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Critical Review

School Resources and Student Achievement: Worldwide Findings and Methodological Issues

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Abstract *The issues raised in the Education Production Function literature since the US 1966 Coleman Report have fuelled high controversy on the role of school resources in relation to student performance. In several literature reviews and some self estimates, Erik Hanushek (1986, 1997, 2006) systematically affirms that these two factors are not associated one to another – neither in the US nor abroad. In recent cross-country analyses, Ludger Woessmann (2003; 2005a; 2005b) links international differences in attainment to institutional differences across educational systems – not to resourcing levels. In the opposite direction, Stephen Heyneman and William Loxley (1982, 1983) tried to demonstrate in the 1980s that, at least for low income countries, school factors seemed to outweigh family characteristics on the determination of students' outcomes – although other authors show evidence that such a phenomenon may have existed only during a limited period of the 20th Century. In the 1990s, meta-analyses raised the argument that school resources were sufficiently significant to be regarded as pedagogically important. The turn of the Century witnessed a new movement: the recognition that endogenous determination of resource allocation is a substantial methodological issue. Therefore, efforts have been made to incorporate the decision-making processes that involve families, schools and policy-makers in economic models. This implies changes in research designs that may affect the direction of future policy advices patronised by international development and educational organisations.*

Main Findings and Controversies

The "foundation stone" and evolution of the literature in the United States

In 1966, The United States Government launched a report on educational inequality (Coleman, Campbell, Hobson, McPartland, Mood *et al.,* 1966) that found family background and peer effects to be the major determinants of student achievement. Despite several criticisms about the methodologies used and the inferences made (Cain and Watts, 1970; Vergestegen and King, 1998), that report is even now considered the first major study of education production functions (Hanushek, 1986; Card and Krueger, 1996; Hanushek, Rivkin and Taylor, 1996; Levacic, 2005; Nascimento, 2007a, b), and a reference point for both education production function (hereafter called EPF) and school effectiveness research (Levacic, 2005).

EPFs are an analogy made by economists between the learning process and the production process that takes place in a firm: schools are then seen as the place where educational resources (teachers, books, buildings, equipment etc, and the students themselves) interact to produce an output, which is the student outcomes, normally expressed in terms of test scores or future wages. Economists estimate EPFs using data available on these resources (inputs) and outcomes (outputs). The major criticism on this paradigm is its failure to account for the processes by which educational resources interact to help students to achieve desirable outcomes – and for educationalists understanding these interactions may be more important than a simple relationship between resource-level and pupil achievement (Levacic, 2005). Moreover, it depends on the quality of the data and the statistical procedures applied by the researcher (Nascimento, 2007a). The findings of an EPF are, at best, estimated impacts of resources on attainment – as it will be seen later, methodological issues impose limitations on the conclusions that one can reach with an EPF, and the researcher must be very careful before claiming any causality in his or her results.

School effectiveness research, on the other hand, tries to open the black box and identify the contexts, processes, methods and methodologies that transform educational resources in student outcomes – rather than examining resources per se (Levacic, 2005). Notwithstanding, estimating EPFs may be useful to assess efficiency and efficacy of the use of educational resources – in other words, a way to address which educational resources are relevant, to what extent and level, and given the school context.

Since the advent of the so-called Coleman Report, little dispute exists on the associations of family background with achievement (Ross and Zuze, 2004), but the role of educational resources as a predictor of student performance has been severely controversial in the EPF literature. An economist called Eric Hanushek has become a key author in this debate due to his successive summaries of the literature (Hanushek, 1986, 1997) as well as to estimates conducted by himself alone or with others (Harbison and Hanushek, 1992; Hanushek and Luque, 2003) or by commenting on the implications of data aggregation (Hanushek, Rivkin and Taylor, 1996). His conclusions are always that additional resources per se do not improve educational outcomes.

This position did not remain unchallenged. During the 1990s, three other authors produced a number of influential papers (Hedges, Laine and Greenwald, 1994a; Hedges, Laine and Greenwald, 1994b; Hedges and Greenwald, 1996) in an attempt to demonstrate that Hanushek's compilation and interpretation of the available studies were inappropriate and that meta-analysis shows a different picture, in which resources' impact is big enough to be educationally important. Other literature reviews at the time also tended to see a greater number of findings for, rather than against positive effects of school resources on student attainment (for example, Vergestegen and King, 1998).

