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If You Pay Peanuts do You Get Monkeys? A Cross Country Analysis of Teacher Pay and Pupil Performance

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Cross Country Analysis of Teacher Pay and Pupil Performance.

SUMMARY

Why are teachers paid up to four times as much in some countries compared to others and does it matter? Specifically, is the quality of teachers likely to be higher if they are paid higher up the income distribution in their own country, and are pupil outcomes influenced by how well their teachers are paid? If the quality of an education system cannot exceed the quality of its teachers' then teacher quality and its relationship to pupil performance is at the very heart of the debate about educational policy. In this sense each country will get the teachers it deserves by choosing to pay them at a given point in the income distribution it will get the requisite quality of teacher. We exploit the existing variation of where countries pay their teachers in relative terms to examine the relationship between teacher relative pay and pupil performance. This paper considers the determinants of teacher's salaries across countries and examines the relationship between the real (and relative) level of teacher remuneration and the (internationally) comparable measured performance of secondary school pupils. We use aggregate panel data on 39 countries published by the OECD to model this association. The results confirm the importance of market supply forces in the determination of teacher pay and suggest that relative (and absolute levels) of teacher salaries exert a powerful influence on pupil performance. Our results suggest that recruiting higher ability individuals into teaching and permitting scope for quicker salary advancement will have a positive effect on pupil outcomes.

-- Peter Dolton and Oscar Marcenaro-Gutierrez

Biographical summaries:

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FORTHCOMING ECONOMIC POLICY

If You Pay Peanuts do You Get Monkeys? A Cross Country Analysis of Teacher Pay and Pupil Performance

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1. INTRODUCTION

Why do teachers in Switzerland earn four times what those in Israel and why are teachers in Korea paid at the 78th percentile in their country's wage distribution whereas those in the USA are paid at only the 49th percentile? Do these massive variations in the way different countries treat their teachers matter for the educational outcomes of their children? It is often contended that 'the quality of an education system cannot exceed the quality of its teachers' and that the esteem that teachers have in different societies varies widely[2] which means that teacher quality and its relationship to pupil performance is at the very heart of the debate about educational policy. Some of the best performing education systems clearly recruit their teachers from the top third of each graduate cohort. Indeed, according to McKinsey (2007) in South Korea and Finland, which perform at the very top of the international league table of pupil achievement, teachers are recruited from the top 5% and top 10% of graduates respectively. Turning this logic around we suggest that the quality of teachers is likely to be higher if they are paid higher up the income distribution in their own country. In turn, we wish to logically suggest that a higher quality graduate intake of teachers will have a positive effect on pupil achievement. Therefore without even having to address the extremely difficult question of what teacher quality is, or how we can measure it, we can take teacher salaries as a good proxy for it. Hence our interest is in posing the question of how pupil outcomes are influenced by how well their teachers are paid? The answer to this 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 national comparisons that we cannot learn by looking at individual countries by themselves since those individual countries all have systems which pay their teachers similarly and face similar internal supply constraints and influences. This paper considers the determinants of teacher's salaries across countries and examines the relationship between the real (and relative) level of teacher remuneration and the (internationally) comparable measured performance of secondary school pupils. We use aggregate panel data on 39 countries published by the OECD to model this association.

In seeking to model the relationship between teachers pay and pupil outcomes one seeks a theoretical 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. In most countries medical doctors and lawyers are paid high up in the earnings distribution and as a result these professions attract the most able young people in each cohort. There is no reason, in principle, why teaching could not be added to this list of elite professions. 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[3] for them to make more effort to improve the educational outcomes

[2] See McKinsey (2007) p4.

[3] In some countries 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).

of the children they teach. The second mechanism is more subtle – namely that improving the pay of teachers improves their standing in the country's wage distribution and hence the status of teaching as a profession in that country. As a result of this higher status, more kids in that country will want to be teachers in the future. A consequence of this will be to make teaching as a profession more selective and hence facilitates the recruitment of more able individuals. The central proposition is that better pay in teaching induces a higher quality of graduates into the job and that this will improve student performance. We seek to establish whether aggregate country data supports this hypothesis, and if so, can we retrieve an estimate of the relative size of this effect. A final and more difficult question is the degree to which we can interpret the effect we find as a causal effect. Retrieving a causal effect in the 'holy grail' of empirical economic work, but rarely are experiments possible in an aggregate setting where an external validity is high. It therefore behoves economists to try and retrieve existing data on all the relevant economic variables and model carefully the underlying relationships between them.

In most developed economies the demand for schooling has been rising and there has not been a sustained rise in the relative pay of teachers. In the countries where teacher pay is not rising this could have resulted in a higher utilization of teachers either in terms of hours of work or intensity of work via increased pupil-teacher ratios. These pressures may be affecting teacher recruitment and motivation, contributing, at least partly, to a lower quality of education provision. However, if the quality of education is affected by relatively worse teachers' salary conditions, this could impact - in the long run - on pupil performance and adversely affect the process of human capital accumulation. This is potentially very important as the quality of human capital production will directly affect future economic growth.

The main emphasis of the literature on the relationship between school quality and pupil outcomes has focused on class size. This means that other significant dimensions of resource input policy decisions have received less attention. Specifically, the relationship between some teachers' attributes, such as a teacher's highest degree attained or their experience, and their pupil's achievement, is less well-known. This seems to be shifting to some extent, as the knowledge and skills required by the teachers is a matter of increasing concern from a policy perspective in most countries.

Comparative international analysis could be a useful instrument to illuminate this less explored strand of the ongoing educational debate, particularly in a context in which the national policies do not seem well orientated in that they are not sensitive enough to substantiate the link between good teachers and effective student learning. Within a country it is difficult to get a satisfactory measure of teacher quality as most public school teachers are paid (conditional on experience) very similarly on the same pay scale. This is not true if we consider cross country data as Figures 1a and 1b show how variable teachers pay is across countries. We propose to use this variability over countries and across time, to try and identify the effect of teacher's salaries on pupil educational outcomes.

Our argument is that within a country the relative wage in teaching will, on average, determine the ability and hence the quality of teachers the country gets. Clearly if teachers are paid in the top 20% of the earnings distribution of a country then one would expect that this profession would attract some of the most able graduates in the country (provided that the compensating wage differential of poor working conditions was not too large). Likewise, if teaching is really poorly paid in relative terms then one would expect that only the less able would end up in the job. (The exception of course is that some individuals may be highly motivated by teaching as a vocation and not care about the remuneration – but we assume that this will not be a totally dominating effect.)[4]

So, our thesis is that we expect that each country will get the quality of teacher it deserves by choosing to set the relative wage in teaching. Since there is huge variation in different education systems and priorities there will be a large variation in relatively how well different countries pay their teachers. As a result we suggest that in cross country data the relative wage of teachers is a very good proxy for their average quality.

In the context of the pressure to reduce overall government spending, there is a growing concern about the allocation of resources to public educational institutions. This has direct implications in terms of education and teachers, to the extent that most countries spend a large proportion of their government budgets on education and a very high fraction of that spending goes for teachers' salaries. On average (across OECD countries) 64% of current school expenditure is allocated to teacher compensation.[5]

This paper is organised as follows: in section two we provide a brief overview of the main contributions to the literature on the determination of teachers' salaries and their association with pupil performance. Section three sets up an educational production function framework for our analysis. In section four we provide a description of the cross country data to be used in our econometric analysis. The more technical considerations of the econometric model and efficiency issues are outlined in Box 1 and Box 2 but can be omitted with no loss of continuity by readers. The econometric estimation results relating to the factors affecting teachers' salaries relative to GDP per head and average teachers' salaries per hour are evaluated in section five as are the results which show a link between teachers salaries and educational performance. Finally, in section six we summarise the main conclusions and discuss possible policy implications of our findings.

2. THE LINK BETWEEN TEACHER QUALITY, TEACHER REMUNERATION AND PUPIL ATTAINMENT

We argue that teacher wages can be used as a direct proxy for (inherently unobservable) teacher quality. In order to verify the validity of this proposition it is necessary to review the available evidence of how teachers wages are related to teacher quality and how teacher quality relates to pupil attainment. This will lead us to explore the logical

[4] Some have even argued (Heyes 2005 and Barigozzi and Raggi 2010) that the 'intrinsic motivation' or sense of vocation associated with the' caring profession' can result in higher wages leading to lower productivity.

[5] See Table 2.1 p 28 in OECD (2005b).

relationship between teacher wages and pupil outcomes where we are using teachers wages as a direct indicator of teacher quality.

2.1. The Link 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, employee quality can only be demanded and worker motivation elicited 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) and Ferguson (1991) find that higher salaries are associated with better-qualified teachers.

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. The link between salaries and teacher quality is also 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 and consequentially lowered teachers relative earnings and possibly teacher quality. This may help to explain why advanced countries have managed to lower pupil-teacher ratios while experiencing reductions in relative teacher quality (Lakdawalla, 2002, 2006). The low quality of education and especially basic education is a severe problem in most developing countries (Glewwe, 1999). Although this problem does not exclusively affect poor countries, Hanushek and Luque (2003), show that there is a clear positive relationship between spending per student and GDP per capita. Poorer countries tend to spend less per student than richer countries, nevertheless, there are several countries, e.g. Japan and the Netherlands, which have comparatively moderate expenditure per student and still remain among the countries 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 were 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. These papers model the declining share of female teachers over much of the last century and most of these changes have happened prior to 1995 when our data start. In addition these papers focus on the USA only. This pattern of the de-feminisation of teaching has not occurred in most countries. Notwithstanding these caveats, we do control for the fraction of teachers who are women within each country over time in our analysis.

2.2. The Link Between Teacher Quality and Pupil Attainment

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 statistical problems[6] not least because 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 countries, Lavy (2009), using data from Israel, and PISA, shows that instructional time has a positive and significant effect on test scores. He also finds that this relationship is qualitatively different for developed and developing countries. With the latter having around twice the effect size of the former. It is therefore important we control explicitly for this factor in our econometric study whilst appreciating that it is common in some societies for state school teaching hours to be supplemented by private school hours on a Saturday - particularly in Japan and Korea. Regrettably we do not observe the extent of this.

[6] See Hanushek (1986) and Lazear (2001) for different takes on this debate.

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 countries. 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 and Luque (2003) provide a wide and critical review of the evidence around the world on the effectiveness of input-based schooling policies. In fact, Goldhaber (2002) asserts that it is key to attract and retain high quality teachers, because of the link between teacher salaries and student outcome. Rivkin *et al.* (2005) found that the best teachers can achieve an additional year's worth of learning from their students compared to the least effective teachers. Further, 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).

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 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[7]. 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 countries (planned Economies, OECD countries, Asian, African and Latin American countries) 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[8]. We perform a new analysis of the Barro and Lee model on an annual country by country 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 country data and the TIMSS test scores as outputs. In most of the 15 European countries 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 another strand of the literature, 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. This work is continued in a large scale cross country analysis of the link between cognitive skills and economic development, where Hanushek and Woessman (2008) have sought to examine the link between all the different pupil attainment data (including PISA, TIMSS and other 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 countries.

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 directly affect a country's growth[9]. 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).

[7] 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).

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

[9] This argument is strongly supported by the human capital theory, which relies on the assumption that more educated workers enjoy greater productivity, thereby contributing to the country's economic growth.

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), 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 from 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 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 pupil drop-out rates by 3-6%.

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.

3. ECONOMIC MODELLING OF EDUCATIONAL OUTCOMES

The most straightforward economic model of educational outcomes is to consider the production of educational outcomes as a function of inputs and resources; like pupil teacher ratios, teacher quality and other factors. Cross national comparative analysis is then possible using achievement in specific areas like Maths and Reading and Science. Using cross country data the family factor cannot even be considered. The bulk of the literature which uses international cross country data has focussed on the variation in the use of resources to try and explain the variation in pupil outcomes. We seek to extend this literature and specifically focus on the role of teacher remuneration. In this context, teacher pay – or the amount spent on teacher pay, is just one of the resources used in the production of pupil outcomes.

The logic of teacher pay as an input into the production of pupil outcomes is that higher pay will facilitate the recruitment of higher ability graduates into the profession. Clearly, if teacher pay is low relative to other professions, then the quality of new recruits will be lower than in those alternative professions.

We start from the premise that higher teacher quality induces higher pupil performance, Y – and that this induces a linear association based on the idea that any more able

workers are more productive. We suggest that teacher wages are set in any country by the forces of supply and demand, as determined by the government in terms of their spending constraint and their spending priorities. Once set, the teacher wage, *W,* will generate a specific level of the quality or ability of the graduate who is recruited. Specifically we assume that the percentile point[10], *p%* of the income distribution that *W* is set from will, on average, be some positive function of the percentile point on the ability (or teacher quality) distribution from which teachers are drawn.

This means that, although the level of teacher quality in any country is not observed, we do in fact observe a good proxy for it, namely the teacher wage, *W*. This can be derived by simply assuming the relationship between teacher ability influencing pupil outcomes and the wages of the more able being higher; taken together they would directly imply that, on average, teachers drawn from higher up the income distribution will secure better pupil outcomes.

Our approach is to estimate a two equation model to explain the variation in teacher pay and pupil performance across countries. The econometric model we estimated is outlined in Box 1. Technical details of our econometric methods are provided in Appendix C (available upon request). Basically we have the usual econometric problems of trying: to work out if there are significant missing explanatory variables which contribute to unobserved heterogeneity; to establish whether our model can adequately summarize the data in terms of a single equation; whether our results are sensitive to the particular estimation method we use; and attempting to make the most of the panel nature of our data. Our additional problem is that we have several different measures of our key variable – the real relative wage of teachers. Ultimately, of course, we cannot 'prove' that drawing teachers from higher up the earnings distribution will 'cause' students to perform better. All we can do is to use the available econometric estimation procedures to examine aspects of the strength and robustness of this statistical association. Hence our approach to these problems was basically to use the variety of different econometric estimation procedures which attempt to circumvent these problems. We report and comment on only the synthesis of these labours and provide technical details in Appendix C (available upon request).

Inevitably the potential problem is one of identification. One can consider that this is a problem if the same unobservables influencing teacher pay also influence pupil outcomes. It could be that there are unmeasurable, inherent characteristics of certain 'good' educational systems which make pupils learn effectively and reward teachers well. This may itself be determined by the importance attached to education by politicians, and voters. Alternatively one can consider this as a simultaneity issue – i.e. how can we be sure that it is not the prospect of teaching well performing kids that tempts recruits into teaching – rather than it being well paid, able teachers who facilitate good pupil performance?

Our econometric analysis seeks to identify the relationship between teacher's salaries and its determinants and average pupil attainments and its determinants. Since we are

[10] See Data Appendix for a description on how the teachers wage percentile position has been retrieved.

fortunate to have panel data, identification of the parameters of interest relies on there being cross country variation in the dependent variable across countries over time, and that unobserved heterogeneity for each country is constant across time or that such unobserved heterogeneity, if it varies across time, is independent of the explanatory variables in our regressions. Under the above conditions, our panel data estimation will provide consistent estimates of the marginal relative importance of the determinants of average salaries in explaining average pupil attainment.

The scope for there being considerable country specific unobserved heterogeneity which changes across time is strictly limited. This is because all the data we use is measured at an average level within the country so that many idiosyncratic observations within a country (for example by school) will be averaged out. There is also limited scope for changing unobserved heterogeneity within a country over time since most of the political and educational institutions of each country will remain constant and relatively unchanged over the 12 year period of our data. We discuss the problem in more detail in Appendix D (available upon request).

Examination of Figure 2 and Figures 1a and 1b show us that there is considerable variation in both average teacher salaries and average pupil attainment across countries. This gives us some confidence that we are seeking to estimate models to explain changes in the underlying earnings structure based on the changes in the educational performance of children.

4. DATA SOURCES: TEACHER SALARIES AND INTERNATIONALLY COMPARABLE PUPIL ATTAINMENT SCORES

The most comprehensive source of comparative information about teachers in different countries around the world is from the OECD (2001b, 2005b). Together with the other *'Education at a Glance'* publications from the OECD (1996-2009) it is possible to build up a picture of what has happened with teachers in different countries. This is done by collating all the data from each of these separate publications. This collated data provide information on teacher salaries, both starting salaries and salaries at the top of the profession as well as after 15 years of teaching experience. The same sources also provide country by country details of: educational expenditure, the percentage of teachers who are women, teacher work hours, educational personnel as a percentage for the labour force and instruction time by subject. In addition, much of this information is available separately across primary, lower secondary and upper secondary school sectors.

Data of the kind examined for the USA and the UK by Dolton *et al.* (2003) relating to pupil numbers, teacher numbers, teacher wages and other factors relating to teacher supply are difficult to obtain on a consistent basis for most other countries for any reasonable time series. Hence, in order to understand what is happening across countries we examine evidence by pooling OECD (and WEI program) countries data. In this paper,

we examine the relationship between teachers' salaries and some economic and educational variables for the OECD countries.[11]

The data which are available from the OECD *'Education at a Glance'* publications allows us to construct a panel data set relating to 1995, 1996, 1998-2007[12]. For most of these years up to 39 countries are observed. At the maximum this gives us a panel data set of 1404 observations (i.e. 39 countries, times 3 education sectors times 12 years). However, for some variables not all years are observed. This means that our resulting panel data is 'unbalanced' – in the sense that it has some holes in it – but in most situations if we have enough countries for enough years this does not matter much. In this data, basic characteristics of the educational system are observed (or derived) from other sources. These are detailed in our Data Appendix.

Our task is to explain the variation in teacher's salaries across different countries by relative supply and demand factors having controlled for the basic cross country heterogeneity which can be observed. A major difficulty in any study of this sort is the existence of heterogeneity in the educational systems of the different countries that cannot be easily observed[13]. A major concern is that there is considerable variation in teacher training, teacher recruitment procedures, teacher retention and other organizational features – this makes any comparison at the international level more difficult. These are inevitable shortcomings of the data we use. It is also important to acknowledge that we have no measure of physical capital differences by country. For example, some countries have integrated computers and IT software into their educational structure more than others. Nevertheless an examination of this nature, i.e. using a cross-country set of data provides advantages that single country datasets do not. In such an analysis, each country would be at different points in the economic cycle and hence, any significant relationship between the variables representing teacher supply and the economic cycle in this data set would be evidence of a link between these two components. A further area of concern is that we do not observe countrywide controlling data on family background. Although PISA data does record some simple information about the parents of the children tested we do not have any comparable aggregate measure of family background across countries. It should be recognised that omitting family factors in our estimation analysis is an important limitation especially since family human capital could be a natural compliment in the production of better educational scores for children. A mitigating factor in the deficiencies of our data are that since we are using panel data – a cross section of countries measured over different years – then these omitted variables in our econometric estimation will not be very important if they do not change much for each country from year to year. This is the case with many of the variables that we do not observe. In essence the explanatory power of our econometric model comes from variations across countries over time.

