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Teacher density and student achievement in Swedish compulsory schools

Christian Andersson

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Postal address: P.O. Box 513, 751 20 Uppsala
Visiting address: Kyrkogårdsgatan 6, Uppsala
Phone: +46 18 471 70 70
Fax: +46 18 471 70 71
ifau@ifau.uu.se
www.ifau.se

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Teacher density and student achievement in Swedish compulsory schools*

Christian Andersson♣

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Abstract

This paper analyzes how student achievement is affected by resource increases in the Swedish compulsory school due to a special government grant that was enforced in the academic year of 2001/02. The analysis is based on register data that contains all students that completed compulsory schooling (ninth grade) between 1998 and 2005. The results show that socio-economic variables explain a great deal of the variation in student achievement. The study also shows that the increased resources have not had a statistical significant positive effect on the average student's achievement. This conclusion holds true when different measures of student achievement are used. Increased resources have however improved student achievement for students with low educated parents. If teacher density is increased with 10 percent students with low educated parents are expected to increase their grade point average ranking with about 0.4 percentile units.

Keywords: Teacher density, student achievement, government grant
JEL-code: I21

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♣ Uppsala University, Department of Economics, Box 513, SE - 751 20 Uppsala, Sweden.
E-mail: christian.andersson@nek.uu.se.

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1 Introduction

During the severe economic crisis in Sweden during the 1990's a great deal of reductions in the public sector took place and the educational sector was no exception. Annual expenditures per student in relation to GDP per capita in compulsory schooling fell from 34 to 24 percent between 1991 and 2000 (OECD (1995), (2003)). The number of students in compulsory schooling increased during the same period which contributed to a fall in the number of teachers per 100 students from 8.7 to 7.8 during the period 1992 to 2001. The decentralization of the Swedish schooling system that took place in 1993 affected the total resource allocation to schools and it also increased the dispersion of resource between municipalities. The resource dispersion widened the most for student that initially was at the lower part of the resource distribution (Björklund et al (2005)). To counteract this development the Swedish government decided to introduce a special government grant aimed specifically at schools and after-school recreation centers. Between 2001 and 2006 a total of SEK 17.5 billions has been set aside to increase personnel density in Swedish schools.[1] Funds were distributed stepwise to municipalities; approximately one billion SEK was allocated during the academic year 2001/02 and almost two billion during 2002/03. Three billion SEK was distributed in the academic year 2003/04 and two billion during the autumn semester of 2004. In 2005 the original plan changed and part of the special government grant was reallocated to the general government grant that municipalities receive.

The intention of this special government grant was to improve students' possibilities to reach the goals of their education. To quantify the causal effect of resource changes on student achievement is however a difficult task, which have resulted in some disagreement in the literature about the true effect of marginal resource changes. The difficulties have mostly to do with the fact that all educational systems invest more resources in disadvantaged students. To deal with this problem one has to find some exogenously determined variation in the resource changes. The change in the resource allocation system, introduced by the special government grant, is possibly an exogenous source of variation which can be used to estimate the effect of resource changes on student achievement.

[1] € 1 is approximately equal to SEK 9.4.

This paper analyze if changes in student achievement co-vary with changes in the resources that has been invested in the Swedish schooling system. The purpose is to estimate the magnitude of the effect of the special government grant on teacher density and the effect of resources on student achievement. The analysis is based on register data that include all students that completed compulsory schooling (ninth grade) between 1998 and 2005. Student achievement is measured by students' grades when they finish ninth grade, results on national tests in English, Swedish and Mathematics and if students reach high school eligibility by passing the core subjects.

The remainder of this paper is structured as follows; section 2 gives a short overview of the previous literature and section 3 briefly describes the Swedish compulsory school system and discusses the functioning of the special government grant and what conditions municipalities have to meet to receive the grant. Section 4 describes the data and the variable definitions used. Section 5 describes how resources and student achievement have developed over time. Section 6 gives a more detailed description of the methodological problems and the possibilities to evaluate the effect of resource changes on student achievement. The results are presented in section 7 and section 8 concludes.

2 Previous literature

Research regarding the effect of school resources on student achievement dates back to the 1960´s and since the "Coleman report" was published in 1966 literally hundreds of studies have been published. A great deal of these studies concerns the effect of class size on student achievement. There is no doubt about the fact that large changes in school resources have an effect on student achievement, but the results are ambiguous when it comes to marginal resource changes. Not even comprehensive surveys give a unanimous picture of the relation between resource changes and student achievement. Some surveys find that smaller classes have a positive effect on student achievement (for example Hedges, Laine & Greenwald (1994) and Kreuger (2003)) while others (for example Hanushek (1997)) do not find such an effect. The main reason for the disagreement is that it is very hard to quantify the effect of reductions in class size since disadvantage students often are placed in smaller classes.

If extra weight is given to studies with experimental character it is however reasonable to conclude that smaller class sizes has a (small but) positive effect on student achievement and that the effect is larger for younger individuals and students with low socio-economic status. Studies of this type utilize regular experiments or data of quasi-experimental character.

The most ambitious and extensive study of this kind is probably the Tennessee STAR experiment. This study was a big scale experiment that begun in 1985 and affected 11,600 students in about 80 schools in the United States. The purpose of the experiment was to study the effect of smaller class sizes on student achievement. Students and teachers within every school were randomized into one out of three different groups; small class, regular-sized class or regular-sized class with a teaching's aide.[2] The experiment with different class sizes continued from first to third grade. Students thereafter returned to regular-sized classes. Student knowledge was tested at the end of each academic year. In this experiment there would in principle be no problem with endogenous determined resources if students and teachers were randomized into different groups according to the design of the experiment. Hanushek (1999) however question parts of the randomization process in the experiment. Schools in the experiment were for example not random and since there were considerable attrition of students between years it is hard to verify the randomization in the STAR experiment. Most studies based on data from the STAR project find that students assigned to small sized classes perform better on standardized achievement tests and that these students are more likely to take the collage entrance test (see for example Kreuger (1999) and Kreuger & Whitmore (2001)). Krueger (1999) finds that a reduction in class size with one student increased the students' percentile rank with almost one unit.[3] The effect was even larger for minority students and students with low socio-economic status.

