VERY PRELIMINARY FIRST DRAFT: STRICTLY DO NOT QUOTE

Does Higher Teacher Pay Improve Pupil Performance?: State Evidence from the US.

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ABSTRACT

Some teachers are paid nearly twice as much in some US states compared to others. Does this cause the pupils in those states to perform better in achievement tests? Specifically, are pupil outcomes influenced by how well their teachers are paid? In some sense, each state will get the teachers is deserves by choosing to pay teachers at a given point in the income distribution of the state they will get the requisite quality of teacher. This paper examines the relationship between the real (and relative) level of teacher remuneration and the (nationally) comparable measured performance of secondary school pupils. We use aggregate panel data on 50 US States on NAEP scores, over the period 1990-2009, as the outcome measure to model this association. The results suggest that relative (and absolute levels) of teacher salaries exert a powerful influence on pupil performance.

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Introduction.

It is widely known and verified by numerous empirical studies that education is a key determinant of the future economic and social performance of an individual and an entire society.[1] Thus, the organization of school education within a country or state is of special importance and interest. Accordingly, it is crucial to identify the decisive determinants of success. Especially since the OECD started to conduct (international) student assessments and publish data on schooling outcomes in various countries,[2] the comparison of student achievement among countries has prompted a lot of interest. These comparisons have been widely used to compare the success of education systems in different countries or states. In particular, policy makers are interested in the analysis and comparison of the outcomes of school education and its determinants across countries in order to derive specific measures and make recommendations for education policy.

Various economic studies attempt to identify those factors (inputs) that influence student achievement (output), linking these factors through an economic production function. For example, Hanushek and Raymond (2005) evaluate the effect of the expansion of school accountability in the U.S. They show that accountability systems introduced during the 1990s had a clear positive impact on student achievement. Fuchs and Wößmann (2004) show that external exit exams, which report performance relative to an external standard, are statistically significantly positively related to student performance, using data from the PISA student-level achievement database.[3] A factor that has gained particular interest concerning its influence on student performance is class-size. One reason for its prominence and importance might be that it is easy to observe, measure and influence and the consequences of large classes compared to smaller classes are directly observable and easy to imagine. However, the findings and results from various studies using data from different countries and states are ambiguous and suggest that class size is not a major determinant of student performance in industrialized countries.[4]

[1] See the studies by Card (1999) and Harmon et al. (2003) for evidence at the micro level and Wößmann (2003) and Pritchett (2006) for evidence at the macro level.
[2] See, for example, PISA.
[3] Similar results have been found by Bishop (1998).
[4] For example, Hoxby (2000) and Wößmann (2005a) find that class size does not seem to be a major determinant of student achievement in the U.S., respecitvely 15 Western European countries. Glewwe (2002), finds evidence for a positive impact of class size in several developing countries, Wößmann (2005b) for newly industrializing countries and Ammermüller et al. (2005) for East European transition countries.

Hence our interest is in posing the question of how pupil outcomes are influenced by how well their teachers are paid? The answer to these question is of central policy importance. We suggest that it is possible that we can learn a lot about the relationship between teacher quality and pupil outcomes from cross State comparisons that we cannot learn by looking at individual States since those individual States all have systems which pay their teachers similarly and face similar internal supply constraints and influences. This examines the relationship between the real (and relative) level of teacher remuneration and the (nationally) comparable measured performance of secondary school pupils. We use aggregate panel data on 50 States over the period 1990-2009 to model this association.

In seeking to model the relationship between teachers pay and pupil outcomes one seeks a potential causal mechanism to link them. There are basically two potential explanations as to why they may be causally linked. The first is that higher pay will induce the more able graduates into the profession. As the potential supply of teachers rises because of the higher pay on offer - then this will make entry into teaching as a profession more competitive. This, in turn, will mean that the average ability of those entering the job will rise. Once recruited, higher relative pay will provide teachers with more incentive[5] for them to make more effort to improve the educational outcomes of the children they teach. The second mechanism is more subtle – namely that improving the pay of teachers improves their standing in the State's wage distribution and hence the status of teaching as a profession in that State. As a result of this higher status more kids in that State will want to be teachers in the future and as a consequence this will make teaching as a profession more selective and hence recruit the more able individuals. We will not be able to distinguish between these different causal mechanisms but essentially this does not matter. The central proposition is that better pay in teaching induces a higher quality of graduate into the job and that this will improve student performance. We seek to establish whether aggregate State data supports this hypothesis, and if so, can we retrieve an estimate of the relative size of this effect.

In contrast, one factor proofs to be of particular importance in the determination of the success of school education and accordingly regarding student achievement: teachers and in particular teacher quality.[6] Consequently, it is vital for the success of an educational system to attract and motivate qualified teachers. In this regard, the compensation schemes offered to

[5] In some States this could possibly operate directly through incentive or performance related pay. For example the UK has had a performance pay threshold for classroom teachers since 2000. See Dolton et al (2003).

[6] See, for example, studies by Figlio and Lucas (2004), Rockoff (2004) or Rivkin et al. (2005). More detailed empirical evidence of the importance of teacher quality with respect to student achievement is given in section 2 "Related Literature".

teachers play a crucial role as they are an important parameter with respect to the attraction and motivation of teachers.

In general, compensation schemes work in two different dimensions, thereby both attracting and motivating individuals. On the one hand, the particular features of compensation schemes attract individuals with certain characteristics. For example, Dohmen and Falk (2011) show in a laboratory experiment that more productive workers prefer variable payment schemes that create a link between payments and performance over fixed payment schemes. Furthermore, they find evidence that subjects' risk attitude is an important driver in individuals' sorting decisions for or against certain payment schemes.[7] On the other hand, once an individual decided to work under a given compensation scheme/in an occupational area, the design of this particular compensation scheme motivates individuals, directly creating specific incentives to work.

First and foremost, it is particularly important for the success of an educational system to attract the desired high quality teachers. Thus, we focus in this paper on the particular role of compensation schemes or rather the level of teacher wages (i.e. "how much is paid") in attracting the "right", i.e. high quality, teachers.

According to the efficiency wage hypothesis labor productivity depends on the (real) wage paid (by a firm or institution). This relationship can (among others) be justified by the adverse-selection approach, which identifies an improvement in the average quality of job applicants as a benefit resulting from higher wages.[8] Assuming that individuals are heterogeneous with respect to their ability and that ability is positively related to performance on a job, a positive correlation between ability and individuals' reservation wages can be exploited, with higher wages attracting more able individual.[9] Accordingly, firms/organizations pay an efficiency wage and hold-off from employing those workers who offer to work for less than this efficiency wage, using this willingness of an individual to work for less than this wage as an indication of their potential ability. Thus, the (average) productivity of individuals employed increases as the wage increases due to a self-selection of more productive individuals who are assumed to have higher reservation wages. Hence,

[7] Further evidence for the importance of payment schemes in attracting employees with different characteristics has been found, for example, by Cadsby et al. (2007) or Eriksson and Villeval (2008).

8 See Yellen (1984) and Akerlof and Yellen (1986) for more details on efficiency wage models.

[9] See, for example, Stiglitz (1976), Weiss (1980) or Malcomson (1981).

with respect to teachers' labor market, it is reasonable to argue that higher (relative) teacher salaries attract more able or capable teachers, thereby increasing the quality[10] of teachers.[11] Consequently, (relative) teacher wages will - on average - determine the ability of teachers and thus their quality.

According to this positive relationship between teacher wages and teacher quality and the positive relationship between teacher quality and student achievement it is reasonable to assume a direct (empirical) link between teacher wages and student achievement. However, the majority of studies that attempts to find a direct link between teacher salaries and student achievement has failed (for example, Hanushek 1986, Betts 1995 and Grogger 1996).[12] One possible explanation for this lack of an empirical relationship might be found in the data used. In particular, it might be caused by the fact that teachers within the same cross-sectional unit might roughly be of the same quality because the payment schemes that are used are more or less the same. Hence, there is not enough variation in teachers' wages (and thereby quality) that facilitates the identification of a (positive) relationship between teacher wages and student achievement with cross-section data. Another possible explanation, discussed by Loeb and Page (2000), might be the lack of accounting for alternative labor market opportunities of teachers when using data from a single state if a state comprises one labor market. Accordingly, they argue that it is in particular the usage of data for multiple states that allows to address this issue. Accordingly, they use a state-level panel data set for the U.S. in order to identify the effect of teacher wages on student achievement, measured by dropout rates. They estimate that, holding all else equal, raising teachers' wages by 10% would reduce dropout rates by between 3% and 6%.

Due to the shortcomings of a variety of existing studies, we constructed a completely new and extraordinary rich set of U.S. panel data in order to find out whether there is in fact a direct relationship between teacher wages and student achievement. Using this data we can exploit variations across states and time in order to identify the effect of teacher wages on student achievement. One decisive advantage of this approach, in contrast to a cross-country

[10] Throughout this paper we will refer to "teacher quality" to mean interchangeably: teachers' ability, productivity and capability.

[11] It is important that this argument only holds if teachers' wages increase relative to those in other fields. If all wages in an economy would rise by the same fraction this would not change anything in the relative wages of teachers and therefore nothing concerning the attractiveness of the teaching profession relative to other occupations.

[12] A clear link between teacher wages and student achievement is shown by Dolton and Marcenaro-Gutierrez (2011) in a recent paper using aggregate panel data on 39 countries. The present paper builds on this paper and adopts a similar methodology.

analysis, is that our study allows us to exploit cross-state variation while holding those factors and characteristics fix that affect all U.S. states (for example, the same language, federal laws and regulations). Accordingly, we can avoid and overcome the shortcoming of potential biases resulting from unobserved country specific heterogeneity which might arise when cross-country data is used.

When focusing on the determinants of student achievement in school education, it is not only important to control for various resource inputs. It is well known and documented in the literature that different family and individual characteristics of the students play an equally important role in the determination of achievement. For example, Wößmann (2008), finds large and significant effects of parents' educational background on student performance in the U.S. and Western European countries. Häkkinen et al. (2003) obtain comparable results using Finnish data and Fertig (2003) using data from the reading examination of PISA 2000. However, these factors cannot be easily influenced by policy makers. Accordingly, this evidence continuously raises political discussion and questions regarding the fairness of school systems.[13]

Due to the large evidence of the significant influence of family factors on student achievement, one needs to control for the influence of these factors in order to obtain unbiased estimates of the influence of teacher wages on student achievement. We account for the influence of these factors in a completely new way due to the unique structure of data used. The data on student performance we use allows us to measure student achievement not only in general but also conditional on family and individual background. For example, we are able to distinguish between students' achievement (measured by average scale scores) contingent on gender, ethnic background or their parents' level of education. Accordingly, we do not need separate information on family and individual factors of each individual tested. In fact, we use information on student achievement conditional on different individual and family characteristics. Using this method, we are able to avoid any problems of how to capture or measure family factors. Furthermore, this method allows us to use our data set in a completely new way and in addition to include measures on family factors and individual factors that have, as far as we are aware, not been used before (for example, the eligibility to the National School Lunch Program (NSLP)[14] or the disability status of students).

[13] For example, due to the significant influence of parents' educational background on student achievement equal opportunities for students in the German education system are extensively debated.

[14] Detailed information on this program is given in the appendix.

Using our data set as a basis to perform different regression analyses our findings provide evidence of a significant and direct relationship between teacher wages and student achievement, suggesting that teacher wages have a significant positive impact on student achievement. Using different measures for teacher wages, our estimates provide consistently positive coefficients of the marginal importance of teacher wages on student achievement. Furthermore, these results are robust to different specifications of the data used as basis for our estimations. In addition, using data on student achievement conditional on various individual and family factors our results confirm the importance of these factors in the determination of student achievement. On the one hand, our results confirm the importance of several of these factors which has already been shown in previous studies. For example, our results confirm that the higher the educational level achieved by either parent the higher the achievement of their children. On the other hand, we are able to provide new evidence with respect to additional factors that have not been accounted for in previous studies. For example, we find evidence of a significantly negative impact of the eligibility for the National School Lunch Program, as a measure for the financial background of a family, on achievement.

The remainder of this paper is organized as follows. The next section gives a short overview of the related empirical literature. An overview of the school system in the U.S. is given in section 3. The economic model of educational production that is used as a basis for the regression analyses is described in section 4. We describe the data we use and its sources in section 5. The econometric identification strategy is explained in section 6. Section 7 contains our main results on the relationship between teacher wages and student performance as well as on family and individual factors. We summarize our results in the final section and discuss possible policy implications of our findings.

2. Related Literature

2.1 The Relationship between Teacher Wages and Teacher Quality.

Competitive salaries and benefits for teachers are crucial to attracting and retaining high-quality teachers (Murnane et al, 1991, Ballou and Podgursky, 1997). Research has shown that levels of compensation and criteria for awarding salary increases affect who goes into teaching, who stays in teaching and for how long (Odden & Kelley, 1997; Dolton, 1990, 2006, Dolton and van der Klaauw 1999). Without motivated and qualified teachers the positive impact of teaching on student learning may be constrained. As in any other

occupation, quality can only be demanded and motivation can only be expected if working conditions, including salary, are attractive. Of course good working conditions alone do not guarantee high-quality education but poor pay in teaching is unlikely to attract high quality teachers and secure favourable pupil outcomes. Figlio and Stone (1997), Figlio and Lucas (2000), Ferguson (1991) and Leigh (2006) find that higher salaries are associated with better-qualified teachers.. Dolton (1990) shows that the higher teacher salaries are relative to salaries in other fields, the more likely graduates in England are to become teachers. Leigh and Ryan (2008) find evidence of the validity of the relationship in the reversed direction: one reason for a decline in teacher quality in Australia is a fall in average teacher pay. Manski (1987) highlights an additional aspect by showing that teacher salaries have an effect on the size of the pool of American college graduates who enter the teaching profession: the higher the salaries the larger the pool.

