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Resources and student achievement – evidence from a Swedish policy reform

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WORKING PAPER 2007:26

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ISSN 1651-1166

Resources and student achievement – evidence from a Swedish policy reform*

by

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19 October 2007

Abstract

This paper utilizes a policy change to estimate the effect of teacher density on student performance. We find that an increase in teacher density has a positive effect on student achievement. The baseline estimate – obtained by using the grade point average as the outcome variable – implies that resource increases corresponding to the class-size reduction in the STAR-experiment (i.e., a reduction of 7 students) improves performance by 2.6 percentile ranks (or 0.08 standard deviations). When we use test score data for men, potentially a more objective measure of student performance, the effect of resources appears to be twice the size of the baseline estimate.

Keywords: Student performance, teacher/student ratio, policy reform, differences-in-differences
JEL-codes: I21, I28, J24

* We acknowledge the helpful comments from two anonymous referees, Göran Arvidsson, Robert Erikson, Bertil Holmlund, Steve Machin, Erik Mellander, Eva Mörk, and Roope Uusitalo. This paper is a spin-off from a project supported by the SNS. Thanks to Anders Björklund, Melissa Clark, Per-Anders Edin, and Alan Krueger for very stimulating collaboration during this project.

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1 Introduction

One of the most controversial (and important) issues in the economics of education is whether additional resources are beneficial for scholastic achievement. The disagreement is so profound that not even the quantitative reviews of the literature are in agreement. Some reviews (e.g., Hedges, et al. 1994 and Krueger, 2003) find positive impacts of smaller classes on student outcomes, while others (most prominently, Hanushek, 1997) find no beneficial effects of smaller classes.

This paper revisits the question of whether student outcomes are improved by an increase in the amount of resources invested in schools. The evidence that we offer comes from a policy change that affected the allocation of resources over schools. In the beginning of the 1990s, authority over schools was decentralized to the local level. Prior to this reform, school resources had been determined by a system with ear-marked money granted from the central government. After the reform, the central government distributed a block grant and the local authority could decide on the allocation of spending over its various responsibilities (including schooling). This reform induced a clear change in the allocation of resources over localities and we utilize this change to estimate the causal effect of resources on student performance.

The previous literature on the relationship between school resources and student achievement is very extensive. Space prevents us from giving a representative overview of the literature; useful summaries of the literature are available in Krueger (2003) and Hanushek (1997). Let us just mention here that studies using some kind of experimental variation – be it actual or quasi – tend to find positive effects to a greater extent than studies relying on observational data.

The bulk of the evidence which is experimental in nature pertains to the US. Analysis of the Tennessee STAR experiment (e.g., Krueger, 1999) suggests that the effect on test scores of a class size reduction by seven students was on the order of 0.2 standard deviations.

Studies of the link between resources and schooling outcomes using European data along with a credible identification strategy are much less common. In the Swedish context, Lindahl (2005) represents the only serious attempt to examine the issue. He used a sample of 556 5th graders in Stockholm and found that the achievement gains in response to class size reductions by seven students are comparable to STAR. His preferred set of estimates corresponds to gains ranging from 0.10 to 0.24 standard deviations.

In contrast to Lindahl (2005), our analysis is based on data which are representative for the entire population of compulsory school students in Sweden. We use the decentralization reform to calculate difference-in-differences estimates of the effect of teacher density (i.e. the number of teachers per student) on student outcomes.[1] Our identification strategy is thus akin to the one applied by, e.g., Duflo (2001).

This paper is outlined as follows. Section 2 provides a background by documenting the evolution of resources over the 1990s and early 2000s and describing the institutional changes that were implemented in the early 1990s. Section 3 examines whether the distribution of resources changed after decentralization. In Section 4 we investigate whether resource changes has a causal effect on student achievement. We look at the average effect, but we also pay particular attention to pupils from disadvantaged backgrounds. Section 5 concludes. Throughout this paper we focus on the compulsory schools (i.e. schooling at the primary and lower secondary level). Our principal measure of resources is the number of teachers per student.

2 Resources and institutional change

The 1990s was a very eventful decade for Swedish youth education. Among other things, this decade saw a substantial decline in education expenditures relative to GDP. Expenditure per student in compulsory schools, as a share of GDP per capita, declined from 34 percent in 1991 to 24 percent in 1999; see OECD (1994, 2002). These developments took place during a time period when the typical OECD country experienced no major changes in resources. In 2002, Sweden spends about as much on primary education relative to GDP per capita as the average OECD country.

Part of the decrease in resources should certainly be attributed to the severe economic slump that hit Sweden in the beginning of the 1990s. But there were also other changes: in the beginning of the 1990s, authority over schools was decentralized to the local level. Formally this change took place in 1991. But it

[1] Note that we will use “the teacher/student ratio” and “teacher density” interchangeably throughout the paper.

was not until 1993 that the local authority could decide on the allocation of spending over its various responsibilities. Between 1991 and 1993 the system with ear-marked money granted from the central government was still running, albeit in a less strict form.

2.1 Institutional change

Prior to decentralization – i.e. prior to 1991/92 – the allocation of resources was determined through a strict system with ear-marked money.[2] The central government – via the regional schooling authorities (*länsskolnämnderna*) – more or less determined the amount of resources at the school level. For instance, the number of teachers at the school level was effectively determined by a central government grant. The municipalities had little freedom to allocate expenditure on different items within, e.g., the compulsory schooling system.