[11] The data is available for countries which participated in the WEI program. This program was carried out by the OECD and UNESCO, with the support of The World Bank.

[12] There are unfortunately no data for 1997 published by the OECD.

[13] An additional difficulty is based on the changes in policy and institutional settings in each country that have contributed to growth aside from the changes in inputs of physical and human capital.

The pupil performance data we use are provided by PISA tests in 2000, 2003 and 2006 and TIMSS tests in 1995, 1999 and 2005. TIMSS data relate to tests in the 4th and 8th grade in Maths, Science. PISA tests are sat by 15 year old pupils in Maths, Science and Reading and are unseen by the pupils prior to the date of the test and are not rehearsed for. These tests are identical across countries and there is no evidence of 'teaching to the test', as occurs with country's own exams. (For example Key Stage test in the UK have had the same structure and kind of content since their inception and hence are practised for by pupils in class up to a year before they are sat.)

It is clear that in some countries PISA tests have recently caused major controversy – e.g. in Germany[14] and hence there is a cause for concern that this may have influenced the German education system to gear its pupils more towards the core subjects covered in the PISA tests. However, this can only be a very recent phenomenon and it is unclear to what extent this could change the profile of their country's results – even in the most recent tests.

Another issue is that the PISA and TIMSS test only focus on the core subjects and ignore subjects like – History, Geography, Languages and the rest of the curriculum. Indeed some countries may attach much more weight to these subjects in the belief that they are more useful or productive for the needs of the labour market. This is unlikely to affect our conclusions since all the evidence points to the core subjects being the most important for measuring productive effectiveness of the curriculum. Dolton and Vignoles (2002b) show how curriculum breadth is not important in the returns to education To the extent that the PISA and TIMSS measure core skills we know that there is a link between them and earnings in later life. In a separate paper Dolton and Vignoles (2002a) show how the return to high school Maths is very clear, despite conditioning on all previous education. However there is no direct evidence of a link between PISA and TIMSS scores and earnings, as the school pupils tested have never been followed up to find out how they fared in the labour market in terms of earnings.

In this paper we have used three different ways of measuring relative teacher salaries. The first is to take the power of teacher salaries to purchase goods and services (taking account of the cost of living differences in each country) as measured by converting salaries to U.S. dollars using purchasing power parities (PPPs). Teacher salaries converted using PPPs represent the sacrifice of other goods and services that a country gives up to support a teacher. In other words, teacher salaries expressed in U.S. dollars indicate the cost of teachers relative to the general market basket of goods. The second measure of relative pay is to take this level of teacher pay in real terms and normalise it to an hourly rate by dividing by the number of working hours to facilitate homogenous comparisons across countries. The third measure of the real value of a teacher's salary we have used is to work out the percentile in the countries wage distribution that a teacher is paid at.[15] A further alternative measure of the value of teacher's salary across

[14] See the website of Joachim Wutte at www.messen-und-deuten.de/pisa/biblio.htm for a full list of references critical of PISA scores and rankings and Hopman and Brinek (2006) for a summary.

[15] This is done by comparing the teachers wage with the average GDP per worker in the country and using the Gini coefficient in the country to measure inequality then under the assumption of the lognormality of the earnings distribution it is possible to retrieve the percentile that teachers are paid at Appendix A provides details (available upon request).

countries is to take the salary expressed as a fraction of the average GDP per head in the country. We also used this definition of an internationally comparable teacher's wage and report the results for this type of deflation in Appendix B (available upon request).

Another measure of the investment in teaching is the statutory teacher salary relative to the number of working hours per year. It provides an estimate of the cost of an hour of teacher instruction time across countries and makes an explicit correction for the larger variability in the number of teaching hours there is across countries.

The cross country average statutory salary in 2007 per teaching hour after 15 years of experience was $39 in primary education, $47 in lower secondary education, and $57 in upper secondary (general) education across OECD countries (OECD, 2009). For primary education, Mexico, Turkey and Hungary have relatively low costs per hour of instruction (below $25); by contrast, costs are relatively high in Germany ($66, $76 and $87, respectively), Japan ($69, $81 and $98) and Korea ($73, $100 and $114).

Salary and teaching time are only two components of teacher working conditions. 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 teachers ages, we decided to use all the salary data available to us. We therefore use the data on: beginning teachers, teachers with 15 years of experience, and teachers on the top of their salary scale. This makes use of the maximum amount of information for each country for each year. In using all this data it is worth pointing out that this will then embody all the structural differences in the determination of teachers pay in each country. Specifically we will then have the both flat, declining and very progressive wage structures as well as data from country's where teachers wages have been rising, constant or falling.

We measure the nature of the country's investment in education by the level of educational expenditure as a fraction of GDP and we control for the rate at which a country is growing, since clearly this will constraint its choice set of educational investment possibilities open to the country's educational authorities.

The relationship between educational and total spending repeats itself in nearly all developing countries and across all continents. In Latin America, for example, countries, such as Uruguay, that experienced high economic growth generally increased public spending as a percentage of GDP, which led to hikes in educational spending of 5% and 4.3% per annum, respectively. Across OECD countries there is a broad range of expenditure per student. At the primary level, expenditure ranges in 2006 from US$1130 in Turkey to US$9709 in United States (or US$13676 in Luxembourg). Differences between countries are even greater at the secondary level.

To get a clearer picture of the relative importance of the educational sector, in the WEI countries at least 4% of all employed persons work in the education system, but in some cases (e.g. Tunisia) this figure rises to 7% and represents a high proportion of the labour force that have a tertiary qualification (OECD, 2001a).

Examining the data allows us to check that educational expenditure on instructional services, below the tertiary level, account for the highest proportion of educational spending. What is more, changes in enrolments do not seem to have been the main factor driving changes in expenditure per primary and secondary student.

The relative supply of teachers is measured by the number of teachers (and other educational staff) as a fraction of the labour force and the Pupil/Teacher ratio in the education system. An additional supply factor relates to the composition of the teacher stock in terms of the proportion of teachers in the country who are women. We also control for the number of teacher hours supplied in the country, as obviously fewer teachers can be compensated for by a lower number of teachers working more hours. The changing nature of the demand for teacher services is proxied for in this data by the demographic growth in the size of the population of school age. In addition we are able to control for the salary differences in the three education sectors: primary, lower secondary and upper secondary schools. It is further possible in some countries to observe the fraction of curriculum time devoted to science and mathematics but such factors proved not to be significant in the determination of teacher wages or pupil outcomes[16].

The second part of our analysis is to examine the relationship between teacher remuneration and educational attainment. To this end we collected data to measure the quality of educational output – by using results on the PISA (2000, 2003 and 2006) and TIMSS (1995, 1999 and 2003)[17] tests across all countries for all available years. We report the results of our investigation after setting out the econometric framework of our analysis in the next section.

The basic form of the salary data can be seen in Figures 1a and 1b which examine the pattern of secondary school teacher salaries after 15 years in 2007 in PPP$ in Figure 1a, and relative to the position in the earnings distribution in Figure 1b. Although there is some concordance in the ordering of the countries in the measures there is also some notable differences. Some countries pay their teachers well no matter how we measure relative pay – like Korea, Switzerland, the Netherlands and Germany. On the other hand, some countries, like Turkey, fare well in terms of relative ranking (Figure 1b) but are low in terms of real $PPP salaries (Figure 1a). Likewise, Norway and Sweden pay their teachers well in money terms, they fair rather badly in relative terms compared to the percentile position in the earnings distribution. Such differences will make consistent results found on the relationship between educational outcomes and teacher salaries logically more robust.

Figure 2 illustrates another characteristic of teacher salary data across countries. Namely, how teachers wages rise (on average) with years of experience. Specifically, in this figure we graph the average salary at the start of the career, 15 years into the job,

[16] The suggestion here is that since there is a relative shortage of teachers in these subjects in most schools then this might show up in the relative earnings of teachers if the fraction of time devoted to science and mathematics was higher. In the event neither of these two variables were significant in our regressions and since they reduced our sample size somewhat further we have omitted these results.

[17] See Woessman (2005) for a country by country production function study which uses TIMSS but does not consider the role of teacher remuneration in the production process.

and towards the end of their career. In most countries there is a clear return to experience with a definite gradient to this wage-experience profile. However, some countries, most notably the South American and former communist countries (Brazil, Chile, Uruguay, Peru, Czech Republic, Hungary) but some others too (Indonesia, Israel, Philippines, Tunisia and Turkey) have a very flat experience wage profile which indicates quite a different structure to the rewards in teaching those countries. Specifically the job is regarded as a career position without a hierarchy or the need to reward experience and time served.

An indication of the data available to us from PISA and TIMSS is captured in Figures 3a and 3b. Here we order the standardised scores and their variability by country. Looking at Figure 3a and 3b we see there is a remarkable difference between the orderings. It seems that the countries with the highest standardised mean score are slightly more likely to have a low variability and vice versa. This impression is borne out in Figure 3c where we can see a loose negative association between standardised score and the variability of the score. This relationship is worthy of some further investigation in our regression analysis.

Figure 4 is the figure at the heart of our investigation. It plots the relationship between standardised scores and average teacher salaries by country. Here we can see quite a good positive association between these two variables of interest. Naturally this relationship needs careful analysis including all the conditioning information which is relevant – but this basic scatter plots provides the rationale for a thorough investigation.

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 some of the variables in the OECD data sources measure what they purport to measure. All we can do when faced with this criticism is to use the best available data, making clear our sources, and acknowledge its published limitations. A further obvious criticism of the data we use is that it ignores huge disparities within countries between schools, teacher and pupils. Most importantly, working with country averaged data means that we ignore the variability of education provision sorting which takes place within a country which shows how high quality teachers get allocated to the best pupils[18] – or indeed – some teachers move into administrative jobs in schools which take them away from direct pupil contact and teaching.

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. At this juncture it is also worth pointing out that many of the forces which determine the variability of the teacher labour market across countries are actually largely fixed over time. The working conditions of teachers vary a lot over countries. In some countries public school teachers are pensioned civil servants – this means their effective remuneration over their lifetime may not be adequately captured in their wage whilst working as their pension may be very generous. Clearly there are many components to total remuneration – including:

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

pay, pension, retirement age, health insurance, holidays and hours of work. All these conditions should ideally be included in a 'total remuneration' figure for each country for each year when satisfactorily comparing different countries remuneration of teachers. Unfortunately we do not observe all these components of pay. However there are two factors which mitigate this limitation to our data: firstly, as detailed in our Appendix D (available upon request) most of these benefits do not change over time within a country and secondly, to a large extent, the countries with the best teacher pay also have the best total reward in terms of added benefits. So if anything this means there may be a downward bias in our results.

We are also aware that teaching is heavily unionised profession with quite dominant unions that bargain directly with the government over their pay on an annual basis. In other countries teachers are hardly unionised at all. In some countries the private sector of education is really rather large – in other countries it barely exists at all. We are also aware that countries differ hugely in their methods for teacher selection and teacher certification. There are also major differences in the approach to continuing professional development and training in different countries. These huge differences between countries are excellently described in OECD (2001b) and (2005b). Whilst we recognise that this huge unmeasured and largely unobserved heterogeneity across countries exists and may affect our estimations it is worth pointing out that if this unobserved heterogeneity remains largely constant across time – then to a large extent - it does not make any difference to our results. In Appendix D (available upon request) we provide more details of this unobserved heterogeneity and evidence which suggests that much of it remains constant over time.

There are many important determinants of the way in which teachers are hired, trained and other wise treated which will affect the quality of person who becomes a teacher. The policy on teacher hiring is remarkably different in each country. In the OECD (2005b) (Figure 5.1, p 153) there is a clear difference between the responsibility for hiring and dismissing teachers from it being 100% the task of the principal (Luxembourg) to not the school's responsibility at all (Hungary, New Zealand, Iceland). There are also huge differences in: teacher pre-service educational requirements, OECD (2005b) (Table 4.1, p 106) the way teachers are trained OECD (2005b) (Table 4.2, p 118), how long it takes and the frequency and availability of Continued Professional Development OECD (2005b) (Table 4.3, p 124). A further way in which teacher recruitment differs across countries is that the alternative occupation which may be considered by teachers in each country - i.e eg Social Worker, University academic or Librarian has a completely different status and relative salary as compared to teachers in different countries, OECD (2005b) (Table 3.2, p 76). Unfortunately all of this data was only available as a special adjunct to the PISA survey and hence only available for the year 2004 and hence not in a form one can use in a panel data analysis. Of course this is regrettable but since most countries do not change these policies very often then, arguably most of the effects of these differences in teacher policies can be netted out in our panel econometric analysis estimation.

5. EMPIRICAL EVIDENCE

5.1. The Determination of Teacher Pay

In the first part of the empirical analysis we seek to explain the determination of teacher wage across all our countries. As explained in section 3 there are a variety of ways of measuring a teacher's salary and we seek to examine the determinants of each proposed measure of salary. We measure the nature of the country's investment in education by the level of educational expenditure as a fraction of GDP and we control for the rate at which a country is growing, since clearly this will be a constraint its choice set of educational investment possibilities. The relative supply of teachers is measured by the number of teachers (and other educational staff) as a fraction of the labour force and the student/teacher ratio in the education system. An additional supply factor relates to the composition of the teacher stock in terms of the proportion of teachers in the country who are women. We also control for the number of teacher hours supplied in the country, as obviously fewer teachers can compensated for by a lower number of teachers working more hours. The changing nature of the demand for teacher services is proxied for in this data by the demographic growth in the size of the population of school age. In addition we are able to control for the salary differences in the three education sectors: primary, lower secondary and secondary schools.

Table 1 presents the regression estimates of the aggregate factors that have an impact on the teachers' salaries measured in two ways; firstly, as average teachers' salaries per hour, secondly as salary expressed in PPP. Separately we examine in Table 2 relative pay of the teacher expressed as the percentile that the person is paid at in the earnings distribution of the country in question[19]. In these regressions we make use of all the data on teacher's earnings on starting in the career, after 15 years and also at the top on the pay scale. In each case we use data on teacher's salary in primary education, lower secondary education and upper secondary education. Table 1 shows the results of the two different specifications for each of the first two dependent variables, those obtained by using OLS (in a pooled regression) on the whole data and those based on panel data estimation (variable definitions are found in the Data Appendix). It should be borne in mind that this table represents a diversity of results as there are two different dependent variables and two different estimation procedures reported in this table. As a result we would not expect there to be full agreement across the rows of this table with respect to the sign and significance of particular marginal effects of specific regressors on different dependent variables using different estimation methods. Table 2 then presents the same results for the teachers wage expressed as a percentile in the earnings distribution.

Looking at both Table 1 and Table 2 there is an indication that the relative supply of teachers, as measured by the stock of teachers in the labour force, has a clear effect on teacher salaries in the appropriate way – that it to say – the greater the potential supply, the lower will be teacher's earnings. In Table 1 we find this effect clearly when OLS is

[19] Separately in the Appendix B (available upon request) we also consider teachers pay measured relative to GDP per head.

used but somewhat dissipated when panel estimation is used in the salary specification – i.e. column 2. When we consider teacher relative pay in Table 2 the effect is even clearer. This finding accords with numerous studies of individual countries (for example Dolton *et al.* 2007) which show that the size of the stock of inactive teachers (mainly qualified women teachers on career or family breaks) will affect the salary earn by those serving in the profession.

Our educational model suggested that one way of teaching more pupils is to increase the pupil/teacher ratio. To compensate teachers for this deterioration in their working conditions one would expect to have to pay them more. Therefore one would expect that as the pupil/teacher ratio rose we would expect salaries to rise. This is what we see in the panel estimates for teacher pay in panel 2 of Table 1. We also find in Table 2 that this effect is strongly significant for beginning teachers on the lowest wage, teachers with 15 years experience and those at the top of their profession.

Another way to increase resources into educational production is to simply put more hours into the school year. There is some evidence that this will reduce the hourly wage of teachers – this is logical as if we increase the denominator of the hourly pay computation then as hours rise the hourly wage rate will fall. If however we look at the absolute wage in real terms at any point of the teaching career (Table 1 panel 2) or we look teachers wage percentile (Table 2) then we see that as hours rise pay will rise as a compensating wage differential. Turning to the effect of a higher pupil- teacher ratio - this will raise teacher pay and this effect is invariant to how we measured relative pay. This is evident from Table 1 and 2.

Further evidence of the influence of supply factors is present in the significance of the percentage of teachers who are women for both of the dependent variables under consideration. Worldwide (in our sample) this fraction has not been falling and shows a slight rising trend up to the most recent figures of around 67%. This variable has a negatively significant impact on teachers' salaries when OLS is used and for teachers salaries per hour when panel estimation is used. This may result from the possibility of gender wage discrimination or from the occupational segregation which takes place in most countries where teaching is still regarded as predominantly a female occupation. Alternatively, it may be a consequence of the different career promotion prospects faced by the male and female teachers in the various countries that we examine.

On the demand side it appears that as the stock of school age children grows then this demand push will translate into lower wages and lower wages per hour (Table 1, panel 1) and lower percentile relative wages at every point on the teacher pay scale (Table 2). One explanation of these findings is that as the demographic size of the cohort rises then, in the short run, there is more pressure for teachers to add extra hours to their teaching day for no extra pay or that the more experienced teachers bear this burden[20].