Figlio (1997) finds that in all metropolitan areas studied in the US (Boston, Chicago, Detroit, Pittsburgh and Portland) higher teacher salaries are associated with higher teacher quality as measured by the probability that a teacher graduated from a selective institution. Salaries and teacher quality are discussed in Ehrenberg and Brewer (1994), Ballou (1996) and Antos and Rosen (1975).

Another small bit of evidence that the quality of the people in a job is dependent on the going rate of pay comes from Nickell and Quintini (2002) who compare two birth cohorts of UK individuals 16 years apart. Over this time teacher real pay had fallen. They find that over the same period the ability - as measured in IQ type tests - of the men entering the job had significantly fallen. This finding is echoed more generally in the work of Murnane et al (1995) who find that individual test scores are positively associated with wages. These papers provide evidence that the going rate of pay in a job will determine the quality or ability of people who enter that job.

Advanced economies have faced an increasing demand for skill outside teaching, which has pushed up its price. This reduces teacher quality and may raise teacher quantity, which becomes relatively cheaper than quality. This helps explain why advanced States experience a growth in primary school teacher-student ratio, while experiencing reductions in relative teacher quality (Lakdawalla, 2002, 2007). The low quality of education and especially basic education is a severe problem in most developing States (Glewwe, 1999). Although this problem does not exclusively affect poor States, Hanushek and Luque (2003), show that there is a clear positive relationship between spending per student and GDP per capita. Poorer States tend to spend less per student than richer States, nevertheless, there are

several States, e.g. Japan and the Netherlands, which have comparatively moderate expenditure per student and still remain among the States with the highest level of students' attainment.

Another important factor which may affect the relationship between teacher wages and teacher quality which has been well documented, particularly for the US (See Flyer and Rosen 1997, Temin 2002, Goldin 2006 and Perlmann and Margo 2001) is that teaching used to be a more or less exclusively feminine profession as there was relatively few other occupations open to women. This means that many of the high ability women were drawn into teaching. In more recent years, as other professional labour markets opened up to women, the high ability women have increasingly been drawn into alternative occupations. As a result their places have been taken by lower ability males – quite possibly to the detriment of pupil performance. The declining quality of intake into the US teaching profession has been studied by Corcoran et al (2004) and Hoxby and Leigh (2004). Corcoran et al find that this decline is due to women near the top of the test score distribution being much less likely to enter the profession. Hoxby and Leigh find that the relative salaries and school desegregation play an important role in this declining quality.

However, it is important to note that this evidence of a decisive role of teacher wages with regard to teacher quality is derived from countries and states in which teachers do not have a special status as civil servants. In contrast to these findings, teacher wages do not seem to play such a decisive role in those school systems in which teachers have a special status as civil servants (for example, in Germany) and therefore numerous additional (non-monetary) benefits.[15] For example, Oesterreich (1987) points out that financial reasons were of minor importance for German students who decided to become teachers.[16]

2.2. The Relationship between Teacher Quality and Student Achievement

Following the "Coleman Report" (Coleman et al. 1966)[17] Hanushek (1971) was one of the first to empirically estimate whether teachers have an impact on student achievement. "In other words, does it matter which teacher a student has, or are all teachers perfectly

[15] For example, leisure time, holidays and a high degree of self-determination.

[16] Similar results for Germany are reported for, example, by Ulich (2004), Rausch et al. (2008) and Nieskens (2009).

[17] The Equality of Educational Opportunity Study (EEOS), also known as the "Coleman Study", was commissioned by the United States Department of Health, Education, and Welfare 1966 in response to the 1964 Civil Rights Act, to evaluate the availability of equal educational opportunities to children of different race, color, religion, and national origin. Source: Inter-University Consortium for Political and Social Research, Study No. 6389 - Summary - http://www.childcareresearch.org/ICPSR/studies/6389/detail (accessed August 17, 2010).

substitutable?"[18] Using data from a large school system in California on student achievement in reading in the third grade, he finds that performance of white students in his sample is dependent upon the specific teacher.

The debate on different measures of school quality has predominantly focused on class size, sidelining other significant dimensions of input policy decisions, like teacher remuneration. The findings relating class size to pupil performance are bedevilled with identification problems[19] and since in many education systems streaming or sorting takes place providing smaller classes to the less able pupils. This confounds the estimation of the production function relating more teacher input to pupil outcomes. Notwithstanding this problem, many papers (Card and Krueger 1992, Hoxby 2000, Woessman 2005). have found a positive relationship between more favourable (smaller) class size and pupil outcomes.

It is less common to study the explicit relationship between instructional time and pupil outcomes. Taking as his starting motivation the huge variation in teaching input time across States, Lavy (2009), using data from Israel, and PISA, shows that instructional time has a positive an significant effect on test scores. He also finds that this relationship is qualitatively different for developed and developing States. With the latter having around twice the effect size as the former. It is therefore important we control explicitly for this factor in our econometric study.

Until recently the relationship between teachers' attributes, such as a teacher's qualifications or experience, and student achievement, was not well understood. In the last 15 years this position has changed, as the knowledge and skills required by teachers is becoming a matter of increasing concern from a policy perspective in most States. Recent studies suggest the impact of teacher quality is far larger than any other quantifiable schooling input (Rivkin et al, 2005, and Goldhaber, 2002). Hanushek (2003) provides a wide and critical review of the evidence around the world on the effectiveness of input-based schooling policies. In fact, Goldhaber suggests that it is key to attracting and retaining high quality teachers, because of the link between teacher salaries and student outcomes[20]. Rivkin et al. (2005) report similar findings using unique matched panel data from the UTD Texas Schools Project for 3rd to 7th graders. They find "that the effects of a costly ten student reduction in class size are smaller than the benefit of moving one standard deviation up the teacher quality distribution." They found that the best teachers can achieve an additional year's worth of

[18] Hanushek (1971), page 283.
[19] See Hanushek (1986) and Lazear (2001) for different takes on this debate.
[20] Hanushek et al (1998) found that the best teachers can produce an additional year's worth of learning out of their students compared to the least effective teachers.

learning from their students compared to the least effective teachers. They estimated that variations in teacher quality account for at least 7.5 percent of the total variation in student achievement. This is a much larger share than any other school characteristic. Much of the evidence cited above uses data from specific US states like Texas. There is relatively little research which takes a US wide perspective (Flyer and Rosen 1997 being one dated exception and Temin 2002 being a qualitative overview). Aaronson et al. (2007) verify the importance of teacher quality regarding student achievement using administrative data from the Chicago public High Schools. They estimate that a one standard deviation improvement in math teacher quality raises student math scores by 0.13 grade equivalents, measuring teacher quality through the effect of a given teacher on ninth-grade math scores of a semester of instruction, controlling for eighth-grade math scores. Furthermore, Hanushek and Kimko (2000) demonstrate that observed differences in measures of labour-force quality based on student cognitive performance have a dramatic impact on productivity and national growth rates.

One of the first studies to examine the effect of teacher quality was that by Summers and Wolfe (1977) who found that 6th grade pupil scores from the Philadelphia School District were positively related to whether or not their teachers received their BAs from highly rated colleges. They also found that only above average students benefited from teachers with more experience. Another early contribution to the importance of teacher attributes in measuring schooling quality was Behrman and Birdsall (1983) who used average schooling of teachers (in a geographical area) as their measure of school quality and showed that this quality measure had a clear positive effect on subsequent earnings for Brazilian males.

Goldhaber and Brewer (1997) using individual student data from the National Education Longitudinal Study of 1988 on the 8th grade Math scores found that teachers who majored in Math or certified in Maths had a clear positive effect on pupil test scores. The authors found no effect of teacher experience.

Perhaps the most revealing study so far is that by Rockoff (2004) who uses a panel data set of pupils and teachers (and there assignment to each other) over a number of years where the same pupil is taught by different teachers in different years. This enables him to estimate the individual, teacher specific effects directly. His results suggest significant scale differences in teacher quality and that this has a clear effect on pupil performance. Specifically a one standard deviation increase in teacher quality raises test scores by 0.1 standard deviations in reading and math.

A further interesting piece of direct evidence on the relationship between teacher quality and pupil performance comes from the recent 'Teach for America' program which targets graduates from top US universities. The evidence from this program (Decker et al 2004) is that these new recruits (with no previous experience), get significantly better outcomes for their students than do other teachers.

There is a small but growing literature which seeks to examine the relationship between pupils educational attainment and school inputs at an institutional cross county level[21]. A sequence of papers by Barro and Lee (1993, 1996, 2001) and Lee and Barro (2001) examine data on educational attainment (as measured variously by: mean school years, school completion rates and highest educational attainment) by decade across groups of States (planned Economies, OECD States, Asian, African and Latin American States) used educational spending, pupil teacher ratios and teacher salaries as inputs in this education process. They find that spending and pupil teacher ratios act in a clear positive way in this production process but that the effect of teacher salary is not always significant[22]. We perform a new analysis of the Barro and Lee model on an annual State by State basis and reaffirm their results relating to pupil/teacher ratios and educational spending as inputs but also clearly find the positive role teacher salaries have in producing pupil attainment as measured directly in term of test scores. At a more detailed level Woessman (2005) has sought to model the process of educational production using individual State data and the TIMSS test scores as outputs. In most of the 15 European States examined he finds significant class size effects but mixed effects on instruction time, teacher experience and teacher gender and education. He does not analyse the role of teacher remuneration. In a large scale cross State analysis of the link between cognitive skills and economic development, Hanushek and Woessman (2008) have sought to examine the link between all the different pupil attainment data (including NAEP, PISA, IALS, PIRLS, SISS, SIRS, FIRS, TIMSS data) on growth in income. They find a clear link between pupil attainment and economic growth - but again no role is accorded to teacher remuneration as a proxy for teacher quality across States.

A well-educated labour force is vital for every economy. The human capital and endogenous growth models suggest that the level and/or quality of education in an economy

[21] Much of this literature is now concerned with the data quality necessary for establishing whether there has been a convergence in educational attainment levels. See Cuaresma (2005).

[22] Although Sequeira and Robaldo (2008) find in replicating Barro and Lee (2001) that teacher salaries is always consistently positively significant in the determination of pupil test scores.

directly affect a State's growth[23]. Hence one clear motivation for this study is to identify factors affecting the stock of human capital in the economy. (See Krueger and Lindahl (2001) and Hanushek and Woessman (2008) for a summary of recent evidence.) Hanushek and Kimko (2000) demonstrate that observed differences in measures of labour-force quality based on student cognitive performance have a dramatic impact on productivity and national growth rates. There is also a considerable literature focused on the factors affecting the stock of human capital in the economy. However, there is not much evidence regarding the quality of formal education as a relevant dimension of human capital. Specifically, the relationship between teacher supply and economic growth is of interest (see Tamura, 2001). We present some evidence of how economic growth and teachers supply conditions have interacted with each other in the OECD (and WEI) States. To be precise, we have used teachers' salary level as a proxy measure of teacher supply conditions. In this paper we will use three different ways of measuring teachers' salaries to pick up the power of teachers salaries to purchase goods and their power to attract individuals to the teacher profession, respectively.

2.3. The Link between Teacher Wages and Pupil Outcomes.

To date most studies which have attempted to find a direct link between teacher wages and pupils outcomes have been unsuccessful. Specifically, Hanushek (1986) (1987) Grogger (1996) and Betts (1995) have all found that teachers salaries play no role in the determination of pupil outcomes. A clear reason why this finding is prevalent is that it is not possible to use cross sectional variation to identify the effect of teacher wages because school districts face different teacher supply curves. A further reason for this result is that within any one system of teacher recruitment and teacher remuneration, teachers will, by and large be drawn form roughly the same percentile in the ability (quality) distribution and paid on the same pay scale. Hence there is too little variation in the quality of teachers used and their wages to be able to identify the relationship between teacher wages and pupil outcomes. One study which attempts to get round this problem uses US state specific data over 3 decades 1969, 1979 and 1989 and attempts to identify the relationship via the degree of state variation in teacher supply and teacher wages and a first difference identification strategy. This paper, by Loeb and Page (2000), finds that a 10% increase in teacher relative wages would reduce drop out rates by between 3-6%.

[23] This argument is strongly supported by the Human Capital Theory (HCT), which relies on the assumption that more educated workers enjoy greater productivity, in that manner contributing to the State's economic growth.

A further area of research which looks at the relationship between teacher pay and pupil performance relates to the situation where there is some system of performance pay or performance incentive for teachers. Usually the identification strategy is that there has been a reform which generates a form of quasi experimental change in teacher remuneration. Papers by Lavy (2002), Ballou (2001), Eberts et al (2002), Figlio and Kenny (2007) and Atkinson et al (2004) in a variety of contexts show some degree of relationship between performance pay and positive student outcomes.

