What Education Production Functions *Really* Show: A Positive Theory of Education Expenditures

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Abstract: The existing empirical work on educational production functions provides powerful insights into a positive theory of the allocation of educational expenditures. An optimizing model of expenditure allocations predicts that input use should be chosen so that the marginal product per dollar of each input is equalized. In decided contrast, the existing literature shows that the marginal product per dollar of inputs not directly valued by teachers are 10 to 100 times higher than that of inputs valued by teachers. This implies that inputs which provide direct benefits to educators (like teacher wages) are vastly over-used relative to inputs that contribute directly (but only) to educational output (like books or instructional materials). One class of positive models of expenditures consistent with this empirical finding invoke a very high ratio of teacher to parental (or student) influence in the determination of expenditures. This implies that in some circumstances educational reforms that shift the relative strengths of parents versus teachers in the allocation of expenditures can lead to enormous gains in the cost effectiveness of schools.

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What Education Production Functions *Really* Show: Towards a Positive Theory of Education Expenditures[1]

Introduction

There is broad consensus that expansion in the skills, knowledge, and capacities of individuals --increasing human capital-- is a key element in economic progress and raising living standards. Schooling within formal education systems plays an important role in the expansion of human capital and governments and international fora have often made explicit targets for the expansion of schooling in enrollment or targets for expenditures. However, there is a big difference between children sitting in a classroom and an increase in human capital. The quality of education is a deep concern in many developing countries. On internationally comparable tests some developing countries, such as Korea and China, do quite well, but others do abysmally[2]. In some countries students' achievement test scores after years of instruction are little better than random guessing. If these quality deficiencies were due merely to the lack of inputs the policy prescription would be obvious: increase resources. However, a cumulation of empirical literature using comparisons of student performance across countries, across regions within countries, and across schools within regions consistently produces the puzzling and worrisome finding that resources are only tenuously related to measured achievement.

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[1] We would like to thank Marlaine Lockheed, Emmanuel Jimenez, Elizabeth King, Harold Alderman, Michael Kremer, and Jonah Gelbach for helpful comments and discussion.

[2] On the comparison of reading performance of 10 years olds, Venezuela and Indonesia were an amazing 6.5 standard deviations below the average of the developed countries. On a similar assessment of science performance of 10 year olds, students from Nigeria and the Philippines were 2.6 and 3.7 standard deviations below the developed country mean.

In this paper we build on Hanushek's (1995) argument that since budget differences do not account for performance, the incentives that determine how well the budget is spent must play an important role. We argue the evidence is grossly inconsistent with the assumption that resources are allocated to maximize educational output (however defined). The key indicator of this misallocation is that the cost effectiveness, or achievement gain per dollar, of teacher related inputs is *orders of magnitude* lower than alternative inputs. Relative overspending on inputs that are of direct concern to teachers is so pervasive that it is consistent only with a model of the allocation of education spending in which teacher welfare influences spending, over and above its impact on school quality.

When performance is more a function of incentives than of spending the policy implications are less obvious. While in some cases merely increasing the budget is the appropriate educational policy, it is increasingly recognized that in many other situations more fundamental reforms that enhance the importance of outputs of education in spending decisions are necessary (Inter-American Development Bank, 1996).

We want to stress that although we argue that the evidence is consistent with enormous inefficiencies in education spending due to relatively high spending on teacher inputs, this should not be construed as an attack on teachers, who are the backbone of any educational system. But "government" actions are neither *deus ex machina* nor *satanas ex machina*, but the result of the interaction of differing interests. Suggesting that educators defend their interests is a methodological assumption common to all economics, not an *ad hominem* attack. Just as there are "market failures" intrinsic to the incentives of decentralized, uncoordinated exchange, there are "government failures" which are equally inherent in the structure of incentives created by allocation through the political process[3]. The political pressures on the allocation of expenditures across functional categories that we explore here for education are almost certainly present in other sectors: health clinics with personnel but without drugs or needles, or highways without maintenance are depressingly common.

I) Theories of the allocation of expenditures

This section first explains why a behavioral theory of expenditure allocation is important for understanding the results of empirical examinations of the determinants of educational outcomes. One such theory, an output maximizing model is presented along with three variants: a simple single educational output, a model with uncertainty, and a model that accommodates multiple educational outputs. We then introduce an alternative model of expenditure allocations in which both educational outputs and teacher welfare enter directly into the determination of spending.