With our two different dependent variables we must be careful how we control for the relative wealth of a country and the effect of economic growth. Specifically in the

[20] The result is the opposite if we use teacher wages relative to GDP per head (see Table B1). One explanation of this finding is that, it may simply be that as the demographic burden of increasing pupils to teach rises then teachers wage relative to GDP per head rises accordingly in the longer run.

teachers wage per hour equation, we control for this absolute wealth effect, although this will limit the specification to exclude growth in GDP as a regressor. The results relating GDP growth to teachers' relative salaries compared to GDP per head indicate that there exists a positive relationship between the changing wealth of a country and their teachers' salaries. In both the teacher pay and the teacher pay per hour results we find that the wealthier a country is (as measured by GDP per head) the more likely they are to pay their teachers more per hour. This is logically related to the relative wealth of the country with more developed economies having the potential for larger public sectors.

As expected, any increase in the expenditure on educational institutions (as a percentage of GDP) has a significant and positive effect on teachers' salaries when we consider OLS estimations. This occurs because a large part of any country's educational budget is taken up with salary costs as logically when a country chooses to spend more on education it is more or less obviously spending more, in proportionate terms, on teacher remuneration. This effect is mostly a result of absolute values of the fraction of GDP per head spent on education as the panel estimation results do not reveal that changes in this variable affect teacher's salaries.

In the equations reported in Table 1 we use two dummy variables to control for whether the teacher pay variable is for those with 15 years experience or those at the top of the teacher pay scale (relative to those just starting the job) and two dummy variables are used to measure the differences among teachers' salaries in the lower secondary, upper secondary and primary education levels (the latter is the reference group). These variables have positively significant coefficients when the panel models are estimated suggesting that when cross country heterogeneity is accounted for then there is evidence that teachers in lower or upper secondary schools are paid slightly more than their primary school counterparts. Likewise, the dummy variables being a teacher with 15 years experience or at the top of the scale show a reasonable marked return to experience. The nature of these coefficients is that they give average marginal effects which may disguise the plethora of salary reward patterns in different countries. Considering again the evidence in Figure 2 we see that in some countries the pay schedule by experience is fairly flat - (Sweden, Norway, Peru, Germany, Tunisia, Spain and Turkey) but that in others there is a marked difference between wages at the beginning of the career and after 15 or more years - notably in Portugal, UK, USA, Austria, Netherlands, France, Thailand, Korea, Belgium, Uruguay, Malaysia, Hungary, Denmark, Argentina and the Czech Republic).

5.2. The Determination of Pupil Performance

The first systematic studies of the determination of student performance across countries were presented in the work of Barro and Lee (1996, 2001) and Lee and Barro (2001). Our contribution in this paper extends their pioneering work in a number of key respects. Firstly we have much more modern and comprehensive data on the cross country education performance of school pupils. Secondly our data is of sufficient quality and quantity to permit the unit of analysis to be the country rather than the 'country group' as

in this earlier work. Finally, and most importantly, we are exploring in some detail the link between teacher's remuneration and pupil outcomes – this was only a peripheral concern in their work and not its central focus. This focus is facilitated by the extraordinary quality and detail of the teachers wage data across countries provided by the OECD – which to our knowledge – has hitherto not been exploited.

Having examined the determination of teacher remuneration we now turn to the question of whether the relative pay that a teacher receives in any given country has an impact on pupil performance. Logically one would expect that where teachers are paid in the wage distribution of a country is a measure of how teachers are regarded in that country. Or more specifically we can take this relative pay of teachers to be an indication (or proxy) of the relative quality of teachers. With our data we know this relative quality by country across time. Hence we know from what part of the wage distribution teachers in each country are paid at over time. We would expect this to be potentially related to the possible relative performance of the pupils provided that higher teacher relative wages induce more able recruits to become teachers and secondly that more able recruits make better teachers. Since these two assumptions are a natural starting point for the analysis we do not rehearse them any more on the grounds that the first assumption constitutes a logical property of labour markets and the second assumption should be a logical basic premise of selective teacher recruitment.

Naturally in this investigation it is important to have standardised tests of school children which are the same across countries. Such tests are provided by TIMSS and PISA. We use the scores on these tests – suitably standardised – to examine how the performance of pupils in different countries over time is affected by the resources that have been used to teach them in terms of Teaching hours, Pupil/Teacher ratios and other factors. Conditioning on these factors we then address the question of whether there is any relation between teachers relative pay and pupil performance.

Our main results are tabulated in Table 3a. Here we use two different possible regressors to examine the effect of teachers pay – namely, salaries after 15 years experience and percentile in the GDP per worker distribution. Our main result is that we find that pupil scores rise significantly as teacher salaries rise (in both real terms and relatively). Our (OLS) results suggest that a $5000 dollar rise in teacher pay (or a 10% increase in real pay) increases pupil standardised performance by .26 of a standard deviation in the standardised score which is equivalent to around a 10.3% increase in pupil performance. The panel estimates imply that a $5000 dollar rise in teacher pay increases pupil standardised performance by 5.9%. Likewise, a 5% increase in the relative position of teachers in the salary distribution increases pupil performance by between 5.1% (OLS), and 9.8% (Panel estimates).

There are also other interesting effects of what determines pupil performance apart from teacher salaries. The most important effects found in Table 3a are that in the simultaneous estimates and OLS estimates Pupil/Teacher ratios have a 5.7-8.2% negative effect on pupil performance – i.e. that as the pupil teacher ratio rises this will affect pupil performance by a sizeable factor. Likewise we find that an increase of pupil contact hours of 100 hours will increase pupil performance by between 5-10%

depending on whether simultaneous estimation or OLS is used[21]. Since average teaching contact hours are around 750 hours this constitutes a rise of teaching hours of around 13%.

One important caveat of the results in Table 3a are that as panel estimates they depend crucially on the assumption that the unobserved heterogeneity does not vary across time. Whilst this seems not to be a very strong assumption with respect to the unobserved characteristics of educational systems over a 12 year period this is something which we should investigate. One way to investigate the robustness of our results is to estimate the model using a simultaneous estimation method to capture the possibility that teacher wage determination is simultaneously. The results of the simultaneous equation estimations are reported in column 3 and column 6 of Table 3a for the two specifications we estimated by panel estimation methods. Reassuringly when we estimate our pupil performance equation using this method we see that the results of our estimation are directly comparable to those we found with OLS, and panel estimation. Specifically we find that the effect of teachers wages on pupils outcomes is still positive and statistically significant and with a marginal effect which is directly comparable to our earlier results.

A second form of robustness check we can perform is to consider the growth in teacher's earnings over the life cycle rather than simply the level of teachers wages. This we can do as we have teacher's earnings at the beginning, after 15 years in the job and at the end of the job. Hence, with this data we can approximate the slope of the age earnings profile over the whole life cycle and use this as our regressor instead of the level of teachers earnings per se as we are concerned about the endogeneity of the former variable. Hence our suggested regressor is an average difference (of wages over the lifetime) and this, it could be argued, will not be endogenous. Table 3b reports our estimation results when we use this growth in earnings variable. Here we see that using panel estimation we again have an earnings effect on pupil outcomes. The implication of this result is that a positive wage profile – in terms of a steady advancement of earnings over the life cycle – will give able teachers the appropriate incentive to stay in the job. As a result of this we are suggesting that pupil test scores will benefit directly.

Further robustness checks to establish whether the estimation was sensitive to using a nonlinear specification or to which countries were included in the estimation were conducted. Again our results do not change much at all. We report our results in Appendices E and F, available upon request.

A final form of robustness check is to consider the separate pupil tests scores we have in Maths, Reading and Science as separate entities – as up to now we have averaged them. The advantage of this is that we are then estimating the model as a system exploiting the possibility that the errors in the separate equations are related. This will lead to more efficient estimation. Since this technique has already been used in this context by Lee and Barro (2001) we adopt exactly their specification to estimate this model. Our results are reported in Table 5. Despite the fact that their model uses quite different regressors – namely Expected Years of Education and Educational Expenditure

[21] When we add a dummy for PISA (vs TIMSS) and/or a dummy for science, read (vs math), their coefficients are not significant and do not change the rest of coefficients.

we continue to get a clear effect of teacher's earnings on children's educational outcomes. Indeed our estimation results may be encouragingly compared to those of Lee and Barro (2001) since we get clear effects of Educational spending, Expected years of education and Pupil/Teacher ratios whilst the Lee and Barro paper (2001) do not get clear results on the presence of teacher wage effects.

One logical question which arises with this result linking average student performance with average teacher salaries is whether this relationship is affected if we consider the effect on the distribution of pupil attainment.[22] In other words, does rewarding teachers better (or recruiting a higher quality teacher) drive up average performance of pupils at the expense of narrowing the distribution of performance. This can be investigated in two ways. Firstly to see if our original result is robust to controlling for the standard deviation (SD) of pupil performance within the country (last two columns of Table 3b) and secondly by using the measure of the variance of performance as a dependent variable to see what is driving its variation across countries (Table 4). In Table 3b we report that the link between teachers salary and pupil performance is not changed much by conditioning on the SD of pupil performance – i.e. that a $5000 rise in teacher pay would increase pupil performance by around .24 of a standard deviation or around 9.5%. Likewise the effect of the relative pay of teachers, in percentile terms is robust to adding the SD of pupil performance as a control. Adding the SD of pupil performance to this regression shows that there is a negative effect on pupil performance i.e. that there is some trade off resulting in higher average performance of pupils may result in a lower SD of performance – in which case there is some evidence that putting resources into pushing up mean pupil performance may result in there being a smaller variance in this performance. Such a result is not surprising as initiatives which 'teach to the test' – can result in bringing up the performance of the less able children whilst curtailing the performance of the most able children and hence reducing the variance of pupil performance overall.

Continuing this line of investigation, that is, what determines the variability of student performance, we explore the statistical correlates of this variable in Table 4. Here we see that, as the teacher quality rises (in terms of percentile position) or as teacher pay rises in PPP terms, then the variability of pupil performance increases. It is not immediately clear that there is a logical explanation for this finding. Perhaps the most interesting determinant of the variability of pupil performance is that it rises as the number of teaching hours rises. This is a fundamental relationship which suggests that as teaching hours rises by 100 per year then the SD of pupil performance will rise by around .22-.25 – of a SD for a standard normal variate. At the mean of such a variate this is equivalent to around a 9% rise in the SD. Such a finding has a logical plausibility as it suggest that as more hours are taught then the brighter students will learn more and increase the gap of achievement between themselves and the weaker students.

[22] Other studies concerned with the equality of educational opportunity have examined the role of family factors and educational tracking Brunello and Checchi (2007)/

6. CONCLUSION AND POLICY IMPLICATIONS

Our starting point for this investigation was the proposition that teacher quality is not easy to observe within a country but may be measured by teacher relative wages when we consider cross country data. This is a reasonable hypothesis on the grounds that where a teacher is paid in a country's income distribution will result in drawing out candidates for teaching of the appropriate quality. The idea is that each country 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 countries in the world could help to explain the variation in the performance of 15 year olds in cross country national tests in maths, reading and science.

Since our measure of teacher quality was the wage teachers are paid in a country we sought to model the determination of teacher salaries and pupil outcomes. We first considered simple, single equation estimations for a teacher salary equation and a pupil outcome equation. Using panel data for 39 countries for 12 years we attempted to establish the relationship between teacher salaries and pupil outcomes. The advantage of panel data in this context is that if country specific unobserved heterogeneity does not vary over time then we are able to explore the link between teacher wages and pupil outcomes.

We also sought to test our findings by estimating a variety of other models as robustness checks. Specifically we estimated a simultaneous equation model in which we suggested that movements in the supply and demand for teachers (in terms of the number of trained teachers in the economy and the changing population of school children) were exogenous to pupil test scores. Additionally we investigated models of: the growth in teacher earnings, the distributional effects of teacher quality on the dispersion of test scores and the separate performance on subject by subject specific tests. We also investigated nonlinearity in the production function and the sensitivity of the results to which countries were included. In each case we found that there was still a highly significant and positive effect of teacher wages on pupil test scores.

To provide some idea of the scale of the effects we find our coefficients suggest that a 10% percent increase in teacher pay would give rise to around a 5-10% increase in pupil performance. Likewise a 5% increase in the relative position of teachers in the salary distribution would increase pupil performance by around 5-10%. These effects are significant and robust to the estimation procedure we use and the different identification assumptions we make to facilitate each estimation technique. Having said this – it is also true that lowering the pupil/teacher ratio would achieve the same goal. Clearly there are trade-offs and policy resource implications of these alternate measures. We examine this trade off and the whole issue of relative efficiency in Box 2 and spell out which are the countries which are relatively efficient using a stochastic frontier production function analysis.

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 government is concerned with the educational outcomes of

its children then it should be aware that the quality of its teachers is 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 country'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 country (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 government was 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 professional development and in-service training to improve the quality of those already employed, 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. As we saw in Figure 2 there is a huge variation across countries in the form of this earnings schedule and it is unclear what the optimal shape of this function is to secure the best teachers. 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 setting relative teachers pay would have to be right in the first place if the appropriate, high quality, people were to be attracted into the job.

Another dimension of problem is the time scale over which any improvement in pupil outcomes is sought. If replacing the present teachers with ones of higher quality would take a lot of time then a quicker fix might be to change the pupil/teacher ratio in the short run by simply employing more teachers from the pool of inactive teachers. Our production frontier efficiency analysis in Box 2 suggests an alternative route to improving pupil performance which could achieve results in a quicker time frame.

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 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 country'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 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. At a wider policy level the improvement in human capital appears to be a common factor behind economic growth in recent decades in all OECD countries, especially in the so called Mediterranean countries[23], where the increase in human capital accounted for more than half an extra percentage point of growth in the 1990s compared with the previous decade. Therefore it would seem that one clear way to improve the human capital stock is to invest in higher quality teachers.

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BOX 1. Econometric Model Estimation.

Lee and Barro (2001) have suggested a simple education production function:

$$Y=Y(F,R)+\varepsilon \quad (1)$$

where Y denotes schooling outcomes, F family resources, R resources used by schools and ε is a stochastic error term. In this context the educational outcomes can be measured by the achievement of pupils or students on international tests.

Any number of more sophisticated theoretical models could be proposed. Since our concern here is the empirical examination of the determination of aggregate pupil outcomes at the country level we are only interested in a 'reduced form' econometric model which would consider the following simultaneous empirically estimable relationship:

$$W=W(S,D,H,P,G,E)+\upsilon \quad (2)$$

$$Y=Y(H,P,W)+\varepsilon \quad (3)$$

where: W is teacher wages, S is relative teacher supply (as measured by the proportion of teachers in the labour force), D is relative changing demand (as measured by changing pupil numbers), H is total teaching hours, G is aggregate country economic growth, E is aggregate educational spending, P is the Pupil/Teacher ratio, Y is average pupil performance or output of the educational process and υ and ε are a stochastic error terms.

Our attempt to identify the influence of teacher wages on pupil outcomes will be fairly eclectic. Firstly we estimate equation (3) as single equation relying on the panel data variation of countries across time to attempt to identify the teacher wage effect.

Secondly we seek to model equation (2) and (3) simultaneously. In this model our assumption will be that supply and demand for teachers determines teacher salaries but that in the short run teacher supply cannot change as teacher wages change and that pupil numbers have been (exogenously) demographically predetermined at the level of the individual country pupil teacher ratios and teacher contact hours remain fairly constant from year to year and (in the short run at least), they are largely exogenously determined. Teacher pay on the other hand is variable and can be changed in the short run subject to the supply and demand pressures –specifically the number of trained teachers who are available (S), and the demographically determined number of pupils to be educated (D). Note however that the number of new teachers coming into the system cannot really be changed within a year– as it takes between 3-5 years to train new teachers. Therefore, the intensive margin for education administrators is changing the wage to entice already qualified teachers back into the profession. This means that the availability of newly qualified teachers –the outflow from teachers training colleges– will have a direct impact on teacher supply in the short run. In this sense supply and demand for teachers is assumed to play no role in the determination of pupil outcomes other than their indirect effect through changing teacher pay. These exclusion restrictions facilitate the estimation of the model in (2) and (3).

BOX 1. (*Continued*)

Our third approach will be to consider how the growth in teacher wages (within a country) over the life cycle affects pupil outcomes where this is akin to a generalised model of differences in that we will be averaging over teacher wages at the beginning of a career, 15 years into a career and at the end of a career. Finally, since we actually have a variety of pupil outcome measures in different subjects (at each point in time) we can also model these specific outcomes jointly. This approach includes an investigation of whether our panel and simultaneous equation estimation provide different results to our simple single equation regression by Ordinary Least Squares (OLS). The reason for this multiplicity of estimation approaches is that we remain agnostic about the specific identification assumptions to be invoked on the grounds that if our estimated coefficients reveal broadly comparable results with different estimation techniques then we can have some confidence that marginal changes in identification assumptions have no effect and that our data and conclusions are reasonably robust.

BOX 2. Comparing the Educational Efficiency of Countries.

The focus of our enquiry has been the relationship between teachers pay and children's educational scores. We have suggested that recruiting teachers from higher in the ability distribution would improve these educational outcomes. However, there are alternative resource options open to each country vis-à-vis the mix of: teaching contact hours (*H*), Pupil/Teacher ratios (*P*) and teacher wages (*W*) within the overall spending and resource envelope of the country. So, for example a country could choose to have higher pupil teacher ratios but pay their teachers more. The question is which is the most efficient resourcing mix? This can be modelled explicitly using a stochastic frontier production function analysis, which provide us with a measure of the relative technical efficiency of the set of countries consider in our analysis, for a set of inputs and a common output.

The details of our frontier efficiency analysis are reported in Appendix G (available upon request). This analysis shows the clear trade off between Pupil/Teacher ratios and teacher wages across countries. Below we plot the summary outcome of this analysis and the resultant efficiency scores by country. What this analysis shows is that countries do not necessarily have to pay higher teacher wages to secure better pupil outcomes. Looking at a country like the Czech Republic – it secures an efficient outcome by a different combination of inputs. Plotting efficiency scores against teacher salaries shows us which countries are achieving these high pupil scores by more favourable pupil/teacher ratios rather than higher teacher salaries. To be precise the intuition of the efficiency scores is that a country like Czech Republic, with an efficiency score of 84.8% is using only 15.2% more inputs than the optimal 'completely efficient' combination, to produce the performance level actually achieved by their students. This can be compared to countries like Argentina or Tunisia which are using almost 50% more than they need to get the educational performance achieved by their students. So the Czech Republic is relatively much more efficient.