The paper which shows the clearest link between teachers pay and pupil outcomes is by Dolton and Marcenaro (2010) which adopts the same methodology as the present paper. The present paper has a number of clear advantages over this earlier work. Firstly, by 'stacking' the data we get multiple observations on each state in each year we have a lot more precision on our estimates of the marginal effects relating to the key variables of interest. Secondly, specifically we have NAEP scores relating to sub-populations and can hence distinguish and identify differences by gender, ethnicity and family educational background. Thirdly, since we have data on: teacher certification by State, teacher unionisation and many other factors then we can condition out for much of the unobserved heterogeneity which may cause biases in this earlier study.

3. Education in the United States

3.1 Organization of School Education

The U.S. does not have a homogeneous school system across all states, but the U.S. government sets guidelines and funding for federal educational programs. [24] These programs affect public as well as private schools. The states execute direct control over most parts of education at all levels, performing fiscal, political and administrative functions. However, each of the U.S. states has its own laws regulating education. In particular, educational standards and standardized tests are normally specified by state governments as well as all issues regarding teacher certification. For primary and secondary education the local level is of particular relevance. For example, at the local level schools are operated, state laws implemented and enforced, professional teaching staff is hired and supervised and money is raised.

[24] General information on the organization of school education in the U.S. was obtained from www.usaeducation.us and from the website of the USNEI U.S. Department of Education: http://www2.ed.gov/about/offices/list/ous/international/usnei/us/edlite-org-us.html (accessed August 17, 2010).

In the U.S. the public sector is the primary supplier of school education. About 90% of American students attend public elementary and secondary schools.[25] Child education in the U.S. is compulsory, but the starting ages differ among states.[26] In general, children start kindergarten (followed by the first grade) and finish after the 12th grade (the final year of High School).[27]

Influence on educational policies comes also from non-governmental institutions, especially from teacher unions as well organized and powerful voices in education politics. The two national education unions - the National Education Association (NEA) as the largest union in the U.S. and the American Federation of Teachers (AFT) - are of particular importance. The NEA represents most of the country's teachers along with other school personnel and has 3.2 million members.[28] "At the local level, affiliates perform a variety of activities (as determined by the local members) (...)"[29]. Among other things, they bargain contracts for school district employees. The AFT, as the second largest union has 1.5 million members, of which approximately 850,000 are Prek-12[30] public school teachers.[31] Among other things, the AFT teacher division is working to support guidance in National Board certification and professional development through the Educational Research and Development Program and has been a major force in influencing and raising teacher salaries. Due to the power and influence of these two unions, in particular with regard to the determination and setting of teacher salaries, their influence needs to be taken into account when analyzing the effect of teacher wages in the U.S.

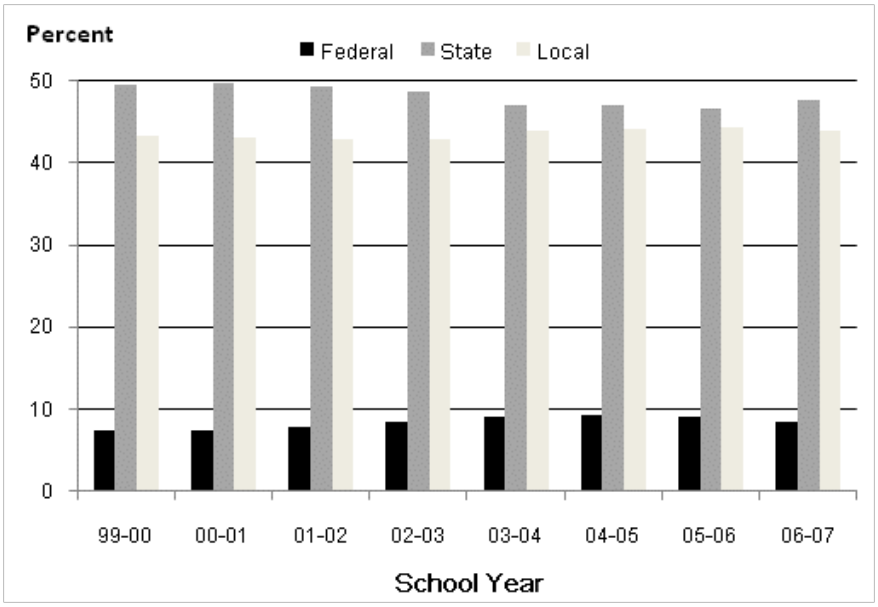
3. 2. Expenditure and Revenue.

The distribution of education expenditures and revenues mirrors the importance of the state and local level.[32] The bulk of approximately $1 trillion that have been spent on education at all levels in the school year 2009/2010 in the U.S.,[33] came from the state, local and private

[25] Detailed information on enrolment in public and private school can be obtained from the Digest of Education Statistics.
[26] Laid down in the "State Compulsory School Attendance Laws".
[27] We use data on students in grade 8 who are aged around 13, attending either "Middle Schools" or "Junior High Schools".
[28] Information was obtained from the NEA-website: http://www.nea.org/aboutnea/whatwedo.html (accessed August 17, 2010).
[29] http ://www.nea.org/aboutnea/whatwedo.html (accessed August 17, 2010).
[30] The expression is an abbreviation for "Pre-Kindergarten through 12th grade".
[31] Information was obtained from the AFT-website: http://aft.org/about/ and http://aft.org/yourwork/teachers/about.cfm (accessed August 17, 2010).
[32] Information was obtained from the website of the U.S. Department of Education: http://www2.ed.gov/about/overview/fed/role.html (accessed August 17, 2010).
[33] Source: www.usgovernmentspending.com (accessed August 17, 2010).

sources. Figure 1 illustrates the importance of the state and local level in the U.S. school system as by far the largest fraction of revenues comes from these sources.

Figure 1: Percentage distribution of revenues for public elementary and secondary schools by source and year.



[Note: This figure shows annual school revenues by source from school year 1999-2000 to 2006-2007. Source of data: U.S. Department of Education, National Center for Education Statistics, Common Core of Data (CCD), "National Public Education Financial Survey," 1989--90 through 2006--07. Online available from: "The Condition of Education" - Contexts of Elementary and Secondary Education - Finance - Table A-33-1, Public School Revenue Sources: http://nces.ed.gov/programs/coe/2010/section4/table-sft-1.asp]

Especially for primary and secondary education about 90% of the funds come from non-federal sources.[34] Due to the particular importance of the local and state level and the resulting financing structure, public schools vary widely with respect to the resources available. For example, the U.S. average of total revenues[35] was about $11.5bn in the school year 2007/2008, while it was only $1.6bn in Wyoming, $8.2bn in Tennessee but $52.8bn in New York.[36] Compared to this, the average of total expenditures[37] for education was $11.7bn, $1.5bn in Wyoming, $8.5B in Tennessee and $52bn in New York. Out of this, total current

[34] More detailed information can be obtained from the U.S. Census Bureau - Statistical Abstract - Education - Elementary and Secondary Education.
[35] This is the sum of subtotals for local government, state government, intermediate government agencies, and federal government. This measure does not include other sources of revenue.
[36] All data and classification on revenues and expenditures used in this section was obtained and taken directly from the U.S. Department for Education, National Center for Education Statistics, Common Core of Data (CCD), "National Public Education Financial Survey (State Fiscal)", 2007-2008 (FY2008) v.1a at http://nces.ed.gov/ccd/bat/ (accessed August 17, 2010).
[37] These are total expenditures as published in the Digest of Education Statistics; the sum of total expenditures for education, direct state support expenditures for private school students, and interest on long term debt.

expenditures for public elementary and secondary education was on average $9.9bn, $1.2bn in Wyoming, $7.5bn in Tennessee and $46bn in New York.[38]

However, taking the (average) numbers of students into account this leads to average per pupil expenditures for public elementary and secondary schools in the U.S. of $10,000, $13,856 in Wyoming, only $7,820 in Tennessee, but $16,794 in New York. Exemplary, these numbers illustrate the large difference in monetary resources available to all students and per student in the different states.

With respect to the different blocks of education expenditures, salaries and wages account for the largest fraction of expenditures. For example, in 2007-2008, about 60% of total expenditures on education were spent on salaries and wages (including payments for teachers and support services).[39] Taking only instruction expenditures into account leads to an even higher fraction of about 67% which was spent on teacher wages which corresponds to roughly 40% of overall educational expenditures.[40]

3.3 Recent Reforms

Initiated by George W. Bush in 2001 and signed into law on January 8, 2002, the No Child Left Behind Act (NCLB) aims at improving education in all U.S. states.[41]

In general, it is based on the four pillars: stronger accountability for results, more freedom for states and communities, proven education methods and more choices for parents. With respect to our research question the aim of strengthening teacher quality is of special interest. As stated in the NCLB this includes high quality professional development for teachers and strategies to recruit and retain qualified teachers. One way to reach this aim is the provision of additional funds that can be used at the local level to hire new teachers, increase teacher pay and improve teacher training and development. Accordingly, our study can help to work out whether the method of increasing teacher wages is appropriate to reach the aim of an improvement in student achievement which can be derived from the NCLB.

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[38] These are total current expenditures for public elementary and secondary education, grades prekindergarten through grade 12, including ungraded students. Expenditures for equipment, non-public education, school construction, debt financing and community services are excluded from this data item. Expenditures by state governments for and on behalf of LEAs are included in these expenditures. This is the sum of expenditures for instruction, support services, and non-instructional services (excluding community services) and direct program support (excluding support for private school students), and excludes property expenditures.

[39] Source: Authors' own calculations using data from the U.S. Census Bureau, public elementary and secondary finances: 2007-2008.

[40] Instruction expenditures are for services and materials directly related to classroom instruction and the interaction between teachers and students. Teacher salaries and benefits, textbooks, classroom supplies and extra curricular activities are included in instruction expenditures.

[41] Information on the NCLB was obtained from the website of the U.S. Department of Education: http://www2.ed.gov/nclb/overview/intro/4pillars.html (August 17, 2010).

4. Economic Model

Following Lee and Barro (2001) educational outcomes "(…) can be analyzed with an education production function that relates the output of education to various inputs"[42] in a simple form by:[43]

$$Y=Y(F,R)+\varepsilon$$

Here, Y denotes outcomes from schooling,[44] F denotes family factors (for example, family income or parents' education level) and R resources[45] used by schools. ε captures unmeasured factors that influence schooling quality.

The majority of existing empirical studies which uses international cross-state data in order to analyze educational outcomes focuses on the role and relevance of various school resources and family factors. We contribute to the literature by analyzing the specific role of teacher wages (W) used as one input in the production of schooling outcomes.

As discussed above, there is evidence for a positive relationship between teacher wages and the quality of teachers.[46] Consequently, a specific level of teacher quality is associated with any given level of teacher wages. Furthermore, teacher quality and student achievement are positively related, as higher teacher quality leads to higher student performance. Taking the effect of teacher wages on teacher quality and of teacher quality on student achievement together and following this line of argumentation, it is straightforward to assume that higher teacher wages lead to higher student achievement. Hence, educational outcomes can be expressed as a function of teacher wages, with positive marginal returns of teacher wages on outcomes.

However, as educational outcomes are not only influenced by teacher wages, one needs to consider the influence of further input factors (F and R) in order to be able to identify the specific effect of teacher wages on student achievement.

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[42] Lee and Barro (2001), page 467.

[43] We denote educational outcomes by Y, which corresponds to schooling quality (Q) in the specification used by Lee and Barro (2001).

[44] Outcomes from schooling can be measured in different ways. Measures used in different studies are, for example, drop-out rates, test scores or student retention.

[45] These can be measured through various indicators such as pupil-teacher ratios, expenditures per pupil, availability of teaching materials, etc.

[46] As already discussed, one needs to take into account that teacher wages seem to play a decisive role primarily in those education systems in which teachers do not have a status as civil servants. Accordingly, the derived relationship is primarily valid for these educational systems.

As already discussed, it is not only the level of compensation that attracts certain individuals but also the design of the particular compensation scheme (i.e. "how are individuals paid"). Various U.S. states use pay incentives in order to attract teachers to teach in less desired areas or fields of shortage.[47] Hence, one needs to account for this incentive effect (I) created through the specific method of payment, as it has an effect on the attraction of teachers, in order to be able to obtain unbiased estimates of the effect of the level of teacher wages on student achievement.

In any (state) budget of educational spending teacher wages are just one - although the largest - item of expenditures. However, other inputs for the education production function are also part of the education expenditure budget. As different states might use different combinations of input factors this difference in the composition needs to be taken into account. For example, there is basically a trade-off for politicians between the number of teachers employed and, as teacher quality is positively related to teacher wages, their quality: either less teachers are employed and earn higher wages or more teachers are employed earning (relatively) lower wages. Consequently, teacher wages are related to pupil-teacher ratios (P),[48] as the employment of less teachers (with high quality) will lead to fewer teachers teaching larger classes and vice versa. In order to account for this interrelation of different resource variables used in the education production function within the overall spending budget of each state, we explicitly account for the composition of resources used in each state: the mix of pupil-teacher ratios, those resources that are not devoted to pay teacher wages (S) and teacher wages, by including these resource variables as inputs for the production function.