This was changed in 1991/92. The municipalities still received a grant for, e.g., compulsory schools from the central government. However, the municipalities could freely allocate the money across schools and various items within the compulsory schooling system. Thus, the system is still one of ear-marked money but it contained more degrees of freedom for the municipalities. The reform was implemented such that the real amount of resources for each municipality was the same as in the old system.

The new system survived only one additional year, however. As of 1 January 1993, the money, previously ear-marked for education, was incorporated into an overall equalization grant (a block grant). Unlike the previous reform, the (real value of the) equalization grant in 1993 was lower than the sum of the components in 1992; see Johansson (2003). From this year and onwards, the municipalities can freely allocate resources over its different responsibilities. Arguably, this is the big change in terms of the allocation of school resources over municipalities.

2.2 School inputs during the 1990s and early 2000s

Figure 1 shows the evolution of the median teacher/student ratio (i.e. the number of teachers per student) in compulsory schools during the school years 1990/91—2002/03.[3] These numbers are calculated as the median over munici-

[2] Du Rietz et al. (1987) contains an excellent description of the resource allocation system prior to decentralization.

[3] To calculate these numbers we use the teacher register, a register of all individuals employed in Swedish schools; section 4.1describes these data more fully.

palities weighted by the size of the student population and, hence, they have the interpretation of the resource development facing the median student.

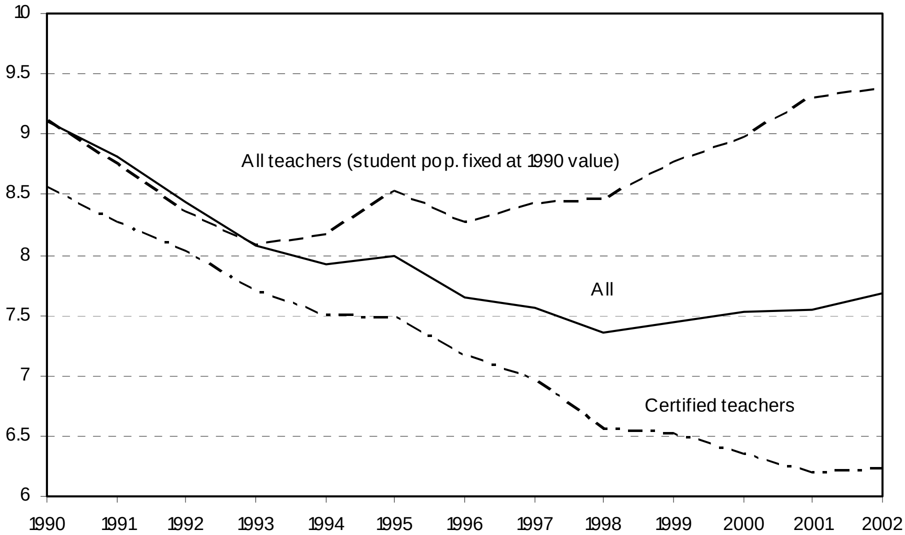

Figure 1 Median teacher/student ratios, percent, 1990/91—2002/03

Source: Calculations using the Teacher register.
Notes: The figure shows the population weighted median over municipalities. Certified teachers refer to those with a degree from teacher education. During 1990/91—1997/98 the number of teachers have been converted to full time equivalents using 25.3 stipulated teaching hours per week as the measure of full-time teaching load. For later years there is a (reliable) measure of employment intensity directly available in the data. In doing these calculations, we have imposed the restriction that individuals holding more than one position can work no more than 120 % of full time.

The 1990s saw a continuous decrease in the teacher/student ratio (solid line). From 1990/91 to 1999/00 the median teacher/student ratio decreased by 1.7 percentage points – from 9.1 to 7.4 percent. The decline during the 1990s is driven by the fact that the number of teachers has not kept pace with the increase in the student population. Between 1990/91 and 1999/00 teacher density declined by 0.4 percentage points holding the student population fixed at the 1990 value.

There is evidence suggesting that the monetary incentives for becoming a teacher declined substantially between the late 1960s and early 2000s.[4] The evidence further suggests that this development contributed to a decline in the demand for teacher education, implying that the supply of certified teachers has been stagnant for some time and that there has been a decline in the academic performance of those opting for teaching (Björklund et al, 2005; Fredriksson and Öckert, 2007).[5] *Figure 1* shows that when the teacher/student ratio increased, starting in 1998/99, this was primarily accomplished through the hiring of non-certified teachers (i.e. teachers without pedagogical training). By 2002/03 almost 19 percent of teachers did not hold a certification. The density of certified teachers has declined rather dramatically, from 8.6 percent in 1990/91 to 6.2 percent in 2002/03. The most likely culprit for the sharp increase in the number of non-certified teachers is that the municipalities were constrained by the supply of certified teachers. The recent work by Andersson and Waldenström (2007) lends support to this hypothesis. They show that increases in the resources made available for compulsory schools imply a greater decrease in the fraction of non-certified teachers if unemployment among certified teachers is high.

There is thus some evidence suggesting that the skill composition of teachers has changed over time. The only available indicator reflecting such a change is whether teachers are certified or not. We will therefore present evidence where we hold the change in the share of non-certified teachers constant. We note already at this stage that our results do not depend on whether we hold the share of non-certified teachers constant or not.

The literature on the effect of resources on outcomes is generally about class size. It is somewhat unfortunate, therefore, that there is no recent information on average class sizes available. The most recent information dates back to the beginning of the 1990s. In 1991/92, the average class consisted of

[4] There was a reform to teacher wage determination in 1996. Prior to 1996, teacher wages were governed by "wage-scales" determined in central negotiations. After 1996, teacher wages have been determined locally. Fredriksson and Öckert (2007) show that the post-reform distribution of teacher wages is remarkably compressed, despite de-regulation; further, the return to teacher education seems to have been unaffected by de-regulation.