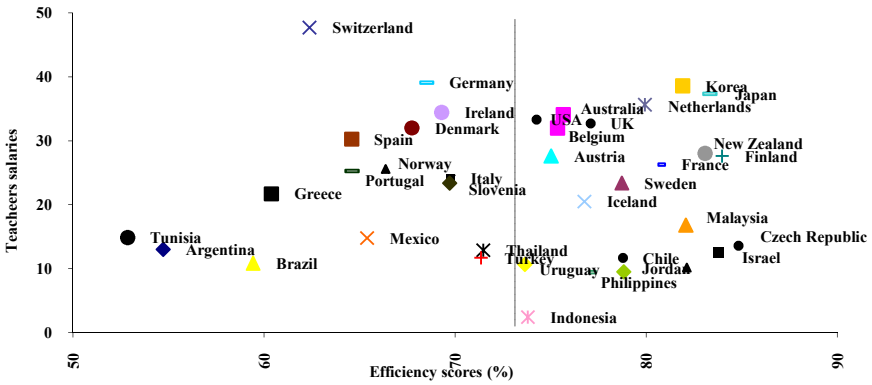

Figure Box2. Relative countries position in terms of efficiency scores relative to teachers' wages.

Table 1. **The Determination of Teachers Salaries Across Countries 1995-2007**
Pool of Salaries, controlling for the type of salary, i.e. starting (reference group), after 15 and top.

	Teachers' salaries/hour		Teachers' salaries (1000 $)	
	OLS	Panel	OLS	Panel
Dummy for wages after 15 years of experience	10.111***	10.128***	6.951***	6.961***
	(0.678)	(0.508)	(0.421)	(0.283)
Dummy for wages at the top of the earnings dist.	19.533***	19.394***	13.196***	13.089***
	(0.681)	(0.511)	(0.423)	(0.285)
Teachers and ed. staff as fraction of labour force	-8.230***	-1.800*	-5.027***	-0.692
	(0.487)	(1.052)	(0.303)	(0.587)
Teaching hours per year (100s)	-4.247***	-3.681***	-0.048	0.307*
	(0.233)	(0.321)	(0.145)	(0.179)
Women fraction of teaching staff (%)	-0.261***	-0.107***	-0.122***	-0.007
	(0.026)	(0.032)	(0.016)	(0.018)
Lower secondary dummy	0.763	3.332***	0.078	1.899***
	(0.809)	(0.773)	(0.502)	(0.431)
Upper secondary dummy	3.532***	5.429***	1.169	3.851***
	(1.154)	(1.265)	(0.717)	(0.706)
Expenditure on educational institut./GDP (%)	2.152***	-0.011	0.917***	0.238
	(0.455)	(0.445)	(0.283)	(0.248)
Pupil/Teacher ratio	0.280***	0.137*	0.139***	0.109**
	(0.067)	(0.079)	(0.041)	(0.044)
Growth in the size of the population	-0.089***	-0.098***	-0.043***	-0.007
	(0.014)	(0.026)	(0.009)	(0.015)
GDP per head (1000 $)	1.101***	0.762***	0.839***	0.462***
	(0.040)	(0.212)	(0.025)	(0.118)
Year dummies	√	√	√	√
Constant	71.663***	47.649***	23.563***	5.736*
	(3.405)	(6.121)	(2.115)	(3.415)
Observations	1555	1555	1555	1555
F-statistic	198.88***	105.89***	161.68***	109.74***
R-squared Within		0.60		0.60
R-squared Between		0.73		0.62
R-squared Overall	0.73	0.66	0.68	0.54

Notes:
[1]Standard errors in parentheses.
[2]List of countries included in the estimates: Argentina, Austria, Belgium, Brazil, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Spain, Sweden, Switzerland, Turkey, USA.
[3]* significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

Table 2: Percentile position of teachers' salaries in the earnings distribution.

	Percentile position of teachers' salaries		
	Starting salaries	**Salaries after 15 years of experience**	**Salaries at the top of the scale**
Teachers and ed. staff as fraction of labour force	-0.047***	-0.044***	-0.057***
	(0.010)	(0.010)	(0.009)
Teaching hours per year (100s)	0.006	0.009**	0.008*
	(0.005)	(0.004)	(0.004)
Women fraction of teaching staff (%)	0.000	-0.000	-0.000
	(0.001)	(0.000)	(0.000)
Lower secondary dummy	0.030*	0.023	0.022
	(0.016)	(0.015)	(0.014)
Upper secondary dummy	0.086***	0.075***	0.066***
	(0.022)	(0.022)	(0.020)
Expenditure on educational institutions/GDP (%)	0.040***	0.038***	0.030***
	(0.009)	(0.009)	(0.008)
Pupil/Teacher ratio	-0.007***	-0.006***	-0.005***
	(0.001)	(0.001)	(0.001)
Growth in the size of the population	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)
GDP growth (%)	0.004*	0.006***	0.005**
	(0.002)	(0.002)	(0.002)
Year dummies: (reference year 1995)	√	√	√
Constant	0.660***	0.741***	0.843***
	(0.065)	(0.063)	(0.058)
Observations	497	497	485
F-statistic	7.21***	7.04***	8.22***
Adjusted R-squared	0.22	0.22	0.25

Notes:
[1] OLS estimates. Standard errors in parentheses.
[2] List of countries included in the estimates: Argentina, Austria, Belgium, Brazil, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Indonesia, Ireland, Italy, Japan, Korea, Malaysia, Netherlands, New Zealand, Norway, Philippines, Spain, Sweden, Switzerland, Turkey, UK, USA.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

Table 3.a. Determinants of Standardised Pupil Scores across Countries 1995-2006 (Each type of Assessment).

	Specification I			*Specification II*		
	OLS	**Panel**	**Simultan.**	***OLS***	**Panel**	**Simultan.**
Teaching hours per year (100s)	-0.027	0.093	-0.094**	0.102***	0.089	0.049
	(0.030)	(0.066)	(0.038)	(0.035)	(0.072)	(0.040)
Pupil/Teacher ratio	-0.066***	0.037*	-0.057***	-0.082***	0.041*	-0.075***
	(0.009)	(0.022)	(0.010)	(0.012)	(0.022)	(0.010)
Women fraction of teaching staff (%)	0.004	0.014**	0.004	-0.017***	0.014**	-0.010
	(0.005)	(0.006)	(0.007)	(0.005)	(0.007)	(0.006)
Teachers' salaries after 15 years in 1000$	0.052***	0.030**	0.044***			
	(0.006)	(0.015)	(0.011)			
Percentile position of teachers (after 15 years)				2.559***	1.496*	4.947**
				(0.687)	(0.895)	(2.150)
GDP growth (%)	0.145***	-0.062**	0.184***	0.108***	-0.073***	0.171***
	(0.024)	(0.025)	(0.027)	(0.028)	(0.028)	(0.028)
Year dummies: (reference year 1995)	√	√	√	√	√	√
Constant	-2.063***	-3.470***	-0.967	-1.959***	-3.712***	-3.175*
	(0.475)	(0.723)	(0.603)	(0.702)	(0.832)	(1.788)
Observations	205	205	192	194	194	192
F-statistic	26.20***	18.15***	0.490	13.79***	17.30***	17.46***
R-squared Within		0.50			0.49	
R-squared Between		0.19			0.49	
R-squared Overall	0.54	0.01	0.44	0.37	0.05	0.44

Notes:
[1] Standard errors in parentheses.
[2] List of countries included in the estimates (Specification I): Austria, Belgium, Brazil, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Italy, Japan, Jordan, Korea, Netherlands, New Zealand, Norway, Philippines, Portugal, Spain, Tunisia, USA; Specification II: same countries except Iceland and Jordan.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%. Source: Authors' own calculations.

Source: Authors' own calculations.

Table 3.b. Determinants of Standardised Pupil Scores across Countries 1995-2006 (Using Overall Teachers Wage Growth on Each type of Assessment).

	Specification I		Specific. I	Specific. II
	OLS	Panel	OLS	OLS
Standard Deviation for each type of Score			-0.115**	-0.191***
			(0.049)	(0.061)
Teaching hours per year (100s)	0.076**	0.046	-0.012	0.094**
	(0.037)	(0.067)	(0.032)	(0.038)
Pupil/Teacher ratio	-0.067***	0.037*	-0.033***	-0.041***
	(0.011)	(0.022)	(0.013)	(0.016)
Women fraction of teaching staff (%)	-0.021***	0.010	0.009*	-0.009*
	(0.005)	(0.007)	(0.005)	(0.005)
Overall growth in teachers wage average	0.394	4.560**		
	(0.879)	(2.125)		
Teachers' salaries after 15 years in 1000$			0.048***	
			(0.005)	
Percentile position of teachers' salaries (after 15 years)				2.341***
				(0.674)
GDP growth (%)	0.113***	-0.060**	0.103***	0.046
	(0.028)	(0.025)	(0.024)	(0.029)
Year dummies: (reference year 1995)	√	√	√	√
Constant	-0.570	-6.445***	-2.090***	-1.564**
	(0.882)	(1.791)	-0.115**	-0.191***
Observations	203	203	208	194
F-statistic	12.01***	18.60***	16.29***	6.31***
R-squared Within		0.50		
R-squared Between		0.39		
R-squared Overall	0.36	0.04	0.45	0.26

Notes:
[1] Bootstrapped standard errors in parentheses. Panel estimates are Fixed Effect Estimates.
[2] List of countries included in the estimates: Austria, Belgium, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Korea, Netherlands, New Zealand, Norway, Philippines, Portugal, Spain, Tunisia, USA.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

Table 4. Estimates explaining the Standard Deviation of the *Standardised Scores* for *each type of Assessment*.

	Specification I		Specification II	
	OLS	Panel	OLS	Panel
Teaching hours per year (hundreds)	0.247***	0.064	0.222***	0.041
	(0.043)	(0.085)	(0.043)	(0.090)
Pupil/Teacher ratio	0.015	-0.181***	-0.000	-0.175***
	(0.018)	(0.053)	(0.019)	(0.054)
Women fraction of teaching staff (%)	-0.005	-0.011	-0.002	-0.015
	(0.007)	(0.015)	(0.006)	(0.016)
Teachers' wages after 15 years in 1000$	-0.014*	0.129***		
	(0.007)	(0.036)		
Percentile position of teachers (after 15 years)			0.086	8.321***
			(0.821)	(2.192)
GDP growth (%)	-0.053	0.026	-0.026	-0.039
	(0.034)	(0.061)	(0.035)	(0.068)
Year dummies:				
1999	-1.226***	-1.169**	-0.987**	-0.639
	(0.465)	(0.479)	(0.463)	(0.481)
2000	-1.035**	-1.402***	-1.129**	-0.731*
	(0.452)	(0.409)	(0.452)	(0.424)
2003	-1.322***	-2.127***	-1.414***	-1.476***
	(0.445)	(0.427)	(0.446)	(0.393)
2006	-0.833*	-1.800***	-1.030**	-0.998**
	(0.456)	(0.454)	(0.453)	(0.434)
Constant	3.286***	3.636**	3.028***	1.766
	(0.682)	(1.407)	(0.840)	(1.683)
Observations	210	210	194	194
F-statistic	11.94***	4.64***	9.30***	4.51***
R-squared Within		0.19		0.20
R-squared Between		0.35		0.17
R-squared Overall	0.32	0.01	0.30	0.02

Notes:
[1] Standard errors in parentheses.
[2] List of countries included in the estimates (Specification I): Austria, Belgium, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Korea, Netherlands, New Zealand, Norway, Philippines, Portugal, Spain, Tunisia, Turkey, USA; Specification II: same countries except Iceland, Israel and Jordan.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

Table 5. PISA Standardised Score Determinants – estimated Jointly by Subject.

	Specific. I	Specific. II	Specific. III	Specific. IV
Log (GDP per capita)	-0.756***	-0.809***	-0.908***	-0.900***
	(0.113)	(0.104)	(0.139)	(0.150)
Pupil/Teacher ratio	0.026***	0.029***	0.006	0.010
	(0.007)	(0.007)	(0.008)	(0.008)
Log (Teachers' salary after 15 years experience)	0.821***	0.808***	0.673***	0.572***
	(0.072)	(0.068)	(0.085)	(0.091)
Log (Educational expenditure)	0.160***	0.169***	0.283**	0.516***
	(0.047)	(0.044)	(0.112)	(0.113)
Log (Teaching hours)	0.042		-0.929***	
	(0.109)		(0.176)	
Expected years of education			0.044**	0.072***
			(0.022)	(0.021)
Asia Pacific			1.044***	0.771***
			(0.075)	(0.080)
Constant	-8.870***	-8.477***	-1.762	-7.238***
	(1.127)	(0.721)	(1.341)	(0.835)
Observations	147	159	125	136
R^2 (for each equation)	0.252	0.254	0.579	0.520
	0.155	0.147	0.527	0.436
	0.300	0.289	0.582	0.542
	0.295	0.286	0.659	0.599
	0.072	0.075	0.399	0.354
	0.275	0.287	0.527	0.481
	0.247	0.254	0.522	0.446
	0.188	0.183	0.392	0.390
	0.233	0.231	0.569	0.459

Notes:
[1] These are Seemingly Unrelated Regression estimates. Standard errors in parentheses.
[2] List of countries included in the estimates: Austria, Belgium, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Korea, Netherlands, New Zealand, Norway, Philippines, Portugal, Spain, Tunisia, Turkey, USA; Specification II: same countries except Iceland, Israel and Jordan.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

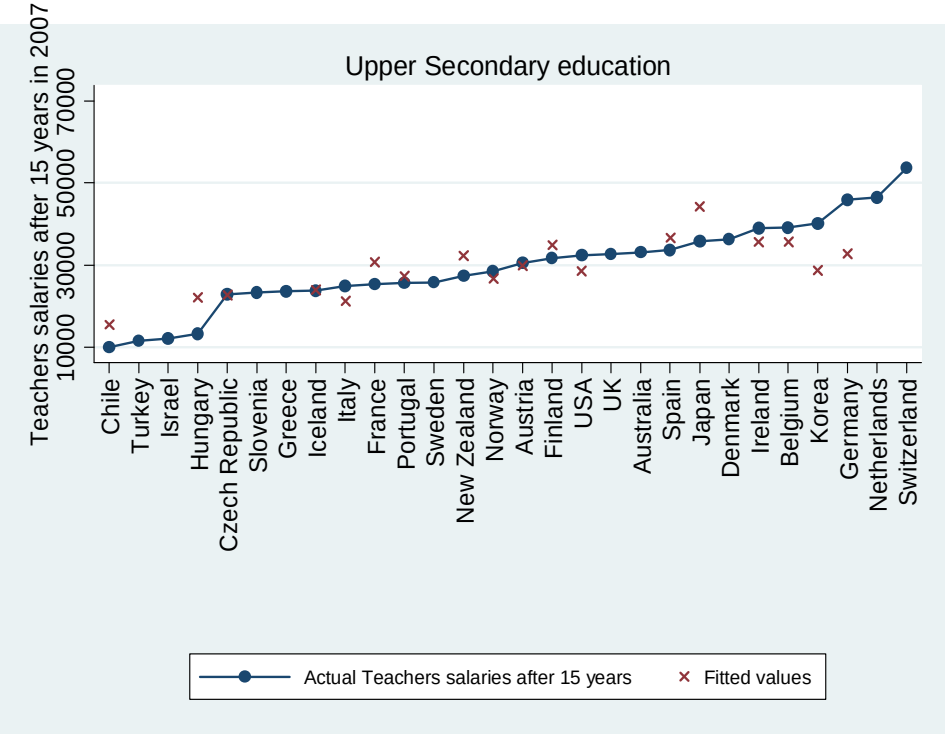

Figure 1.a. Actual and fitted Upper Secondary school teachers' salaries after 15 years experience in 2007 $ PPP

Note:
[1] Fitted value based on a regression controlling for teachers and educational staff as a fraction of the labour force, teaching hours per year (100s), women fraction of teaching staff(%), expenditure on educational institutions as a percentage of GDP, students/Teacher ratio and GDP annual growth (%).

Source: Authors' own calculations.

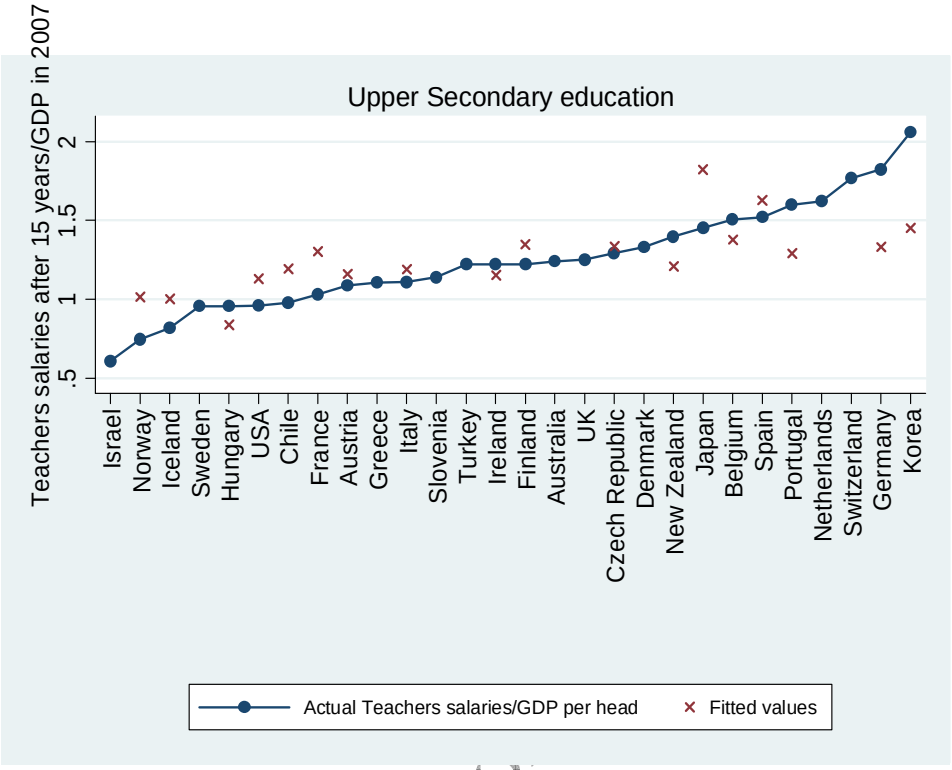

Figure 1.b. Actual and fitted Upper Secondary school teachers' salaries after 15 years experience relative to the earnings distribution of the whole population (2007)

Note:

[1] Fitted value based on a regression controlling for teachers and educational staff as a fraction of the labour force, teaching hours per year (100s), women fraction of teaching staff(%), expenditure on educational institutions as a percentage of GDP, students/Teacher ratio and GDP annual growth (%).