Analyzing the payment schemes for teachers it becomes obvious that teacher wages are often contingent on teaching experience and education levels. Hence, teacher wages depend on experience/qualification. Accordingly, this influence needs to be taken into account. Furthermore, one can assume that it must be believed "that increased experience (E) and further schooling (i.e. the degree obtained/qualification D) have a positive effect to educational output"[49]. Hence, it is important to account for these factors in order to obtain unbiased estimates for the relationship between teacher wages and student achievement.

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[47] Accordingly, compensating wage differentials are paid to teachers teaching in less desirable areas or fields of shortage.

[48] Note that pupil-teacher ratio is a different measure than class size. According to Lewit and Baker (1997) page 113 "class size is an administrative measure typically defined as the number of students for whom a teacher is primarily responsible during a school year". In contrast, "pupil-teacher ratios are typically calculated by dividing the number of enrolled students in an educational unit--school, district, or state -- by the number of full-time-equivalent (FTE) teachers assigned to that unit". Therefore, data on pupil-teacher ratios reflect the total number of teachers and the total number of students at anytime, not the utilization of these (Hanushek, 1998, page 12).

[49] Hanushek (1971), page 282.

With respect to the U.S. context of our study and due to the power and influence of the two largest teacher unions it is important to account for this fact, as it is possible that the unions have a significant impact on teacher wages. Accordingly, we account explicitly for the "degree of unionization" (U).

As shown above in the very general production function and highlighted by numerous studies, various family factors need to be taken into account when analyzing the determinants of student achievement, as the family background proves to have substantial influence on student achievement. In previous studies family resources (F) have been taken into account (just like resource variables) through various control variables that capture different aspects of family and individual background. Due to the structure of data used in this study a completely new approach to account for the influence of family resources is adopted. The data on student performance used allows us to measure student achievement not only in general but also conditional on family background (denoted by Y_{Fi} in the following, where F_i denotes individual or family factor i). Accordingly, the influence of family factors is taken into account by using data on student achievement conditional on family resources and individual background (Y_{Fi}).

This leads to the following 'reduced form' that can be empirically estimated:

$$Y_{Fi} = Y(W,I,P,S,E,D,U,F_i)+\varepsilon \qquad (1)$$

Where:

Y_{Fi}	student achievement (conditional on family factor F_i)
F_i	dummy that captures the effect of family/individual factor i
W	teacher wage
I	pay incentives to cover shortages
P	pupil-teacher ratio
S	educational spending excluding teacher wages
E	teacher experience
D	degree/teacher qualification
U	degree of unionization
ε	error term

5. Data

Using U.S. state data in order to identify the relationship between teacher wages and student achievement has several advantages compared to data from other countries or states. On the one hand, this is due to the availability of data across states and years for numerous variables

that are important and of particular interest. On the other hand, the specific structure of the U.S. itself and the education system in the U.S. facilitate the estimation of the relationship between teacher pay and student achievement.

A major concern is that there is considerable variation in teacher recruitment procedures in different States – this makes any comparison at the across states more difficult. This is an inevitable shortcoming in the dataset that we have used here. Nevertheless an examination of this nature, i.e. using a cross-State set of data provides advantages that single State datasets do not.

A major difficulty that arises in any study that aims at identifying the influence of certain factors using empirical data is the availability and quality of the data that is needed and used. As we cannot control for the quality of the data used we try to minimize potential problems by using official sources to obtain the data of interest.[50] As argued above, a set of panel data is best suited to answer our research question as it allows for enough variation in teachers' wages and student achievement to be able to identify a potential relationship between teacher wages and student achievement. Accordingly, we constructed a set of panel data including data for 50 states[51] of the U.S. for the years 1990, 1992, 1996, 2000, 2003, 2005 and 2007 and make use of the variability across states and over time in order to estimate the relationship of interest.

It should be noted that the analysis of teacher wages and student achievement across states comprises the existence of heterogeneity in the educational systems of the different states. Therefore, we try to capture and account for as much heterogeneity between states as possible, on the one hand by including relevant control variables and on the other hand by using adequate estimation models. In addition, by using data for 50 states over several years we get multiple observations which allow for a high precision in the estimation of the relationship of interest. All in all, this set of data is a unique composition of variables which has not been used before. It is best suited to answer our research question and allows for additional instructive analyses and results.

[50] Detailed information on the variables used and their sources is given in the appendix.
[51] A list of the specific states included is given in the appendix.

5.1. Student Achievement

In general, educational outcomes, and thereby the quality of schooling can be measured in different ways.[52] The main source used to obtain information on student achievement for this study is the National Assessment of Educational Progress (NAEP) conducted by the National Center for Education Statistics (NCES) which is located within the U.S. Department of Education and the Institute of Education Sciences. "By law, the Commissioner of Education Statistics who heads the NCES is responsible for carrying out the NAEP project.[53]

The NAEP is the largest nationally representative and continuing assessment of the knowledge of U.S. students in various subject areas. It provides results on subject-matter achievement, instructional experiences, and school environment for populations of students (e.g., all eighth graders) and groups within those populations (e.g., female students, Hispanic students). Assessments are conducted periodically in mathematics, reading, science, writing, the arts, civics, economics, geography, and U.S. history. The NAEP assessments are administered uniformly using the same sets of test booklets across the nation. Accordingly the results can be used as a common metric for all states. The assessment is essentially the same from year to year. Accordingly, NAEP data can be used to get a clear picture of student academic progress over time.

NAEP results are based on representative samples of students at grades 4, 8, and 12 for the main assessments, or samples of students at ages 9, 13, or 17 years for the long-term trend assessments. These grades and ages were chosen because they represent critical junctures in academic achievement."

In order to analyze the relationship between teacher wages and student achievement across all U.S. states comparable data on student achievement is needed. Therefore, we use data from the NAEP state assessments which assesses grades 4 and 8 and was conducted in 1990 for the first time. These assessments allow us to construct a set of panel data for 50 states of the U.S. for the years 1990, 1992, 1996, 2000, 2003, 2005 and 2007.[54] In particular, we use NAEP scale scores for students in grade 8 in mathematics as a (nationwide) comparable measure of

[52] Measures that have been used so far are, among others, dropout rates and college attendance rates (Loeb and Page, 2000), NAEP scores (Darling-Hammond, 2000), test scores from PISA performance tests (Fuchs and Wößmann, 2004) or from TIMSS (Wößmann and West, 2006).

[53] The information on the NAEP was obtained and taken directly from the website of the NCES: http://nces.ed.gov/nationsreportcard/about/ (accessed August 17, 2010).

[54] Data is available for the majority of years and states. Only for the early years data was not available for single states/years and is therefore also missing in our data set. Data on conditional scores is not always available for all years and states. Detailed information on the NAEP data used is given in the appendix.

student performance.[55] We use data on achievement in mathematics for several reasons. First, this is generally viewed as being most easily comparable (see Wößmann, 2007). Second, it has been found that performance in mathematics is most strongly related to economic productivity (see, for example, Bishop, 1992). Third, NAEP scores on performance in mathematics are one of the variables which is primarily used as a measure for student achievement in empirical studies (see, for example, Louis and Marks, 1998 or Carnoy and Loeb, 2002). Finally, this data is available for numerous years and states and conditional on individual and family factors and is gathered and published by an official source.

The NAEP state assessments enable us to use data on student achievement over time as well as for various states. Furthermore, this data offers the opportunity to account for student and family characteristics through the use of conditional NAEP scores. This is because results conditional on various individual/family factors within each states' population are provided. This structure of data allows us to use a completely new approach to account for and analyze the influence of individual student and family factors. In order to make use of this structure of the data and capture the effects of different individual and in particular family factors we include NAEP scale scores for the same years and states conditional on various factors. Thereby, we include data on scores conditional on gender (Male, Female), ethnicity (White, Black and Hispanic), the disability status of students (Student disability or No student disability) and students' eligibility to the National School Lunch Program (students classified as being Eligible for NSLP, Not eligible for NSLP or Information on eligibility for NSLP not available) as a measure for the financial background of families. Furthermore, we control for parents' educational background as the highest educational level achieved by either parent (Did not finish High School, Graduated High School, Some education after High School, Graduated college or Unknown). Therefore the data is in a 'stacked form' with each block of the stack consisting of results relating to specific groups for a given state and year. The advantages of this form of data are that we essentially have summary data pooled from extremely large sample sizes. One disadvantage of this data is that conventional 'interaction terms' in a regressor are untenable as we do not have individual data. An additional characteristic of this form of data is that because we retain data for the overall average of each state by year we can measure the performance of each group relative to the overall average. This means we can estimate separate effects for EACH group and do not need to omit a category from each group as one would normally have to in conventional regression

[55] The NAEP mathematics scale ranges from 0 to 500. In the following, we refer to this NAEP scale scores of 8th graders in mathematics as NAEP data.

analysis to avoid the dummy variable trap. This has the advantage of being able to literally have an estimate of how each group – e.g. males and females or whites, blacks and Hispanics vary from the overall average. This means that the marginal effects of being in any category can be compared – whereas in normal regression analysis the reference group might be white males and all other effects have to be measured relative to his group. This is not a limitation in our data and regression analysis.

Important caveats regarding the data we are using are of course in order. Specifically we cannot control for the quality of the data we use or its reliability - and there has been some disquiet about whether the NAEP data sources measure what they purport to measure. For example, because some states have excluded more of the disabled pupils from testing than others. All we can do when faced with this criticism is to use the best available data and acknowledge its published limitations. Ravitch (1995) provides a comprehensive discussion of the collection, use and limitations of this data. A further obvious criticism of the data we use is that it ignores huge disparities within States between schools, teacher and pupils. Most importantly, working with State averaged data means that we ignore the variability of education provision sorting which takes place within a State which shows how high quality teachers get allocated to the best pupils.[56]

5.2. Teacher Wages

Particular attention needs to be paid to the measurement of teacher wages. On the one hand, this is due to the fact that there is no single source or measure of teacher wages in the U.S. On the other hand, especially with respect to the determination of teacher wages the two largest teacher unions in the U.S. play an important role. Accordingly, this fact needs to be taken into account when using and analyzing measures of teacher wages in the U.S.

As there is no single measure of teacher wages in the U.S. we construct our own (basic) measure, taking the fact into account that data on teacher wages in the U.S. is published by the two largest teacher unions. Accordingly, we use data provided by the two largest unions as sources to construct our (single) measure of teacher wages in the U.S. Data on average salaries for public and elementary school teachers published in the Statistical Abstract is provided by the NEA, while the AFT publishes its own information on average teacher wages. In order to create one single measure out of these two measures and simultaneously account

[56] See Bonesronning et al (2005) for a recent study of this sorting phenomenon in Norway.

for their sources, we use the following procedure: we use data on teacher wages from these two sources for each state and year and weight this data by the relative size of each union in each state. This relative size is measured by the relative size of the revenue of each union in each state. Accordingly, our single measure of teacher wages is a weighted average of data on teacher wages published by the NEA and AFT.

In order to identify the particular effect of teacher wages on student achievement we use four different ways of measuring real and relative teacher wages in our regression analyses:[57] As a first measure we take the purchasing power of teacher salaries, measured by converting average salaries to indexed (2000) real U.S. dollars using a national consumer price index to deflate teacher wages.[58] As a second measure we take the average level of teacher wages in real terms relative to a state specific cost of living index (COL). As a third measure we measure teacher wages relative to state average earnings measured by average annual wages reported in the Statistical Abstract. As a fourth measure we take the percentile in the states' income distribution that a teacher is paid at.[59] Using these four different measures of teacher wages in the U.S. we can perform homogeneous comparisons across states, albeit under slightly different assumptions.

It should be recognised that salary is only components of teacher working conditions. The actual amount of teaching contact time as well as the amount of professional development time supported by a school or district, student behaviour, participation in school decision making, class size, quality of facilities, and adequacy of resources are examples of conditions that could also influence a teacher's desire to teach or not teach at a particular school. Many of these conditions, however, are very difficult to measure. As trends in teacher salaries have been affected by demographic shifts in the distribution of teacher's ages, we decided to use all the salary data available to us.

Before completing our discussion of the available data it is important to review the data we do not have on the grounds that this gives us some idea of the extent of unmeasured heterogeneity in the relationships we seek to estimate. There are many important determinants of the way in which teachers are hired, trained and other wise treated which will

[57] We use our single (basic) measure of teacher wages as a basis to construct all these four measures.

[58] The constant 2000 dollar estimates are based on the annual U.S. Consumer Price Index for all urban consumers.

[59] This measure is derived in the same way as the corresponding measure used by Dolton and Marcenaro-Gutierrez (2011). The percentile is obtained by comparing teachers' wages to the median household income in each state (in the corresponding year, relative to a state specific COL) and using a Gini coefficient for each state (and year) to measure inequality. Assuming that earnings are log-normally distributed, it is possible to derive the percentile a teacher is paid at. The appendix provides detailed information on this measure.

affect the quality of person who becomes a teacher. The policy on teacher hiring is different in each county as well as each State. It may also even vary a lot between schools in a given county.