A) Why it takes a theory

Production possibilities are determined by an underlying technological process. The maximum amount of output possible for an amount of inputs given the constraints imposed by

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[3] Although it should be pointed out this trend in considering market and government failures is a renewed, not new, interest for economists:

> It is not sufficient to contrast the imperfect adjustments of unfettered private enterprise with the best adjustment economists in their studies can imagine. For, we cannot expect that any State authority will attain, or will even whole heartedly seek, that ideal. Such authorities are liable alike to ignorance, to sectional pressures, and to personal corruption by private interest (Pigou, 1912).

the underlying technical process is the "production function." The relationship between plant growth and water or sunlight or fertilizer is determined by a biological process, the relationship between coal burned and heat produced is determined by a physical process. Similarly, applying the metaphor to education one can talk of the educational "production function" which is determined by an underlying pedagogical process.

Even though the production function is derived from technical, not behavioral relationships, one needs a behavioral theory to understand the results of estimating a production function for two reasons. First, the increment to output from additional inputs is not constant. The second algebra book per student will likely help less than the first, and the tenth much less (perhaps even have a negative impact). The contribution to output of an input depends on the rate of input utilization at which it is assessed. Nearly all education production function studies are not experiments in which input use is chosen by a researcher, but rather use data drawn from reality. In reality, the spending on inputs (e.g. teacher wages, class sizes, buildings, textbook use) is chosen for reasons other than research and since input use is chosen, the theory of the input choice predicts the observed input productivity and guides the interpretation of results.

This is particular important in educational research, as there is a crucial distinction between testing whether inputs have low productivity at their current rate of application versus testing whether they are "inputs" at all. One could study the effect of either fertilizer or Mozart piano concertos on corn production. Even though at sufficiently high rates of application the size of fertilizer's impact could be small (or even negative), fertilizer is clearly an input, and the only question is the magnitude of the impact. On the other hand, Mozart's music, while delightful, might not be an input into corn production, in the sense that it has zero corn production impact across all soil conditions, concerti, and volumes.

Teachers, classrooms, and instructional materials are clearly inputs into education. If one understands the statistical tests of whether the effect of class sizes or teacher wages are different from zero as tests of whether these inputs *ever* matter (as with Mozart music) the whole endeavor appears silly and pointless (which in fact has often been the reaction of the education community to this line of empirical research). However, as the model described above suggests, a failure to reject zero marginal product of higher teacher wages or reduced class sizes may simply mean that the rate of application is so high that the marginal product *at the chosen rate of application* conditional on other inputs is (statistically) indistinguishable from zero.

Second, as discussed in section III, the policy implications of empirical findings depend critically on the theory behind the data. If the input use is the result of some endogenous political process, changes in input use may not be feasible without changes in the underlying process that determines budgets. Simple statements like "spend more on input x" are not necessarily valuable contributions to policy making when policies are politically determined.

B) A plausible (at least to economists) theory, with variations

Variation 1: Simple output maximizing. How would someone fully informed about the production function allocate spending of a fixed budget across inputs to maximize output (or, equivalently, allocate inputs in order to minimize the input costs of a specified level of output)? If educational output is denoted by S and is related to educational inputs (e.g. books, teachers, desks) denoted as elements x_i of a vector X, each of which has a price p_i, according to a technically determined production function f^S, then the maximization problem subject to a fixed money budget B is:

$$\begin{aligned} &Maximize\ S = f^s(X) \\ &s.t.\quad p^{/}X = B \end{aligned}$$

The assumption that inputs are allocated in this optimizing fashion creates very strong predictions about the results of estimating educational production functions. Whatever the budget, inputs should be allocated such that the marginal product per dollar (MPPD) is equalized across all used inputs. That is, the first order conditions are[4]:

$$\frac{f_i^S}{p_i} - \frac{f_j^S}{p_j} = 0, \quad \forall\ i,j \tag{1}$$

which means that the ratio of the marginal products in the production function should be exactly the same as the ratio of the prices, or the increment to educational output per dollar, or technical cost effectiveness spent, should be exactly the same for each input[5].

Two objections to this simple model can be incorporated as more or less minor variations of the optimizing model: first, that those allocating inputs are not fully informed and second, that schooling cannot be characterized as a single output.

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[4] These are the conditions for an interior maximum involving some use of inputs i and j,

[5] This is of course the old (and by now obvious) condition for economic efficiency in any endeavor. As Frank Knight pointed out in 1921 “In the utilization of limited resources... we tend to apportion our resources among the alternative uses that are open in such a way that equal amounts of resource yield equivalent returns in all fields.”