Source: Authors' own calculations.

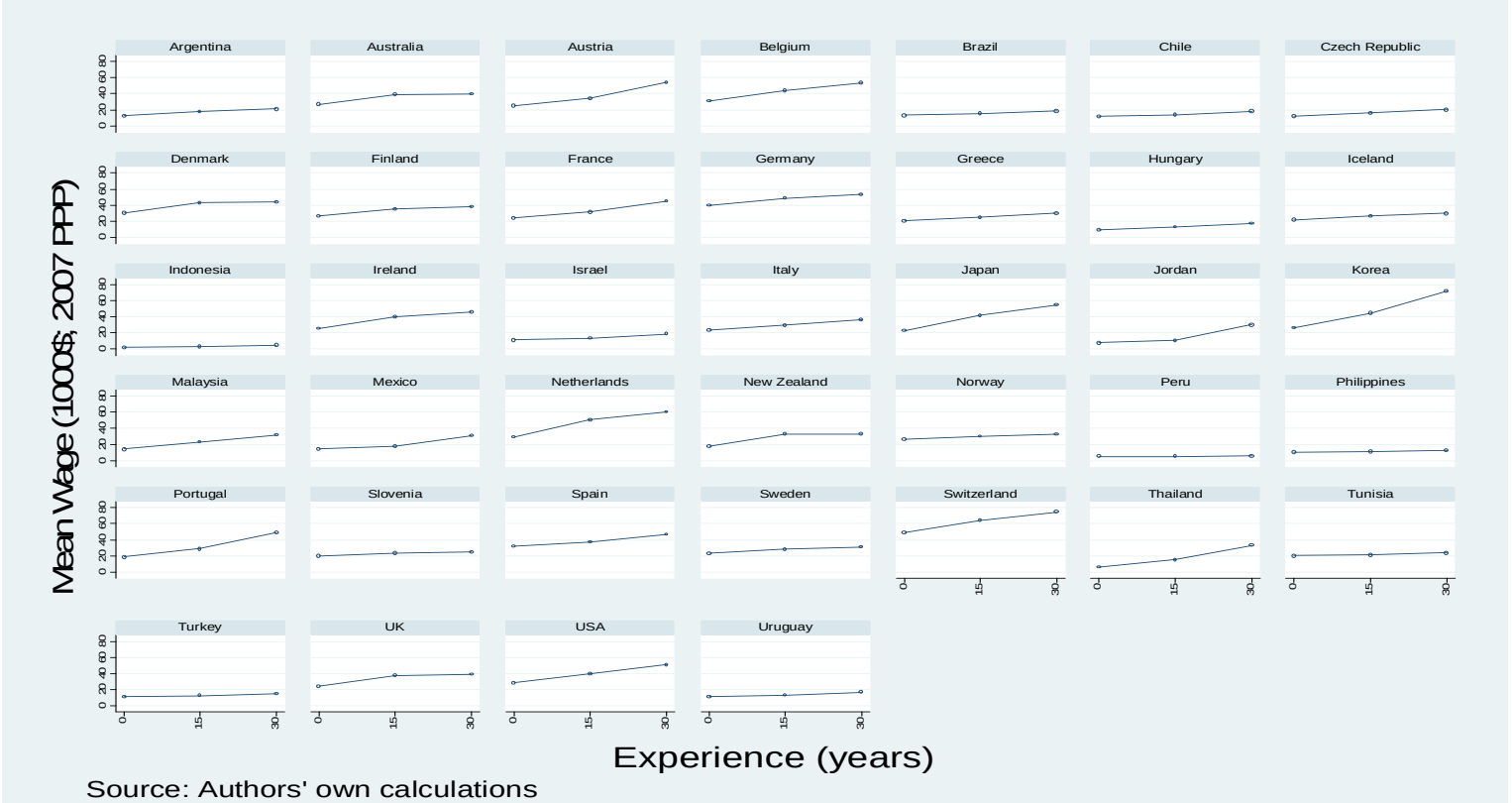

Figure 2. Average Teacher Wage-Experience Profiles by Country

Source: Authors' own calculations.

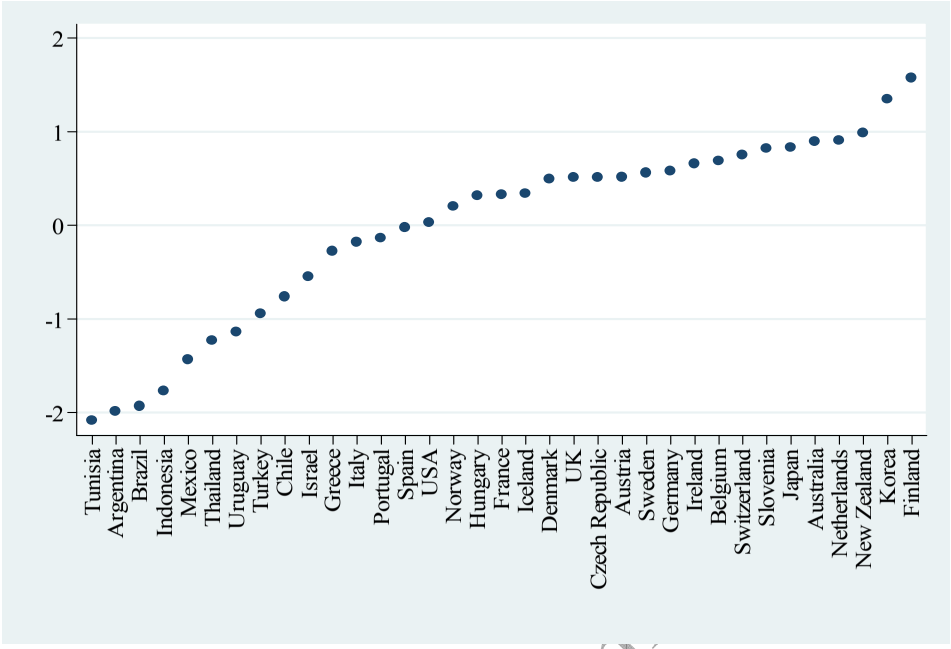

Figure 3.a. Standardised Average Scores by country (2006)

Source: Authors' own calculations.

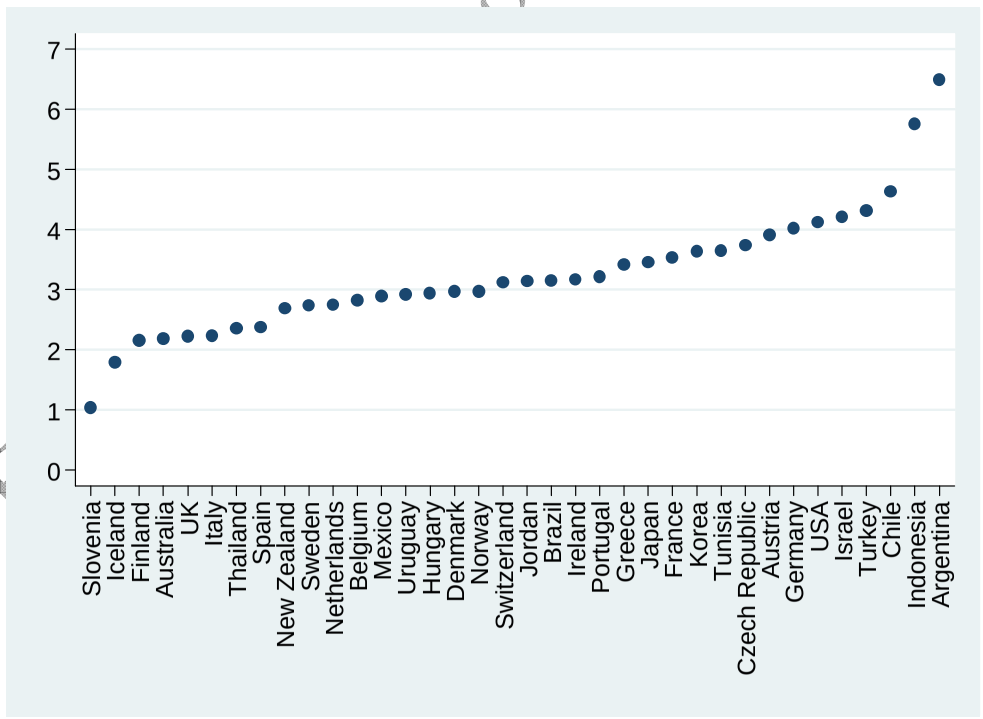

Figure 3.b. Average Score's Standard Deviation by country (2006)

Source: Authors' own calculations.

Figure 3.c. Standardised Scores against average standard deviation of the scores (2006)

Source: Authors' own calculations.

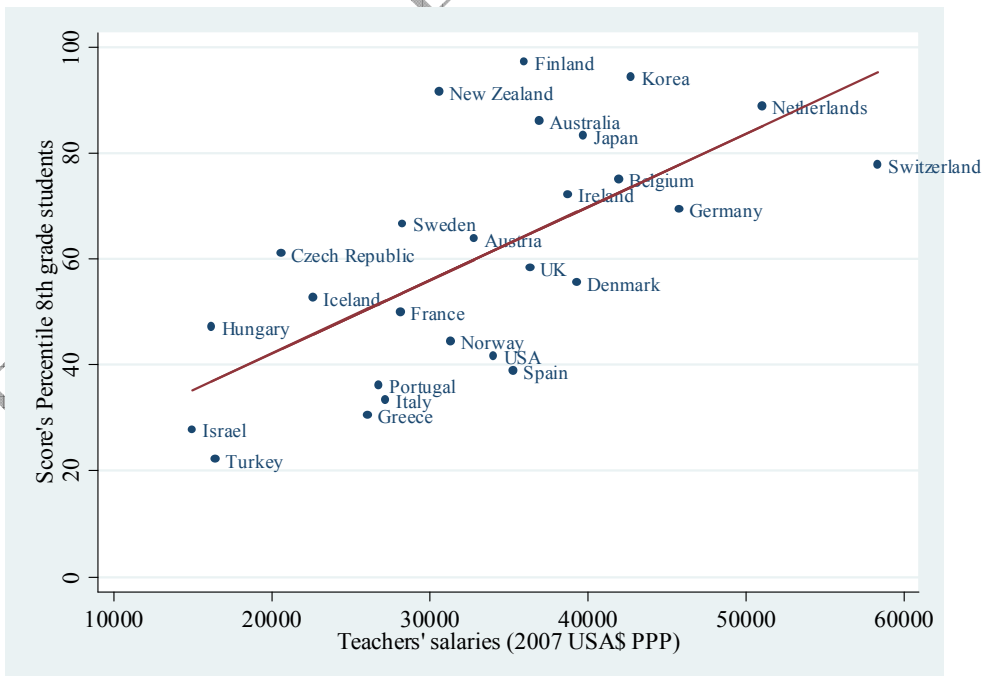

Figure 4. Score's percentile as a function of teachers' salaries after 15 years experience

Source: Authors' own calculations.

DATA APPENDIX. Definition of variables[25]:

Teachers and educational staff as a fraction of the labour force (%), based on head counts (1998 and 1999)[26].

(*Source*: Education at a Glance, OECD (2000 & 2001), table D2.4).

Teachers' salaries[27]:

- ***Teachers wage per hour***: This variable refers to the teachers' average salaries per statutory hour of teaching in primary education, lower secondary education and upper secondary education; 1995-2007.

(*Source*: Education at a Glance, OECD (1997-2009), table D1.1 continued & D3.1 continued).

- ***Teachers annual statutory salary at starting of their careers/after 15 years/at the top of the scale***: Annual statutory teachers' salaries in public institutions at starting salary, after 15 years of experience and at the top of the scale by level of education, in equivalent US dollars converted using PPPs; 1995-2007[28].

(*Source*: Education at a Glance, OECD (1997-2009), table D1.1 continued & D3.1 continued).

- ***Teaching hours per year*** (1996-2007): This refers to the statutory number of teaching hours per year (1996-2002), i.e. net contact time in hours per year in primary, lower secondary and upper secondary education[29].

(*Source*: Education at a Glance, OECD (1997-2009), table D3.1 continued & & D4.1).

Women fraction of teaching staff (%); 1996-2007: Percentage of women among teaching staff in public and private institutions, in primary, lower secondary and upper secondary education. [30]

(*Source*: Education at a Glance, OECD (1997-2009), table D2.3 continued & table D7.2 & table D6.2).

Lower secondary: This is a dummy variable that is equal to 1 if the observation refers to teachers of lower secondary education (primary education teachers is the reference group).

Upper secondary: This dummy variable is equal 1 if the observation refers to teachers of upper secondary education (primary education teachers is the reference group).

[25] For the year 1999 Education at a Glance was not published, which means that we have missing data for 1997.
[26] For the period 1995-1998 we impute the figures from 1998 and for the rest of the period we impute the 1999 figures.
[27] For Uruguay, after 1999, teachers' salaries were reported for working 20 hours per week. Most teachers hold two positions, therefore the figures have been multiplied by 2 to make then comparable with the rest of countries.
[28] Teachers' salaries at the top of the scale for Thailand in 2002 have been dropped, as they do not make sense.
[29] Information for 1995 is not available. To overcome this we computed the ratio teachers' salaries after 15 years experience/wage (after 15 years experience) per teaching hour to obtain a proxy for teaching hours in 1995.
[30] Teachers' salaries at the top of the scale for Thailand in 2002 have been dropped out, as they do not make sense.

GDP growth (%): This measures the GDP (per capita, in equivalent US dollars converted using a Purchasing Power Parity Price Index) growth per year in each OECD and WEI program country (%) between 1995 and 2005.

(*Source*: http://www.imf.org).

Expenditure on educational institutions as a percentage of GDP (1995-2007): The direct and indirect expenditures on educational institutions, in primary and secondary education expressed as a percentage of the Gross Domestic Product[31].

(*Source*: Education at a Glance, OECD (1997-2007), table B2.1 & B2.2).

***Pupil/Teacher ratio* (1995-2007):** Ratio of student numbers to teaching staff for public and private institutions in primary, lower secondary and upper secondary education.

(*Source*: Education at a Glance, OECD (1997-2007), table D2.2 continued).

Growth in the size of the population at the age of primary/lower secondary and upper secondary education (%); 1995-2007: This is calculated as a proxy of the growth in demand for education, using the relative change in the population at the age of primary/lower secondary and upper secondary education between 1995 and 2007.

(*Source*: Education at a Glance, OECD (1997-2009), table A2.1).

Retrieving the Teachers Pay Percentile in the Income Distribution:

How to retrieve the teachers pay percentile in the income distribution from a knowledge of their average wage and the average wage in economy. Provided we know the above two pieces of information as well as the Gini coefficient as a measure of the income inequality in the economy and we assume that the income distribution is Lognormal then we can retrieve the percentile that teachers on average are paid at. The logic is as follows.

Let $ln(x) \approx N(\theta,\sigma^2)$ so that x has a lognormal income distribution with parameters θ and σ^2. The median is $\exp\{\theta\}$, the mode is $\exp\{\theta-\sigma^2\}$ and the mean is $\exp\{\theta+(1/2)\sigma^2\}$. If $u(p)$ is the value in the $N(0,1)$ distribution at percentile point p (so that $u(1/2)=0$, etc) then $x(p)=\exp\{\theta+u(p)\sigma\}$ is the income level at percentile p. The Gini coefficient is $G=1-2u|\ \sigma/\sqrt{2}|$, or, indeed, twice the area under $N(0,1)$ between the ordinates $u = 0$ and $u = \sigma/\sqrt{2}$. So if you know the Gini coefficient, you can infer σ. And then, knowing the mean (or median or mode) you can infer θ. So if the teachers' average wage is $\overline{x}$, you can get their average percentile $\overline{p}$ by solving $\overline{x} = x(\overline{p})$.

PISA: Is the *Programme for International Student Assessment.* It has been conducted in 2000, 2003 and 2006, assessing math, reading and science skills of 15 year olds students.

(*Source:* http://www.oecd.org/document/43.html).

TIMSS: *Trends in International Mathematics and Science Study*: 4th grade (1995, 1999 and 2003) and 8th grade assessments (1995, 1999 and 2003).In 2003, some 46 countries participated in TIMSS, at either the fourth- or eighth-grade level, or both.

[31] The data for 2002 has been imputed using information from 2001.

(*Source*: NCES (2004). Highlights from the Trends in International Mathematics and Science Study (TIMSS) 2003)[32].

Educational outcomes at different point in time:

1995	1999	2000	2003	2006
		PISA- math	PISA - math	PISA- math
		PISA - reading	PISA - reading	PISA - reading
		PISA - science	PISA - science	PISA - science
TIMSS - math	TIMSS - math		TIMSS - math	
TIMSS - science	TIMSS - science		TIMSS - science	

[32] See Appendix A (available upon request) for a description of the criteria followed to compute the standardised scores.

APPENDIX A. Summary Statistics.

Table A1. Descriptive Statistics for all countries by year.