[5] For instance, Björklund et al (2005) examine how the share opting for teacher education has varied across birth cohorts. Among those born in 1948, around 30 % of university graduates had a teaching degree; for those born in 1972 the corresponding share had declined to around 20 %, suggesting that the relative demand for teacher education declined over time. Across the same two cohorts, the relative performance at ability tests conducted at age 13 declined for those who subsequently got a teaching degree.

21.8 students. Let us make a rough translation of the resource development shown in *Figure 1* into changes in class size. The numbers shown in *Figure 1* implies that the number of students per teacher increased by 18 percent between 1991/92 to 1999/00. Thus, multiplying 21.8 with 1.18 gives a predicted class size of 25.8 students, i.e., an increase of four students per class. In 2002/03 the predicted class size, calculated analogously, equals 25 students.

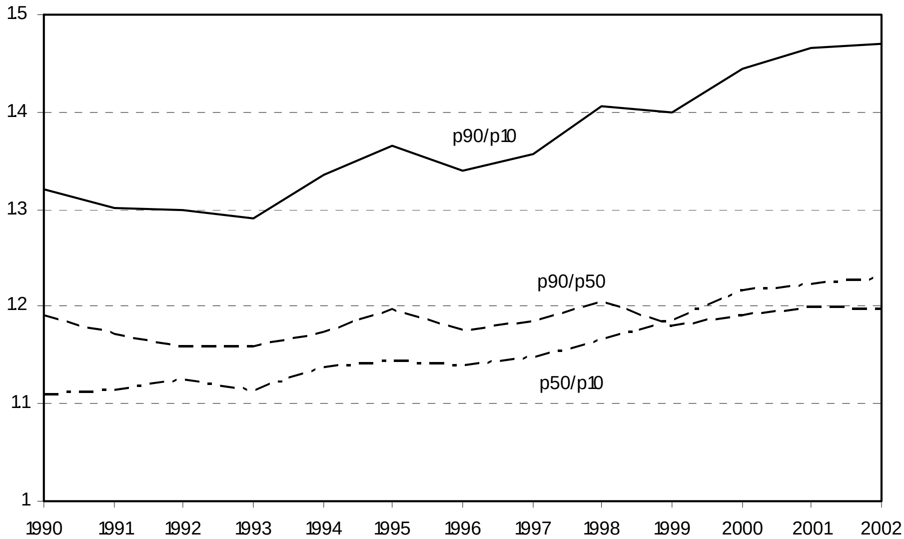

Figure 2 Percentile ratios of the teacher/student distribution, 1990/91—2002/03

Source: Calculations using the Teacher register.
Notes: These numbers have been obtained by first calculating the population-weighted percentiles over municipalities and then forming the percentile ratios.

Now let us look at the distribution of resources over students. *Figure 2* shows percentile ratios of the distribution of the teacher/student ratio over municipalities. The solid line shows the 90/10 ratio, while the dotted lines “decompose” this ratio into 90/50 ratio and the 50/10 ratio. The spread of the distribution stood at a low in 1993/94. Since then there is an upward trend in the 90/10 ratio. The widening of the distribution appears to have taken place mainly at the bottom of the distribution. The 90/50 ratio is largely constant throughout the period; but there is an upward trend in the 50/10 ratio. Thus, the evolution of the distribution of resources over students during the 1990s has primarily been to the disadvantage of students at the lower end of the resource distribution.

3 Did decentralization change the allocation of resources?

In *Figure 2* there appears to be an increase in the spread of the distribution of resources over students during the 1990s. But it is not a priori clear whether this increase should be attributed to the institutional reforms. In this section we present some evidence suggesting that the reform drastically changed the allocation of resources over municipalities. To do this we look at mobility in the overall distribution of resources. Since the decentralization reform implied that the rule for allocating expenditure over municipalities changed, we would expect that the ranking of individual municipalities with respect to inputs invested in schools should have changed. *Figure 3* examines whether this was the case.

Figure 3 reports the rank correlation in teacher densities over time. The solid line shows the correlation with the rank in the preceding year (e.g., the entry for 1991 shows the correlation between 1991/92 and 1990/91). The dashed lines show the correlation with the rank three or six years prior to the year in question (e.g., 1991/92 with 1988/89 or 1985/86).

There is clear evidence that the reform shifted municipalities around in the distribution of resources in 1993. The first solid line shows the correlation between adjacent years. It is evident that the correlation is markedly lower for years involving 1993, i.e., 1992/93 and 1993/94. This is illustrated even more sharply by the dashed lines in the figure; the correlations are substantially lower for years that come from different resource allocation systems. This is particularly evident for the rank correlation between years that are six years apart; prior to the reform the correlations hover around 0.70–0.75 while after the reform the correlations hover around 0.45–0.50. The six year correlation picks up in 1998/99 which involves years from the same resource allocation system (i.e. 1998/96 and 1992/93). Overall, it seems that the stability of the resource distribution is lower in the new system; this is perhaps what one should expect given that the state of the municipal budget has become more important for the determination of schooling expenditures.