A study by Angrist & Lavy (1999) analyzes the effect of class size on student achievement using a regression discontinuity design. The size of school classes in the Israeli school is determined by the so called "Maimonides' rule". The maximum class is according to this rule 40 students. If the total number of students is greater than 40 two classes are automatically created. If the number of students is greater than 80 there will be three classes and so on. This rule creates a saw tooth pattern between class size and the total number of students in one grade. The authors exploit these discontinuous changes and find that

[2] A small class consisted of 13–17 students while a regular-sized class consisted of 22–25 students.

[3] Percentile ranking is a way to normalize the effect estimate. Students are ranked from 0 to 100, where 0 is given to the student with the lowest result and 100 to the one with the highest result. The estimate is then expressed in terms of the effect on this ranking.

class size has a positive and significant effect on results in Reading comprehension and Mathematics. The average effect is approximately as large as in the STAR project and the positive effect is larger for students with weak family background.

There are no Swedish studies on the effect of class size or resources on student achievement based on experimental data. Lindahl (2001) use a longitudinal approach to examine the effect of natural variation in class size. The unique dataset in the study comes from a test in Mathematics that was administrated by Lindahl. A total of 556 students in 16 schools in Stockholm took a standardized test on three occasions. The tests were carried out during the spring semester in fifth grade and in both autumn and spring of the sixth grade. The study uses the fact that that there is a summer holiday between two of the tests. Class size is assumed to have no effect during the summer holiday and it is therefore possible to isolate the causal effect of class size from the effect of home environment. The results show that smaller class sizes yields significant better student achievement than larger classes. A reduction in class size with one student increased the average student's percentile rank with between 0.37 and 0.98 units (depending on model specification). The study also shows that immigrant students gain more from smaller class sizes than native Swedes.

Björklund et al (2005) exploit the changes in the Swedish schooling system that affected the resource distribution during the 1990's and analyze the effect of resources on students' grade point averages (*GPA*:s) when they complete ninth grade. Their analysis show that municipalities whose teacher density have increased relative others, have had a better development of *GPA*:s compared to other municipalities. Teacher density fell with about 15 percent between the academic years 1990/91 and 2002/03. The results show that if teacher density is reduced by that much the average student's position in the percentile rank is expected to decrease with about 1.1 percentile units. The authors also show that students with low educated parents and those students that recently have immigrated to Sweden are the ones that gain the most from a higher teacher density. The results are consistently significant and in magnitude in line with the estimated effects from Lindahl (2001).

3 Institutional detail

3.1 The Swedish compulsory school

The size of the educational sector is considerable in most countries. The teacher labor market across OECD countries, considering primary and secondary education only, corresponded to 2.6 percent of the total labor force in 1999. The corresponding figure for Sweden was 2.8 percent. (Santiago (2004)) In 2005 there existed around 4,300 public compulsory schools in Sweden. In addition to these public schools there existed almost 600 independent compulsory schools. The total number of full time equivalent teachers in compulsory schooling amounted to 81,276 in 2005. 75,482 of the total number of full time equivalent teachers, or 93 percent, worked in public schools while the rest, 5,583 full time equivalent teachers, worked in independent schools.

The Swedish educational system has gradually been decentralized since the beginning of the 1990's. Responsibility for provision of schooling was gradually transferred from the central government to municipalities and schools. In 1991 the municipalities took over the responsibility for providing compulsory, upper secondary and adult education and in 1993 grants from the central to the local authorities were included in the general grant frame. Municipalities thereby got more autonomy when it comes to resource allocation.

The Swedish grading system was reformed in 1994 when the previous five-step norm-referenced grading system was replaced by the three-step criterion-referenced system which relates grades to curriculum goals. The new system also implied that grades are awarded first in 8^{th} and 9^{th} grade. Apart from receiving subject grades students take standardized tests. These tests are mandatory in 9^{th} grade. Standardized tests are given in Mathematics, Swedish and English and teachers are obliged to take the test scores into consideration when awarding their final grades in these subjects.

Swedish compulsory schooling is nine years long. During the first six years students are taught by the same teacher irrespectively of subject. The last three years students are taught by specialist teachers in each subject. The school starting age is normally seven years of age.

3.2 The special government grant

Swedish municipalities can since the academic year 2001/02 receive a special government grant, the Wärnersson grant (*WG*), to cover expenditures for personnel increases in preschools, nine-year compulsory schools, special schools, after-school recreation centers and high schools. It is up to municipalities to decide on which personnel categories and in which sectors of the Swedish school system they would like to invest the grant. Municipalities that would like to utilize the special government grant must apply yearly to the Swedish National Agency for Education.[4] Independent schools are not allowed to apply for the grant, but municipalities could distribute part of the grant to independent schools. A very low share of the grant resources was however allocated to independent schools. Before every application round a grant frame is calculated by the National Agency for Education that is decisive of how much resources every municipality will receive if they fulfill the condition of increased personnel density. The grant frame is solely based on the number of residents in the municipality aged between 6 and 18 the calendar year before the grant year.

Almost one billion SEK was distributed to municipalities in the academic year of 2001/02 and in the academic year 2002/03 municipalities were allocated almost two billion SEK. In 2003/04 the amount was 3 billion SEK and in 2004/05 almost two billion SEK.[5] By dividing the amount allocated to a municipality with the total number of students in the same municipality it is possible to calculate the grant level per student. The average grant level in real values amounted to SEK 647 per student in 2001/02, SEK 1,271 in 2002/03, SEK 1,911 in 2003/04 and SEK 1,287 in 2004/05.[6] If municipalities would have used the total grant amount to employ new teachers in compulsory schools it would have amounted to on average 9.5 extra full time positions in the academic year 2001/02 and an additional 18.3 extra full time positions in 2002/03. The feasible number of full time teachers in 2003/04 was 26.3 and 16.9 in 2004/05. If municipalities would have used the entire grant to employ new teachers in compulsory schooling and adjusting for changes in the number of students this would have implies that the average teacher density would have

[4] All municipalities except two (Umeå and Österåker) applied for and received the grant during the first grant year, that is the academic year 2001/02. During the second grant year all municipalities applied and received the grant. In the academic year 2003/04 all municipalities except two (Nacka and Sundbyberg) applied and received the grant. In the autumn semester of 2004 all municipalities except three (Nacka, Sundbyberg and Osby) applied and received the grant.

[5] The amount in 2004/05 is based on the allocated grant level during the autumn semester of 2004 since the grant rules changed during the spring semester of 2005. About SEK 500 millions was allocated during the spring semester of 2005.