	1995			1996			1998			1999		
	N. Obs.	Mean	Std. Dev.	N. Obs.	Mean	Std. Dev.	N. Obs.	Mean	Std. Dev.	N. Obs.	Mean	Std. Dev.
Teachers' starting salaries	51	20122.35	5646.14	86	16819.98	8263.61	96	16774.14	8165.54	108	16276.72	7902.36
Teachers' salaries after 15 years experience	51	27403.53	7979.89	86	23386.01	11810.25	96	23411.26	11386.71	108	21774.62	10864.02
Teachers' salaries at the top of the pay scale	51	33843.33	11278.64	83	29270.20	15093.32	94	31289.82	13879.45	105	27527.63	13567.49
Teachers' salaries/hour	46	36.57	11.57	84	29.68	20.48	64	40.35	15.49	101	30.16	17.50
Teachers' salaries/GDP per head	51	1.81	0.58	86	1.98	0.93	96	1.87	0.78	108	1.87	0.88
Teachers' percentile position in the earnings distribution	51	0.66	0.08	83	0.63	0.13	91	0.63	0.13	96	0.60	0.16
Teaching hours per year	86	732.06	162.07	83	739.61	158.84	61	687.39	154.80	98	749.02	158.36
Pupils/teachers ratio	53	15.69	6.29	80	18.34	7.75	90	18.72	7.15	104	18.43	7.26
Women fraction among teachers staff	38	58.00	14.65	72	63.19	15.43	78	63.21	16.16	84	63.20	16.06
Teachers as a fraction of the labour force	54	2.94	0.73	54	2.95	0.74	57	2.97	0.73	99	3.24	0.82
Expenditure on education/GDP (%)	-	-	-	53	2.11	0.72	82	2.08	1.10	102	1.99	0.91
GDP growth (%)	117	5.19	3.97	117	5.00	2.02	117	7.27	6.06	117	3.70	3.00
GDP per head	117	14843.01	7895.76	117	15538.21	8205.23	117	16824.11	9015.45	117	17531.74	9459.52
Standardised Scores 8th grade students	26	-2.43e-07	1.02	-	-	-	-	-	-	30	7.4e-8	1.01

	2000			2001			2002			2003		
	N. Obs.	Mean	Std. Dev.	N. Obs.	Mean	Std. Dev.	N. Obs.	Mean	Std. Dev.	N. Obs.	Mean	Std. Dev.
Teachers' starting salaries	110	16470.20	7990.71	107	17037.30	8239.39	110	16845.34	8302.97	110	17468.02	8488.14
Teachers' salaries after 15 years experience	110	22401.31	11286.90	107	23191.54	11386.94	110	23094.50	11705.49	110	23800.25	11871.67
Teachers' salaries at the top of the pay scale	107	28575.91	14001.16	107	28873.35	13788.28	101	29252.65	14689.59	110	29240.67	14241.85
Teachers' salaries/hour	97	32.32	18.15	90	33.33	17.36	68	40.17	15.60	63	40.84	13.03
Teachers' salaries/GDP per head	110	1.76	0.75	107	1.69	0.67	110	1.66	0.63	110	1.60	0.55
Teachers' percentile position in the earnings distribution	99	0.62	0.12	99	0.62	0.13	99	0.62	0.14	99	0.62	0.14
Teaching hours per year	98	751.05	170.80	98	749.15	169.70	95	753.79	174.06	87	762.15	178.77
Students/teachers ratio	89	18.46	7.57	107	17.43	7.14	111	17.20	6.76	114	16.67	6.43
Women fraction among teachers staff	76	64.07	15.62	93	64.13	16.44	90	63.72	16.69	72	64.54	15.82
Teachers as a fraction of the labour force	99	3.24	0.82	99	3.18	0.88	99	3.21	0.83	99	3.18	0.85
Expenditure on education/GDP (%)	99	1.94	0.87	105	2.05	0.94	102	2.05	0.91	90	2.03	0.85
GDP growth (%)	117	5.77	1.96	117	3.22	2.55	117	2.92	3.26	117	4.15	2.06
GDP per head	117	18559.44	10003.66	117	19206.97	10406.35	117	19756.46	10702.81	117	20470.57	10969.67
Standardised Scores 8th grade students	74	-2.1e-4	0.99	-	-	-	-	-	-	128	-1.85e-8	1.0

Table A1. (Continued)

	2004			2005			2006			2007	
	N. Obs.	Mean	Std. Dev.	N. Obs.	Mean	Std. Dev.	N. Obs.	Mean	Std. Dev.	N. Obs.	Mean	Std. Dev.
Teachers' starting salaries	84	20637.28	6787.04	78	21611.96	6407.24	86	20309.34	6637.34	86	20466.36	6862.09
Teachers' salaries after 15 years experience	80	28634.64	9325.19	80	29020.10	8931.89	86	27457.50	9497.53	86	27663.34	9673.43
Teachers' salaries at the top of the pay scale	81	33671.10	12051.85	78	34877.31	11579.63	83	33056.50	12188.54	83	33488.59	12497.61
Teachers' salaries/hour	60	41.67	13.16	60	42.01	12.52	71	37.83	16.48	72	38.93	17.03
Teachers' salaries/GDP per head	80	1.44	0.46	80	1.40	0.44	86	0.95	0.26	86	0.89	0.24
Teachers' percentile position in the earnings distribution	75	0.65	0.12	72	0.67	0.08	78	0.63	0.12	78	0.63	0.12
Teaching hours per year	81	749.35	170.31	75	743.11	175.49	78	736.94	148.74	79	730.33	147.93
Students/teachers ratio	87	15.38	6.03	87	15.05	5.23	86	14.65	5.18	89	14.57	5.22
Women fraction among teachers staff	78	66.19	14.93	87	66.69	15.14	84	81.00	15.22	84	80.81	15.16
Teachers as a fraction of the labour force	99	3.13	0.83	102	3.25	0.83	102	3.25	0.83	102	3.25	0.83
Expenditure on education/GDP (%)	75	2.09	0.77	75	2.09	0.77	87	2.19	0.87	84	2.12	0.79
GDP growth (%)	117	6.46	2.02	117	6.37	2.64	117	7.03	3.30	117	6.10	3.34
GDP per head	117	21667.18	11475.61	117	22909.82	11992.29	117	24347.74	12519.84	117	25739.68	13156.38
Standardised Scores 8th grade students	-	-	-	98	3.4e-8	1.00	98	4.6e-8	1.00	35	-1.9e-7	1.01

Source: Authors' own calculations.

Table A2. Descriptive Statistics for all years by country.
(The rows for each country denote: number of observations/mean/standard deviation)

	Starting salaries	Salaries After 15	Salaries at top	Salaries /hour	Wage Perc.	Teaching hours	Pupils/ teacher	Women fraction	Teachers /labour force	Expen. /GDP	GDP growth	GDP/ head	Standardised 8th Grade Scores
Argentina	21	21	21	9	21	27	21	18	27	18	36	36	2
	9338.4	13028.9	15300.7	10.3	0.45	846.9	18.0	75.2	4.4	2.0	4.6	9646.6	-2.0
	2567.7	3566.4	4494.9	6.3	0.11	53.9	4.8	10.4	0.0	0.9	7.5	1603.4	0.1
Australia	33	32	33	29	32	30	29	-	27	33	36	36	15
	23418.9	34057.7	34079.8	41.0	0.67	831.7	14.8	-	3.1	2.4	4.9	28542.7	0.5
	1572.9	838.3	844.1	2.2	0.02	35.5	2.4	-	0.0	1.1	1.6	4570.6	0.6
Austria	36	36	36	36	36	36	33	33	36	33	36	36	9
	20818.1	27616.4	42910.3	42.3	0.66	659.1	11.3	71.7	3.2	2.1	4.7	29962.5	0.4
	883.3	2050.2	2686.4	6.4	0.02	63.6	2.0	16.8	0.0	0.6	1.7	4548.7	0.2
Belgium	36	36	36	36	36	36	25	33	9	30	36	36	15
	22961.0	31953.6	39133.4	45.0	0.65	720.0	11.3	67.2	4.1	1.8	4.6	28106.5	0.6
	2897.1	4575.7	5630.3	9.7	0.03	66.1	1.9	12.8	0.0	0.6	1.6	4181.0	0.3
Brazil	21	21	18	9	21	30	33	27	27	27	36	36	9
	8894.2	10829.9	13158.2	8.7	0.51	773.4	26.1	85.7	3.1	1.9	3.9	7686.3	-2.4
	3364.1	3133.3	3121.9	5.8	0.16	54.1	7.8	8.6	0.0	1.0	2.1	1008.1	0.7
Chile	30	30	30	15	30	30	33	30	27	33	36	36	6
	9908.4	11694.9	15280.4	13.8	0.25	863.4	30.0	69.3	2.1	2.3	6.1	10395.5	-1.2
	1557.6	1669.9	2463.6	2.3	0.07	5.1	4.2	14.1	0.0	0.8	3.0	1891.8	0.4
Czech Republic	35	35	35	35	35	36	36	33	27	33	36	36	13
	10408.6	13587.8	17026.9	20.5	0.64	668.6	15.3	77.8	2.7	1.7	6.2	17018.5	0.5
	3634.0	4821.6	5661.6	7.5	0.06	76.5	3.2	13.5	0.0	0.4	2.3	3550.5	0.4
Denmark	36	36	36	36	36	36	34	34	36	33	36	36	9
	25865.4	32038.0	32344.5	55.1	0.70	610.6	11.5	57.7	3.4	2.6	4.4	29642.4	0.2
	1457.2	3470.6	3762.0	16.2	0.04	60.8	1.2	12.7	0.1	1.4	1.7	4224.3	0.4
Finland	35	36	36	30	36	33	31	35	27	33	36	36	9
	21474.5	27634.2	29752.3	47.3	0.68	597.6	14.3	70.4	3.0	2.1	6.3	25882.1	1.3
	3491.3	3646.2	4883.0	9.4	0.04	72.2	3.0	9.0	0.0	0.5	4.0	4926.7	0.3
France	36	36	36	36	36	36	33	32	36	33	36	36	9
	19885.8	26279.3	37792.2	37.9	0.64	718.9	15.6	67.4	3.3	2.3	4.2	27062.8	0.4
	1271.1	1411.8	1646.7	7.7	0.02	134.3	4.2	11.7	0.1	0.6	1.5	3759.6	0.2
Germany	36	36	36	36	36	36	36	36	36	33	36	36	9
	31923.9	39110.9	42252.7	53.2	0.74	739.5	16.4	62.6	2.3	1.8	4.0	27455.6	0.2
	2725.5	3166.0	3626.1	6.4	0.02	42.0	2.6	19.1	0.1	0.4	1.6	3631.5	0.4
Greece	36	36	36	36	36	36	36	18	18	24	36	36	9
	17871.8	21729.0	26256.6	35.1	0.58	662.7	10.8	63.5	3.0	1.2	6.0	21016.9	-0.5
	2295.0	2560.0	2911.9	8.4	0.03	85.4	2.2	14.5	0.2	0.2	1.7	4533.8	0.4
Hungary	33	33	33	33	33	34	36	33	36	33	36	36	17
	7372.8	10161.7	13465.7	17.1	0.56	597.9	11.0	80.2	3.7	1.7	6.9	13601.0	0.4
	2155.1	2770.9	3670.3	5.1	0.06	100.9	0.8	12.8	0.7	0.4	2.4	3266.3	0.4
Iceland	27	27	27	27	.	27	28	28	30	9	36	36	9
	17690.8	20537.8	23071.8	34.5	.	609.1	11.6	69.5	3.8	3.2	5.7	29210.4	0.3
	2011.4	2990.0	3583.0	8.4	.	65.8	1.6	16.9	0.9	1.3	3.0	5725.3	0.2
Indonesia	20	20	20	12	20	15	18	18	27	15	36	36	12
	1595.8	2461.2	4133.5	2.8	0.44	912.0	20.0	44.4	2.8	0.7	5.1	2755.0	-1.7
	963.9	1304.7	2245.5	1.5	0.14	254.7	3.1	7.2	0.4	0.3	4.9	486.4	0.4
Ireland	36	36	36	36	36	36	28	29	36	33	36	36	9
	21503.9	34411.2	39111.5	43.7	0.65	796.7	17.6	72.1	3.7	1.8	8.9	30974.4	0.6
	1179.2	2188.6	2524.8	5.4	0.03	88.8	3.1	14.5	0.2	0.8	4.5	7997.3	0.3
Israel	15	12	15	6	.	6	18	21	-	27	36	36	6
	10612.2	12574.3	17775.3	14.8	.	826.0	14.6	79.6	-	2.5	3.3	21403.3	-0.2
	559.8	979.5	1288.4	2.9	.	163.7	2.9	9.9	-	0.2	4.0	2911.1	0.3
Italy	36	36	36	36	36	36	36	36	36	30	36	36	15
	19595.2	24068.2	29685.4	37.4	0.56	653.0	10.5	78.7	3.7	1.8	3.8	25410.1	-0.2
	1157.8	1646.3	2191.4	5.6	0.03	68.0	0.5	14.7	0.1	0.4	1.3	3086.3	0.2
Japan	27	27	27	12	27	21	30	21	36	33	36	36	17
	20116.0	37329.3	47906.8	67.4	0.73	549.0	16.6	50.0	1.9	1.7	3.1	26914.5	1.2
	619.4	722.7	1274.2	10.0	0.01	78.0	2.9	22.7	0.0	0.6	2.6	3444.5	0.4
Jordan	15	15	15	9	.	21	19	14	-	12	36	36	6
	6835.5	9522.8	24465.6	13.2	.	792.8	19.0	50.2	-	2.6	5.1	3649.0	-0.8
	1024.8	1610.6	1240.6	1.5	.	85.2	2.0	14.1	-	1.5	2.4	693.1	0.3
Korea	35	35	35	33	35	34	36	36	36	33	36	36	17
	22568.1	38562.3	61939.7	65.5	0.78	599.5	23.6	58.0	1.8	2.4	7.2	18547.1	1.3
	936.2	1966.4	2929.8	14.1	0.02	126.5	5.4	19.1	0.0	0.7	3.1	4406.8	0.4
Malaysia	21	21	21	12	21	18	21	16	27	12	36	36	6
	10388.5	16817.0	22434.8	22.7	0.53	771.7	19.1	61.1	3.5	2.1	5.7	9875.4	0.0
	3174.0	5064.1	6991.7	7.6	0.11	7.6	1.6	2.6	0.0	0.4	3.3	1810.2	0.5
Mexico	23	21	23	12	.	26	27	27	36	30	36	36	9
	11658.1	14815.8	24991.5	16.0	.	914.5	28.9	56.0	3.5	2.4	6.3	11171.0	-1.8

Table A2. (Continued)

	Starting salaries	Salaries After 15	Salaries at top	Salaries /hour	Wage Perc.	Teaching hours	Pupils/ teacher	Women fraction	Teachers /labour force	Expen. /GDP	GDP growth	GDP/ head	Standardised 8th Grade Scores
	1475.0	1973.0	3257.2	1.1	.	147.9	3.6	15.4	0.3	1.1	7.6	2114.7	0.4
Netherlands	36	36	36	33	36	34	27	29	27	33	36	36	12
	24517.2	35628.9	41600.5	41.2	0.71	866.1	16.4	58.4	3.4	1.9	4.9	30835.6	0.8
	1614.1	6702.6	7436.1	11.1	0.04	71.5	1.0	19.0	0.0	0.8	2.2	4716.7	0.3
New Zealand	36	36	36	36	36	33	36	35	36	27	36	36	15
	15283.1	28004.9	28005.4	29.8	0.70	964.2	17.5	70.0	3.1	2.5	4.6	20973.9	0.5
	1134.5	2542.1	2540.6	1.9	0.03	22.5	3.6	13.6	0.5	0.8	0.9	3385.6	0.7
Norway	36	36	36	36	36	36	33	25	27	27	36	36	15
	22042.7	25563.2	27277.8	42.0	0.55	630.6	10.2	63.8	4.4	2.3	4.9	41240.8	-0.1
	2847.1	2930.7	3343.4	7.9	0.04	84.8	1.3	13.1	0.0	0.8	1.9	6318.9	0.4
Peru	15	15	15	9	15	12	14	6	27	12	36	36	-
	4500.3	4500.3	4629.9	7.9	0.39	677.5	24.2	51.2	3.8	1.9	5.6	5602.7	-
	369.1	369.1	203.3	0.7	0.06	71.6	5.5	10.2	0.0	1.1	3.0	1009.7	-
Philippines	21	21	21	10	21	27	21	18	27	15	36	36	4
	8733.6	9448.2	10442.0	9.6	0.78	1176.0	34.4	80.2	2.3	2.6	5.1	2535.4	-2.1
	1417.2	1692.1	1856.8	1.4	0.05	0.0	6.0	5.4	0.0	1.9	1.7	427.7	0.2
Portugal	32	35	35	35	35	36	25	21	-	30	36	36	8
	16028.8	25247.6	42366.9	37.8	0.70	682.9	9.8	75.7	-	2.3	4.4	18007.7	-0.3
	648.4	1223.6	2383.7	6.8	0.01	121.5	1.8	9.5	-	0.8	2.6	2435.3	0.3
Slovenia	6	6	6	6	6	6	9	9	-	6	36	36	7
	19937.1	23358.8	24764.6	34.9	0.65	670.5	13.2	88.5	-	2.3	7.2	19358.7	0.1
	52.8	20.7	50.1	1.7	0.01	30.5	2.2	11.4	-	0.8	2.1	4488.1	0.8
Spain	35	35	35	35	35	36	36	32	36	17	36	36	9
	25976.3	30300.7	37815.3	44.8	0.67	707.9	13.3	62.0	3.8	2.1	5.3	23563.0	-0.1
	2078.3	2342.1	2662.4	11.2	0.03	144.7	3.0	11.1	0.1	0.7	2.0	4016.1	0.2
Sweden	35	35	23	5	35	6	36	36	36	33	36	36	15
	19223.2	23392.0	26900.0	35.7	0.67	576.0	13.2	66.7	3.4	2.5	5.4	28038.6	0.5
	1921.6	1678.3	2265.6	5.1	0.02	42.9	1.3	14.9	0.0	0.8	1.7	4985.9	0.3
Switzerland	35	35	35	14	35	18	29	18	27	33	36	36	9
	36276.6	47686.4	56077.6	60.0	0.77	802.8	13.1	58.8	2.8	2.4	4.0	32646.2	0.5
	4930.8	6327.4	6799.8	17.4	0.03	95.3	2.1	22.0	0.0	0.5	2.0	4511.4	0.4
Thailand	18	18	15	12	18	18	15	3	27	18	36	36	8
	5260.8	12928.9	27329.8	14.7	0.78	650.9	21.9	62.3	2.1	1.7	5.5	5733.4	-1.1
	356.3	876.3	6614.0	7.8	0.03	73.0	2.4	1.2	0.0	1.0	5.4	1122.0	0.2
Tunisia	15	15	15	11	.	21	15	15	27	0	36	36	12
	14214.9	14842.7	16657.8	26.8	.	609.1	21.6	44.4	6.0	.	6.6	5319.3	-1.7
	2653.9	2810.1	3122.0	14.7	.	90.2	2.8	3.9	0.0	.	2.2	1197.5	0.6
Turkey	27	27	27	26	27	9	34	13	36	21	36	36	8
	10335.6	11724.8	13494.5	19.4	0.63	538.0	22.8	51.5	2.7	1.4	6.4	9036.4	-1.0
	2033.3	2007.0	2207.2	3.5	0.05	121.0	8.9	19.3	0.3	0.6	5.6	1922.3	0.2
UK	32	32	32	4	32	6	36	32	36	30	36	36	10
	21379.3	32706.9	34002.6	42.9	0.68	760.0	17.1	68.9	3.0	1.9	5.2	27527.3	0.5
	1780.1	1672.2	4878.9	2.4	0.02	31.0	3.4	13.2	0.1	0.7	1.4	4749.4	0.6
USA	36	36	24	24	36	36	36	36	36	6	36	36	16
	24584.6	33315.6	41732.9	32.6	0.49	1054.7	15.6	70.2	2.7	2.3	4.6	36478.1	0.1
	1097.5	2058.8	1731.8	1.2	0.04	74.6	1.0	15.3	0.2	1.0	1.8	5535.6	0.5
Uruguay	18	18	15	9	18	9	18	-	27	15	36	36	6
	8912.7	10639.8	13613.1	10.7	0.44	662.9	19.4	-	2.8	1.2	4.6	8707.2	-1.1
	1562.5	1845.1	1263.1	7.8	0.22	75.4	5.8	-	0.0	0.6	6.8	1413.7	0.1

Source: Authors' own calculations.