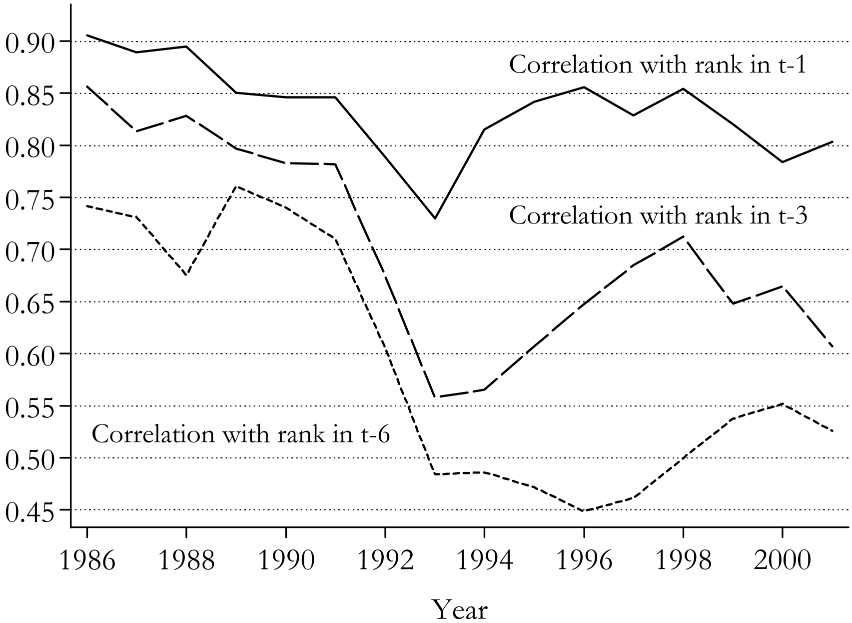

Figure 3 The rank correlation in the current and lagged teacher/student ratio, 1986-2001

Source: Unpublished statistics, Statistics Sweden.
Notes: The solid line shows the correlation with the closest preceding year. The entry for, e.g., 1991 thus shows the correlation between the ranks in 1991/92 and the ranks in 1990/91. The dashed lines show the correlations with the rank lagged three or six years. The data have kindly been supplied by Inge Göransson at Statistics Sweden.

In this analysis we have not taken into account that some of the change in the distribution of resources may be due to changes in the characteristics of students. Now, the characteristics of students change slowly over time so it is highly unlikely that they will account for the sudden shift in *Figure 3*. This conjecture is substantiated by the analysis in Björklund et al. (2005).

In short, there is clear evidence of a shift in the allocation of resources over municipalities.[6] The timing of the shift suggests that the most likely culprit for

[6] This can also be substantiated by some formal analysis. We have decomposed the changes in teacher density over the entire time period relevant for our subsequent empirical analysis (1991/92—2000/01) into two year changes in teacher density (1991/92—1993/94, 1993/94—1995/96, etc.). It turns out that the changes over the entire time period are highly correlated with the initial changes during 1991/92—1993/94 (the correlation is 0.53) but not so much with the changes over the other sub-periods. This suggests that the reform caused a one-off change in the allocation of resources.

explaining it is the change in funding responsibilities, where the system was changed from one where the central government provided ear-marked money for schools to one where the municipalities received block-grants which was intended to finance all their responsibilities (e.g. schools, elderly care, and social assistance).

4 Resources and achievement: the evidence

It is notoriously difficult to estimate the causal effect of resources on student performance. The difficulties stem from compensatory behavior on the part of educational authorities. Credible evidence presumably requires some kind of experimental – either explicit or quasi – variation. In this section we make use of a variation that is potentially exogenous: the change in schooling expenditure induced by the decentralization reform. We thus ask the question: Did the change in schooling inputs induced by the reform have an effect on student performance?

Although the reform clearly represents an exogenous shift in the distribution of resources over municipalities, it is not evident that the induced resource change is exogenous to student achievement. A particular source of concern is that resource changes are correlated with the unobserved determinants of changes in student performance. To deal with this concern we also control for the trend in student achievement.

4.1 Data and descriptive analysis

The data we use come from population registers maintained by Statistics Sweden. There are two main sources of data: (i) the register of final grades from compulsory school; (ii) the teacher register. The first register contains grade information for individuals graduating from compulsory school (compulsory school is 9 years and individuals normally graduate at age 16). These data have been matched with different registers using the unique identity number. Thus we obtain information on gender, age, immigrant status from the population registers and also information on key parental characteristics such as educational attainment and immigrant background. From these data we extract two cross-sections of individuals finishing compulsory school: those who completed compulsory school in 1992 and 2001. Those who graduated in 1992 are unaffected by the decentralization reform (implemented on January 1st 1993) and those who graduated in 2001 have spent their entire compulsory school careers in the decentralized system. In between these two time-points there is also a reform of the grading system. To make these two different grading systems comparable, we attach a percentile rank to the grade point average (GPA).[7]

The teacher register is essentially a register of all individuals employed in Swedish schools. This register records, *inter alia*, where the individual is employed, if he or she holds a teaching position, whether the individual is certified to be a teacher or not, and the working-time. From this information we calculate the number of teachers (measured in full-time equivalents) per municipality at different time points.

In the subsequent analysis we also use some auxiliary data. First, we collect information on municipality characteristics that we know are important for predicting resources in the old resource allocation system, i.e. the one prevailing before the reform. These characteristics include municipal income and basic characteristics about the pupil population such as the fraction of foreign-born and the fraction of students with university educated parents. Second, we exploit data from the military enlistment tests. The virtue of the test score data is that they provide more objective measures of student performance than grades. The drawback, of course, is that they pertain to men only.

Table A1 presents some descriptive statistics. It shows, for instance, that the share of foreign-born students increased by two percentage points in between the two time points, and that parental education rose rather substantially.