[6] Figures are deflated to 2003 years value using the consumer price index as deflator.

increased with about 10 percent between 2000/01 and 2004/05.[7] Teacher density did in reality only increase with slightly more than 6 percent between 2000/01 and 2004/05. This is so because the entire grant was not used to employ teachers and also because part of the grant was used in other sectors of the schooling system apart from compulsory schooling.

The fundamental claim on municipalities to be applicable for the grant is to increase the personnel density compared to the academic year 2000/01.[8] Municipalities with increasing number of students have to invest own resources to receive the entire grant frame. For municipalities with a decreasing number of students it is sufficient not to reduce the amount of personnel to meet the conditions of increased personnel density. If a municipality does not apply with the rules attached to the special grant the National Agency for Education can decide to withhold future payments or reclaim already disbursed payments.

In total 57 municipalities have exceptions from the requirement of increased personnel density. These municipalities have a difficult economic situation caused by weak economic growth in the region, negative population development, unbalanced population structure or large needs for infrastructure investments. The tax pressure is also generally high in these municipalities.

4 Data and variable specifications

The population of interest in this study is students that have completed ninth grade from the Swedish compulsory school. This information can be found in the Grade nine register administrated by Statistics Sweden (SCB). Information from the IFAU database, the Teacher register, the School register and data from the National Agency for Education has then been match to the Grade nine register using students' unique identifiers and municipality codes.

The analysis is based on register data and includes all students that completed compulsory schooling in Sweden between 1998 and 2005 (in total 849,446 students).[9] Information about these individuals is collected via SCB

[7] This number takes into account the fact that teachers that are being employed one year have to be financed also in the following years.
[8] By a government decision the rules for the grant changed in 2005. Part of the original grant was then transferred to the general governmental grant framework. The index year, which municipalities were to increase their personnel density compared to, changed in the spring semester of 2005. The last part of the government grant was allocated during the spring semester of 2006.
[9] The data do not include special schools or students that went to hospital schools etc.

from the Grade nine register. This register contains information about all students that have completed ninth grade. It contains information about students' year of birth, month of birth, school and which year they completed ninth grade. The Grade nine register also contain information indicating if students were eligible to apply to high school.[10]

To analyze whether the increased school resources has had an affect on achievement students' *GPA* will be used as dependent variable. The *GPA* is the sum of a student's 16 best grades and varies between 0 and 320. Alternative dependent variables such as if a student is eligible for high school and results on standardized test (in Mathematics, Swedish and English) will also be used. Information about results on the standardized test in Mathematics is available for a sample of students (about 150 schools and 10,000 students every year) for the years 1999, 2000 and 2002. There are no observations for 2001. All students' results are available for the years 2003, 2004 and 2005. Information about results on standardized tests in English and Swedish are available for a sample of students (about 150 schools and 10,000 students every year) for the years 1999, 2000 and 2001. No information is available for 2002, 2003 and 2004, but information for the whole population is available for 2005.

The different measures for student achievement are percentile ranked in order to make them comparable. This implies that (for every year) students with the lowest scores receive the value 0 and that students with the highest score receive the value 100. Percentile ranking makes different measures comparable but it also implies that the effect estimates are normalized and can be compared to previous research.

SCB have with the help of students' unique identifiers matched the Grade nine register with the IFAU database that contains detailed information about all individuals in Sweden that are between 16 and 65 years of age. Information about *parental education*, *wages*, and *disposable income* as well as *students and parents' ethnical background* are available. A dummy variable is created that takes the value one if a student's parents are born abroad. Another dummy variable takes the value one if the student has immigrated to Sweden within five years before he or she completed ninth grade.[11] Information about immigration status is unfortunately not available for the year 2005. Parental

[10] High school eligibility is achieved if a student passes in all core subjects. The core subjects are Swedish, English and Mathematics.
[11] Other definitions for immigrant status have been used but the quantitative results stay the same regardless of which definition that is used.

education is measured separately for the mother and the father. Parental education is divided into the following categories: a maximum of nine years of education, high school education, a maximum of two years of university and more than two years of university studies. In those cases when information about parental education is missing this is reported by a dummy variable.[12] To be able to study if the effect of resource changes is different between groups the following dummy variables are created: (i) both parents have at least nine years education, (ii) at least one parent has high school education and (iii) at least one parent has a university education.[13] Parental education can be seen as a proxy for socio-economic status, since education is strongly correlated with for example income and immigration status. The IFAU database contains information on parental education up until 2003. The educational level of parents whose children completed compulsory schooling in 2004 and 2005 are therefore taken to be the same as in 2003.

As a measure of available resources, and changes in these, *teacher density* will be used. Teacher density is defined as the number of full time equivalent teachers per 100 students.[14] The Teacher register is used to calculate the number of teachers and the School register is used for calculating the number of students. Both these registers are administrated by SCB. Schools with extreme teacher density are excluded from the analysis since these are likely to be misreported.[15] This reduces the dataset with about 10,000 students. Independent schools are also excluded from the analysis since they do not have the opportunity to apply for the special government grant and also because a few independent schools have their own grading system. This reduces the dataset with another 35,500 individuals.

Information about resources at the municipality level is made available from databases administrated by SCB and the National Agency for Education. Information about teacher density, educational expenditures per student and total expenditure per student (excluding premises) are collected from these databases. All prices are denominated in 2004 years prices.[16] Almost half of

[12] About 56,000 observations (8 percent) have missing information for the father's education and about 30,000 observations (4 percent) for the mother's education.
[13] Groups are mutually exclusive. That is; every student belongs to one of these groups.
[14] This is the only resource variable that is available at the school level and it includes certified as well as non-certified teachers.
[15] Schools that are within the highest and lowest two percentiles of the teacher density distribution are excluded from the sample.
[16] Consumer Price Index (CPI) has been used as deflator.

total educational expenditures are compensation to teachers, i.e., direct expenditures for carrying out education.

The final dataset for the years 1997/98–2004/05 contains 735,433 students. For some individuals in the final dataset there is missing information about immigration status. This reduces the sample size to 733,449. Descriptive statistics can be found in the Appendix.

5 Resource allocation and student achievement

This section gives a descriptive analysis of how resources have developed at the school and municipality level during the academic years 1997/98 - 2004/05. There will also be an analysis of how *GPA*:s in ninth grade have changed over time and between schools.