5.3. Additional Variables and Sources

In order to be able to obtain unbiased estimates of the effect of teacher wages on student achievement we need to separate this effect from the effect of particular pay incentives that are explicitly used in the U.S. to attract teachers to teach in less desirable areas or fields of shortage. Therefore, we include a control variable that measures the percentage of districts in each state that use pay incentives for these reasons to account for their particular influence.

In addition, we use a measure for the degree of unionization within each state and year. This variable measures the percentage of teachers within each state who are a member of a teacher union.[60]

In order to capture a potential influence of teacher qualification we measure the fraction of teachers with a bachelor's or post graduate degree (master or doctor) or a degree as "education specialist". Teachers' experience is accounted for by using the fraction of teachers with a certain length of full-time teaching experience: less than 3 years, 6 to 9 years, 10 to 20 years or more than 20 years of teaching experience. Both variables are derived from the Schools and Staffing Survey (SASS) "Public Teacher Questionnaire" and "Charter Teacher Questionnaire".

As derived in section 3 the influence of school/state resources is covered by two additional variables. On the one hand, we include information on pupil-teacher ratios which was obtained from the Digest of Education Statistics.[61] On the other hand, we include information on education spending excluding teacher wages per pupil for each state and year.

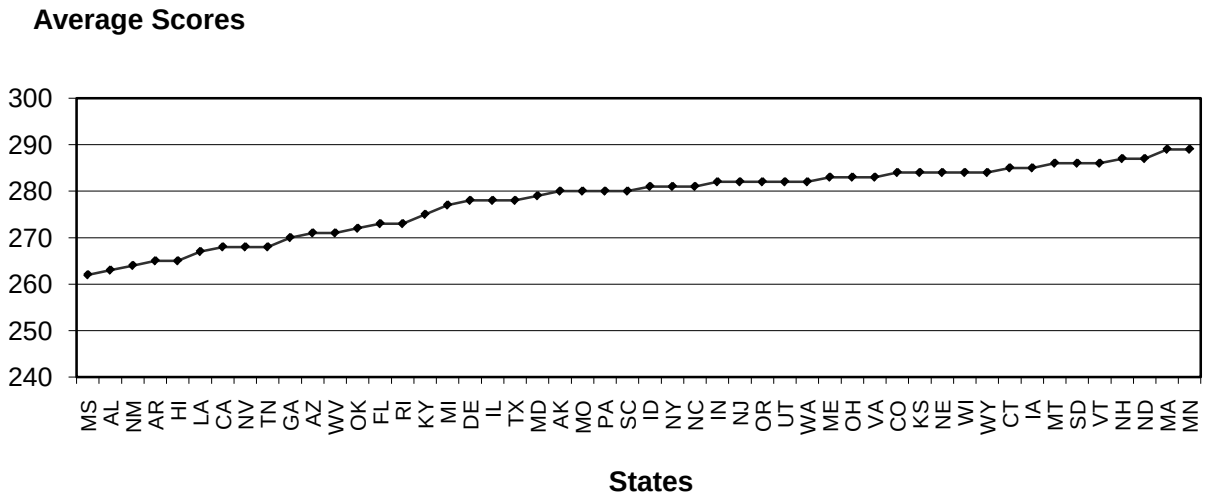
5.4. Descriptive Statistics

Examining the NAEP data it is clear that there is considerable variation in this data across states. For example, averages of the overall average NAEP scores are shown in figure 2 for all states in 2003.

[60] This variable was kindly by provided by Terry Moe (2011) where he derived the variable from the raw data from the special licence SASS.

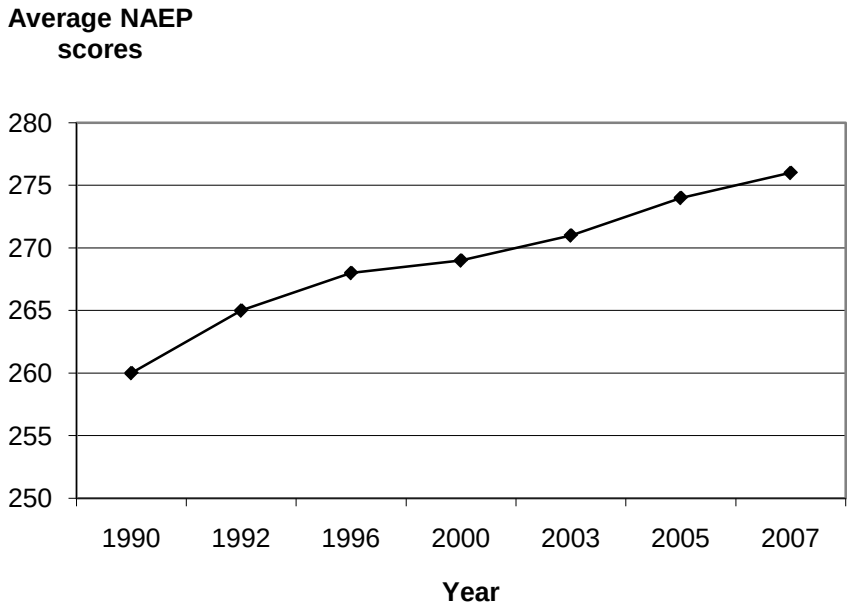
[61] Reported by the NCES as the total reported students divided by full-time-equivalent classroom teachers.

Figure 2: Overall average NAEP scores by state in 2003



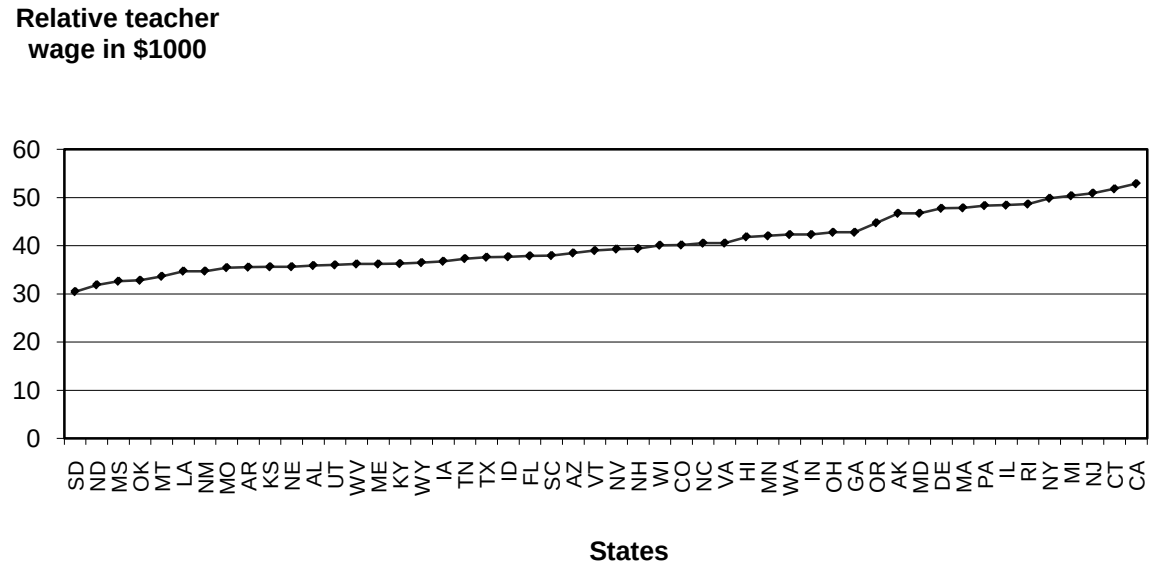
In addition to this variation across states there is considerable variation within each state over time. As an example, figure 3 illustrates average NAEP scores in Arizona over time.

Figure 3: Evolution of overall average NAEP scores in Arizona over time.



Furthermore, variation in teacher wages is needed in order to be able to identify a potential relationship between teacher wages and student achievement. We illustrate the existence of variation in teacher wages for our measure of teacher wages relative to state average earnings (measured by average annual wages) in 2003. As can be seen from figure 4 there is considerable variation in this measure of teacher wage across states. Consequently, we are justified in making use of the existing variation in order to identify the relationship between teacher wages and student achievement.

Figure 4: Relative teacher wage by state in 2003.



The descriptive statistics of the NAEP data (conditional on individual and family factors - shown in table 1 already illustrate the importance to take these factors into account. It can be seen, that average NAEP scores (averaged across all states for each year) vary significantly with individual and family background. For example, the average scores of white students are much higher than those of black students. Furthermore, students classified as having a disability have on average much lower scores than students which are not classified as having a disability. Furthermore, average NAEP scores of those students who are eligible to receive free school lunch are lower than the average scores of students who are not eligible for the

NSLP. As already shown in various studies (for example, by Ermisch and Francesconi, 2001, Fuchs and Wößmann, 2004 or Ammermüller et al. 2005) this descriptive analysis already illustrates the substantial influence of parents' education on student achievement. It can be easily seen that the higher the parents' educational background (measured as the highest level achieved by either parent) the higher their children's average performance. For example, overall average NAEP scores are about 11% higher for those students with at least one parent who graduated from college (as highest level of degree achieved by either parent) compared to those with parents who did not finish High School (as highest level of degree achieved by either parent).

Table 2 provides the means and standard deviations of all non-NAEP data used in the regression analyses. Examination of this data highlights various interesting aspects. For example, analyzing the evolution of the fractions of teachers with different degrees (qualification) shows a substantial decrease in the fraction of "Bachelor's" over years. As we find a significant decrease (measured in percentage points) in our measure from 2003 to 2005 one can conclude that this decrease in the fraction of teachers with a relatively low qualification might be one result of the effort to strengthen teacher quality, laid down in the NCLB. With regard to the different measures of teacher wages several trends can be observed. The averages of our first two measures of teacher wages (teacher wages deflated to 2000 prices and deflated by state specific COLs) vary by about $1000, respectively $2000 in the analyzed period, which corresponds to a variation of about 3%, respectively 4% of the respective average over all years. It seems that especially during the last years teacher wages deflated by state COLs have been decreasing. A similar conclusion can be derived from the two relative measures of teacher wages (relative to the average wage in each state and as percentile in a states income distribution). Both measures clearly have decreased in the last years.

In addition to this decrease in our measures of (relative) teacher wages over the last years there is a decline in pupil-teacher ratios.[62] Accordingly, one can conclude that more teachers have been employed earning (relatively) lower wages. This relationship highlights the interplay of various resources used as input factors for the production function and verifies the necessity to include these variables in the regression analyses to account for differences in the mix of these resources in the determination of student achievement.

[62] A detailed analysis of the numbers of teachers employed and students enrolled verifies that the decline in pupil-teacher ratios is not cause by a decline in the numbers of students enrolled. This decline is rather caused by a comparable smaller increase in the numbers of students enrolled compared to the numbers of teachers employed.

Table 1: Descriptive statistics of NAEP scores for all states by year.

	1990		1992		1996		2000		2003		2005		2007	
	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)
Average scale score	37	263.87	41	267.05	40	271.20	39	272.15	50	277.44	50	278.38	50	281.34
		(8.77)		(9.05)		(9.11)		(8.60)		(7.45)		(7.28)		(7.47)
Conditional on individual/ family factors														
Male	37	265.49	41	268.10	40	271.81	39	272.31	50	278.14	50	278.84	50	282.22
		(9.12)		(9.15)		(9.28)		(8.06)		(7.51)		(7.53)		(7.73)
Female	37	262.35	41	266.22	40	270.46	39	271.87	50	276.78	50	277.88	50	280.30
		(8.06)		(9.07)		(9.02)		(8.61)		(7.43)		(7.128)		(7.35)
White	37	270.46	41	273.93	40	278.45	39	279.80	50	285.26	50	286.28	50	289.26
		(6.73)		(6.70)		(6.38)		(6.45)		(5.85)		(5.99)		(6.47)
Black	28	235.46	32	239.63	30	243.71	28	244.89	40	252.18	40	253.98	40	258.78
		(4.45)		(7.62)		(6.67)		(7.08)		(6.65)		(7.00)		(7.86)
Hispanic	15	243.93	16	246.88	16	250.77	19	251.90	36	258.94	37	261.89	42	264.93
		(8.41)		(8.54)		(6.47)		(7.77)		(6.07)		(5.67)		(6.83)
Student disability	n.a.		n.a.		n.a.		37	233.18	50	242.93	50	244.30	50	247.17
								(11.91)		(9.39)		(9.41)		(10.20)
No student disability	n.a.		n.a.		n.a.		39	276.28	50	282.01	50	282.67	50	285.03
								(8.68)		(7.52)		(7.30)		(7.52)
Eligible for NSLP	n.a.		n.a.		40	254.72	39	255.01	50	261.07	50	263.38	50	266.53
						(9.77)		(8.88)		(6.62)		(6.79)		(6.36)
Not eligible for NSLP	n.a.		n.a.		40	278.78	39	280.74	50	286.12	50	287.35	50	290.30
						(6.77)		(6.74)		(5.66)		(5.64)		(6.02)
Info on eligibility for	n.a.		n.a.		38	270.29	36	272.56	35	279.03	13	281.20	50	278.31
NSLP not available						(11.07)		(8.66)		(11.01)		(12.12)		(13.43)
Education level of parents														
Did not finish	37	245.84	41	249.00	39	251.42	37	251.51	49	257.53	49	260.35	48	263.27
High School		(7.22)		(6.54)		(6.10)		(7.05)		(5.53)		(6.25)		(5.73)
Graduated High	37	254.62	41	257.46	40	261.20	39	261.95	49	268.14	49	267.82	49	270.47
School		(8.42)		(8.51)		(8.89)		(8.06)		(6.99)		(6.69)		(6.72)
Some education after	37	268.95	41	272.10	40	275.49	39	277.00	49	280.18	49	280.53	49	283.43
High School		(7.15)		(7.12)		(7.29)		(7.19)		(5.78)		(5.50)		(5.79)
Graduated college	37	275.24	41	277.83	40	282.14	39	283.39	49	286.92	49	288.25	49	291.00
		(7.81)		(8.90)		(8.61)		(8.17)		(7.61)		(7.38)		(7.40)
Unknown	37	245.08	41	250.07	40	255.34	39	255.64	49	260.14	49	262.10	49	264.69
		(9.89)		(9.02)		(7.77)		(7.98)		(6.44)		(7.03)		(7.39)

[Note: This table shows the (overall and conditional) means (over states) of the average NAEP scale scores (ranging from 0 to 500) for 8th graders in mathematics by years. Standard deviations are shown in parentheses. Numbers of states for which data is available are shown for each variable (n.a. indicates that data was not available from the NCES for any state for the particular variable). Source is authors' own calculations.]