Our basic strategy is to calculate difference-in-differences estimates of the induced resource changed due to the reform. *Table 1* illustrates the logic of this estimator.

[7] To provide some feeling for the units involved we performed the following calculation. We took all students who participated in the PISA study from 2003 and lived in an EU15 country or the US and then ranked the math scores of these students. Along this metric, a percentile rank can be translated into 2.4 score points on the PISA math test. An average student from the EU15 scored 506 on the math test, while the average US student obtained a score of 482 (the PISA scores are normalized to 500); 2.4 score points thus corresponds to a tenth of the EU15-US gap in math performance.

Table 1 Means of teacher density and GPA by reduction in teacher density

	Reduction in ln(teacher density) 1991-2000		
	1/3 biggest	1/3 smallest	Difference
	Panel A: ln(teacher density)		
Year 2000/01	1.983	2.053	-0.071
	(0.008)	(0.011)	(0.014)
Year 1991/92	2.258	2.159	0.098
	(0.010)	(0.007)	(0.012)
Difference	-0.275	-0.106	-0.169
	(0.007)	(0.007)	(0.010)
	Panel B: Ninth grade GPA (percentile ranks)		
Year 2000/01	48.203	51.230	-3.027
	(0.467)	(1.017)	(1.119)
Year 1991/92	49.209	50.800	-1.591
	(0.317)	(0.695)	(0.764)
Difference	-1.006	0.430	-1.436
	(0.519)	(0.517)	(0.731)
	Wald estimate of teacher density on GPA		
		8.495	
		(4.163)	

Notes: Ninth grade GPA is in percentile ranks. The municipalities are grouped based on their reduction in ln(teacher density) 1991-2000. The observations are weighted with the average number of compulsory school completers in the municipality in 1991 and 2000. Standard errors adjusted for clustering (municipality) are in parentheses.

For purposes of illustration, we divide the municipalities into three groups on the basis of their reductions in teacher density between the 1991/92 and 2000/01 school years. In the first column we show data for the municipalities with the greatest reductions in the teacher/pupil ratio (1/3 biggest). On average, teacher density fell by 28 log points – or 24 percent – in this group (see Panel A); concomitantly student performance was reduced by one percentile rank (see Panel B). The second column shows data for the group of municipalities with the smallest reduction in the teacher/pupil ratio (1/3 smallest). In this group, teacher density was reduced by 11 log points (10 percent), while performance was improved by 0.4 percentile ranks. There was thus a greater reduction in student performance in municipalities which saw a greater decrease in teacher density. If we calculate the ratio of the two changes (-1.4 percentile ranks divided by -0.17 log points) we obtain the Wald estimate of teacher density on the GPA. As shown by the bottom panel, the Wald estimate of increasing teacher density by 100 log points (72 percent) is to improve student performance by 8.5 percentile ranks. Thus, taken seriously, student achievement is improving in the number of teachers per student. In the remainder of the paper we investigate whether this result holds up to more formal regression analysis.

4.2 Baseline regression estimates

In principle one should think of the entire resource development during compulsory school as being important for student performance towards the end of compulsory school. Thus, the change in achievement may be given by

$$y_{jt}^{g} - y_{jt_0}^{g} = \sum_{k} \beta_{g-k} (d_{j(t-k)}^{g-k} - d_{j(t_0-k)}^{g-k}) + \varepsilon_{jt}^{g} - \varepsilon_{jt_0}^{g} \tag{1}$$

where y denotes mean student performance in municipality j, d (the log of) teacher density, t (t_0) post- (pre-) reform observations, and g grade levels. For simplicity we have suppressed all observed covariates and taken a difference to eliminate a municipality fixed effect. Now, we do not observe teacher density by grade. Rather we observe average teacher density in all grades at time t (t_0). The question is what an estimate on this variable captures in our differences-in-differences set-up. Under what condition(s) is the estimate interpretable, given equation (1)?

By manipulating equation (1) a little bit, one can establish that the key assumption – if equation (1) is the true model – is that the change in average teacher density over grades is a reasonable approximation of the change in teacher density by grade. This assumption does not have to be literally true – if there are random deviations from this requirement we estimate the effect of resources on student achievement with attenuation bias. In other words, if the change in resources is roughly uniform by grade, our estimate is biased towards zero. It is not key, however, that $\beta = \beta_{g-k}$ because the estimate is still interpretable as the effect of resources averaged over grades $\beta = E(\beta_{g-k})$. But, given reasonable priors about how the effect varies over grades our estimate is presumably lower than the effect of class-size variations in, say, grades 1 to 3 on student achievement in third grade.

Another specification issue concerns whether teacher density should be introduced in levels or logs. We do not have strong priors on this but have chosen to enter this variable in logs.[8] The choice between levels or logs proves to be unimportant as the results are very similar if we enter teacher density in levels.[9]

Table 2 presents a set of baseline regression results. The dependent variable is the percentile ranked grade point average.[10] As we move along the columns we increase the level of sophistication of the specification. In column 1 we report the results of a simplistic OLS equation. We find no correlation between resources and student performance. This estimate is of course misleading for a number of reasons. Therefore we move on to the second column, which shows the bare-bones difference-in-differences estimate (DD) which is akin to the Wald-estimate reported in *Table 1*. This estimate is slightly higher than the Wald-estimate; it is also more precise since we use the entire range of the changes in the teacher/pupil ratio to identify the effect.