Variation 2: Optimizing with uncertainty Some might claim that the person allocating the inputs is trying to maximize the test score increment from spending a fixed budget but the "true" educational production function is a very complex thing about which the chooser knows very little. That the educational production function is complex is almost certainly true as the underlying pedagogical relationships, like any relationships that involve purposive human behavior, are enormously complicated. The exact processes and procedures followed inside the classroom, including almost intrinsically unobservable factors such as the match of the personality of the teacher and the student, certainly matter for educational outcomes in ways that will be impossible for any large sample empirical research to capture. Moreover, there are bound to be interactions between various inputs which will be very difficult to empirically specify.

However, no matter how complex the true function, the situation can be formally characterized by assuming the person making the allocation decision believes that on average the true relationship is some production function, *g*. Therefore, the optimizing allocation will be such that:

$$\frac{g_i^S}{p_i} - \frac{g_j^S}{p_j} = 0 \quad \forall \; i,j \tag{2}$$

that is, the person deciding on the allocation *believes* he or she is equalizing the marginal products per dollar in the production function.

Variation 3: Optimizing with multiple outputs A second objection is that many would allege that researchers are missing a large part of what schools are all about with their narrow minded obsession with test scores[6]. In every society schools are meant to transmit more than information: they also transmit expected and acceptable patterns of social interaction and cultural norms and beliefs (Piccioto, 1996). Moreover, parents, children and society at large care about many more features of a school than just the improvement they provide to test scores: the pleasantness of the environment in general (e.g. personal safety), non-academic cultural opportunities (e.g. music), non-academic recreational opportunities (e.g. sports), equalization of outcomes across students with different innate abilities (e.g. remedial education spending).

However, in spite of the complexity, this situation can also be formally characterized as a variation on the optimizing model. Suppose that the objective function involves two outputs: test scores, *S*, and some measure of non-academic output, *C* (C for "Citizenship" or "Culture" or "not being a Criminal"). In this case the optimizing problem is to maximize the total value of all school output subject to the production function for each of the outputs and the budget constraint (expanding this set-up to include more than two outputs or to allow a non-linear objective function would also be straightforward). That is, inputs will be allocated in order to maximize the value of:

$$S(X) + p_c C(X)$$

subject to the production functions for *S* and *C*:

$$S = f^s (X^S, X^C)$$
$$C = h^c (X^S, X^C)$$

[6] Since most researchers have been selected (self or otherwise) to be researchers at least to some extent on the basis on their performance on test scores during their academic career this obsession is perhaps understandable.

and the budget constraint.

The first order conditions for an interior maximum in this case imply that the marginal product of each input in the production of each output ("scores" and "citizenship") will not be equalized. The way these vary will depend on both the relative value placed on the two outputs (p_c) as well as the relative marginal products and prices of the various inputs.

$$\frac{f_i^S}{p_i} - \frac{f_j^S}{p_j} = p_c * \left[\frac{h_j^C}{p_j} - \frac{h_i^C}{p_i} \right], \quad \forall\ i,j \tag{3}$$

This model implies the marginal product per dollar in producing scores at the optimum will be different if the marginal products of inputs in producing scores and "citizenship" is different. If one input is relatively more productive in the production of "citizenship" then its input use will be higher (and hence marginal product per dollar in scores production lower) than if one were optimizing over scores alone.

While this has been presented as a normative model, what a person should do if in fact they wanted to optimize, the simplest behavioral model of the allocation of spending is to assume the *normative* model is the *positive* model. That is, just assume that the chooser actually behaves as if he/she were optimizing. While this assumption is heroic, it is implicit (and sometimes explicit) in nearly all educational production function research[7].

C) A new positive model of expenditure allocations

[7] To estimate and interpret the cost function as the dual of the production function requires the assumption of maximization (Jimenez, 1986, Jimenez and Paqueo, 1996, James, King and Suryadi, 1996).

Very few people would accept the optimizing model as a complete or accurate description and in fact the production function has had very little empirical success in explaining school performance. However, since the intuitive foundations are so clean and attractive the difficulty in rejecting the optimizing model is proposing a specific, concrete, alternative against which to judge it. Therefore, before turning to the empirical evidence we propose a very simple alternative model, which embeds the optimizing models as a special case.

Suppose the person allocating inputs accepts a certain budget as fixed and maximizes a weighted average of the utility of school output *S(X)* and teacher's utilities *T(X)* (expressed in units of test scores). The implied objective function is:

$$C(X) = (1-\alpha)*S(X) + \alpha*T(X)$$

where α, the weight given to teacher utility, lies between 0 and 1. In this set-up the outcome depends not only on the underlying production function determined by the pedagogical process but also on the structure of the teacher's utility function[8].