Table 2: Descriptive statistics of teacher and resource data for all states by year.

	1990		1992		1996		2000		2003		2005		2007	
	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)	No. States	Mean (SD)
Years of teaching														
less than 3	46	9.66%	50	10.02%	50	10.87%	50	12.72%	50	12.04%	50	11.58%	50	11.13%
		(2.29)		(2.28)		(2.12)		(2.33)		(2.13)		(2.68)		(3.52)
3 to 9	50	26.70%	50	26.28%	50	26.60%	50	28.08%	50	30.76%	50	32.55%	50	34.34%
		(4.19)		(3.76)		(3.36)		(4.15)		(3.85)		(4.61)		(5.83)
10 to 20	50	41.28%	50	38.43%	50	33.68%	50	29.28%	50	30.61%	50	31.51%	50	32.40%
		(3.19)		(3.61)		(3.45)		(3.16)		(6.41)		(8.99)		(11.66)
over 20	50	22.50%	50	25.26%	50	28.85%	50	29.92%	50	28.20%	50	27.06%	50	25.91%
		(5.50)		(6.05)		(5.67)		(5.46)		(5.40)		(6.13)		(7.30)
Teacher qualification														
Bachelor	50	54.72%	50	54.22%	50	53.63%	50	53.51%	50	52.48%	50	51.79%	50	51.10%
		(14.15)		(13.70)		(13.25)		(13.10)		(12.40)		(12.31)		(12.53)
Master or Doctor	50	39.35%	50	40.52%	50	40.98%	50	41.17%	50	41.00%	50	40.90%	50	40.79%
		(12.22)		(12.08)		(11.57)		(11.44)		(10.71)		(10.58)		(10.74)
Education Specialist	28	6.79%	50	4.60%	50	4.67%	50	4.61%	50	5.52%	50	6.14%	50	6.75%
		(5.91)		(4.77)		(4.47)		(4.31)		(4.52)		(4.78)		(5.12)
Educational spending excluding teacher wages - per pupil	50	1829.83	50	1928.69	50	2110.96	50	2609.86	50	3065.53	50	3392.50	50	3848.61
		(516.52)		(563.27)		(455.24)		(495.02)		(600.88)		(716.55)		(858.41)
Pupil-teacher ratio	50	16.94	50	16.98	50	16.70	50	15.66	50	15.54	50	15.25	50	15.154
		(2.28)		(2.21)		(2.19)		(2.18)		(2.48)		(2.56)		(2.53)
Percentage of teachers who are union members	50	78.18%	50	78.18%	50	77.06%	50	77.06%	50	75.78%	50	75.06%	50	75.06%
		(16.56)		(16.56)		(18.49)		(18.49)		(19.80)		(20.45)		(20.45)
Percentage of states that use pay incentives	50	6.79%	50	12.13%	50	15.81%	50	16.76%	50	17.71%	50	23.59%	50	23.59%
		(5.47)		(14.32)		(15.53)		(14.99)		(15.89)		(18.14)		(18.14)
Teacher wage deflated to 2000 prices in $	50	38874.34	50	39569.71	50	39163.32	50	39175.77	50	40257.12	50	39558.66	50	39797.33
		(6554.06)		(6825.55)		(6795.63)		(5908.35)		(5814.48)		(5753.52)		(5506.30)
Teacher wage deflated by state COLs in $	50	47429.57	50	48848.40	50	48733.56	50	48234.94	50	48878.55	50	47038.69	50	46605.4
		(6066.97)		(6126.93)		(6273.65)		(5420.44)		(5357.66)		(5120.55)		(4922.81)
Teacher wage relative to average wage in each state	50	1.34	50	1.34	50	1.33	50	1.22	50	1.24	50	1.20	50	1.18
		(0.09)		(0.09)		(0.10)		(0.09)		(0.09)		(0.09)		(0.09)
Teachers percentile position in states income distribution	50	0.71	50	0.73	50	0.71	50	0.68	50	0.70	50	0.70	50	0.69
		(0.03)		(0.03)		(0.03)		(0.04)		(0.04)		(0.04)		(0.04)

[Note: This table shows the means (over states) of the resource variables used by years. Standard deviations are shown in parentheses. Numbers of states for which data is available are shown for each variable. Minor deviations from 100\% in "Years of teaching" and "Teacher qualification" are due to rounding. Source is authors' own calculations.]

6. Econometric Model Identification

In the following the `reduced form' of the education production function derived in section 3 is taken as a basis for the identification of the relationship between teacher wages and student performance. According to formula (1) we control for the influence of various

school/individual factors, as well as resource factors. Simply regressing student achievement on teacher wages and the additional controls according to (1) implies the potential problem of biased estimates of the effect of teacher wages if teacher wages are correlated with other factors that influence student achievement for which we can not/do not control (unobserved heterogeneity). As we constructed a set of panel data in order to answer our research question we make use of panel data methods which allow to control for these potential problems. Consequently, the identification of the parameters relies on the one hand on variation in teacher wages and student achievement across states over time. On the other hand, it relies on the reasonable assumption that unobserved heterogeneity is constant over time for each state. Accordingly, fixed effect estimations can be used in order to estimate consistent coefficients of the marginal importance of the determinants of student achievement and identify the relationship between teacher wages and student achievement. This procedure allows us to remove all time-invariant differences between states.

As described in the previous section, we will use different approaches to measure teacher wages. We use different approaches and in particular the four measures described for several reasons. First, there is no single way of how to measure teachers wages. Second, using different approaches to measure teacher wages allows to strengthen/weaken our findings subject to the results of our estimations. If we find significant influence of all our measures of teacher wages on student outcome into the same direction this provides evidence that the relationship between these variables is quite stable and robust and our findings are not due to the particular measures of teacher wages used. The reverse argument holds if we find mixed results, depending on the measure of teacher wages used. Third, all measures used capture different aspects of wages. For example, measuring teacher wages relative to average salaries within each state allows to account for alternative labor market opportunities (see Loeb and Page, 2000).

As already highlighted we use a specific and new structure of data to identify and estimate the relationship between teacher wages and student achievement as we account for individual and family factors by using data on student achievement conditional on these factors. Accordingly, we devote particular attention to the analysis of these factors. Therefore, we use two different specifications of our data as a basis for the regression analyses. First, we use all data available on student achievement: the overall average scale scores and the conditional scores. As the overall average scale scores are basically a (weighted) average over all conditional scores, including this average might have an effect on the estimated results. Furthermore, it slightly changes the interpretation of results because the influence of all

conditional variables is measured relative to the overall average. Our second specification uses just the data on overall student achievement as we omit all observations on achievement conditional on individual or family factors. Using this procedure to estimate the effect of teacher wages and student achievement we can rule out biases in our estimates resulting from our new method to control for the influence of individual and family factors.

7. Empirical Evidence.

The results for the two different specifications with respect to the data used are shown in tables 3, 4 and 5 in the following two subsections.[63] Tables 3, and 4 show the main results regarding our research question on the influence of teacher wages on student performance in the next subsection. In the second subsection table 5 illustrates the results of individual and family factors on student achievement. The results shown in tables 3 and 5 result from the same regressions and were just split in order to highlight the respective results of interest.

As mentioned above, on the one hand, we use two different specifications with respect to the NAEP data used as basis for our regressions. In this regard, tables 3 and 5 show the estimation results using all NAEP data. Accordingly, we use data on the overall average of NAEP scores as well as conditional NAEP scores. The results in table 4 are based on estimations that use just the overall NAEP scores as dependent variable. Accordingly, NAEP scores conditional on individual/family background are not included in this regressions and so there is no second part of table 4. On the other hand, we use four different measures for teacher wages. All in all, the following three tables show estimation results for the two different specifications with respect to the data used while each of these tables contains four different specifications of the model, each including another measure of teacher wages.

7.1. The Influence of Teacher Wages on Student Achievement.

In table 3 estimation results for the resource variables are shown based on all NAEP data. Focusing on our variable of interest, that are the different measures of teacher wages, it is straightforward to see that this variable is positively significant no matter which measure of teacher wages is used. For example, our results suggest that an $5000 increase in (real) teacher salaries (measured by teacher wages deflated to 2000 prices - column 1) is associated with an increase in student standardized scores of about 0.145 a standard deviation which is equivalent to a 1% increase in student achievement. Similar results can be obtained

[63] All results shown in the tables are obtained by running all regressions on standardized scores (z-scores) of the NAEP scores, using all NAEP data available to compute standardized scores.

measuring teacher wages deflated by state specific COLs. Likewise, our results suggest that increasing teachers' relative salaries (compared to the average salary in each state and year) or improving their standing in a states income distribution will result in a significant increase in student achievement.

The positive and statistically significant relationship between all four measures of teacher wages and student achievement is robust as our estimation results are not sensitive to the differences in equation specifications used. As can be seen from table 4 using just the overall average of NAEP scores (in the states in each year) as dependent variable changes the marginal effects of the different measures only slightly. It does not affect either their positive sign nor their level of statistical significance. These estimation results consistently suggest that an $5000 increase in (real) teacher salaries (which is around a 12% increase in average teacher salaries) (measured by teacher wages deflated to 2000 prices - column 1) is associated with an increase in student standardized scores of about 0.145 a standard deviation which is equivalent to around 3.8% increase in student achievement (at the mean). Our main finding suggests that teacher wages and student achievement are directly and positively related. On the one hand, this result is not sensitive to the specification of NAEP data used as basis for our estimation results, i.e. it does not change if we use all our data or just the overall average State of the NAEP data on student achievement in a given year as a basis for the regression analysis. On the other hand, this result is not sensitive to the specification we use to measure teacher wages. Furthermore, the more similar the different measures are the smaller is the difference between the estimated effects of teacher wages on student achievement. All in all, our results consistently provide evidence in favour of a significantly positive and direct relationship between teacher wages and student achievement.

Table 3: Estimation results for resource variables based on all NAEP data

Dependent variable	Standardized NAEP scores			
	1	2	3	4
Individual/family background	✓	✓	✓	✓
Year dummies	✓	✓	✓	✓
Years of teaching:				
less than 3	0.023***	0.023***	0.023***	0.023***
	(0.008)	(0.009)	(0.009)	(0.009)
3 to 9	0.013*	0.012**	0.013*	0.014*
	(0.007)	(0.006)	(0.007)	(0.007)
10 to 20	-0.011***	-0.011***	-0.012***	-0.011***
	(0.003)	(0.003)	(0.003)	(0.003)
over 20	0.007	0.006	0.007	0.009
	(0.005)	(0.005)	(0.005)	(0.005)
Teacher qualification				
Bachelor	0.050	0.046	0.039	0.040
	(0.041)	(0.041)	(0.043)	(0.042)
Master or Doctor	0.050	0.047	0.040	0.041
	(0.038)	(0.039)	(0.041)	(0.040)
Education Specialist	0.032	0.037	0.024	0.026
	(0.045)	(0.047)	(0.048)	(0.047)
Deflated educational spending ex-	0.120***	0.111***	0.143***	0.144***
cluding teacher wages - per pupil	(0.041)	(0.043)	(0.044)	(0.043)
Pupil-teacher ratio	0.036**	0.036**	0.033*	0.031*
	(0.017)	(0.017)	(0.017)	(0.016)
Percentage of teachers who	-0.003	-0.003	-0.003	-0.002
are union members	(0.004)	(0.004)	(0.004)	(0.004)
Percentage of states that	0.004**	0.004**	0.004**	0.004**
use pay incentives	(0.002)	(0.002)	(0.002)	(0.002)
Teacher wage deflated to	0.029***			
2000 prices in $1000	(0.010)			
Teacher wage deflated by		0.019***		
state COLs in $1000		(0.007)		
Teacher wage relative to			0.561*	
average wage in each state			(0.319)	
Teachers' percentile in				2.001**
income distribution				(0.706)
Constant	-7.283*	-6.675	-5.874	-6.826
	(4.300)	(4.308)	(4.349)	(4.411)
F-statistic	919.89***	883.23***	890.21***	873.94***
Adjusted R-squared	0.909	0.909	0.908	0.909
Number of Observations	3954	3954	3954	3954

[Note: Source is authors' own calculations using all NAEP data of students in grade 8 in mathematics. The four different models include different measures for teacher wages and show estimation results for fixed-effects models. Standardized NAEP scores are used as dependent variable. Robust standard errors are reported in parentheses. Significance at the 10%, 5% and 1% level is denoted by *, ** and ***, respectively.]