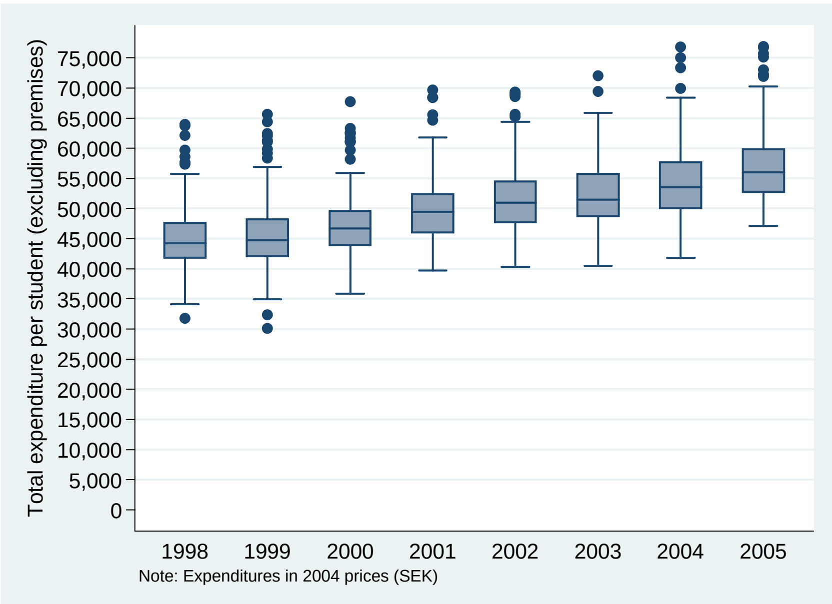

Figure 1. Total expenditures per student (excluding premises) in compulsory schools at the municipality level.

Figure 1 illustrates municipalities' total expenditures (excluding premises) per student in compulsory schools. The academic year 1997/98 is because of space constraints indicated by 1998 and similar for the rest of the years.[17] The figure describes the distribution of expenditures between all municipalities. The line inside the rectangle constitutes the median. The top of the rectangle is the 75th percentile and the bottom is the 25th percentile, thus the rectangle contains 50 percent of the distribution. The horizontal lines give the lower and upper adjacent values.[18] Extreme values that end up outside these limits are reported by dots. Total expenditure for operating the Swedish compulsory school has experienced a steady upward trend during the studied period. The median expenditure per student has increased with above SEK 9,000 (in real values) between 1997/98 and 2004/05.

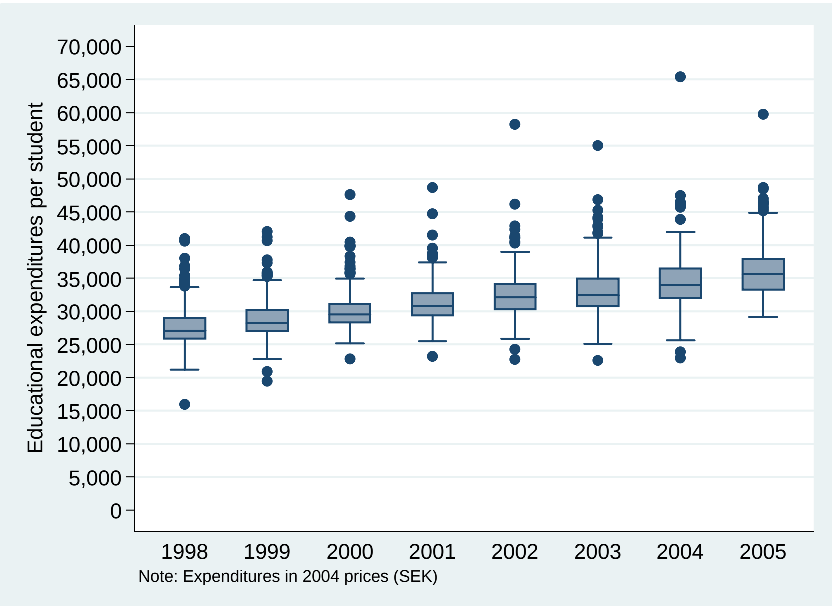

Figure 2. Educational expenditures per student in compulsory schools at the municipality level.

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[17] The same notation will be used throughout the rest of the figures.

[18] The lower adjacent value is defined by the 25th percentile – 1.5 · the interquartile range and the upper adjacent value is defined by the 75th percentile + 1.5 · the interquartile range.

Above 60 percent of total expenditures (excluding premises) per student constitute of educational expenditures. These expenditures are illustrated in Figure 2. There is a relative large variation in expenditures and the dispersion has widened somewhat over time. Part of the variation can be explained by the fact that some municipalities have few students and that expenditure per student is high because of that. Even if one consider this fact there still exists large differences between municipalities that invest a lot of resources and municipalities that makes relatively small resource investments in compulsory schooling. The increase in expenditures over time can partly be explained by an increase in the number of teachers, but also by increased teacher wages (Skolverket (2003)). Björklund et al (2005) and Andersson & Waldenström (2006) find that the number of certified teachers has decreased during the 1990's and the beginning of the 2000's which suggests that formal teacher quality has decreased. It can of course not be ruled out that expenditures would have increased even more if the share of certified teachers would have stayed constant.

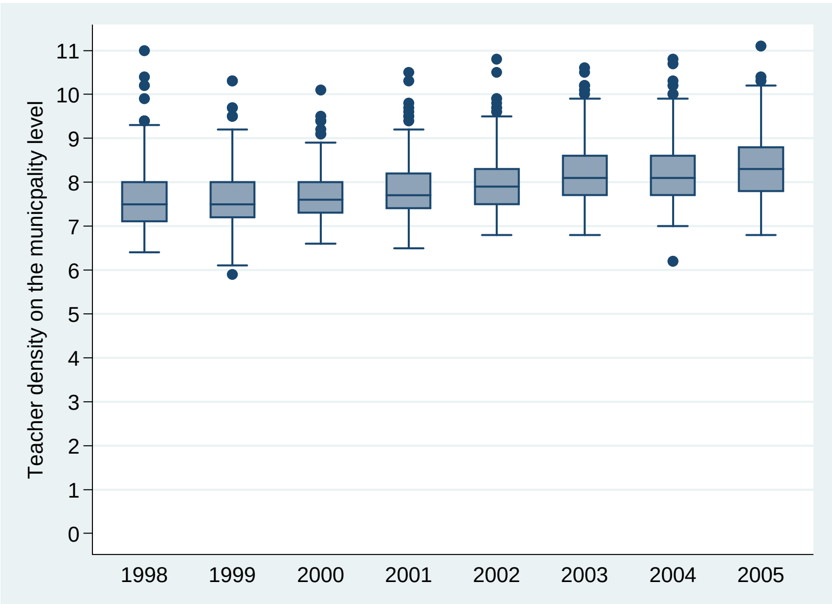

Figure 3. Distribution of teacher density in compulsory schools at the municipality level.