The simplest way to formalize this is to think of the teacher's utility as the sum of two components: the utility derived directly from spending on educational inputs and that derived from greater educational output. The teacher utility derived *directly* from educational spending depends on how the spending on those inputs effects their own welfare *independently* of its effect on scores. For instance, higher teacher wages raise direct teacher utility dollar for dollar, while spending on physical amenities within the school (like larger classrooms) or spending on

[8] This is not referring to the direct effect teacher morale or satisfaction or compensation might have on output, as this is already embedded into the production function (so far have said nothing about the structure of the production function).

reducing workload (like smaller classes) would raise teacher welfare, but not by the equivalent of an unrestricted dollar given to the teacher, and spending on items like books or desks for students would have zero (or near zero) impact on *direct* utility. Teacher utility also depends, through altruism or professionalism, directly on educational output. The total teacher utility function is:

$$T(X) \; = \; (1-\delta)*U(\gamma^{/}X) \; + \; (\delta)*S(X)$$

where *U()* is the direct utility derived from inputs, γ is a vector which gives a weight to each of the inputs (weights which lie between 0 and 1). The individual γ_i's for each input are the relative prices, in that they are the teacher's willingness to pay for an additional dollar of spending on input i relative to their willingness to pay for a dollar of salary and hence are pure numbers. The "professionalism" parameter, δ, also lies between 0 and 1.

Now the optimization problem in allocating spending to raise this weighted average of teacher utility and test scores is:

$$\begin{aligned} &Maximize \; [\; (1-\alpha) \; + \; \alpha*\delta \;]*f^{S}(X) \; + \; \alpha*(1-\delta) \; *U(\gamma^{/}X) \\ &\qquad s.t. \;\; p^{/}X \; = \; B \end{aligned}$$

While this model is in many ways a modest generalization of the previous model, it has very different predictions about the allocation of expenditures. In particular, the ratios of the marginal educational output per dollar of input will not be equalized across inputs. Instead of implying the difference in marginal utility per dollar of inputs will be zero, as in the simple optimizing model, the first order conditions of this model imply:

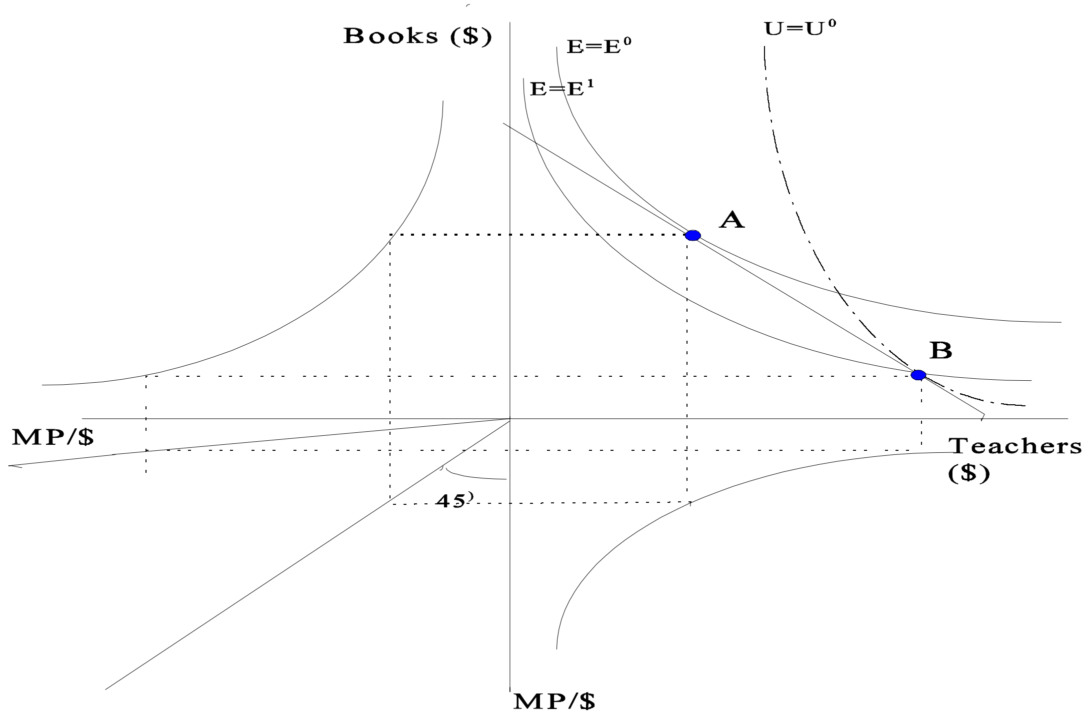
$$\frac{f_i^S}{p_i} - \frac{f_j^S}{p_j} = \frac{\alpha(1-\delta)}{(1-\alpha) + \alpha\delta} * U_x * [\frac{\gamma_j}{p_j} - \frac{\gamma_i}{p_i}] \tag{4}$$

