Technology\,change \quad = \quad \left[\frac{y_{t+1}/y_c}{y_{t+1}/y_d} \times \frac{y_t/y_a}{y_t/y_b}\right]^{\frac{1}{2}} \tag{IV.12}$$

Thus the Malmquist index is the product of both effects:

$$Malmquist\,index \quad = \quad \frac{y_{t+1}/y_d}{y_t/y_a} \times \left[\frac{y_{t+1}/y_c}{y_{t+1}/y_d} \times \frac{y_t/y_a}{y_t/y_b}\right]^{\frac{1}{2}} \tag{IV.13}$$

4.2 Results of Malmquist Index

For our purpose, we analyze the change of total factor productivity (tfpch) by the Malmquist index for two periods. At first we look at the period before the Excellence Initiative started (2001-2005) and then we evaluate the time during the first round of financial support (2006-2010).[25] Table A 2.1 (Appendix) shows that the majority of German universities increased their total factor productivity from 2001 to 2005. Thereby the share of East German universities is with 43.75 percent smaller than the share of West German universities (53.7 percent). Since small higher education institutions (University of Vechta and Clausthal University of Technology) and large counterparts (University of Cologne) improved their total factor productivity, the university's size seems to play no role in this regard. While the total factor productivity for the entire sample stayed almost constant (0.996), the universities which were entitled to the third funding line later show an above average increase in total factor productivity (see Table IV.6). In contrast, the respective differences in technical efficiency change (effch) are not so large, that the advantage in total factor productivity change can be explained by this source. The difference in technology change (techch) is rather the cause for the relative efficiency gain of these nine universities.

[25] Thereby we evaluate the average change of total factor productivity, technical efficiency and technology change in the observation period. Since the Malmquist index is calculated from one year to the following year we have four values for each university in both periods. Thus we consider more information in our analysis which is helpful due to the fact that the contributions of the Excellence Initiative can vary from year to year.

In the next step we evaluate the period during the first round of financial support (Appendix A 2.2). A total number of 44 German universities increased their total factor productivity in this period (43.75 percent of the East German universities, 68.5 percent of the West German universities) what is even more than in the previous period. The average change in total factor productivity is higher than one, while again the nine elite universities show with 1.087 an above average value (Table IV.6). As expected almost all universities which are supported by the third funding line show an increase in total factor productivity and furthermore these gains are higher as in the period before the Excellence Initiative started.[26] However, the Free University of Berlin and the University of Karlsruhe show decreasing total factor productivity although both were benefiting from the third funding line during the entire period. Interestingly, the Humboldt University of Berlin and the University of Dresden moved from decreasing to increasing total factor productivity. Additionally the University of Cologne shows a clear increase of total factor productivity change than before (from almost constant to a value of 1.10). All three of them applied successfully for the third funding line in 2012 and were officially appointed to an "Elite University" together with the University of Bremen for the first time.[27] These results reveal that despite the financial support in the first round of the Excellence Initiative some universities with the elite status became relatively less efficient. Simultaneously some higher education institutions without additional financial resources in the first round were able to improve their relative efficiency in research activities.

[26] Again we want to point out that beside the nine "Elite Universities" other universities were also supported by the first and second funding line (cluster of excellence and graduate schools). The extent of additional financial resources is up to 6 million Euro per year for a cluster of excellence and 1 million per year for a graduate school. Nevertheless, a successful application for the third funding line is associated with an additional financial support up to 14 Million Euro per year.

[27] The second round of the Excellence Initiative started in 2012. From the existing "Elite Universities" three lost their status and consequently the additional financial support (University of Göttingen, University of Karlsruhe and University of Freiburg). The remaining institutions with elite status were able to keep the third funding line. Unfortunately, we do not have the necessary data of application years 2011 and 2012. Nevertheless, the DEA for the year 2010 shows that the new "Elite Universities" the Humboldt University of Berlin, the University of Dresden and the University of Bremen are on the efficient frontier line.