Figure A1 provides a visual picture of how teacher's salaries and their structure vary across countries and years. Specifically this figure graphs the percentile position of teacher's wages in the income distribution of the country. We focus on two types of countries – those which are relatively efficient according to our Production frontier analysis and those which are not. In some countries (e.g. Czech Republic) it is clear that relative teacher salaries have been rising in the sense that they are climbing up the income distribution, whilst in others they have been relatively constant (e.g. Portugal) or falling (e.g. Korea). The figure also makes clear how in some countries there is a large difference in teacher salaries at the beginning of their career compared to the end of their

career (by looking at the vertical distance between the circles and crosses) and (e.g. Korea, and Portugal) whilst in other countries the teacher wage profile is very flat (e.g. Switzerland, and Finalnd) This figure also nicely illustrates the variability of the data we have at our disposal by considering countries in a panel over years from 1995-2007.

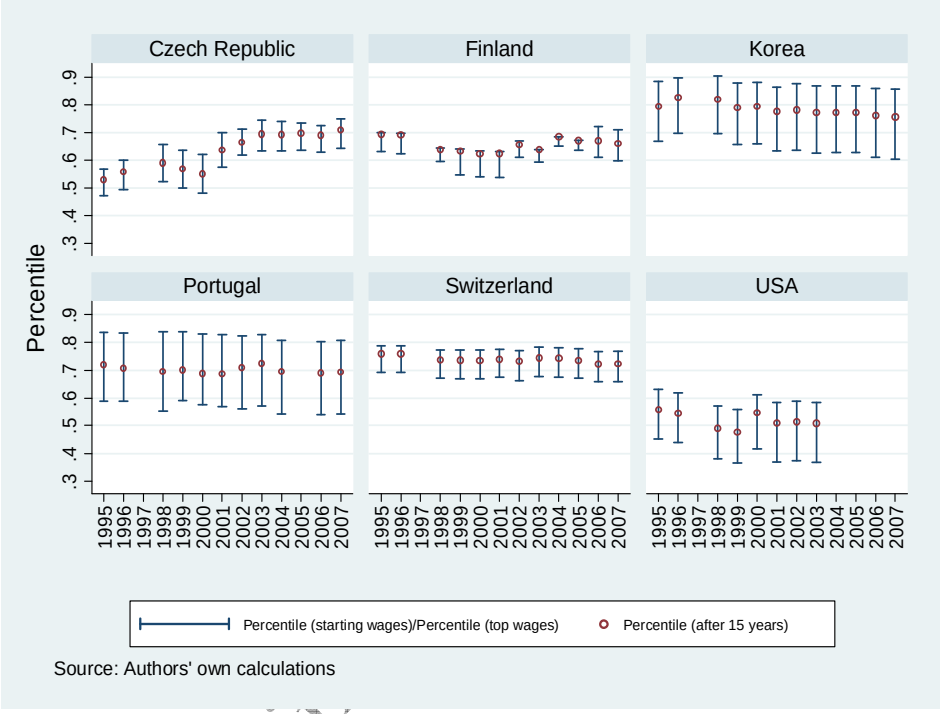

Figure A1. Relative position (percentile) of teachers' salaries in the earnings distribution of the whole working population (Upper secondary education); selected countries.

Imputation of Gini indices:

For the whole set of countries 2007, 2006 and 2005 Gini index=2004 (except for those countries where the information for 2005 and/or 2006 is available). On top of that we have interpolated the data for the following countries and years:

Argentina	2007
Australia	1999, 2003; 2006-2007
Austria	2002, 2007
Belgium	2002, 2007
Brazil	2000; 2006-2007
Chile	2001, 2002; 2004-2007
Czech Republic	2004, 2007
Denmark	1996, 2007
Finland	2007
France	2007
Germany	2007
Greece	2001, 2007
Hungary	2007
Indonesia	1998, 2000, 2001, 2003, 2004, 2007
Ireland	2002
Italy	2003, 2007
Japan	1999-2007
Korea	1999-2007
Malaysia	1996-1998; 2000-2007
Netherlands	2004, 2005,2007
New Zealand	1999-2000,2002-2003,2005-2007
Norway	2007
Peru	1995, 1996; 2006-2007
Philippines	1995-1999; 2004-2007
Portugal	2002, 2003, 2006-2007
Slovenia	2007
Spain	2007
Sweden	2007
Switzerland	1995, 1996; 2003-2007
Thailand	1995; 2003-2007
Turkey	1995-1999; 2004-2007
UK	2004; 2006-2007
United States	2005-2007
Uruguay	1999; 2006-2007

The gini index has been taken from the "World Income Inequality Database", developed by United Nations University (UNU)-World Institute for Development Economics Research (WIDER)[33].

[33] See in Appendix A the criteria to impute Gini coefficients.

APPENDIX B. Teacher Pay relative to GDP per Head.

The power to attract individuals to become teachers as measured by the ratio of teacher salaries to gross domestic product (GDP) per capita. Teacher salaries relative to per capita gross domestic product (GDP) are an indication of the extent to which a country invests in teaching resources relative to the financial ability to fund educational expenditures. A high salary relative to per capita GDP suggests that a country is making more of an effort to invest its financial resources in teachers. Relative to per capita GDP, teacher salaries are relatively low in the Czech Republic, Hungary, and Indonesia and relatively high in Philippines and Denmark. Wealthier countries do not necessarily spend a greater share of their wealth on educational resources, however. Although the Czech Republic and Hungary have both relatively low GDP per capita and low teacher salaries, other countries with GDP per capita below the OECD average, including Philippines and Tunisia, have comparatively high teacher salaries. In contrast, Norway and France, two countries with relatively high GDP per capita, have below-average teacher salaries.

When using the teacher's wage relative to GDP per head we can clearly only control for economic growth and not the absolute size of the wealth in the country. The results relating GDP growth to teachers' relative salaries compared to GDP per head indicate that there exists a negative relationship between the changing wealth of a country and their teachers' salaries. This may be due to the rate at which an economy grows is largely determined by the productivity of the private sector. Those countries which have private sectors which are growing more rapidly are more likely to be leaving their public sector workers behind – in relative pay terms.

Table B1. Estimation explaining the variation in teachers' salaries/GDP per head from 1995-2007

	Teachers' salaries/GDP per head	
	OLS	Panel
Teachers and educational staff as a fraction of the labour force	-0.3676***	-0.0344
	(0.0423)	(0.0441)
Teaching hours per year (100s)	0.1153***	0.0310**
	(0.0198)	(0.0134)
Women fraction of teaching staff (%)	0.0063***	0.0013
	(0.0022)	(0.0013)
Lower secondary dummy	0.3586***	0.1989***
	(0.0686)	(0.0322)
Upper secondary dummy	0.8615***	0.3416***
	(0.0987)	(0.0527)
Expenditure on educational institutions as a percentage of GDP	0.1921***	0.0143
	(0.0386)	(0.0187)
Pupil/Teacher ratio	0.0264***	0.0130***
	(0.0051)	(0.0033)
Growth in the size of the population at the age of primary/lower secondary and upper secondary	0.0007	-0.0014
	(0.0012)	(0.0011)
GDP growth (%)	-0.0196**	-0.0074*
	(0.0085)	(0.0038)
Year dummies	√	√
Constant	0.2885	0.9715***
	(0.2759)	(0.2160)
Observations	521	521
F-statistic	23.38***	7.95***
R-squared Within		0.26
R-squared Between		0.48
R-squared Overall	0.45	0.35

Note: Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

APPENDIX C. Technical Econometric Details.

Our attempt to identify the influence of teacher wages on pupil outcomes was eclectic. Firstly we estimate equation () as 'a reduced form' equation relying on the panel data variation of countries across time to attempt to identify the teacher wage effect. Secondly we modelled equation (1) and (2) simultaneously. In this model our assumption will be that supply and demand for teachers determine teacher salaries but that they play no role in the determination of pupil outcomes other than their indirect effect through changing teacher pay. Clearly our measure of demand - the growth of the children of school age is exogenous and determined only by demographic forces. The supply of teachers in any specific year as measure by the stock of teachers in that year is exogenous in the sense that any measure to change supply would require a change in teacher training places to be effected which would take at least 4 years to see an effect. We performed the relevant tests on these Instrumental variables (IVs). These exclusion restrictions facilitate the estimation of the model in (5). Our third approach was to consider how the growth in teacher wages (within a country) over the life cycle affects pupil outcomes where this is akin to a generalised model of differences in that we will be averaging over teacher wages at the beginning of a career, 15 years into a career and at the end of a career. Finally, since we actually have a variety of pupil outcome measures in different subjects (at each point in time) we can also model these specific outcomes jointly by Seemingly Unrelated Regressions (SUR). Our approach investigated whether SUR, Two Stage Least Squares (2SLS), Fixed Effects (FE) and Random Effects (RE) provide different results to OLS. The reason for this multiplicity of estimation approaches is that we remain agnostic about the specific identification assumptions to be invoked on the grounds that if our estimated coefficients reveal broadly comparable results with different estimation techniques then we can have some confidence that marginal changes in identification assumptions have no effect and that our data and conclusions are reasonably robust.

Whilst with 'observational' data it is impossible to 'prove' there is a causal effect of teacher wages on pupil outcomes we suggest that if our estimated marginal effect stands up to all of our different estimation methods it is quite possible that there is some systematic relationship between teacher pay and pupil outcomes which may be more than a simple statistical correlation. Notwithstanding this logic it must be recognised that the estimated relationships do not identify causal parameters, but rather reveal the strength and significance of the statistical association between the variables of interest in our underlying reduced form relationships.

In each panel of Table C1 we report the Hausman test statistics which report the test on the null hypothesis that the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator. Since all of the test statistics indicate that there is a significant P-value, this suggests that the FE should be preferred. Hence in all our tables where we report Panel Estimates - these are FE estimates. The RE estimates are available from the authors on request. In nearly all cases the estimated parameters of RE were very close to the FE estimates.

One way to investigate the robustness of our results is to estimate the model using a simultaneous estimation method to capture the possibility that teacher wage determination is simultaneously. Hence we use our reduced form estimation of teacher salary determination (i.e. equation (2)) to estimate a first stage regression which we use to compute an IV for teachers wage. Here our exclusion restriction is that our supply and demand forces of teacher numbers in the economy and growth in pupil numbers (respectively) do not directly influence pupil test scores. The results of the 2SLS estimations are reported in column 3 and column 6 of Table 3a under the heading

Simultaneous, for the two specifications we estimated by panel estimation methods. Reassuringly when we estimate our pupil performance equation using this 2SLS IV we see that the results of our estimation are directly comparable to those we found with OLS, FE and RE. Specifically we find that the effect of teachers wages on pupils outcomes is still positive and statistically significant and with a marginal effect which is directly comparable to our earlier results.

Another form of robustness check is to consider the separate pupil tests scores we have in Maths, Reading and Science as separate entities – as up to now we have averaged them. This then facilitates a Seemingly Unrelated Regression (SUR) estimation of our model. The advantage of this is that we are then estimating them model as a system exploiting the possibility that the errors in the separate equations are related. This will lead to more efficient estimation. Since this technique has already been used in this context by Lee and Barro (2001) we adopted exactly their specification to estimate this model. The results are reported in Table 5 in the paper.

Table C1. Hausman test Fixed vs Random effects
(Ho: difference in coefficients not systematic)

	Table 1	
FEvs RE panel 1	$X^2(15)=244.94$***	Prob.> $X^2=0.0000$
FEvs RE panel 2	$X^2(15)=11.54$**	Prob.> $X^2=0.9309$
	Table 3a	
FEvs RE panel 1	$X^2(9)=143.63$***	Prob.> $X^2=$ 0.0000
FEvs RE panel 2	$X^2(8)=31.37$***	Prob.> $X^2=0.0000$
	Table 3b	
FEvs RE	$X^2(9)=31.01$***	Prob.> $X^2=$ 0.0003
	Table 4	
FEvs RE panel 1	$X^2(9)=17.26$***	Prob $X^2(9)=0.0449$
FEvs RE panel 2	$X^2(8)=23.76$***	Prob $X^2(8)=0.0025$

Source: Authors' own calculations.

In the course of our research on this paper we did many other robustness checks and tried many other forms of econometric specification. Specifically we:

- Ran models using, as dependent variables, the difference in standardised scores for two consecutive time periods.
- Ran models using each score on each test separately by subject.
- Included, as additional regressor, the teachers hours relative to the average hours worked in the economy.
- Checked whether the results were sensitive to excluding certain countries.
- Used log(wages) instead of wages.
- Estimated Arellano's type models using wage after 15 years experience as the dependent variable and various forms of lagged variables as IVs.
- Estimated the same specification for 4th grade students as for 15 year old students.

In all these cases our results either confirmed our previous findings or were slightly less clear than the results we report. In the interests of brevity and clarity of exposition we have not attempted to provide details of all these different estimations and robustness checks.

APPENDIX D. Unobserved Heterogeneity.

There are a large number of relevant omitted explanatory variables from our analysis. Some are completely immeasurable:

- Family and social class factors.
- The political sympathies of the incumbent government towards education spending as a priority.
- The prevailing view amongst the electorate about education spending and teachers.
- The cultural factors which contribute to the importance attached to the 'main stream' curriculum subjects of Maths, Reading and Science.
- The societal factors which contribute to learning outside the school classroom.

Others are unmeasured on a sufficiently infrequent basis so as to prevent their inclusion as regressors in our estimations:

- Teacher trade union membership and activity rates across countries.
- The extent of pension arrangements for teachers.
- The factors which contribute to increases in base teacher salary.
- The methods of training and selection of teachers.
- The qualifications and entry requirements of teachers.

The potential list is huge and unlimited and those listed above are by no means exhaustive. Our central contention is that most of this unobserved heterogeneity is that it remains relatively constant over time. Such 'Fixed Effects' allow us to estimate our models with some expectation that they are free from substantial bias. In the rest of this appendix we set out to demonstrate that this unobserved heterogeneity is relatively constant over time.

One important factor which varies across countries is the extent to which teaching is a unionised profession. Kasten and Fossedal (2009) describe the cross country variation in this unionisation. It is true that many countries have a high degree of teacher unionisation, namely: Denmark (95%), New Zealand (84%), Canada (81%, Netherlands (80%), Sweden (80%), Australia (80%, US (68%), France (67%0, South Korea (65%), Spain (63%), Germany (60%), UK (60%). A smaller number of countries have a low degree of unionisation, namely: Japan (34%), South Korea (5%) and Taiwan (5%). However this pattern of cross country variation was set a long time ago and there is no evidence that this factor has changed much over the 1995-2007 period of our data.

Turning to consider teacher pension variations – we see that in most countries teachers are treated very similarly. According to Ivosevic (2009) in most countries in our data teachers are formally treated as public servants, namely: Denmark, UK, Poland, Hungary, France, Portugal, Finland, Norway, Israel, Iceland, Austria, Belgium, Czech Republic, Switzerland, Sweden, Greece, Spain, and Germany. In relatively few countries are teachers not treated as public servants with respect to pensions. It is true that in several countries, e.g. UK, France, Sweden, Italy there have been recent reforms to the pensions of teacher announced – but most of these changes will be introduced after 2007 when our data end. Even here the fact still remains that the position of teachers vis-à-vis pensions has not changed over the period of our data.

Our key regressor of interest relates to teachers pay. One important source of unobserved heterogeneity is the diverse ways in which teachers are actually paid. This we do not observe on a consistent basis for each year of our study. However we do know details of this across countries for some limited specific years. Using OECD data Table D1 shows the main variants of the determinants of teachers pay for two years, namely 2007 and 2002 across most of the countries in our data. Examining the changes in these methods of giving additional pay supplements we see that between these two years there

is a concordance rate of 88%. In other words, in only 12% of cases does a country change its specific methods of making additional payments over the 5 year period from 2002 to 2007. (These changes are highlighted for convenience by dark shading on the cell where a change has taken place in a given country from 2002 to 2007.) Since this is quite a long period we can only deduce that methods of payment do not change from year to year in different countries.

Unfortunately this kind of analysis is not available for all of the variables – unobserved.

Turning finally to the pattern of selection, qualifications and training teachers have in different countries. The various OECD publications we have consulted sometimes list the qualifications required of teachers in different countries, e.g. OECD (2001b and 2005b). Our reading of those infrequent tables that can be compared is that there have been virtually no changes in these conditions within any country over our time period.