That is, as long as the weight given to teacher utility is not exactly zero ($\alpha > o$) and the degree of professionalism of teachers is not sufficiently high that they are completely selfless ($\delta<1$) then marginal products per dollar will not be equalized. The more directly an input enters teacher utility (a higher γ_i) the *lower* the marginal product per dollar of that input in producing education will be, relative to another input at the optimum.

The intuition is clear: since the chooser of inputs cares directly about teacher utility this will lead to a higher level of spending on inputs that teachers care about and because marginal products are declining this higher level of utilization will lead to a lower marginal product per dollar of that input. Conversely, those inputs that do not enter directly into teacher's utility will have *higher* marginal product per dollar because their level of use will be lower than under pure optimizing. In this model, the marginal product per dollar of inputs that teachers value directly (e.g. wages) will be smaller than the marginal product per dollar of inputs which teachers value indirectly (e.g. smaller class sizes, better physical facilities) which, in turn, will be smaller than those that teachers value only because of their effect on achievement (e.g. books).

Figure 1 illustrates the case with only two hypothetical inputs, call them “books” and “wages.” The educational output optimizing choice would be to choose point A, where the educational output isoquant[9], whose slope is the relative marginal product of books to teachers, is

Figure 1: Score versus other objective maximizing, implications for marginal products per dollar of inputs



tangent to the budget line, whose slope is the relative price of books to teachers. At this point the conditions for an (interior) maximum are reached.

Adding teacher’s utility directly to the chooser’s objectives implies that the isoquants of this new objective function are steeper than those of the educational output only isoquant. This

[9] The combinations of books and teachers that produce constant amounts of educational output.

implies the new equilibrium for a given budget will involve more teacher and less book spending (point B). This higher level of spending reduces the marginal product per dollar of teachers (illustrated in the southeast quadrant) and increases the marginal product per dollar of books (illustrated in the northwest quadrant), which were equal when the objective function included only achievement. When teacher's utility is added to the objective function, relatively less is spent on "books" and relatively more is spent on "wages" so that the marginal product per dollar of "books" is high relative to the marginal product per dollar of "wages."

Before moving to the evidence, let us make two points. First, our alternative model is not derived from first principles. At this stage we do not propose a particular reason why teacher utility is present in the objective function: it could be the result of patronage maximization of politicians, it could be the result of budget maximizing bureacrats. Therefore "α" is our alternative model does not necessarily represent "teacher power" or the benefits to individual teachers, but rather represents a possible outcome from a broad class of models from which could this weight on teacher inputs could be be derived. We return to this point in Section III below when we discuss policy.

In particular, we are not arguing that teachers are individually overpaid, a point we return to in the final section[10]. Nor are we arguing "too much" is spent on education as we do not

[10] Several recent papers have examined whether teachers are "overpaid" by comparing wages or incomes of teachers either with cross-national norms (Cox-Edwards, 1989, Carnoy and Welmond, 1996) or with wages of other individuals, controlling for individual characteristics, like age and education (e.g Psacharopoulos, 1987). To see why this literature is distinct, imagine that receiving a teaching position was like a sinecure, for which the teacher received a fixed annual payment completely independent of performance, and imagine that therefore teachers did no teaching at all. In this hypothetical case the "wages" of teachers could be arbitrarily low and yet the ratio of marginal product of teacher to non-teacher expenditures still be quite high.

model the determination of the overall budget for education, which could be low. In many cases spending on teachers (or the budget overall) is "too low" in any absolute sense, even if teacher spending is "too high" relative to the productivity of other inputs.

II) Our reading of the evidence

How do the predictions of the two classes of models, output maximizing and teacher influence, fare when faced with the evidence? There is an enormous literature examining the relationship between the level and composition of educational spending and the output of the educational process[11]. We review three types of evidence in the literature: studies of cost effectiveness, education production function estimates, and direct evidence from differences in parental control within educational systems. Together this evidence overwhelmingly rejects all three variants of the educational output optimizing models (simple, uncertainty, and multiple output) in favor of a model which incorporates teacher utility into decision making. To preview the results, the failure of the equalization of marginal product per dollar rejects simple optimizing. The systematic pattern of that rejection across inputs: that educator related inputs tend to be overused relative to non-teaching outputs, rejects the uncertainty (and we believe, multiple output) models. The comparisons between public and private schools, or schools with more or less parental control, or comparisons of outcomes with different teacher unions, definitively reject all three educational output optimizing models.