Table IV.6.: Elite universities vs. other universities

Period	2001-2005			2006-2010		
	tfpch	effch	techch	tfpch	effch	techch
Average Ø	0.996	1.032	0.980	1.067	1.100	0.974
Elite Universities	1.025	1.033	1.003	1.087	1.128	0.963
Other Universities	0.991	1.032	0.976	1.064	1.096	0.976

However, universities with the elite status show a higher increase in technical efficiency change (1.128) than their counterparts (1.096). This means that in average all universities were able to catch up to the best practice frontier, although some institutions did not benefit from the additional financial resources. Since the change in technical efficiency implies an improved production of output given a set of inputs, this result could indicate a positive effect of competition induced by the Excellence Initiative. Note again that some universities were only supported by the first and second funding line (graduate schools and cluster of excellence). Although the increase in technical efficiency change is higher for elite universities, this difference is not significant. Since the difference between elite universities and other universities in total factor productivity is also not significant, our results suggest that the additional financial support from the third funding line did not lead to an unbalanced competition. In this context, an unbalanced competition means that the elite universities have such an advantage from the additional financial resources that they can significantly increase their productivity advantage in comparison to all other universities. From 2006 to 2010 the average change in technology efficiency is smaller than one which is true for elite and other universities. Thus the improved total factor productivity is again caused by the increase in technical efficiency.

In summary, our results show that average total factor productivity increased after the introduction of the Excellence Initiative. In contrast, we cannot observe a remarkable change from 2001 to 2005. The improved total factor productivity is caused by the increased change in technical efficiency. Thereby universities with additional financial resources as well as higher education institutions without support of the Excellence Initiative are able to catch up to the efficient frontier in both periods. The gain of the nine elite universities is higher during the first round of the Excellence Initiative which implies an increase in relative efficiency in comparison to all other universities.

However, this increase is not significant and a few universities are able to show a higher increase in technical efficiency than some elite universities, for instance the Humboldt University of Berlin and the University of Cologne. Both applied successfully for the third funding line in 2012.

5 Conclusion

The aim of our paper is the first evaluation of the reward decisions made by the expert council of the Excellence Initiative and the impact on competition between the German universities. The introduction of a performance based reward program for higher education institutions was a novelty in German tertiary education. Since almost all universities are publicly financed by taxes in Germany, a policy of supporting a small group of universities with an elite status was rejected. However, the federal government and the 16 state governments agreed on a joint funding program to improve international competitiveness in research activities. One core element of the Excellence Initiative is the idea of competition, i.e. the duration of financial support is limited and can only be extended by a new successful application. Therefore, every university has the chance to achieve the prestigious status of an "Elite University" at the beginning of a new round. By using two different methods we are able to evaluate this policy change from various perspectives.

First, we analyze the relative efficiency of German universities according to the criteria of the expert council which reviewed all applications for the Excellence Initiative. For our output oriented DEA we use the amount of research grants and the number of post graduates as output factors, while the information on universities' current expenditures and staff (research and technical) are included as inputs. Interestingly, seven of the nine chosen "Elite Universities" are on the efficient frontier in 2006 and hence more efficient in terms of research than the other higher education institutions.

In a second step we compute the Malmquist index to analyze the change in total factor productivity during the first round of the Excellence Initiative. Our results show that the number of universities which improve their total factor productivity after the start of Excellence Initiative is even higher than before. By decomposing the Malmquist index we see that the average change in technical efficiency increases, i.e. the universities show a catch-up process to the efficient frontier. Although the value is higher for elite universities, the difference in comparison to all other higher education institutions is not significant. On the one hand some universities with the elite status show a decreasing total factor productivity, although these institutions benefited from the additional financial resources. On the other hand universities without financial support of the third funding line of the Excellence Initiative are able to increase their total factor productivity.