Educational expenditures increased between 1998 and 2005, but teacher density has not increased in a comparable fashion. This is because the number of students and teacher wages has increased during the same period. Figure 3 illustrates the dispersion of teacher density between municipalities from 1997/98 until 2004/05. Teacher density is defined as the number of full time equivalent teachers per 100 students. Median teacher density has increased from 7.5 to 8.3 and Figure 3 show that the largest increase occurred between 2000/01 and 2001/02, 2001/02 and 2002/03 and finally between 2003/04 and 2004/05. The academic years 2001/02 and 2002/03 are the first two years when the municipalities received extra resources from the *WG* to increase teacher density in schools.

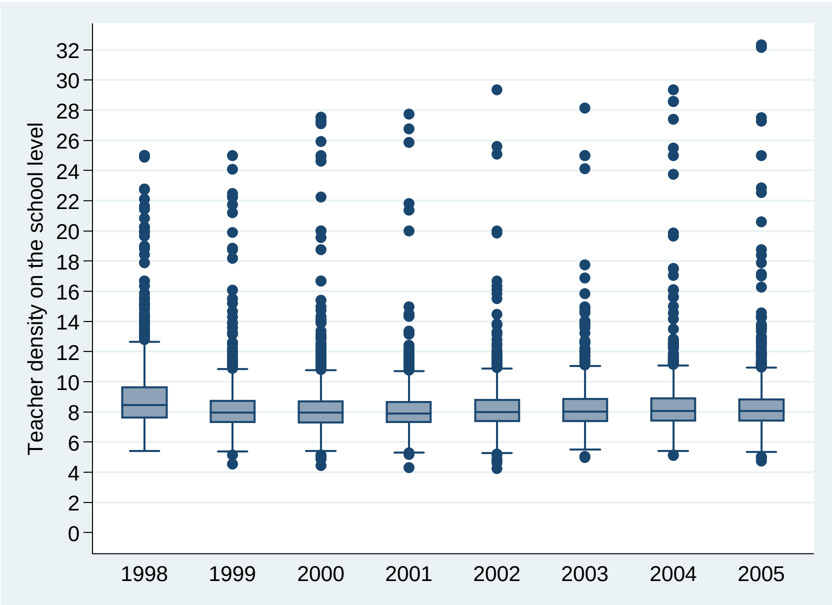

Figure 4. Distribution of teacher density in compulsory schooling at the school level.

Municipalities can independently decide how to divide the grant resources between schools within the municipality. It is for example possible for municipalities to allocate more resources to schools that have a lot of immigrant students or to schools with a lot of disadvantaged students. It is therefore interesting to examine teacher density at the school level instead of at the municipality level. Figure 4 shows that the dispersion, as expected, is a lot wider at the school level than at the municipality level. There are relatively many schools with extremely high teacher density despite the fact that special schools and independent schools are excluded from the analysis. Both the median and the distribution is relative stable between different years and the median teacher density at the school level varies between 7.9 and 8.5 teachers per 100 students.

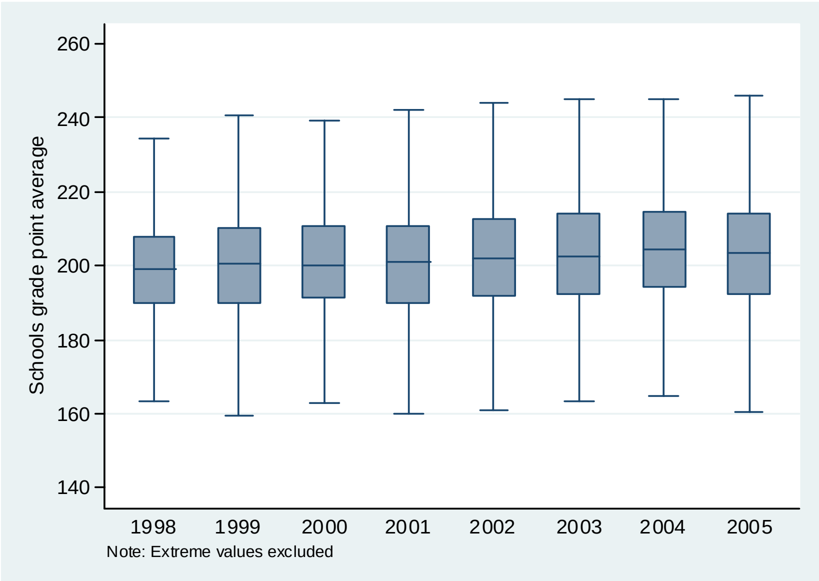

Figure 5. Distribution of grade point averages in compulsory schools.

Expenditures and teacher density has so far only been described for the academic years 1997/98 to 2004/05. The resource development is thus more interesting if it can be compared to the development in student achievement. Figure 5 shows the distribution of *GPA*:s in schools from 1997/98 to 2004/05. The dispersion has widened over time. A considerable amount of schools have both lower and higher average *GPA* in later years than in the beginning of the period. The median school has marginally increasing *GPA* during the studied period. The *GPA* for the median school increased from 199.6 to 204.2 during the period.

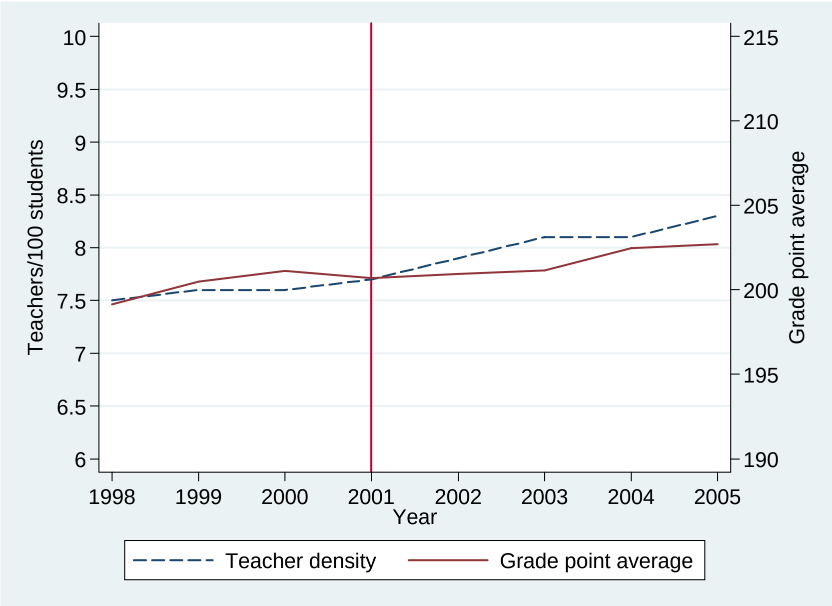

Figure 6. Median teacher density and students grade point average in compulsory schooling at the municipality level.