[11] Much of this literature relevant to developing countries has been done at, or for, the World Bank (Lockheed and Hanushek, 1988, Hanushek, 1995, Harbison and Hanushek, 1992, Glewwe, 1996, Hanushek and Lavy, 1994, Khandker, Lavy, and Filmer, 1994, Tan, Lane and Coustere, 1996, World Bank, 1995).

A) Empirical estimates of the cost effectiveness of various inputs

The key hypothesis to test the simple optimizing versus our model is whether the marginal products per dollar of all educational inputs are equalized. However, studies only rarely go on from estimating the marginal products in physical terms (e.g. the effect of class size on test scores) to calculating the educational gain per dollar spent, typically called "cost effectiveness", which is the best guess at the marginal product per dollar of spending of different inputs at the observed allocations[12].

Table 1 reports the cost effectiveness estimates derived from a large scale evaluation of an education project in Northeast Brazil (Harbison and Hanushek, 1992). These estimates line up exactly as we would have expected if there is a substantial amount of teacher influence. The cost effectiveness of teacher salaries (normalized to 1) is by far the lowest. Material inputs which provide amenities to the school and teachers, such as teacher tables, toilets, bookcases, have a cost effectiveness on average 7.7 times larger than teacher salaries. Instructional materials, which provide benefits to teachers only insofar as they increase scores, have cost effectiveness ratios between 17 and 34 times as large as the impact of additional spending on teacher salary increases. The prediction of the simple optimizing model, that cost effectiveness is equalized, is wrong by at least an order of magnitude.

[12] Unfortunately, it is impossible to recover comparisons of the marginal versus average distinction from the existing empirical literature.

Table 1:	**Ratio of test score gain per dollar in Portuguese and Mathematics for various inputs relative to teacher salary (=1), average estimates from Northeast Brazil**					
		Grand average (years, subjects, grades)	Second grade (Average 1981,83,85)		Fourth grade (Average 1983,85)	
			Portuguese	Mathematics	Portuguese	Mathematics
Material inputs						
	Textbook usage	17.7	33.9	22.7	14.5	0.0
	Writing materials	34.9	11.8	13.8	58.8	55.3
	Software*	19.4	19.4	13.4	24.5	20.3
Infrastructure inputs						
	Hardware*	7.7	3.4	3.5	16.0	8.1
Alternative teacher education strategies						
	Curso de Qualificacao	5.0	1.2	2.5	5.0	11.3
	Logos	8.3	8.3	6.8	13.5	4.6
	4 years primary school	6.7	8.5	13.2	0.0	5.3
	3 years secondary school	1.9	2.5	3.9	0.0	1.5
Teacher salary						
	Teacher salary	1.0	1.0	1.0	1.0	1.0

* Hardware: water, bookcase, teacher table, pupil chair, pupil desk, two classrooms, large room, director's room, kitchen, toilet, store cupboard Software: writing material, chalk, notebook, pencil, eraser, crayons, textbook usage

Source: Derived from Harbison and Hanushek (1992), Table 6-2

Table 2 provides similar estimates from a large scale study of student achievement in eight states in India (World Bank, 1996a). The cost effectiveness of increasing teacher salaries is again normalized to 1. The cost effectiveness of spending on improving physical facilities is higher than that of teacher salaries (1.2 times higher), however that for increasing just classroom size is between 1.7 and 4 times higher. The cost effectiveness of spending on instructional inputs is between 4 and 14 times higher than that of increasing teacher salaries. Again the actual ratio between the marginal product per dollar of salary inputs and instructional materials is different from the level predicted by optimizing model by more than an order of magnitude, 14 to 1.

Table 2:	**Test score gain per rupee for various inputs relative to teacher salary (=1), average across low-literacy districts in eight states of India, 1993**	
Instructional materials		
	Complete package of instructional materials and aids	14.0
	Coverage under Operation Blackboard, equipment only	4.0
Physical facilities		
	Full package of facilities	1.2
	One additional square foot per student	
	Cost based on school construction in Uttar Pradesh	4.3
	Cost based on DPEP average	1.7
Teacher Quality		
	Increasing average teacher salary by Rs. 100 per month per school	1.0
Opportunity to learn		
	Reducing the pupil teacher ratio by one	0.1
	Adding one additional school day per academic year	1.0
	Adding one additional teaching hour per academic year	0.6
	Adding one additional hour of language instruction per academic week	29.0
Source: World Bank (1996a) Annex F		

What is somewhat puzzling is that class size reductions are even less effective than teacher salaries. However both of these results are consistent with recent estimates by Kingdon (1996) using sample survey data for students from 30 schools in urban Uttar Pradesh, who finds that if the cost effectiveness of teacher salary is normalized to 1, the cost effectiveness of class size reductions is .029 but the cost effectiveness of increasing school physical resources is 3.2[13].