Column 3 reports our preferred baseline estimate. On top of the municipality and time fixed effects, we standardize for gender, age, whether the individual is a first or second generation immigrant, whether (s)he immigrated during the five years directly preceding graduation, and the educational attainment of the parents. The regressions also include the (log. of) average municipal income, the average size of schools in the municipality, the size of the student population, as well as the averages of the individual characteristics. The principal motivation for including the municipality variables is that they capture characteristics which were important for determining the allocation of resources in the system with ear-marked money for schools. The coefficient on teacher density is thus identified by the deviation from the prior resource allocation rule induced by the reform. Notice also that we hold the number of

[8] This implies that we are assuming that the effect of a class-size reduction from say 30 to 20 is the same as the effect of a reduction from 15 to 10. Entering teacher density in levels would imply that we are assuming that the effect of a class-size reduction from 30 to 20 is the same as a reduction from 20 to 10. It is not a priori clear which is the most reasonable specification.

[9] For instance, a specification corresponding to column 3 in Table 2 suggests that a 10 percentage point increase in teacher density improves student performance by 7.4 percentile ranks (this estimate has a t-ratio of 2.2).

[10] In 1992, Math and English were taught at two levels (advanced and basic). The subject grade across levels is not comparable. By 2001, this had changed and there was only one level in Math and English. Our measure of the GPA in 1992 does not take the variation in levels across students into account. This is not ideal, but proves to be unimportant for the results. We have also performed the analysis excluding Math and English from the calculation of the GPA. The results are very similar.

students constant, implying that the identifying variation comes from the variation in the number of teachers, which is a variable that local school authorities has some direct influence over.

The preferred baseline estimate thus suggests that the conclusion from *Table 1* holds up to more detailed analysis. An increase in the teacher/pupil ratio improves student achievement. The inclusion of observed characteristics reduces the impact by 2 percentile ranks but the coefficient remains statistically significant.

The remaining three columns show that the baseline estimate is robust to some conceivable alternatives. Columns (4) illustrates that it does not matter if we hold the share of non-certified teachers constant.[11] And the final two columns show that the estimate reported in column 3 is robust to more flexible specifications. Importantly, the point estimate in column 3 is not changed by introducing, *inter alia*, a control for the previous trend in performance; see column 6.[12] This suggests that the results are not driven by resource changes being correlated with the unobserved determinants of changes in student performance. All that happens when we add more flexibility is that the precision of the estimate is reduced somewhat.

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[11] We choose not to include the share of non-certified teachers in our baseline specification since we do not have an instrument that separately identifies the variation in certified as well as non-certified teachers. The share of non-certified teachers is measured as ln(1+(# non-certified teachers)/(# certified teachers)). The reason for using this measure, rather than the share of non-certified teachers as such, is that this is what an exact decomposition of the log of the teacer/pupil ratio produces; moreover, if the # non-certified teachers is small relative to the # certified teachers this approximately equals the share of non-certified teachers.

[12] Ideally, we would have liked to include the previous trend measured in terms of the GPA. However, this is not possible since grades are unavailable before 1988. The test score trends have been estimated separately by municipality using data for individuals who graduated from 9th grade between 1981 and 1990. In estimating the test score trend we did not control for the characteristics of the individuals, since such data were unavailable to us for the time period in question. We think the omission of individual characteristics is unimportant as the characteristics do not change much within municipality over time.

Table 2 OLS and DD estimates of teacher density on ninth grade GPA

Model	OLS	DD	DD	DD	DD	DD
ln(teacher density)	-0.45	9.04	6.91	7.00	7.15	6.89
	(1.62)	(3.43)	(3.04)	(3.06)	(3.16)	(3.24)
Control variables:						
Municipality fixed effects		X	X	X	X	X
Reform fixed effect		X	X	X	X	X
Individual variables			X	X	X	X
Municipality variables			X	X	X	X
Share of non-certified teachers				X		
Individual variables×reform					X	X
Municipality variables×reform					X	X
Test score trend×reform						X
n	200,871	200,871	200,871	200,871	200,871	200,871

Notes: The regressions are based on pooled individual data on ninth grade GPA in 1991/92 and 2000/01. GPA is in percentile ranks. The individual variables are: gender, age at compulsory school completion and its square, whether the individual was foreign born, whether the individual immigrated within the last five years, whether both parents are foreign born, whether there is at least one parent with high school education, and whether there is at least one parent with a college education. The municipality variables are: the fraction of females, the average age at compulsory school completion, the fraction of foreign-born, the fraction who have immigrated in the preceding five years, the fraction with two foreign-born parents, the fraction of students with at least one high-school educated parent, the fraction of students with at least one college educated parent, the log of the average income in the municipality, the log of average school size, the log of the number of pupils in the municipality, and the log of the (geographical) size of the area. The test score trend is the linear time trend coefficient from separate municipality regressions of military enrollment test scores for men who completed compulsory school in 1981-90. The observations are weighted with the average number of compulsory school completers in the municipality in 1991 and 2000. Standard errors adjusted for clustering (municipality) are in parantheses.

Let us translate the estimate in column 3 to a tangible impact estimate. During the period of observation, median teacher density fell from 8.8 (1991/92) to 7.5 percent (2000/01) which corresponds to a decline by 16 log points. The evolution of resources over the 1990s thus contributed to a decline of student performance by 1.1 percentile rank, or 0.03 standard deviations (SD). This may not appear much when compared to the estimates in Krueger (1999) or Angrist and Lavy (1999). But it should be remembered that the class-size reduction in STAR – the most well-known experiment in this field – is much greater than the variation available in the Swedish data.