More recently, Krueger (2003) reinforced the argument put forward by Hedges et al.(1996) that Hanushek's sample of estimates is biased towards his conclusion. Insert a sentence here detailing Krueger arguments and conclusions. Hanushek, however, has barely changed the position maintained since his 1986´s influential paper and continues to suggest the view that "the evidence – whether from aggregate school outcomes, econometric investigations, or a variety of experimental or quasi-experimental approaches – suggests that pure resource policies that do not change incentives are unlikely to be effective" and "the general inefficiency of resource usage are unlikely to be overturned by new data, by new methodologies, or the like", although he admits that "altered sets of incentives could dramatically improve the use of resources" (Hanushek, 2006, pp 2, 38-39).

Findings for Europe, Brazil and Other Developing Countries

The majority of EPF studies were conducted in the US, and tend to reinforce Coleman's most controversial finding, that variation in achievement is more closely tied to family background than to school resources – although evidence for countries with very low per capita income some times suggest contexts where student outcomes tend to be more sensible to the availability of school resources (Gamoran and Long, 2006).

In Europe, the United Kingdom leads EPF research efforts (Vignoles *et al.,* 2000; Levacic and Vignoles, 2002; Steele, Vignoles and Jenkins, 2007), although "the UK literature has relatively few methodologically strong studies […] [and] lacks both depth and breadth of coverage" (Levacic and Vignoles, 2002, p 323, cited in Woessmann, 2005a). Overall, well-designed UK studies (using pupil-level longitudinal data with a range of resource and control variables) point to small resource effects (Levacic and Vignoles, 2002).

Woesmann (2005a), focusing on class-size evidence, mentions a few other European EPF studies, mainly from Scandinavian countries; most of which find little resource effects, some find strong effects, and others find no effects at all or even negative effects – estimated in terms of standard deviations of test scores that could be attributed solely to variations in the provision level of the resource variable under analysis (Azevedo, Ghirardi and Santos, 2003).

A summary for developing countries is given by Glewwe (2002). He highlights four well-designed studies completed in the early to mid-1990s that attempt to estimate EPFs using data specifically collected for that purpose. The first of these was Harbison and Hanushek (1992), which examined the effects of school and teacher characteristics on the performance of primary-school children in rural areas of Northeast Brazil in reading (Portuguese) and Mathematics tests administered in 1981, 1983 and 1985. Facilities, writing materials, textbooks and teacher salaries showed positive impacts. The estimated effects, however, were relatively small in comparison with the other highlighted studies for developing countries.

Glewwe and Jacoby (1993) found large estimated impacts for some school inputs in a study of Ghana, although most estimated effects were actually small and not statistically significant. Many school and teacher variables, which influence achievement tests given in 1988-89 in Reading (English) and Mathematics in middle schools (grades 7-10), were examined. Greater impacts were observed for blackboards and classrooms' maintenance, which raised scores between 1.8 and 2.2 standard deviations.

Glewwe *et al.* (1995) analysed data collected in 1990 in Jamaica on the performance of primary-school students in reading (English) and Mathematics. School and teacher characteristics examined included pedagogical processes and management structure. Although most variables had statistically insignificant effects, some school variables showed significantly positive impacts. The largest impact was a change from never using textbooks in instruction to using them almost every lesson, which raised reading scores by 1.6 standard deviations. Estimated impacts for Jamaica were smaller in size than for Ghana, but greater than the ones Harbison and Hanushek (1992) found for Brazil.

The last study highlighted by Glewwe (2002) is Kingdon (1996), which collected data in 1991 in India for tests in reading (Hindi and English) and Mathematics given to students in grade 8. A range of teacher and school characteristics were examined. Two out of five teacher variables (teacher exam marks and teachers' years of education) and two out of the three school variables had some positive impacts. The size of the estimated effects was smaller than Glewwe and Jacoby's (1993) findings for Ghana and Glewwe's *et al.* (1995) results for Jamaica, but greater than Harbison and Hanushek's (1992) for Brazil.

Recent studies focused on Brazil find positive effects of resource variation on student achievement, but socioeconomic characteristics and previous ability show far more robust influence (Albernaz, Ferreira and Franco, 2002). Most such studies are school effectiveness research rather than EPFs (Espósito, Davis and Nunes, 2000; Soares, César and Mambrini, 2001; Franco, Albernaz and Ortigao, 2002; Soares and Alves, 2003; Mello e Souza, 2005; Andrade and Laros, 2006), but some EPF studies can be found among them (Barros *et al.,* 2001; Albernaz, Ferreira and Franco, 2002; Azevedo, Ghirardi and Santos, 2003; Menezes-Filho and Pazello, 2004; de Felicio and Fernades, 2005; Curi and Menezes-Filho, 2006b; Curi and Menezes-Filho, 2006a; Menezes-Filho, Fernades and Picchetti, 2006; Menezes-Filho, 2007).