Changes in both teacher density and *GPA* are easier to observe if they are illustrated in the same figure. Figure 6 illustrate how median teacher density and median *GPA* have developed between 1998 and 2005. Both variables are measured at the municipality level. Students' *GPA*:s increased marginally during this period and the teacher density showed a positive trend that has been strengthened after the academic year 2000/01. This was the first year that the *WG* for increasing personnel density was allocated to municipalities.

6 Measuring effects of resources on student achievement

The purpose of this study is to measure and quantify the effect of (increased) resources to the educational sector on student achievement. There are methodological problems that arise because resources are distributed unevenly between students and schools within a municipality, but also between different municipalities. One first problem is that expenditures are determined endogenously, i.e., those sectors that are studied (schools and municipalities) can themselves influence the magnitude of the resources that they have at their disposal.

The methodological problem on the individual level constitutes in the fact that disadvantaged students often receive more resources than advantaged students. If one do not hold students' ability constant it is possible to find a negative relationship between resources and student achievement even if the causal relation might be the opposite. This problem can be solved partly by controlling for students' family background. If information about students' prior academic achievements were available this could reduce this problem further by comparing *changes* in individual student achievement and *changes* in available resources. Unfortunately, information about student achievement is only available in ninth grade and there is no information about students' prior attainments.

To handle the problem that the resource distribution to schools might be endogenous the analysis focuses on how changes in resources co-vary with changes in student achievement within different *schools*. At the municipality level the *WG* creates variation in resources between municipalities that is not due to a municipality's decision-making process because the grant is based on the number of 6 to 18 year olds in the municipality the year before the first grant year. Four years of grant payments are observed.

This study analyzes the effect (in terms of changes in student achievement) of resource changes that took place during the period 1997/98–2004/05. Data from 1997/98 - 2000/01 (data prior to the introduction of the *WG*) are used in order to increase the variation in resources and thereby get better precision in the estimates. School fixed effects are used to eliminate differences between schools that can affect resources and/or student achievement and that are constant over time. If it does not exist non-observable differences between schools that vary over time that both affects resources and student achievement it is feasible to obtain effect estimates based on the ordinary least squares, OLS, estimator that are unbiased.

Based on previous international and a few Swedish studies that focuses on the effect of teacher and personnel density as well as class size on student achievement there are reason to believe that if there exist an effect of increased teacher density on student achievement it can mainly be found among younger students and individuals with special needs (see for example Heckman (2000) and Heckman & Kreuger (2003)). When evaluating the effect of school resource investments on student achievement it is consequently important to consider that the effect can be different for different groups, i.e., if there exist heterogeneous effects. Students are therefore divided into different groups depending on their parents' level of education.[19]

Models are estimates using the OLS estimator with fixed effects at the school level and without fixed effects. When using fixed effects at the school level in the regressions the change in student achievement is related to the change in resources at the school. The first model to be estimated is one with percentile ranked *GPA* as the dependent variable. To be able to examine if the increased resources affect student achievement in different subjects a number of regressions are estimated in which the results on standardized tests in Mathematics, English and Swedish are used as dependent variables. Finally a linear probability model is estimated which estimates the probability to reach high school eligibility. Regressions are estimated at the individual level.

7 Results

7.1 Teacher density and student achievement

In a first step to investigate if resource changes affect student achievement a model that include controls for gender, age, month of birth, number of students in the school and time dummies is estimated. No controls for family characteristics are included in the estimations that are presented in Table 1. These estimations are conducted *without* (column 1) and *with* (column 2) school fixed effects. The included time dummies imply that the model controls for differences between schools that are constant over time. The dependent variable is students' percentile ranked *GPA*. The results from the model without fixed effects show that the teacher density is negatively related to the students' position in the distribution of *GPA*:s. The effect implies that if teacher density is increased with 10 percent the average student's position in the distribution would deteriorate with about 1.2 percentile units. There are, however, reasons not too put to much trust into this estimate since the estimate do not take school specific differences into account. These differences are likely to affect both the size of resources that schools receive and student achievement. If schools with students that need more support are allocated

[19] It would also be interesting to analyse the effect of resource changes for immigrant students and if the effect for them are different from non-immigrant students. This has been done but the results are non-robust and vary a lot between specifications. Results are therefore not presented here.

more resources from the municipality then the estimates will be biased because the estimate without fixed effects does not take this behavior into account. When fixed effects are included in the model at the school level the effect is much smaller and now only weakly statistically significant. However this estimate can also be biased because it does not take the differences in family characteristics that vary between different cohorts within a school into account.

Table 1. The relationship between the *GPA* and teacher density without controlling for family background.

Dependent variable: Percentile rank of grade point average	(1) Without FE	(2) School FE
Ln(teachers/100 students) school level	-12.222***	-0.759*
	(0.236)	(0.458)
Observations	735,433	735,433
R^2	0.06	0.10

Note: Standard errors within parentheses. Standard errors in column (2) are cluster corrected (cluster = school · year of finishing). * significant at 10%; ** significant at 5%; *** significant at 1%. Models include controls for gender, age, month of birth and the number of students in the school.

Table 2 present results from a model that more extensively control for family characteristics. The model includes all individuals that completed ninth grade (compulsory schooling) between 1998 and 2005. The dependent variable is students' percentile ranked *GPA* defined in the same way as in Table 1. Family characteristics are measured by three dummy variables for the mother's educational level as well as three dummies for the father's educational level. One dummy variable indicating if both parents are born abroad and one if the student has immigrated within five years before he or she completed ninth grade. The models without fixed effects (see column (1) and (2)) show that teacher density has a negative and statistically significant effect on students' percentile ranked *GPA*, but the estimate is smaller when controls for family characteristics are included in the model (compare with Table 1, column (1)). Column (3) and (4) in Table 2 show the results from models with fixed effects at the school level. The models in column (1) and (3) include those observations for which there are no information about the educational level of the mother and father. The models in column (2) and (4) exclude those observations. The teacher density estimate is negative in both cases, but not statistically significant. It is therefore not possible to conclude that there is any statistically significant effect of teacher density on students' position in the *GPA* ranking.