So let us instead try to link the estimates to the class-size reduction in STAR. The average class size in 1991/92 was around 22 students and the median teacher/student ratio stood at 8.8 percent. Suppose that class size is reduced by seven students, roughly the magnitude in STAR. This corresponds to an increase of teacher density by 4.1 percentage points (around 38 log. points).[13] Evaluated at this point, the estimates suggest that the effect of reducing class size by seven students is a gain in achievement of 2.6 percentile ranks (0.08 SD).

In sum, the estimates reported in *Table 2* imply that class-size reductions have a smaller impact in the Swedish than in the US context. Further, the estimates are smaller than the ones reported by Lindahl (2005) for Sweden. Of course, there are numerous potential reasons for the difference in results. Relative to the US context, the variation in student performance and student socio-economic background is lower in Sweden than in the US. Further, Krueger (1999) looks at students who are younger than the ones we consider here. The age of the students is likely to be an important factor; for instance, the model in Lazear (2001) suggests that class-size reductions should have a bigger impact for younger students. Finally, Krueger (1999) has access to test score information, rather than information on grade points averages, which proves to be of some importance as we will now illustrate.

[13] We obtain this number by first inverting teacher density to get the student/teacher ratio. We then multiply the student teacher ratio by 15/22 to obtain the student/teacher ratio implied by a class-size reduction of 7 students. We, finally, invert the student/teacher ratio to get the teacher density implied by a class-size of 15 students. In doing this calculation one should remember that we are almost outside the range of the data. There were only two municipalities in 1991/92, and none in 2000/01, that had a teacher density of the implied magnitude.

4.3 Some additional results

Here we raise two additional questions: Does the impact of resource changes differ across the distribution of family background characteristics? And are the results robust to using test scores rather than grades?

Table 3 addresses the first question: Are students with different backgrounds differentially affected by resource variations? The results reported in the table are based on the baseline specification corresponding to column (3) in *Table 2*.

Columns (1) and (2) report separate estimates by gender. The impact for females (8.7 percentile ranks) tends to be greater than for boys (5.2 percentile ranks), but the estimates are not statistically different from one another. Columns (3) and (4) report separate estimates by parental education. "Academic parents" refer to children who have at least one parent with a university degree; "non-academic parents" refer to the remainder of the population. The estimate for children from non-academic backgrounds is larger in size, but in the statistical sense there are no differences across the distribution of parental education. Columns (5) and (6), finally, report separate estimates by immigrant status. The estimates are virtually identical across the two groups, but the separate estimate for immigrants is not statistically significant, however.

In sum, we find no differences in the susceptibility to resource variation across the distribution of student characteristics. These results do not quite concur with the conclusions in elsewhere in the literature.[14]

[14] However, had we examined the issue using conventional interaction terms rather than allowing variation in all coefficients across groups we would have concluded that, e.g., children with less-educated parents are affected to a greater extent. The estimate on the interaction term is 7.5 with a t-ratio of 5.9. But the estimates on the interaction terms prove to be rather sensitive to reasonable variations of the specifications. Therefore, we focus on the specifications where we allow all coefficients to vary across groups.

Table 3 DD estimates of teacher density on ninth grade GPA, by individual characteristics

	Females	Males	Academic parents	Non-academic parents	Natives	Foreign born
ln(teacher density)	8.70	5.22	5.69	6.41	7.05	7.28
	(3.61)	(3.89)	(3.78)	(3.26)	(3.14)	(7.41)
n	98,024	102,847	77,322	123,549	184,409	16,462

Notes: The regressions are based on pooled individual data on ninth grade GPA in 1991/92 and 2000/01. GPA is in percentile ranks. The model controls for individual variables and municipality variables. The individual variables are: gender, age at compulsory school completion and its square, whether the individual was foreign born, whether the individual immigrated within the last five years, whether both parents are foreign born, whether there is at least one parent with high school education, and whether there is at least one parent with a college education. The municipality variables are: the fraction of females, the average age at compulsory school completion, the fraction of foreign-born, the fraction who have immigrated in the preceding five years, the fraction with two foreign-born parents, the fraction of students with at least one high-school educated parent, the fraction of students with at least one college educated parent, the log of the average income in the municipality, the log of average school size, the log of the number of pupils in the municipality, and the log of the (geographical) size of the area. Academic parents means that at least one parent have attended college. The observations are weighted with the average number of compulsory school completers in the municipality in 1991 and 2000. Standard errors adjusted for clustering (municipality) are in parantheses.

Table 4 addresses the remaining question: Are the results robust to using test scores rather than grades? The extension to test scores is important as it is a direct measure of student performance. The grade point average, on the other hand, is also affected by teachers' subjective evaluations.

The results presented in *Table 4* are based on scores from the military enlistment tests, where the population is restricted to men who completed compulsory school in 1992 and 2001. The military enlistment test is conducted at age 18. The purpose of the test is to measure general ability and it is similar to the US AFQT (Armed Forces Qualifications Test). The Swedish military enlistment test contains four domains: inductive ability, verbal skills, spatial ability, and technical comprehension.[15] It is well-known that the results on tests such as these depend on schooling (e.g. Neal and Johnson, 1996) and, hence, we can use them as outcome measures. The drawback of these data is that they pertain to men only. Notice, however, that the estimates using the grade point average as the outcome variable are lower for males than for females as was shown in *Table 3*.

Table 4 has the same basic structure as *Table 2*; in other words, the specifications become increasingly flexible as we move from left to right. The basic difference-in-differences estimate – obtained by controlling for individual and municipality characteristics – is reported in column (3). This estimate is actually higher than the corresponding estimate in *Table 2*.