The "Heyneman-Loxley effect": is the picture really different for poor countries?

Another interesting debate concerning the size of school effects on student achievement was started by two papers published by Stephen Heyneman and William Loxley in the early 1980s. Basically Heyneman and Loxley (1982, 1983) try to demonstrate that, at least for lower income countries, where substantial variation in school quality was observed in the early 1970s from the results of the Second International Mathematics and Science Study (SIMSS), the impact of school and teacher quality factors on student performance are comparatively greater than family socioeconomic status. They advocate that "the poorer the national setting in economic terms, the more powerful [school and teacher quality effect] appears to be" (Heyneman and Loxley, 1983, p 1184).

Baker, Goesling and Letendre (2002), examining data from the Third International Mathematics and Science Study (TIMSS), which happened in the1990s, conclude that Heyneman and Loxley's findings for the 1970s were not observable anymore two decades later. Baker, Goesling and Letendre (2002) attribute the "Heyneman-Loxley effect" to the lack of mass schooling investments in most developing countries back in the 1970s. They argue that most developing countries, supported by multilateral agencies, financed a widespread school expansion in the 1980s and 1990s and this is likely to have transformed schooling in poor countries into "a normalised part of the life course for most children and their families and a key to future opportunities", stimulating "family and students throughout the system to take school achievement seriously" and therefore "family inputs can take on larger effects as schooling quality reaches a threshold throughout a nation" (Baker, Goesling and Letendre, 2002, pp 310-311). Moreover, the expansion of education systems in developing countries is likely to have generated better educated cohorts of parents, thus fostering family effects – inducing a catching-up effect for developing nations towards developed countries' relative composition of family and school effects on student outcomes. The authors conjecture, however, that the Heyneman-Loxley effect might persist in countries where extreme poverty or social upheaval such as civil war or epidemics slowed down mass schooling.

Hanushek and Luque (2003) test the Heyneman-Loxley effect using alternative methods that aggregate differences across countries in seven voluntary international tests of student achievement in Mathematics and Science administered by the IEA (five tests) and the International Assessment of Educational Progress (IAEP). Their analysis "does not support the notion that school resource impacts vary systematically with country income or development" (Hanushek and Luque, 2003, p 498). Instead, the authors suggest that organizational and incentive issues incorporated into EPFs by Woessmann (2001, 2003, cited in Hanushek and Luque, 2003) "are likely to be more important than concentration on just resources to schools" (Hanushek and Luque, 2003, p 498).

School resources and educational institutions: an attempt to explain why students in some countries do better

Estimating EPFs for four high-performing Asian countries (Korea, Japan, Singapore and Thailand) and one region (Hong-Kong), Woessmann (2005b) found family background to be a particularly strong predictor of student performance in Korea and Singapore. Resources did not seem to be strongly related to students' achievement. However, "more institutional schooling policies, giving schools autonomy in salary decisions might strengthen educational performance, especially in Japan and Singapore" (Woessmann, 2005b, p 351).

In an earlier cross-country comparison, with a greater number of countries and regions from different continents, the same author found similar results. Indeed, Woessmann (2003), using an international student-level micro database from the TIMSS to estimate an EPF that also includes institutional differences across the varied schooling systems, concludes that international differences in student performance are attributable to institutional differences rather than to resource variation.

However, he admits that the estimates of resource effects may be biased due to *potential endogeneity of resources to student performance* – a methodological problem to be discussed in greater detail in the next section.

Do Resources Impact on Achievement or is it the other way round? Potential biases due to the endogeneity of resources and methodological ways to deal with that

Endogenous determination of school resources is a relevant problem that many EPF studies using data from natural settings widely ignore. The term *endogenous* refers to the fact that educational resources are not randomly allocated into schools – the type, extent, level and continuity of resources available to the schools are a consequence of factors such as financing rules, school performance and parental choices. Without taking account of it, however, serious methodological shortcomings arise and "cast doubt on whether any conclusions can be drawn with confidence" (Glewwe, 2002, p 445).

For example, local districts may have compensatory policies that allocate more resources to schools where the percentage of disadvantaged students is higher. In such a setting, simply examining the correlations between level of resources and achievement will reach misleading conclusions, as it is likely that the numbers will show better resourced schools performing worse. Another common illustration of inter-relationships that distort the impact of resources on achievement refers to the housing choices exerted by parents. In most countries, students are assigned to neighbourhood schools. As a result, the wealthier the family, the greater their capacity for choosing good public schools for their children through the process of choosing where to live. In this case, some popular schools might outperform others in standardised tests because of the proportion of wealthy students studying there – not because of better school resources.