These results seem to dispel two concerns which were associated with the introduction of the Excellence Initiative. Firstly, it shows that the decisions of the expert council were rather based on objective reasons than political influence. Secondly, the advantage of being supported in the first round does not harm the idea of competition between German universities. The Malmquist index shows a positive effect on the technical efficiency of German universities during the first round of the Excellence Initiative. Thus our findings suggest that the initiated competition between German universities improved the efficiency of research activities. Since it is not clear whether the Excellence Initiative will be continued after the year 2017, our analysis also has some policy implications for the performance based funding of higher education institutions.

It is understandable that a rejected application for the Excellence Initiative or even the loss of the prestigious status of an "Elite University" is quite frustrating. However, our paper shows that no university should take the elite status and the additional financial resources as granted. It seems that the idea of promotion and relegation is working.

Appendix

A 1

DEA for the year 2006, ordered by the efficiency score

University	Efficiency score	Students	East/West
U Cologne	1	45568	W
U Munich	1	44174	W
U Hamburg	1	39001	W
U Mainz	1	34252	W
FU Berlin	1	31637	E
TU Aachen	1	30013	W
HU Berlin	1	28895	E
U Heidelberg	1	25941	W
TU Munich	1	21904	W
U Kiel	1	21627	W
U Freiburg	1	21252	W
U Marburg	1	18482	W
U Bremen	1	18161	W
U Karslruhe	1	17975	W
U Trier	1	13513	W
U Mannheim	1	11246	W
U Frankfurt (Oder)	1	4953	E
TU Freiberg	1	4461	W
U Vechta	1	3496	W
TU Clausthal	1	2922	W
U Augsburg	0.9891726	14500	W
U Göttingen	0.9810111	23223	W
U Hildesheim	0.9802673	4208	W
U Potsdam	0.972888	18003	E
U Bochum	0.9720513	32257	W
TU Hamburg	0.9680269	4535	W
U Stuttgart	0.951737	19912	W
U Bonn	0.9139571	29370	W
U Frankfurt a.M.	0.912992	34174	W
U Bamberg	0.9100344	8822	W
TU Dresden	0.9072213	32653	E
TU Berlin	0.9026488	27367	E
U Hannover	0.870043	21575	W
U Bayreuth	0.8675291	9245	W
U Gießen	0.866349	21444	W

University	Efficiency score	Students	East/West
U Konstanz	0.8638362	9684	W
TU Cottbus	0.8615036	4645	E
U Hohenheim	0.8494785	6089	W
U Ulm	0.8463325	7074	W
U Paderborn	0.8424374	13937	W
U Münster	0.8381886	39028	W
TU Darmstadt	0.8341073	16358	W
U Passau	0.8207388	8962	W
U Erlangen-Nuremberg	0.8171395	25983	W
U Tübingen	0.8041001	23041	W
U Bielefeld	0.7806602	18224	W
U Osnabrück	0.7774844	10183	W
TU Braunschweig	0.7751884	12310	W
TU Chemnitz Zwickau	0.7692777	10124	E
U Kaiserslautern	0.7690144	9979	W
U Dortmund	0.7347447	21564	W
TU Ilmenau	0.7212676	6623	W
U Jena	0.7115627	20210	E
U Würzburg	0.7047607	19691	W
U Oldenburg	0.6864485	10115	W
U Leipzig	0.6670159	27600	E
U Kassel	0.6368167	14966	W
U Düsseldorf	0.6362171	17946	W
U Koblenz	0.6257693	11645	W
U Regensburg	0.5848604	17429	W
U Wuppertal	0.5638093	13487	W
U Siegen	0.5571666	12512	W
U Weimar	0.5532501	3795	E
U Greifswald	0.5426802	10778	W
U Lüneburg	0.5316935	9976	W
U Halle	0.5287261	17403	W
U Saarbrücken	0.5046945	14867	W
U Rostock	0.4679159	14076	E
Fernuni Hagen	0.4647675	32608	W
U Magdeburg	0.3837234	12967	E