B) Education production function estimates

Do these few cost effectiveness studies represent the typical case across a variety of conditions? While there are few studies that calculate cost effectiveness for different types of

[13] Since this study did not report cost data for school resources, we used data from World Bank (1996a) to calculate these ratios.

inputs, there are numerous studies which relate student achievement to school characteristics, such as inputs, while controlling for student's background characteristics (e.g. parental income, education) and there have been several prominent reviews of this literature. These reviews face enormous difficulties in summarizing the empirical results of the different studies as the estimated coefficients, which are reported in physical quantity units, (e.g. test scores gain per square foot) are not directly comparable either across inputs or across studies. Therefore the reviews summarize only whether the effect was estimated to be positive or negative and whether it was statistically significant (although some do attempt to report "effect sizes" which, at least normalizes the test scores to standard deviation, Lockheed and Haunshek 1988).

Confirmation percentage evidence. Holding these problems firmly in mind, there are two ways we can bring the enormous educational production function literature to bear on our competing positive models. First, we can compare the "confirmation percentage" of various inputs, that is the frequency with which the variable is found to be statistically significant of the expected sign sorted by our conjectures as to which inputs are of most and which of least *direct* importance to teachers[14,15]. In the most recent of these compendia, Fuller and Clarke (1994) summarized in Table 3, there is a markedly higher confirmation ratio for the inputs, like facilities

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[14] We include only inputs reported in the surveys of the literature that were subject to 10 or more studies.

[15] This ranking is problematic as the interpretation of a coefficient depends critically the other variables included in the regression. For instance, some regressions include "instructional time," if teacher salaries are included in the same regression then more time for the same salary would be a real wage reduction which teachers should oppose so that the marginal product should be very high. If teacher salaries are not included then its sign is ambiguous. Similarly, the coefficients on "teacher training" or "teacher education" all depend on what else is included in the regression.

and instrumental materials, which are *less* likely to appear directly in teacher's utility (two other reviews, Harbison and Hanushek, 1992 and Velez, Schiefelbein and Valenzuela, 1993 report similar results and are included as appendix 1).

In Table 3 "teacher's salary" has a confirmation rate of 36 percent for primary and 18 percent for secondary schools, the confirmation rates of teacher-pupil ratio are 35 and 9 percent respectively. In contrast, the presence of a school library has a confirmation rate of 89 percent and the availability of textbooks a confirmation rate of 73 percent for primary and 54 percent for secondary schools. Interestingly, a review of 43 studies (appendix table A.2) found that only 4 of those found a significant and positive relationship between "teacher satisfaction" and student achievement.

Table 3: Confirmation percentages of various educational inputs sorted by direct importance to teacher utility.

	Number of studies	Positive and significant relation	Confirmation Percentage
Primary Schools:			
Teacher's salary level	11	4	36.4
School teacher pupil ratio	26	9	34.6
Teacher's years of schooling	18	9	50.0
Teacher's experience	23	13	56.5
Class instructional time	17	15	88.2
Class frequency of homework	11	9	81.8
School library	18	16	88.9
School textbooks	26	19	73.1
Secondary schools			
Teacher's salary level	11	2	18.2
School teacher pupil ratio	22	2	9.1
Teacher's experience	12	1	8.3
Class instructional time	16	12	75.0
School textbooks	13	7	53.8
Source: Fuller and Clarke (1994)			

If marginal product per dollar were equalized, there is no compelling reason to believe that the confirmation ratios would not have been roughly equal across inputs. While this evidence is far from airtight, as it is possible the differences in precision could have affected the pattern of statistical significance, the most straightforward way to read this evidence is that studies that use non-experimental data systematically evaluate the marginal product of inputs at points that are not education output maximizing. The results suggest that at the input spending allocations typically observed in non-experimental data in which these allocations are the result of choice, the marginal product of inputs is lower for those inputs more highly valued by teachers and hence they are more likely to be statistically insignificant.