Table 2. The relationship between the *GPA* and teacher density controlling for family background.

Dependent variable: Percentile rank of grade point average	(1) Without FE	(2) Without FE	(2) School FE	(3) School FE
Ln(teachers/100 students) school level	-4.4408*** (0.2188)	-3,4736*** (0,2344)	-0.1406 (0.4466)	-0.0979 (0.4581)
Observations	733,449	670,782	733,449	670,782
R^2	0.22	0.21	0.24	0.23

Note: Standard errors within parentheses. Standard errors in column (2) and (3) are cluster corrected (cluster = school · year of finishing). * significant at 10%; ** significant at 5%; *** significant at 1%. Models include controls for gender, age, month of birth, the number of students in the school, three dummy variables for the mother's educational level, three dummy variables for the father's educational level, a dummy variable if both parents are born abroad and a dummy if the student has immigrated within five years before completing ninth grade. Model (1) and model (3) includes a dummy variable if information about the mother's or father's education is missing. Model (2) and (4) exclude observations where information about parental education is missing.

To examine if changes in teacher density have had any affect on student achievement in individual subjects three different models with the percentile ranked results on standardized tests as the dependent variable are being estimated. The analysis is based on around 250,000 observations for Mathematics and around 100,000 observations for Swedish and English. Results from the estimated fixed effects models are reproduced in Table 3.

The estimates regarding the effect of increased teacher density are negative and statistically significant in all three model specifications. A *positive* effect from the increased teacher density can not be found when test scores on standardized tests in Mathematics, Swedish and English are used as the dependent variable.

Table 3. Standardized tests and teacher density, with school fixed effects.

Dependent variable: percentile rank of composite test score	(1) ST Mathematics	(2) ST Swedish	(3) ST English
Ln(teachers/100 students) school level	-2.0380*	-4.3494**	-4.1381**
	(1.1731)	(1.8852)	(1.8565)
Observations	249,286	112,186	112,613
R^2	0.16	0.22	0.21

Note: Standard errors within parentheses. Standard errors are cluster corrected (cluster = school · year of finishing). * significant at 10%; ** significant at 5%; *** significant at 1%. All specifications include controls for gender, age, month of birth, the number of students in the school, three dummy variables for the mother's educational level, three dummy variables for the father's educational level, a dummy variable if both parents are born abroad, a dummy if the student has immigrated within five years before completing ninth grade and a dummy if information about parental education is missing.

A linear probability model is estimated to analyse if the increased teacher density has had an effect on the probability to achieve high school eligibility. The results are presented in Table 4. Teacher density has according to this model a positive effect on students' probability to achieve high school eligibility, but the effect is not statistically significant. There are again no indications that increased resources in the form of a higher teacher density have had a positive affect on student achievement.

Table 4. High school eligibility and teacher density, with school fixed effects.

Dependent variable: high school Eligibility	(1) High school eligibility
Ln(teachers/100 students) school level	0.0028
	(0.0062)
Observations	733,449
R^2	0.11

Note: Standard errors within parentheses. Standard errors are cluster corrected (cluster = school · year of finishing). * significant at 10%; ** significant at 5%; *** significant at 1%. All specifications include controls for gender, age, month of birth, the number of students in the school, three dummy variables for the mother's educational level, three dummy variables for the father's educational level, a dummy variable if both parents are born abroad, a dummy if the student has immigrated within five years before completing ninth grade and a dummy if information about parental education is missing.

7.2 The importance of control variables and effect heterogeneity

A lot of control variables have been included in the estimations presented so far. The influence of these variables on the *GPA* percentile rank is also of interest. Table A2 in the Appendix gives a complete presentation of all parameter estimates from Table 2, in which students' achievement is measured as the percentile ranked *GPA*.[20] The most important determinant of student achievement is the educational level of the student's parents. The mother's education has the biggest impact. A student with a mother that has at least two years of university studies is, all other things kept constant, positioned almost 20 percentiles higher in the *GPA* distribution than a student with a mother who has at most nine years of education. This corresponds to a *GPA* that is around 40 points higher. The corresponding difference for the father's education is about 16 percentiles.

Furthermore it can be concluded that there are large differences between male and female students when it comes to *GPA*:s. Female students that complete compulsory schooling have on average and other things kept constant a position that is about 11 percentiles higher in the *GPA* distribution. The estimates also suggest differences between native Swedes and immigrant students. A student that have immigrated to Sweden within five years before he or she completed ninth grade has, ceteris paribus, on average a position in the distribution of *GPA*:s that is three percentile units worse than a student that has Swedish background or has lived in Sweden for a longer period of time. The *GPA* is about 1.5 percentile units worse if both parents are born abroad. Another interesting result that is stable and significant in all specifications is that a student that is born a month later than another otherwise comparable student on average has 0.5 percentile units worse *GPA* when completing ninth grade. To be born in December instead of January would therefore, ceteris paribus, imply around six percentile units worse *GPA*. Fredriksson & Öckert (2005) find similar results in their study.

The results so far do not support the view that an increased teacher density has a positive effect on student achievement it could very well be the case that

[20] Corresponding results for the other specifications can be obtained from the author on request. In general, the qualitative effects of the control variables on student achievement are relative robust between different regression models. The magnitudes of the parameter estimates are not exactly comparable, however, because the variance of the outcome variables differs across specifications.

increased school resources has improved student achievement for disadvantaged students. To analyze if such heterogeneous effects are present interaction terms that take into account different combinations of resources and parental education are added to the estimated models. Column (1) in Table 5 with the *GPA* as the dependent variable show that students with low educated parents gain from increased resources. If teacher density is increased with 10 percent a student with low educated parents is expected to improve its position in the *GPA* distribution with slightly less than 0.4 percentile units. This effect is statistically significant at conventional levels. The effect of an increase in teacher density is not statistically significant for students whose parents are high school educated but significantly negative for students with university educated parents. It is however important to note that the dependent variable is the percentile ranked *GPA* so it does not have to be the case that a higher teacher density implies lower achievement for students with highly educated parents but rather that it is redistribution in the distribution of *GPA* that makes the effect negative for this group. The Swedish educational system has an objective to equalize differences between children from different backgrounds. The results from Table 5 show that increased resources to schools might help achieve this goal.