In addition, our estimation results suggest the assumption that teachers' experience, measured by the number of years they have been teaching, is not *per se* an important determinant of student achievement. All specifications we use show that the number of years of teaching is only significantly positively related to student achievement at the beginning of a teacher's career. Also in general it is clear that there is a negative effect of teacher experience between 10 and 20 years, on student achievement. This is consistent with a 'burn out' effect which is not present for those teachers who stay in the job beyond 20 years. Clearly if a teacher lasts this long there are no further negative effects and this may be due to the sorting effect of the best teachers really last the course and staying for their whole career. Furthermore, and in accordance with the findings of numerous comparable studies (see, for example, Goldhaber and Brewer, 1996 and an overview in Hanushek, 2003) teacher qualification in general, measured by the level of degree obtained, does not seem to have a substantial impact on student achievement.[64] Especially with regard to the NCLB initiative these findings question whether the aim of attracting more qualified teachers, measured through the degree obtained, will lead to a significant improvement in student achievement. Our results suggest the assumption, that it is not teacher quality measured by the degree obtained (for example, Bachelor or Master) that is positively related to student achievement. It is rather a "different" kind of teacher quality which is decisive for student achievement and which can be influenced through the level of wages paid to teachers.

[64] It should be noted, that our data does not allow to control for the major of the degree or quality of the institution that awarded the respective degree.

Table 4: Estimation results for resource variables based on overall average NAEP data

Dependent variable	Standardized NAEP scores			
	1	2	3	4
Year dummies	✓	✓	✓	✓
Years of teaching:				
less than 3	0.023**	0.022**	0.023**	0.022**
	(0.009)	(0.009)	(0.009)	(0.009)
3 to 9	0.011*	0.009	0.011	0.011
	(0.006)	(0.006)	(0.007)	(0.006)
10 to 20	-0.010***	-0.010***	-0.011***	-0.010***
	(0.003)	(0.003)	(0.003)	(0.003)
over 20	0.007	0.006	0.007	0.009
	(0.005)	(0.004)	(0.005)	(0.005)
Teacher qualification				
Bachelor	0.025	0.020	0.012	0.011
	(0.037)	(0.038)	(0.040)	(0.040)
Master or Doctor	0.025	0.021	0.013	0.012
	(0.035)	(0.035)	(0.038)	(0.038)
Education Specialist	0.008	0.012	-0.002	-0.002
	(0.042)	(0.043)	(0.045)	(0.045)
Deflated educational spending ex-	0.129***	0.120***	0.149***	0.154***
cluding teacher wages - per pupil	(0.040)	(0.042)	(0.040)	(0.041)
Pupil-teacher ratio	0.031*	0.031*	0.027*	0.025
	(0.016)	(0.017)	(0.016)	(0.016)
Percentage of teachers who	-0.003	-0.003	-0.003	-0.002
are union members	(0.004)	(0.004)	(0.005)	(0.004)
Percentage of states that	0.004**	0.004*	0.004*	0.004**
uses pay incentives	(0.002)	(0.002)	(0.002)	(0.002)
Teacher wage deflated to	0.029***			
2000 prices in $1000	(0.010)			
Teacher wage deflated by		0.018**		
state COLs in $1000		(0.007)		
Teacher wage relative to			0.583*	
average wage in each state			(0.316)	
Teachers' percentile in				1.942**
income distribution				(0.728)
Constant	-4.743	-4.025	-3.153	-3.812
	(3.950)	(3.920)	(4.053)	(4.155)
F-statistic	47.29***	46.31***	45.01***	45.45***
Adjusted R-squared	0.848	0.845	0.842	0.844
Number of Observations	290	290	290	290

[Note: Source is author's own calculation using NAEP overall averages of students in grade 8 in mathematics. The four different models include different measures for teacher wages and show results for fixed-effects models. Standardized NAEP scores are used as dependent variable. Robust standard errors are reported in parentheses. Significance at the 10%, 5% and 1% level is denoted by *, ** and ***, respectively.]

7.2. Additional Determinants of Student Achievement.

As explained above the results shown in table 5 are obtained by using overall averages and conditional NAEP data. Accordingly, the estimated coefficients measure the influence of the different family and individual factors relative to the overall average. As can be seen from table 5 a number of parameters of individual and family background is significantly related to student achievement. As already highlighted by several studies and extensively discussed (see, for example, the studies by Fertig, 2003 or Wößmann, 2008) parents' educational background significantly influences their childrens' school achievement. Our analyses show that a low level of education of parents ("Did not finish High School", and "Graduated High School") is significantly negatively related to their children's achievement, while a higher level of education ("Some education after High School" or "Graduated college") is significantly positively related to student achievement. In addition, it can be seen that the fact whether a student is characterized as having a disability (Student disability)[65] is significantly negatively related to student outcome. This result is intuitively plausible as the characterization of having a disability also includes students that need specialized instruction in order to access the general curriculum (specialized instruction refers to a change in the curriculum content, methodology or delivery of instruction that is provided in general education classroom). Furthermore, our results consistently show that a non-white ethnic background (Black, Hispanic) is significantly negatively related to student achievement. Due to the use of our new method in order to account for the influence of individual/family background we are able to control for the influence of factors that have not been accounted for so far. In this regard, we find consistently negative coefficients for the influence of eligibility for the NSLP. According to the criteria for eligibility, that is "children from families with incomes at or below 130 percent of the poverty level are eligible for free meals", this measure can be taken as a proxy for the financial background of families. Therefore, our results suggest that there is a relationship between student outcomes and the financial disadvantaged of the family as those who are in receipt of NSLP fare significantly worse in their NAEP scores.

[65] Classified according to the criteria of the NAEP

Table 5: Estimation results for NAEP variables based on all NAEP data

Dependent variable	Standardized NAEP scores			
	1	2	3	4
Individual/family background				
Male	0.047***	0.047***	0.047***	0.047***
	(0.010)	(0.010)	(0.010)	(0.010)
Female	-0.046***	-0.046***	-0.046***	-0.046***
	(0.007)	(0.007)	(0.007)	(0.007)
White	0.486***	0.486***	0.486***	0.486***
	(0.041)	(0.041)	(0.041)	(0.041)
Black	-1.567***	-1.566***	-1.567***	-1.576***
	(0.062)	(0.062)	(0.062)	(0.062)
Hispanic	-1.187***	-1.189***	-1.189***	-1.189***
	(0.067)	(0.067)	(0.067)	(0.067)
Student disability	-2.251***	-2.251***	-2.251***	-2.251***
	(0.039)	(0.039)	(0.039)	(0.039)
No student disability	0.265***	0.265***	0.264***	0.264***
	(0.010)	(0.010)	(0.010)	(0.010)
Eligibile for NSLP	-1.013***	-1.013***	-1.013***	-1.013***
	(0.035)	(0.035)	(0.035)	(0.035)
Not eligible for NSLP	0.552***	0.552***	0.552***	0.552***
	(0.025)	(0.025)	(0.025)	(0.025)
Info on eligibility for NSLP not available	0.065	0.066	0.066	0.067
	(0.042)	(0.042)	(0.042)	(0.042)
Education level of parents				
Did not finish High School	-1.196***	-1.195***	-1.195***	-1.196***
	(0.042)	(0.042)	(0.042)	(0.042)
Graduated High School	-0.636***	-0.636***	-0.636***	-0.636***
	(0.020)	(0.020)	(0.020)	(0.020)
Some education after High School	0.231***	0.231***	0.232***	0.232***
	(0.024)	(0.024)	(0.024)	(0.024)
Graduated college	0.664***	0.664***	0.665***	0.665***
	(0.018)	(0.018)	(0.018)	(0.018)
Unknown	-1.063***	-1.063***	-1.063***	-1.062***
	(0.026)	(0.025)	(0.026)	(0.026)
Resource variables	✓	✓	✓	✓
Constant	-7.283*	-6.675	-5.874	-6.826
	(4.300)	(4.308)	(4.349)	(4.411)
F-statistic	919.89***	883.23***	890.21***	873.94***
Adjusted R-squared	0.909	0.909	0.908	0.909
Number of Observations	3954	3954	3954	3954

[Note: Source is authors' own calculations using all NAEP data of students in grade 8 in mathematics. The four different models include different measures for teacher wages and show estimation results for fixed-effects models. Standardized NAEP scores are used as depended variable. Robust standard errors are reported in parentheses. Significance at the 10%, 5% and 1% level is denoted by *, ** and ***, respectively.]

8. Conclusions and Policy Implications.

In order to identify the factors that influence student achievement in school education and thereby influence the success of a whole school system, it is quite intuitive and has been shown in numerous studies that teacher quality and student achievement are positively related. Furthermore, there is a positive relationship between teacher wages and teacher quality. Accordingly, it is reasonable to assume that there exists a direct and positive relationship between teacher wages and student achievement. However, the majority of empirical studies that tries to verify this direct link fails. In order to overcome various shortcomings that might have lead to the problems of identifying a direct relationship in previous studies, we constructed a completely new data set. Using a unique set of U.S. panel data we make use of variation of teacher wages and student achievement across states and time in order to identify the effect of teacher wages on student achievement. This set of data allows us to generate robust estimates of the relationship of interest by measuring teacher wages in four different ways. Furthermore, we use a completely new approach to account for the influence of individual and family factors on student achievement, using data on student achievement conditional on various family and individual factors. This structure of data allows us to perform different regression analyses in order to verify the robustness of our findings.

Using four different approaches to measure our key variable of interest, as well as two different model specifications with respect to the data used for the estimations, our results provide consistently positive and significant estimates of a direct relationship between teacher wages and student achievement. Accordingly, these findings provide strong evidence in favour of a positive influence of teacher wages on student performance.

First and foremost, our results should be taken as important findings with respect to education policy. Our findings would suggest, that an increase in teacher salaries has a positive effect on student achievement due to the increase in the quality of teachers recruited. Accordingly, increasing teacher wages seems to be an appropriate method to reach the aim of an improvement in student achievement which can be derived from the NCLB. However, it is important to note that this effect is solely due to the relative improvement in teacher wages which will result in an increase of the average quality of teachers due to more able teachers being attracted by higher wages (sorting effect). Furthermore, these findings highlight the importance of devoting special attention to teacher wages (and thereby teacher quality) when

analyzing and comparing the success of school education, measured through student achievement within and between different countries. In addition, our findings suggest the assumption that the lack of a significantly positive effect between teacher wages and student achievement in numerous previous studies is due to substantial shortcomings in the different studies.

As teacher wages and teacher quality are positively related it is furthermore intuitive to adopt the same line of reasoning as Dolton and Marcenaro-Gutierrez (2011) and interpret teacher wages as a proxy of (unobservable) teacher quality. Accordingly, the finding of a positive effect of teacher wages on student achievement can be interpreted as evidence in favor of a significant influence of (unobservable) teacher quality on student achievement. As already stated, numerous studies verify the influence of teacher quality on student achievement using different measures of teacher quality. Our results offer a (new) way to account for teacher quality by using teacher wages and thereby avoid any problems of how to measure teacher quality directly.

In addition, it is important to relate the findings of this study to the findings of other studies that aim at identifying the influence of various factors on student achievement. For example, as Wößmann (2007) summarizes, noteworthy effects of class-size on student performance can only be observed in countries with relatively low teacher salaries.[66] Consequently, he concludes that this finding suggests the assumption that high-quality teachers are capable enough to perform well, even when teaching in large classes. In contrast, low-quality teachers teach worse in large classes than in smaller ones. Relating these findings to our evidence of a positive and direct effect of teacher wages on student performance strengthens the argument of using teacher wages to increase average teacher quality and thereby improve student achievement. If high-quality teachers can teach equally well in large and small classes, an increase in teacher wages could go along with an increase in class-size. Especially from an economic point of view, this interplay of input factors is of special interest. In particular, an increase in education spending, namely for teacher salaries, could go along with a decrease in education spending because less teachers are needed if teacher quality increases and consequently, class-size can be increased. Accordingly, it is in particular the interplay of various input factors that needs to be taken into account when trying to find the optimal combination of input factors for school education in order to achieve the best possible outcomes.

[66] For additional details see Wößmann and West, 2006.

Our starting point for this investigation was the proposition that teacher quality is not easy to observe within a State but may be measured by teacher relative wages when we consider cross State data. This is a reasonable hypothesis on the grounds that where a teacher is paid in a State's income distribution will result in drawing out candidates for teaching of the appropriate quality. The idea is that each State gets the teachers it wants and deserves. With this idea in mind we set out to investigate whether the variable quality of teachers in different States in the world could help to explain the variation in the performance of grade 8 pupils year olds in cross State national tests in maths.