A 2.1

Malmquist index for the period 2001-2005, ordered by TFP change

University	TFP Change	Efficiency Change	Technical Change	East/West
U Heidelberg	1.171	1.130	1.067	W
TU Braunschweig	1.095	1.096	0.995	W
U Wuppertal	1.081	1.198	0.911	W
U Freiburg	1.074	1.089	1.016	W
U Osnabrück	1.069	1.170	0.918	W
U Kaiserslautern	1.063	1.065	0.995	W
U Bielefeld	1.059	1.147	0.936	W
U Bochum	1.058	1.112	0.964	W
TU Clausthal	1.056	1.036	1.020	W
U Greifswald	1.056	1.046	1.038	W
U Saarbrücken	1.055	1.086	1.008	W
U Passau	1.053	1.158	0.900	W
U Vechta	1.052	1.197	0.913	W
U Dortmund	1.047	1.110	0.938	W
U Göttingen	1.039	1.054	1.033	W
U Leipzig	1.039	1.076	1.005	E
U Siegen	1.035	1.122	0.926	W
TU Cottbus	1.035	1.034	1.003	E
U Bayreuth	1.033	1.098	0.944	W
TU Hamburg	1.031	1.037	0.996	W
TU Freiberg	1.026	1.031	0.997	W
U Hannover	1.023	1.125	0.927	W
TU Munich	1.021	1.028	0.992	W
TU Darmstadt	1.020	1.003	1.014	W
U Augsburg	1.019	1.104	0.922	W
U Stuttgart	1.018	1.001	1.017	W
U Hamburg	1.013	1.083	0.998	W
U Oldenburg	1.013	1.065	0.956	W
U Trier	1.012	1.074	0.944	W
TU Ilmenau	1.007	1.018	0.990	W
U Cologne	1.005	0.992	1.037	W
U Bonn	1.004	1.082	0.963	W
U Würzburg	1.004	1.043	1.009	W
TU Aachen	1.002	0.991	1.019	W
TU Chemnitz Zwickau	1.000	1.029	0.975	E

Appendix

University	TFP Change	Efficiency Change	Technical Change	East/West
U Rostock	1.000	0.999	1.022	E
U Konstanz	0.997	1.031	0.970	W
Fernuni Hagen	0.997	1.009	0.996	W
U Tübingen	0.997	1.013	1.020	W
U Regensburg	0.995	1.026	0.994	W
U Bremen	0.994	1	0.994	W
U Bamberg	0.992	1.075	0.906	W
U Karlsruhe	0.991	1.002	0.986	W
U Paderborn	0.986	0.995	0.994	W
U Erlangen-Nuremberg	0.980	1.010	0.999	W
U Düsseldorf	0.980	1.002	0.996	W
U Koblenz	0.980	1.021	0.959	W
U Gießen	0.979	1.050	0.995	W
U Halle	0.978	1.011	0.996	W
U Jena	0.975	1.049	0.998	E
U Münster	0.973	1.046	1.005	W
U Frankfurt (Oder)	0.971	1.064	0.916	E
U Magdeburg	0.970	0.973	1.000	E
U Potsdam	0.965	1.024	0.940	E
U Munich	0.965	0.964	1.021	W
FU Berlin	0.965	1.007	0.926	E
U Weimar	0.965	0.989	0.976	E
U Frankfurt a.M.	0.963	0.945	1.030	W
U Lüneburg	0.960	1.017	0.948	W
U Ulm	0.949	0.952	1.012	W
TU Dresden	0.937	0.914	1.029	E
U Kassel	0.928	0.949	0.970	W
U Kiel	0.916	0.885	1.045	W
TU Berlin	0.905	0.988	0.932	E
U Mainz	0.899	0.922	0.993	W
U Mannheim	0.895	0.969	0.937	W
U Marburg	0.892	0.952	0.977	W
U Hohenheim	0.890	0.966	0.938	W
HU Berlin	0.823	0.846	0.964	E
U Hildesheim	0.752	0.832	0.908	W