Therefore, this problem potentially introduces inter-relationships between the variables included in the model (resource measures, student, family and school characteristics, previous achievement etc) up to the point that a dual causality path confuses the findings: would it be resource that affects achievement or the other way round?

The major methodological implication of these inter-relationships is that Ordinary Least Squares (OLS) estimates, the most common estimation method applied to production functions and which relies on the assumption that explanatory variables are exogenous to the model, are biased – and this bias does not disappear no matter how big the sample is (Vignoles *et al.,* 2000).

Some authors consider that well-executed randomised controlled trials and natural experiments are the best ways to overcome this methodological problem (Glewwe, 2002). Despite having their own potential shortcomings, randomised studies and natural experiments would be likely to overcome methodological problems faced by conventional EPF studies (ie, endogeneity of resources). This would be the most appropriate way to avoid the "noteworthy degree of inconsistency" (as expressed by Monk, 1989, p 35) observed in the results for the majority of the input variables examined by the studies reviewed by Hanushek – among 106 studies estimating the relationship between teacher education and educational outcomes, 6 reported a statistically significant positive relationship, 26 a statistically insignificant positive relationship, 5 a statistically significant negative relationship, 32 a statistically insignificant negative relationship, and 37 reported statistically insignificant results that could not be categorised. Similar inconsistency was also the case for teacher/pupil ratios, teacher experience, teacher salary, and expenditures per pupil (Monk, 1989).

Others highlight the limitations of experimental designs in social research and advocate the use of instrumental variables (Hoxby, 2000; Todd and Wolpin, 2003), an approach based on "a statistical treatment of the data that tries to isolate the effect of the endogenous variable on the outcome variable" (Nascimento, 2007b, p 14). The instrumental variable approach will be discussed in more detail in the next section.

Propensity matching scores (comparing groups which members present similar characteristics, but only one group receives a "treatment") and frontier analysis (looking at the performance of individual schools in relation to the education production frontier) are also econometric techniques that can be applied to education production functions (Vignoles *et al.,* 2000). The focus here, however, will be on the most popular and discussed methods among economists to deal with the endogeneity problem – ie, experimental designs and instrumental variables.

Randomised controlled trials, natural experiments and the instrumental variable approach: how they potentially eliminate the risk of endogeneity of resources and what limitations they face in EPF research. Random controlled trials (hereafter, RCTs) are "the closest research design to creating the counterfactual" (Levacic, 2005, p 10). In such studies, "the values of at least a subset of the inputs are chosen by random assignment and are therefore not subject to choices made by parents or schools" (Todd and Wolpin, 2003, p F6). The most cited example of a well-conducted RCT is the STAR experiment - Tennessee Student/Teacher Achievement Ratio (Levacic, 2005; Todd and Wolpin, 2003).

Natural experiments or quasi-experiments arise when extra resources are allocated to some schools and not to others due to an exogenous factor that cannot be controlled or is not expected by parents, schools or even policy-makers. An example of this happened between 1989 and 1993 in Austin, Texas, when fifteen schools were given substantial extra resources as a result of a desegregation court case.

The results of the impact on student performance of Austin's natural experiment were presented by Murnane and Levy (1996). Students from two of the fifteen schools showed significant improvement in achievement and attendance by the end of the "experiment". The performance of students from the other thirteen, however, remained unchanged. The authors conclude that some schools use money wisely and others do not.

Studies based on the STAR experiment also present some results pointing in opposite directions, but Levacic (2005, p 10) highlights that most of them "found that smaller classes raised achievement, in particular for socially disadvantaged children". She adds that, in response to such findings, California implemented a state-wide reduction in kindergarten class size. The policy effect for the whole state, however, "was less effective than expected because of an insufficient supply of good quality teachers" (Levacic, 2005, p 11).This example illustrates a fundamental problem with experimental evidence – that of replicability. Indeed, difficulties arise concerning replicability of the experimental results to the general population "because of differences between the experimental treatment group and the general population or because of behavioural responses to the policy instrument when it is scaled up that do not exist or have a very small impact in the smaller scale experiment" (Levacic, 2005, p 11).