Since our measure of teacher quality was the wage teachers are paid in a State we sought to model the determination of teacher salaries and pupil outcomes. We first considered reduced form estimations for a teacher salary equation and a pupil outcome equation. Using panel data for 50 States for 19 years we attempted to establish the relationship between teacher salaries and pupil outcomes. The advantage of panel data in this context is that if State specific unobserved heterogeneity does not vary over time then we may be able to establish whether the link between teacher wages and pupil outcomes is anything more that a correlation.

To provide some idea of the scale of the effects we find our coefficients suggest that a 15% percent increase in teacher pay would give rise to around a 6-8% increase in pupil performance. Likewise a 5% increase in the relative position of teachers in the salary distribution would increase pupil performance by around 6-8%. These effects are significant and robust to the estimation procedure we use and the different identification assumptions we make to facilitate each estimation technique. Whilst we cannot, of course, claim unequivocally that these effects are causal it seems plausible to suggest that there robust nature across different estimation strategies might lead us to suggest that the relationship between teacher salary and pupil outcomes is more than a simple correlation.

If one were to accept the conclusions of our empirical investigation at face value then one would want to ask exactly what the policy implications would be. Most obviously one would suggest that if a sate is concerned with the educational outcomes of its children then it should be aware that the quality of its teachers are of fundamental importance. This paper would suggest that the route to hiring higher quality teachers is to pay them more - which will mean paying them at a higher point in the State's income distribution. Having stated this bald and obvious conclusion from this work we must then ask how this would be achieved. Most clearly, a State (with say a stock of low quality teachers) cannot just shift up the wage of all teachers immediately and expect the quality of teaching to improve. The existing teachers

would clearly have an incentive to appropriate these economic rents with no responsibility to become better teachers. Clearly the quality of the new recruits to the profession would rise as a result of this upward shift in relative pay - but it would then take a long time - 30-40 years to completely change the quality of the whole stock of teachers. The answer then must be to consider how teacher quality can be raised gradually. If the state authorities were to ratchet up starting pay this would secure a better quality of new teacher. But to improve the stock of existing teachers one would have to put faith in continued CPD and/or attempt to fire the worst teachers who are in the stock. Such policy measures were not in the scope of this investigation but there is a wealth of evidence about them as possible remedies to improve the existing stock of teachers. Further measures which can be used are those schemes which improve the incentive mechanism of the existing teachers - such as those used in Israel (see Lavy 2002) and elsewhere. Another possible solution is to consider improving the salary advancement - by increasing the gradient of the experience wage profile. Another active possibility to help improve teacher quality is to consider the proposal by Barlevy and Neal (2009) that teachers be paid according to the percentile performance (in value added terms) of the children they teach. These authors show how such a scheme would clearly be incentive compatible. But in this context our work would suggest that the norming of teachers pay would have to be right in the first place if the right, high quality, people were to be attracted into the job in the first place.

A further area of policy importance in the results we present is in making explicit the nature of the trade-off between paying teachers more and either increasing contact hours or reducing class sizes. Each of these measures would have a clear impact on pupil outcomes and each state government can think of the political acceptability of choosing one funding alternative over another. A further implication of our work is that our results make clear the context of this possible trade off in the sense that a State's ability to afford any of these measures must depend on their GDP growth into the future.

The policy implications of our findings are relevant to the recruitment of teachers and the improvement of educational standards for young people. The link we have found between high educational standards and teachers' quality has logical implications for any state government's commitment to recruit, retain and reward good teachers. In this regard, it seems that increasing teachers' salaries, and the speed at which they can reach higher pay levels within a particular pay structure, will help schools recruit and retain teachers that schools need to offer all pupils a high-quality education. Therefore it would seem that one clear way to improve the human capital stock is to invest in higher quality teachers.

Appendix

Teachers' Percentile Position in the Income Distribution

We derive teachers' percentile position in the income distribution using data on average teacher wages, the median household income in each state as well as the Gini coefficients for each state in each year as a measure of the income inequality.[67] In order to do so, we assume that teacher wages (w) are lognormally distributed, hence: $\ln(w) \sim N(\theta, \sigma^2)$. Accordingly, the median of w is e^{θ}, its mode $e^{(\theta-\sigma^2)}$ and its mean is $e^{\theta+(1/2)\sigma^2}$. Let u(p) be the value in the N(0,1) distribution at the percentile point p (hence, u(1/2)=0, and so on). Hence, $w(p)=e^{\theta+u(p)\sigma}$ is the income level at percentile p. The corresponding Gini coefficient is $G=1-2u(\sigma/(\bar{\ }))$ which is equivalent to twice the area under N(0,1) between the ordinates u=0 and $u=(\sigma/(\bar{\ }))$. Consequently, σ can be inferred if the Gini coefficient G is known. Finally, knowing the mean (or median or mode) θ can be inferred as well. Hence, for any given teacher wage w* the percentile p* can be obtained by solving w*=w(p*).

The 50 States

We use data of the following 50 U.S. states in our analyses:

Alabama	AL	Louisiana	LA	Ohio	OH
Alaska	AK	Maine	ME	Oklahoma	OK
Arizona	AZ	Maryland	MD	Oregon	OR
Arkansas	AR	Massachusetts	MA	Pennsylvania	PA
California	CA	Michigan	MI	Rhode Island	RI
Colorado	CO	Minnesota	MN	South Carolina	SC
Connecticut	CT	Mississippi	MS	South Dakota	SD
Delaware	DE	Missouri	MO	Tennessee	TN
Florida	FL	Montana	MT	Texas	TX
Georgia	GA	Nebraska	NE	Utah	UT
Hawaii	HI	Nevada	NV	Vermont	VT
Idaho	ID	New Hampshire	NH	Virginia	VA
Illinois	IL	New Jersey	NJ	Washington	WA
Indiana	IN	New Mexico	NM	West Virginia	WV
Iowa	IA	New York	NY	Wisconsin	WI
Kansas	KS	North Carolina	NC	Wyoming	WY
Kentucky	KY	North Dakota	ND		

Data Sources

Data on Student Achievement

Data on students achievement (NAEP average scale scores of 8th graders in mathematics) was obtained from the NAEP Data Explorer from the U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), Mathematics Assessments: http://nces.ed.gov/nationsreportcard/naepdata/dataset.aspx - last update of data used: September 2010.

[67] We use state specific COLs to deflate teacher wages and median household income.

This data is used - if available - for all 50 states for the following years: 1990, 1992, 1996, 2000, 2003, 2005, and 2007.

The following data on conditional NAEP scores is used [categories available from NAEP are shown in brackets]: (labelling used in this paper is shown in parentheses)
Gender [Male, Female]: (Male, Female)
Ethnic Origin - [White, Black, Hispanic]: (White, Black, Hispanic)
Education Level of Parents [Did not finish H.S., Graduated H.S., Some ed. after H.S., Graduated college, Unknown]: (Did not finish High School, Graduated High School, Some education after High School, Graduated college or Unknown)
National School Lunch Program Eligibility [Eligible, Not eligible, Info not available] -- missing for 1990, 1992 and 1996: (Eligible for NSLP, Not eligible for NSLP, Info on eligibility for NSLP not available)
Student Disability [SD, Not SD] - missing for 1990, 1992 and 1996: (Student disability, No student disability)

Data on Teachers
The Schools and Staffing Survey (SASS) is a survey conducted by the NCES in order to identify and emphasize the demand and shortage of teachers, teacher and administrator characteristics, school programs, and general conditions in schools.[68] It consists of four different components: the School Questionnaire, the Teacher Questionnaire, the Principal Questionnaire and the School District Questionnaire. These questionnaires are sent to respondents in public, private and Bureau of Indian Education/tribal schools. The SASS was conducted in 1987/1988, 1990/1991, 1999/2000, 2003/2004 and 2007/2008.

National School Lunch Program
The National School Lunch Program (NSLP) is a federal assisted meal program and is operating in over 101,000 public and nonprofit private schools, as well as in residential child care institutions.[69] It provides either low cost or free lunches to eligible children each day. Children are eligible for free meals if their families' income is below 130% of the poverty level. Those with an income between 130% and 185% of the poverty level are eligible for reduced-price meals. For the period July 1, 2009 - June 30, 2010, 130% of the poverty level was $28,665 for a family of four; 185% was $40,793).

Additional Variables
The following control variables are used in the regressions:

AFT-Average salary:
Data on average teacher salaries was obtained from "Survey and Analysis of (teacher) salary trends" produced by the Research Department - American Federation of Teachers. This study is available for the years 1997-2002, 2004, 2005 and 2007. As the data is always reported for

[68] Information was obtained and taken directly from the website of the U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, Schools and Staffing Survey (SASS) - http://nces.ed.gov/surveys/sass/ (accessed 18 August, 2010)
[69] Information was obtained and taken directly from the website of the United States Department of Agriculture, Food and Nutrition Service, National School Lunch Program - www.fns.usda.gov/cnd/lunch/aboutlunch/NSLPFactSheet.pdf (accessed 18 August, 2010).

an academic years -- e.g. 2006/2007 -- the indicated values are assigned to the second year indicated -- e.g. 2007 -- because this covers the majority of the time of an academic year.

Average wage:
Data on the average annual wage is given by state and was obtained from the 2009 Statistical Abstract (U.S. Census Bureau) - Labor Force, Employment, and Earnings for all years from 1990 to 2006. Data for 2007 was taken directly from the U.S. Bureau of Labor Statistics - http://www.bls.gov/oes/current/oessrcst.htm (accessed January, 2009).

COL:
This Cost of Living Index is a revised 2009 version of the Berry-Fording-Hanson (2000) state cost of living index. It was obtained from an unpublished supplement to Berry et al. (2000), "An Annual Cost of Living Index for the American States, 1960-1995".

Deflated educational spendings excluding teacher wages per pupil:
We use the data on "Educational spending excluding teacher wages" as well as the data on enrollment in public elementary and secondary schools (pupils) in order to calculate the amounts of monetary resources which are not used for teacher salaries per pupil. In order to calculate real values we deflate these values using the state specific Cost of Living Index (COL).

Educational spending excluding teacher wages :
Data on spending in elementary and secondary schools not including monetary resources used for teacher salaries. This data was obtained from the Digest of Education statistics -- Chapter 2: Elementary and Secondary Education -- Revenues and Expenditures (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics). This variable was constructed by calculating (by state and by year) the difference between current expenditures for public school and instruction. The data is always reported for an academic year and hence attached to the second year (for example, data for 1990/1991 is used for 1991).

Median household income:
The data on median household income, by state, was obtained from the U.S. Census Bureau, Housing and Household Economic Statistics Division.

Percentage of states that use pay incentives:
Data on the percentage of districts by state that use pay incentives to recruit or retain teachers to teach in less desirable areas or fields of shortage. This data exists for 1987/8, 1990/1, 1993/4, 2003/4 and 2007/8 and was obtained from was taken from the U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS) (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics). The numbers for 1998-2000 are smoothed numbers from the adjacent years.

Percentage of teachers who are union members:
Data on the percentage of teachers within each state who a member of a union. This variable was derived by Moe (2011) using the raw SASS data.

Pupils:

Enrollment in public elementary and secondary schools. Data was obtained from the Digest of Education Statistics -- Elementary and Secondary Education -- Teachers and Other Staff - Teachers, enrollment, and pupil-teacher ratios in public elementary and secondary schools, by state or jurisdiction (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics). Available for all years from 1991 -- 2007. Data for 1990 was obtained from the Statistical Abstract.

Pupil-teacher ratio:
Data for all years was obtained from the Digest of Education Statistics - Elementary and Secondary Education - Teachers and Other Instructional Staff for the years 1996, 2000 and 2008 (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics). Ratios for 2007 were constructed from the National Center for Education Statistics: http://nces.ed.gov/programs/stateprofiles/ (accessed March, 2009).

Salary:
Data on (nominal) average salaries for Public and Elementary School Teachers was obtained from the Statistical Abstract -- Education -- Elementary and Secondary Education: Staff and Finance.

Teacher experience:(less than 3,3 to 9,10 to 20,over 20)
Data on the fraction of teachers with a certain length of full-time teaching experience: less than 3 years, 6 to 9 years. 10 to 20 years or more than 20 years of teaching experience. Data was obtained from U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public Teacher Questionnaire", and "Charter Teacher Questionnaire", for the years 1988, 1991, 1994, 2000 and 2004 (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics) - numbers for additional years are smoothed numbers from the adjacent years.

Teacher qualification:(Bachelor, Master or Doctor, Education Specialist)
Fraction of teachers with a Bachelor's or Post Graduate (Master or Doctor) degree or who are Education Specialists. The data was obtained from the U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public Teacher Questionnaire" and "Charter Teacher Questionnaire" for the years 1988, 1991, 1994, 2000 and 2004 (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics). Data for additional years are smoothed numbers from the adjacent years.

Teacher wages: (TW)
Teacher wages were constructed using data on AFT-average salaries and on salaries. While the source for the first wage measure is the AFT, the source for the second one is the NEA. Accordingly, our measure of teacher wages is constructed by using these two data sets and weighting the salary data of the two sources for each state and year by the relative size of each union in each state. This relative size is measured by the relative size of the revenue in each state for each union.

Teacher wage relative to average wage in each state:
Relative teacher wages are constructed as the quotient of our measure of teacher wages (TW) and data on the average annual wage per state and year.

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