A 2.2

Malmquist index for the period 2006-2010, ordered by TFP change

University	TFP Change	Efficiency Change	Technical Change	East/West
TU Braunschweig	1.786	1.996	0.931	W
U Trier	1.536	1.580	0.963	W
U Hannover	1.460	1.579	0.950	W
TU Clausthal	1.369	1.453	0.938	W
U Göttingen	1.322	1.406	0.968	W
U Düsseldorf	1.305	1.305	0.997	W
U Hildesheim	1.301	1.316	0.961	W
U Bochum	1.238	1.221	1.010	W
U Hamburg	1.210	1.186	1.011	W
TU Munich	1.200	1.240	0.955	W
U Munich	1.174	1.218	0.950	W
U Bielefeld	1.167	1.238	0.948	W
U Gießen	1.164	1.187	0.982	W
U Augsburg	1.145	1.157	0.993	W
U Mannheim	1.143	1.160	0.991	W
HU Berlin	1.128	1.122	1.015	E
U Marburg	1.114	1.045	1.056	W
U Cologne	1.105	1.146	0.974	W
U Potsdam	1.094	1.207	0.921	E
TU Aachen	1.084	1.131	0.958	W
U Kaiserslautern	1.082	1.077	1.001	W
U Regensburg	1.076	1.056	1.017	W
TU Cottbus	1.065	1.183	0.929	E
U Bonn	1.065	1.090	0.986	W
U Mainz	1.064	1.033	1.018	W
U Bamberg	1.053	1.007	1.053	W
U Saarbrücken	1.053	1.056	0.996	W
U Freiburg	1.052	1.069	0.976	W
U Kiel	1.049	1.011	1.047	W
U Jena	1.046	1.053	0.990	E
U Konstanz	1.037	1.055	0.984	W
U Koblenz	1.034	1.099	0.943	W
U Frankfurt a.M.	1.033	1.039	0.996	W
TU Hamburg	1.032	1.033	0.997	W
U Ulm	1.030	1.128	0.928	W

University	TFP Change	Efficiency Change	Technical Change	East/West
U Münster	1.022	1.044	0.983	W
U Stuttgart	1.021	1.008	1.010	W
U Würzburg	1.020	1.107	0.948	W
U Paderborn	1.015	1.036	0.988	W
U Greifswald	1.015	1.013	1.007	W
U Heidelberg	1.011	1.011	1.004	W
TU Dresden	1.011	1.049	0.970	E
U Bayreuth	1.009	1.059	0.944	W
U Frankfurt (Oder)	1.005	1.095	0.932	E
U Osnabrück	1.000	1.021	0.955	W
U Wuppertal	0.999	1.017	0.983	W
TU Ilmenau	0.998	1.060	0.953	W
U Karlsruhe	0.994	1.023	0.967	W
U Dortmund	0.988	1.017	0.975	W
U Passau	0.981	1.086	0.926	W
U Halle	0.979	0.967	1.016	W
U Kassel	0.974	0.953	1.017	W
TU Freiberg	0.970	1.036	0.943	W
U Bremen	0.968	1.000	0.968	W
U Hohenheim	0.968	0.992	0.964	W
U Rostock	0.965	0.954	1.012	E
TU Berlin	0.954	0.990	0.954	E
U Tübingen	0.953	0.989	0.960	W
U Oldenburg	0.953	0.991	0.960	W
U Erlangen-Nuremberg	0.949	0.956	0.990	W
U Vechta	0.942	1.092	0.893	W
TU Darmstadt	0.937	0.991	0.944	W
U Siegen	0.927	0.937	0.978	W
U Magdeburg	0.919	0.918	1.000	E
U Lüneburg	0.918	1.011	0.932	W
FU Berlin	0.917	1.002	0.911	E
Fernuni Hagen	0.917	0.907	1.012	W
TU Chemnitz Zwickau	0.907	0.928	0.972	E
U Leipzig	0.905	0.929	0.978	E
U Weimar	0.900	0.947	0.945	E

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