One final point that is well known, but bears repeating, is that to the extent that these unobservable factors may be correlated with the regressors that we do include, then classical attenuation bias suggests that the effect of omitting these potential, but unobserved regressors, is that the estimates of our coefficients of importance – on variables like pupil teacher ratios and teachers salaries, will be biased downwards when the coefficient is positive – like on teachers pay and biased upwards if the coefficient is negative – like on pupil teacher ratios. This classical result gives us more confidence in our basic thesis – that teachers relative salaries matter in the determination of pupil outcomes. Indeed, it suggests that if anything the presence of unobserved heterogeneity may even men that our results are understated in terms of the relative size of their effects.

In summary, the evidence available to us suggests that there has been very little change in most of our 'unobserved heterogeneity' over the 1995-2007 period and that this provides us with a reasonable justification of our methods of econometric investigation.

REFERENCES

Ivosevic, I. (2009) 'Pension Reforms in Europe and their impact on Women', Education International.

Kasten, R and Fossedal, G. 'Teacher union 'concentration' in 21 countries', mimeo.

Table D.1. Evidence on Unobserved Heterogeneity. Criteria for base salary and additional payments awarded to teachers in public institutions

	Criteria based on teaching conditions/ responsibilities										Criteria related to teachers' qualifications, training and performance								Criteria based on demography			
Country	**(a)**		**(b)**		**(c)**		**(d)**		**(e)**		**(f)**		**(g)**		**(h)**		**(i)**		**(j)**			
	2007	**2002**	**2007**	**2002**	**2007**	**2002**	**2007**	**2002**	**2007**	**2002**	**2007**	**2002**	**2007**	**2002**	**2007**	**2002**	**2007**	**2002**	**2007**	**2002**
Australia	√	√				√	√	√	√			√		√	√	√				√		
Austria		√	√	√								√					√	√		√		
Belgium (Fl.)				√								√										
Belgium (Fr.)												√		√								
Czech Republic	√	√	√	√			√	√							√	√			√	√		
Denmark	√	√	√	√	√				√		√	√	√	√	√	√						
England	√	√		√	√	√	√	√	√	√	√	√		√	√	√						
Finland	√	√	√	√	√	√			√	√	√	√		√		√						
France		√	√		√	√	√	√									√	√				
Germany	√	√		√														√	√	√		
Greece				√	√	√					√	√	√	√			√	√				
Hungary		√		√	√	√	√	√			√	√	√	√		√			√	√		
Iceland	√	√	√	√			√	√			√	√	√	√					√	√		
Ireland	√	√			√	√					√	√	√	√								
Italy				√	√	√											√	√		√		
Japan		√	√	√	√	√	√	√									√	√				
Korea		√		√			√	√										√				
Mexico	√	√	√	√	√	√			√	√	√	√	√	√	√	√						
Netherlands	√		√	√	√		√		√				√		√							
New Zealand		√			√	√	√	√		√			√			√						
Norway		√		√	√	√	√				√	√	√	√		√						
Portugal		√		√			√	√			√	√	√	√	√	√		√				
Scotland		√			√	√						√	√	√								
Slovak Republic	m		√	√	√	√	m		m		m		m		m		m		m			
Spain		√			√	√												√				
Sweden	√	√		√	√	√	√		√	√	√	√	√	√	√	√						
Switzerland	√	√		√	√	√	√	√									√	√				
Turkey				√	√						√				√	√	√	√				
United States		√		√	√	√					√	√	√	√								

Notes:
(a) Management responsibilities in addition to teaching duties.

(b) Teaching more classes or hours than required by full-time contract.
(c) Teaching in a disadvantaged, remote or high cost area (location allowance).
(d) Teaching students with special educational needs (in regular schools).
(e) Teaching courses in a particular field.
(f) Holding an initial educational qualification higher than the minimum qualification required to enter the teaching profession.
(g) Holding a higher than minimum level of teacher certification or training obtained during professional life.
(h) Outstanding performance in teaching.
(i) Family status (married, number of children).
(j) Age (independent of years of teaching experience).

Source: 2007 - Education at a Glance 2009: OECD Indicators - OECD Table D3.3a. Decisions on payments for teachers in public institutions.
2002 - Education at a Glance 2004: OECD Indicators - OECD Table D3.2a. Adjustments to base salary for teachers in public institutions.

APPENDIX E. Lowest Common Denominator Estimations.

Table E1. Determinants of Standardised Pupil Scores across Countries 1995-2006 (Using Overall Teachers Wage Growth on Each type of Assessment for 8th grade students)

	Specification I	
	OLS	**Panel**
Teaching hours per year (100s)	-0.010	0.030
	(0.029)	(0.074)
Pupil/Teacher ratio	0.004	0.019
	(0.012)	(0.022)
Women fraction of teaching staff (%)	-0.018***	0.008
	(0.004)	(0.007)
Overall growth in teachers wage average	1.446*	5.575**
	(0.765)	(2.779)
GDP growth (%)	0.147***	-0.041
	(0.024)	(0.029)
Year dummies: (reference year 1995)	0.943***	1.628***
1999	(0.297)	(0.169)
	0.938***	1.366***
2000	(0.279)	(0.178)
	1.747***	1.466***
2003	(0.275)	(0.166)
	1.531***	1.528***
2006	(0.280)	(0.189)
	-2.133***	-6.860***
Constant	(0.744)	(2.415)
Observations	176	176
F-statistic	0.452	0.519
R-squared Within		0.50
R-squared Between		0.39
R-squared Overall	0.36	0.04

Notes:
[1] Bootstrapped standard errors in parentheses. Panel estimates are Fixed Effect Estimates.
[2] List of countries included in the estimates: Austria, Belgium, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Indonesia, Ireland, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Philippines, Spain, USA.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

Table E2. Estimates explaining the Standard Deviation of the *Standardised Scores* for *each type of Assessment*, 8th grade students.

	Specification I		Specification II	
	OLS	**Panel**	**OLS**	**Panel**
Teaching hours per year (hundreds)	0.247***	0.086	0.226***	0.043
	(0.044)	(0.097)	(0.044)	(0.095)
Pupil/Teacher ratio	0.012	-0.165***	0.005	-0.166***
	(0.019)	(0.058)	(0.020)	(0.058)
Women fraction of teaching staff (%)	-0.012	-0.005	-0.004	-0.015
	(0.007)	(0.017)	(0.006)	(0.017)
Teachers' wages after 15 years in 1000$	-0.019**	0.149***		
	(0.009)	(0.042)		
Percentile position of teachers (after 15 years)			-0.000	8.492***
			(0.860)	(2.310)
GDP growth (%)	-0.031	-0.034	-0.023	-0.052
	(0.037)	(0.076)	(0.038)	(0.076)
Year dummies:				
1999	-1.065**	-1.167**	-0.890*	-0.578
	(0.469)	(0.514)	(0.468)	(0.503)
2000	-1.035**	-1.319***	-1.112**	-0.694
	(0.448)	(0.436)	(0.452)	(0.442)
2003	-1.235***	-2.305***	-1.396***	-1.489***
	(0.445)	(0.474)	(0.448)	(0.406)
2006	-0.868*	-1.926***	-1.089**	-0.960**
	(0.457)	(0.496)	(0.454)	(0.451)
Constant	3.701***	2.533	3.031***	1.583
	(0.706)	(1.749)	(0.845)	(1.875)
Observations	178	178	178	178
R-squared Overall	0.372	0.198	0.355	0.204

Notes:
[1] Standard errors in parentheses.
[2] List of countries included in the estimates: Austria, Belgium, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Indonesia, Ireland, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Philippines, Spain, USA.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

APPENDIX F: Nonlinear Estimations

Table F.1. Determinants of Standardised Pupil Scores across Countries 1995-2006 (Each type of Assessment for 8th grade students)

	Specification I		
	OLS	**Panel**	**Simultaneous**
Teaching hours per year (100s)	0.001	0.098	-0.070*
	(0.032)	(0.066)	(0.036)
Pupil/Teacher ratio	-0.062***	0.035	-0.057***
	(0.010)	(0.022)	(0.010)
Women fraction of teaching staff (%)	-0.005	0.014**	-0.004
	(0.005)	(0.006)	(0.006)
Log (Teachers' salaries after 15 years in 1000$)	0.911***	0.593**	0.779***
	(0.127)	(0.269)	(0.219)
GDP growth (%)	0.123***	-0.074***	0.186***
	(0.025)	(0.025)	(0.027)
Year dummies: (reference year 1995)			
1999	1.514***	1.722***	0.586**
	(0.354)	(0.168)	(0.286)
2000	0.870**	1.283***	-0.159
	(0.337)	(0.170)	(0.250)
2003	1.285***	1.253***	0.578**
	(0.334)	(0.177)	(0.259)
2006	1.170***	1.363***	0.125
	(0.342)	(0.189)	(0.268)
Constant	-3.405***	-4.553***	-2.034**
	(0.640)	(1.004)	(0.894)
Observations	205	205	192
F-statistic	20.76***	18.32***	18.95***
R-squared Within		0.49	
R-squared Between		0.21	
R-squared Overall	0.49	0.01	0.48

Notes:
[1] Standard errors in parentheses.
[2] List of countries included in the estimates: Austria, Belgium, Brazil, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Italy, Japan, Jordan, Korea, Netherlands, New Zealand, Norway, Philippines, Portugal, Spain, Tunisia, USA.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

Table F.2. Determinants of Log (Standardised Pupil Scores across Countries 1995-2006, re-scaled from 0 to 100) (Each type of Assessment for 8th grade students)

	Specification I		
	OLS	**Panel**	**Simultaneous**
Teaching hours per year (100s)	0.016	0.045	-0.007
	(0.016)	(0.030)	(0.019)
Pupil/Teacher ratio	-0.066***	0.018*	-0.057***
	(0.005)	(0.010)	(0.005)
Women fraction of teaching staff (%)	-0.002	0.005*	-0.001
	(0.003)	(0.003)	(0.004)
Teachers' salaries after 15 years in 1000$)	0.021***	0.011*	0.021***
	(0.003)	(0.007)	(0.006)
GDP growth (%)	0.073***	-0.026**	0.082***
	(0.012)	(0.011)	(0.013)
Year dummies: (reference year 1995)			
1999	0.689***	0.596***	0.371**
	(0.174)	(0.077)	(0.143)
2000	0.129	0.431***	-0.150
	(0.168)	(0.078)	(0.125)
2003	0.329**	0.395***	0.171
	(0.166)	(0.082)	(0.129)
2006	0.235	0.434***	0.009
	(0.171)	(0.088)	(0.134)
Constant	3.828***	2.755***	4.031***
	(0.250)	(0.324)	(0.304)
Observations	204	204	191
F-statistic	29.57***	10.71***	26.09***
R-squared Within		0.363	
R-squared Between		0.239	
R-squared Overall	0.578	0.025	0.565

Notes:
[1] Standard errors in parentheses.
[2] List of countries included in the estimates: Austria, Belgium, Brazil, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Italy, Japan, Jordan, Korea, Netherlands, New Zealand, Norway, Philippines, Portugal, Spain, Tunisia, USA.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

Table F.3. Determinants of Log (Standardised Pupil Scores across Countries 1995-2006, re-scaled from 0 to 100) (Each type of Assessment for 8th grade students)

	Specification 1		
	OLS	**Panel**	**Simultan.**
Teaching hours per year (100s)	0.028*	0.047	0.004
	(0.016)	(0.030)	(0.018)
Pupil/Teacher ratio	-0.064***	0.017*	-0.057***
	(0.005)	(0.010)	(0.005)
Women fraction of teaching staff (%)	-0.006**	0.005*	-0.005*
	(0.002)	(0.003)	(0.003)
Log (Teachers' salaries after 15 years in 1000$)	0.363***	0.242**	0.372***
	(0.066)	(0.121)	(0.110)
GDP growth (%)	0.063***	-0.031***	0.083***
	(0.013)	(0.011)	(0.013)
Year dummies: (reference year 1995)			
1999	0.723***	0.610***	0.365**
	(0.183)	(0.075)	(0.144)
2000	0.197	0.446***	-0.153
	(0.174)	(0.076)	(0.126)
2003	0.404**	0.397***	0.177
	(0.172)	(0.079)	(0.130)
2006	0.352**	0.446***	0.017
	(0.176)	(0.085)	(0.135)
Constant	3.308***	2.298***	3.519***
	(0.330)	(0.450)	(0.449)
Observations	204	204	191
F-statistic	25.54***	10.90***	25.60***
R-squared Within		0.367	
R-squared Between		0.236	
R-squared Overall	0.542	0.030	0.560

Notes:
[1] Standard errors in parentheses.
[2] List of countries included in the estimates: Austria, Belgium, Brazil, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Italy, Japan, Jordan, Korea, Netherlands, New Zealand, Norway, Philippines, Portugal, Spain, Tunisia, USA.
[3] * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

APPENDIX G: Stochastic Frontier Analysis

Table G.1. Stochastic Frontier estimates

	Dependent variable: Mean standardised scores
Teaching hours per year (100s)	-0.079
	(0.078)
Pupil/Teacher ratio	-0.055***
	(0.020)
Teachers' salaries after 15 years in 1000$	0.056***
	(0.009)
GDP growth (%)	0.149*
	(0.079)
Constant	-0.385
	(1.274)
Observations	38
lnsig2v	-1.540
	(1.334)
lnsig2u	-1.688
	(4.330)

Notes:
List of countries included in the estimates: Argentina, Australia, Austria, Belgium, Brazil, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Korea, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Portugal, Slovenia, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, UK, USA and Uruguay.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Source: Authors' own calculations.

Table G.3. Teachers wage increase involved in bringing countries to the level of Findland

	Actual wage	Target wage	% increase to achieve the target
Argentina	13.029	39.220	201.02
Australia	34.058	35.011	2.80
Austria	27.616	29.759	7.76
Belgium	31.954	30.837	-3.50
Brazil	10.830	48.228	345.33
Chile	11.695	47.399	305.30
Czech Republic	13.588	29.846	119.65
Denmark	32.038	30.123	-5.98
Finland	27.634	27.634	0.00
France	26.279	36.198	37.74
Germany	39.111	37.810	-3.33
Greece	21.729	25.807	18.77
Hungary	10.162	22.723	123.62
Iceland	20.538	26.703	30.02
Indonesia	2.461	40.738	1555.20
Ireland	34.411	26.576	-22.77
Israel	12.574	39.043	210.50
Italy	24.068	31.301	30.05
Japan	37.329	37.905	1.54
Jordan	9.523	38.156	300.68
Korea	38.562	34.535	-10.44
Malaysia	16.817	36.360	116.21
Mexico	14.816	46.439	213.44
Netherlands	35.629	37.067	4.04
New Zealand	28.005	40.277	43.82
Norway	25.563	27.742	8.52
Philippines	9.448	58.712	521.41
Portugal	25.248	29.383	16.38
Slovenia	23.359	25.079	7.36
Spain	30.301	30.791	1.62
Sweden	23.392	28.671	22.57
Switzerland	47.686	35.351	-25.87
Thailand	12.929	38.095	194.65
Tunisia	14.843	34.278	130.94
Turkey	11.725	35.073	199.13
UK	32.707	35.551	8.70
USA	33.316	39.579	18.80
Uruguay	10.640	38.178	258.82

Source: Authors' own calculations.

We can think on the educational system as a firm which attempts to obtain an output by the transformation of a set of inputs. If we define y_i as the maximum potential performance which, on average, students can obtain for any given combination of inputs, then equation (1) represents an educational frontier production model. This representation requires some assumption concerning the disturbance term. The two hypothesis which appear to satisfy the greatest level of acceptability, lead us to differentiate between the deterministic frontier model and the stochastic frontier model. The stochastic frontier production, as outlined by Aigner, Lovell and Schmidt (1977), Meeusen and Van den Broeck (1977) and Battesse and Corra (1977) rely on the premise

that the deviations from the production function are due to statistical noise. Such a stochastic factor cannot be attributed to the process of production, and hence should not be embedded in a single error term. Hence we require two stochastic terms as expressed in equation 1)[34],

$$y_i=\alpha+X'_i\beta+v_i-u_i \qquad \begin{matrix} i=1, ..., n \\ u_i \geq 0 \end{matrix} \qquad (1)$$

where v_i is usually assumed to be a normally random variable (distributed independently of u_i) with mean zero and variance σ^2_v, and u_i a non negative error typically assumed to be a half-normal distributed variable[13], with $\sigma^2_u > 0$. Furthermore, we assume both components of the compound disturbance to be independent and identically distributed (i.i.d.) across observations. In this model $\lambda = \sigma_u^2 / \sigma_v^2$, which is a measure of the degree of asymmetry of the (v_i-u_i) disturbance term. The larger is λ the more pronounced will be the asymmetry and the correspondingly the OLS estimation is less justified. When we estimate equation 1 we obtain efficiency scores which can be used as a measured of the relative efficiency for the countries under analyses, showing the 'best' combination of inputs to maximize average student's performance.

Table G.3. Efficiency scores by country (from lowest to highest)

Tunisia	52.861	**Austria**	75.028
Argentina	54.727	**Belgium**	75.356
Brazil	59.422	**Australia**	75.662
Greece	60.391	**Iceland**	76.773
Switzerland	62.377	**Philippines**	77.019
Spain	64.593	**UK**	77.087
Portugal	64.606	**Sweden**	78.721
Mexico	65.391	**Chile**	78.777
Norway	66.372	**Jordan**	78.819
Denmark	67.743	**Netherlands**	79.933
Germany	68.503	**France**	80.640
Ireland	69.297	**Korea**	81.907
Slovenia	69.717	**Malaysia**	82.078
Italy	69.777	**Hungary**	82.120
Turkey	71.363	**New Zealand**	83.080
Thailand	71.471	**Japan**	83.331
Uruguay	73.645	**Israel**	83.791
Indonesia	73.798	**Finland**	83.961
USA	74.256	**Czech Republic**	84.822

Source: Authors' own calculations.

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[34] As a result this model can be regarded as a generalisation of the standard regression model, the distinguishing feature of which is the presence of a one sided error (u_i).