Moreover, although RCTs and natural experiments create "exogenous variations that, under ideal conditions, allows certain policy effects to be identified even in the presence of missing data problems" (Todd and Wolpin, 2003, p F6), this kind of evidence "does not solve the specification problem in modelling the production of cognitive achievement" (Todd and

Wolpin, 2003, p F31). Conclusions based on RCTs are valid only for the setting where the intervention was effective.

Finally, RCTs and natural experiments are rarely seen in education because the former often face ethical and political objections and the latter depends on occasional externally imposed situations.

Experimental evidence is therefore useful for understanding the effects of particular policy interventions (Todd and Wolpin, 2003), as long as problems such as non-random selection and attrition, inadequate sample sizes, and incorrect implementation of the intervention, are addressed in a convincing manner (Glewwe, 2002). However, in order to estimate the parameters of EPFs that are generalisable at least to some extent, "the vast majority of education production function research (…) needs to use non-experimental data – ie, that collected from natural settings" (Levacic, 2005, p 11).

Nevertheless, the need to rely mostly on data generated from natural settings often imposes a risk of unknown bias in the estimated effect sizes. The relationship between school resources and student achievement is likely to present a two-way causality path if schools have the same funding formula or resource allocation is subject to parents and school behaviour. As a consequence, it requires a theoretical framework that goes beyond the 'supply-side' relationship of an education production function (Mayston and Jesson, 1999).

The limitations and scarcity of experimental designs in education drive economists to search for a source of identification that overcome the endogeneity problem (Angrist and Krueger, 2001). The popularity of the instrumental variable approach is a result of this need.

Instrumental variables are vectors (measures or group of measures with particular common characteristics) that must not be directly related to the outcome variable, but do need to be strongly correlated with the endogenous variable (Wooldridge, 2002). They often resemble natural experiments, like the maximum class size rule explored in Angrist and Lavy (1999) and Dobbelsteen et al.(2002), and natural variations in birth rates implying exogenous differences in the various cohorts of pupils, a strategy explored by Hoxby (2000).

This approach normally involves a two-stage estimation process, known as two-stage least squares: basically, the endogenous variable is regressed against the instrument first, and then the coefficient estimated for the instrument in the first equation substitutes the resource variable of interest in the second stage, where the outcome variable is the measure of student achievement (Webbink, 2005). In mathematical terms, it would look like:

Stage 1:
$\text{RESOURCE}_{\text{original data}} = \alpha_1 + \beta_1 \text{ INSTRUMENT} + \varepsilon$
Stage 2:
$\text{ACHIEVEMENT} = \alpha_2 + \beta_2 \text{ RESOURCE}_{\text{after 1st Stage}} + \varepsilon$

Where α´s and β´s are coefficients to be estimated and ε´s are error terms. The "net" impact of resource on achievement is then given by β_2.

Although the instrumental variable approach is generally applied in this way, Steele, Vignoles and Jenkins (2007) argue that multilevel simultaneous equation models deal more effectively with the fact that the endogeneity problem happens primarily at the school level, while the outcome of interest (test scores) is measured at the pupil level.

Does money matter after all? Synthesising what the literature says and the concerns brought up by the endogeneity problem

The EPF literature is equivocal about resource effects on student achievement. Findings often point in opposite directions, fuelling endless controversies on whether “there is no strong or consistent relationship between school resources and student performance” (Hanushek, 1997, p 148) or “school resources are systematically [and sufficiently] related to student achievement […] to be educationally important” (Hedges and Greenwald, 1996, p 90). Indeed, the degree of influence of school resources on student achievement seems to vary widely depending on the sample taken, the level of aggregation of the data, and methodology used (Nascimento, 2007).

Perhaps the point should be how extra resources are used by schools (Burtless, 1996) – as some experiments seem to indicate that extra resources are effective only when they are used efficiently. Looking beyond simple resource policies and analysing how schooling systems operate might be a way to create an efficient manner by which resources could be allocated to schools and then affect student outcomes to the extent parents and policy-maker seem to wish. In this sense, "funding is really an indirect variable of importance to student achievement, and the allocation decisions of this funding are more directly related to student achievement" (Jefferson, 2005, p 121). In other words, "systems of learning are the cause and resources the facilitators or inhibitors of learning" (Cohen *et al.,* 2003, quoted by Levacic, 2005).

EPF researchers should be aware that, unless unusual well-executed educational random assignments or natural experiments take place, generating exogenous variation in the resources allocated to schools, utility maximisation behaviours from parents and schools, as well as possible compensation for students’ background through extra school funds allocated by the Government to disadvantaged schools or districts, demand appropriate methodological solutions due to biases caused by potential endogeneity of resources to student achievement.

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