Table 5. The effect of teacher density by family background.

Dependent variable: Percentile rank of grade point average	(1) School FE
Ln(teachers/100 students) · Parents max 9 years of education	3.7494***
	(0.8381)
Ln(teachers/100 students) · At least one parent with high school education	0.2490
	(0.5226)
Ln(teachers/100 students) · At least one parent with university education	-1.4623***
	(0.5547)
Observations	670,782
R^2	0.21

Note: Standard errors within parentheses. Standard errors are cluster corrected (cluster = school · year of finishing). * significant at 10%; ** significant at 5%; *** significant at 1%. Excludes observations without information about parental education. The model include controls for gender, age, month of birth, the number of students in the school, a dummy variable if at least one parent has high school education, a dummy variable if at least one parent has university education, a dummy variable if both parents are born abroad and a dummy if the student has immigrated within five years before completing ninth grade.

8 Conclusions

This study has analyzed how changes in resources to Swedish compulsory schools have affected student achievement. The study also tries to evaluate the effects of a special governmental grant instituted in the academic year 2001/02 that municipalities received to increase personnel density in schools. Teacher density has been increasing since the introduction of the grant but teacher density in compulsory schooling has not increased as much as if all of the allocated grant resources would have been used exclusively to hire new teachers.

The results show no positive statistically significant connection between resource increases and average student achievement. The resource changes have however not been that large during the studied time period and the question is how large effect one can expect from marginal changes in resources. If the entire special government grant had been used to hire new teachers in compulsory schools then teacher density would have increased from 7.8 to 8.6 teachers per 100 students between 2000/01 and 2004/05. This would have amounted to an almost 10 percent increase and would have been equivalent to a reduction in class size with 1.2 students. In reality was class size reduced with about 0.6 students per teacher from 2000/01 to 2004/05.[21] From Andersson & Waldenström (2007a) we know that the share on non-certified teachers have increased during the studied time period. A significant share of the grant resources have been used to hire non-certified teachers and as is suggested in Andersson & Waldenström (2007b) this may be detrimental to student achievement. The fact that more non-certified teachers have been employed may explain that no significant effect of resources can be found on the average student's achievement.

It is hard to draw causal conclusions from observational studies and it is likely that the effect of recourses on student achievement is underestimated. Even if students' family characteristics are controlled for and fixed effects included, all the problems that have to do with endogenously determined resources are not necessarily solved. It is also possible that the average student's achievement is not affected by small changes in resources. Schools can choose to invest extra resources in special groups of students, for example dis-

[21] Class size can be roughly approximated by the number of students per teacher. A teacher density of 7.8 then corresponds to 12.8 students per teacher and a teacher density of 8.6 corresponds to 11.6 students per teacher.

advantaged students. The results in this study show that increased resources may have improved student achievement for students with low educated parents when resources are measured as teacher density. This result is in line with previous studies and it implies that additional resources may be an important way to equalize the achievement of children from different background.

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Appendix

Table A1. Descriptive statistics for the complete sample.

Variable	Observations	Mean	Std. dev.
Teachers/100 students (school level)	733,449	8.15	1.35
Educational costs per student	727,232	32,040	4,464
Rank of grade point average	733,449	50.07	28.64
Grade point average	733,449	202.17	63.32
Number of students	733,449	471.46	170.42
Girl	733,449	0.49	0.50
Mother: high school education	733,449	0.49	0.50
Mother: university education shorter than 2 years	733,449	0.03	0.18
Mother: at least 2 years of university education	733,449	0.29	0.45
Mother: information about education is missing	733,449	0.03	0.18
Father: high school education	733,449	0.46	0.50
Father: university education shorter than 2 years	733,449	0.06	0.25
Father: at least 2 years of university education	733,449	0.20	0.40
Father: information about education is missing	733,449	0.07	0.25
Student immigrated within five years before completing ninth grade	733,449	0.02	0.12
Both parents born abroad	733,449	0.12	0.33
Month of birth	733,449	6.27	3.37
Age	733,449	16.02	0.25

Table A2. Complete parameter estimates from Table 2.

Dependent variable: percentile rank of grade point average	(1) Without FE	(2) School FE	(3) School FE
Ln(teachers/100 students)	-4.4408***	-0.1406	-0.0979
	(0.2188)	(0.4466)	(0.4581)
Ln(number of students)	0.9597***	0.3300	0.2255
	(0.0760)	(0.5749)	(0.5889)
Girl	11.1359***	11.1298***	11.2530***
	(0.0595)	(0.0784)	(0.0810)
Month of birth	-0.4152***	-0.4223***	-0.4411***
	(0.0089)	(0.0089)	(0.0093)

Dependent variable: percentile rank of grade point average	(1) Without FE	(2) School FE	(3) School FE
Age	-11.8223***	-11.4585***	-12.4249***
	(0.1188)	(0.1335)	(0.1493)
Mother: high school education	7.3527***	7.1223***	7.2836***
	(0.0888)	(0.0900)	(0.0929)
Mother: university education shorter than 2 years	15.6329***	14.9769***	15.0031***
	(0.1851)	(0.1860)	(0.1916)
Mother: at least 2 years of university education	19.5668***	18.8878***	18.8961***
	(0.1019)	(0.1077)	(0.1108)
Mother: information about education is missing	2.3699***	2.3856***	
	(0.2071)	(0.2391)	
Father: high school education	4.4667***	4.5061***	4.5125***
	(0.0790)	(0.0806)	(0.0818)
Father: university education shorter than 2 years	13.6216***	13.4806***	13.5347***
	(0.1341)	(0.1389)	(0.1400)
Father: at least 2 years of university education	16.3477***	15.7784***	15.8895***
	(0.0996)	(0.1045)	(0.1059)
Father: information about education is missing	0.9918***	0.6095***	
	(0.1463)	(0.1504)	
Student immigrated within five years before completing ninth grade	-2.8694***	-2.8078***	-2.2595***
	(0.2946)	(0.3346)	(0.4840)
Both parents born abroad	-1.4363***	-0.6564***	-0.0761
	(0.1057)	(0.1366)	(0.1454)
Constant	224.1640***	213.6053***	229.5696***
	(2.0481)	(4.1799)	(4.3951)
Observations	733,449	733,449	670,782
R^2	0.22	0.24	0.23

Note: Standard errors within parentheses. Standard errors in column (2) and (3) are cluster corrected. (cluster = school · year of finishing). * significant at 10%; ** significant at 5%; *** significant at 1%.

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