Again, more flexible specifications produce virtually identical results, in particular the results are robust for controlling for the previous trend in test scores. Test scores thus increase by 11 percentile ranks in response to a change in teacher density by 100 log-points. These results are even stronger than the ones presented previously and, hence, they support our earlier conclusion.

[15] The design of the Swedish military enlistment battery is described more fully in Carlstedt and Mårdberg (1993).

Table 4 OLS and DD estimates of teacher density on military enlistment test scores, men

Model	OLS	DD	DD	DD	DD	DD
ln(teacher density)	-4.67	12.83	11.12	11.24	10.13	11.28
	(2.13)	(4.35)	(3.31)	(3.32)	(3.62)	(3.67)
Control variables:						
Municipality fixed effects		X	X	X	X	X
Reform fixed effect		X	X	X	X	X
Individual variables			X	X	X	X
Municipality variables			X	X	X	X
Share of non-certified teachers				X		
Individual variables×reform					X	X
Municipality variables×reform					X	X
Test score trend×reform						X
n	76,837	76,837	76,837	76,837	76,837	76,837

Notes: The regressions are based on pooled individual data on military enlistment test scores for men who completed compulsory school in 1991/92 and 2000/01. The test scores are in percentile ranks. The individual variables are: whether both parents are foreign born, whether there is at least one parent with high school education, and whether there is at least one parent with a college education. The municipality variables are: the fraction of females, the average age at compulsory school completion, the fraction of foreign-born, the fraction who have immigrated in the preceding five years, the fraction with two foreign-born parents, the fraction of students with at least one high-school educated parent, the fraction of students with at least one college educated parent, the log of the average income in the municipality, the log of average school size, the log of the number of pupils in the municipality, and the log of the (geographical) size of the area. The test score trend is the linear time trend coefficient from separate municipality regressions of military enrollment test scores for men who completed compulsory school in 1981-90. The observations are weighted with the average number of compulsory school completers in the municipality in 1991 and 2000. Standard errors adjusted for clustering (municipality) are in parantheses.

The estimate of 11 percentile ranks when using test scores as the outcome measure should be compared to the estimate for men using grades as the outcome measure (5.2 ranks). If we believe that test scores capture the variation in student performance more adequately, this comparison thus suggests that the estimates based on grades may be biased downwards (by a factor of 2). If we take this estimate and relate it to the class-size variation in STAR, we get that a class-size reduction corresponding to STAR would increase the performance of boys by 5.5 percentile ranks (or 0.17 SD) which is in the same ballpark as the estimates in Krueger (1999).

5 Conclusions

In this paper we have presented new evidence on the impact of resources on student achievement. The evidence we have offered relies on a policy experiment implemented in Sweden in the beginning of the 1990s. This reform decentralized authority over compulsory schools to the municipalities and subsequently abolished ear-marked central government money for schools. In response to this reform the distribution of resource inputs over municipalities shifted rather drastically.

Using the resource change induced by the reform as the source of identifying variation, we consistently find that increases in the teacher/pupil ratio improve student achievement. The effect sizes are somewhat smaller than in the Tennessee STAR experiment analyzed by Krueger (1999) and the previous analysis of Swedish data by Lindahl (2005). For the average student we find that student performance increases by 0.08 standard deviations in response to increases in teacher density equivalent to the class-size reduction in STAR. This should be compared to the effect-size of 0.2 standard deviations reported by Krueger (1999). It seems, however, that part of the reason for the smaller estimates of the magnitudes involved is the fact that we are primarily measuring student outcomes by grade point averages rather than test scores. In a sensitivity analysis we have shown that the impact on test scores for boys are about twice as large as the impact on the grade point average of boys.

The teacher/pupil ratio fell throughout the 1990s in Sweden. Our estimates thus suggest that student performance deteriorated as a result. An interesting question is whether the resource development during the 1990s feed on labor market outcomes such as employment and wages. Since it is too early to observe these outcomes we leave this question for future research.

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Appendix

Table A1 Means (standard deviations), 1991/92 and 2000/01 school years

	Year 1991/92	Year 2000/01
Dependent variables		
Ninth grade GPA	50.06	49.93
	(28.85)	(28.82)
Military enlistment test score (men)	50.04	50.11
	(28.91)	(28.77)
School resource variable		
ln(teacher density)	2.20	2.01
	(0.08)	(0.07)
Individual variables		
Female	0.49	0.49
Age at compulsory school completion	16.03	16.01
	(0.21)	(0.26)
Foreign born	0.07	0.09
Immigrated within the last five years	0.02	0.01
Both parents are foreign born	0.06	0.05
Parents with high school education	0.47	0.48
Parents with college education	0.35	0.42
Municipality variables		
ln(average income)	4.86	5.20
	(0.09)	(0.12)
ln(average school size)	5.29	5.43
	(0.29)	(0.32)
ln(number of pupils)	8.54	8.72
	(1.07)	(1.13)
ln(geographical size of the area)	6.44	6.44
	(1.20)	(1.20)
Test score trend 1981-90	-0.01	-0.01
	(0.34)	(0.34)
n	97,945	102,926

Notes: Ninth grade GPA and military enlistment test scores are in percentile ranks. The military enlistment test scores refer to men only, and the number of observations are 42,480 in 1990/91 and 34,357 in 2000/01. The observations are weighted with the average number of compulsory school completers in the municipality in 1991 and 2000. A few observations with missing values on parents' origin and/or parents' education have been placed in the reference category. The test score trend is the linear time trend coefficient from separate municipality regressions of military enrollment test scores for men who completed compulsory school in 1981-90. Standard deviations are in parentheses.

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