The second way these production function studies could be brought to bear on the competing hypothesis is to calculate estimates of the marginal product per dollar from the results. Unfortunately, after scouring this literature we found very few studies that report the necessary information, principally because they lack data on the relative costs of various inputs. Even among those that do report some estimates of cost effectiveness, standard practice is to calculate cost effectiveness only for those estimates that happen to be statistically significant (and in the right direction). Table 4 reports the educational production function estimates by Tan, Lane, and Costernane (1996) for which they calculate cost effectiveness only for those few inputs, particularly workbooks and furniture, that were statistically significant. They do not however compare cost effectiveness per dollar with other inputs, such as reductions in class size. Using their estimates and information about teacher salaries and class sizes from other sources we calculate that at the estimates they report, providing workbooks was 800 to 1600 times, and providing furniture 700 to 1200 times, more cost effective than reducing class sizes. One might object we are using a statistically insignificant, and hence potentially imprecise, estimate on class size, but even if we add two standard deviations to the point estimate for class size (that is increase it to the upper range of a 95 percent confidence interval) the impact of workbooks or furniture was 100 times larger than of reducing class size. This is still two orders of magnitude larger than the ratio predicted by an optimizing model.

Table 4: Calculating relative cost effectiveness of teacher to non-teacher inputs while taking precision of estimation into account.

Input:	Subject:	Ratio of cost effectiveness of inputs to increasing class size:	
		At point estimates of all variables	Adding two std. dev. to class size point estimate
Furniture	Math	689	90
	Filipino	1243	113
Workbooks	Math	842	110
	Filipino	1592	145

Notes: In order to calculate the cost of decreasing class size, we use the fact that average teacher salary is 2.5 times GNP per capita (World Bank, 1996b) and assume that each teacher teaches an average of two classes, and that the average class size is 40.19 as reported in Tan and others (1996).

Since most investigators begin with a presumption that the inputs into education are reasonably well known, presumably the key critical question that estimation of a production function could help resolve is whether reallocating inputs given a fixed budget could improve performance. Reporting only estimates of the production function with no estimates of costs is not even relevant to that question. The distressingly common practice of reporting the production function estimates of known educational inputs in quantity units (e.g. class size) text books, physical facilities and their statistical significance without comparative information on costs is nearly devoid of policy interest[16].

This also raises a problem for the "meta-analysis" approach to creating statistical significance, in that it ignores the actual underlying policy question and the asymmetry in what the two sides of the "money matters" debate are asserting. That is, if the impact of teacher inputs (e.g. salaries, class size) is not demonstrably different from zero then it is also not optimal, in the sense of equalized marginal products. However, showing only that teacher inputs, or budgetary inputs generally, have *some* impact (which can be done with meta-analysis Hedges, Laine and Greenwald, 1994) does not address the question of whether those levels of inputs are optimal or whether reallocations in expenditures could increase output. Moreover, calculating cost effectiveness for only those estimates that are *statistically* significant confuses the magnitude with the precision of the estimate[17].

One intriguing aspect of using a normative optimizing production function model as a positive descriptive model of behavior in an empirical study is that these assumptions self-referentially predict the impact of the study itself. If educational policy makers are assumed to be

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[16] By stipulating *known* inputs we distinguish studies of pedagogical innovations such as radio instruction, computer assisted learning, alternative teaching strategies, etc., where the question of zero marginal product over all ranges is actually a useful null hypothesis.

[17] One huge problem with reporting only signs and statistical significance concerns statistical power. Failing to reject that a particular coefficient is zero could result either because the estimated impact was small or because the impact was large, but very imprecisely estimated. If the effect of some inputs is estimated with greater precision then these will tend to be more "significant" even if they are empirically smaller. Moreover, there is no necessary connection between the precision of the estimates in quantity units and cost per unit so one may "fail to reject" the test of zero impact for some inputs which have extremely high cost effectiveness while finding statistically "significant" other inputs with low cost effectiveness.

attempting to optimize, then choosing too much teacher expenditure relative to spending on physical facility, equipment or books could only have been because of a mistaken belief about the "true" production function. But then the behavioral model predicts that the study itself (if believed) should cause a reallocation of resources towards the more productive resources as the new information fixes the previous mistake. Has this (implicit) prediction of output maximizing models been confirmed?

As we presented in the section above, the weight of international evidence of too little spending on some inputs has always been impressive, and has been accumulating over time. Fuller and Clarke, in their 1994 review, point out that while there were 37 new studies since the review of the evidence in 1986 (Fuller, 1986), the new studies mostly confirmed previous patterns, particularly the relatively greater importance of books and instructional materials than class size and teacher inputs (Fuller and Clarke 1994). However, while recent data are very difficult to come by, the share of educational expenditures devoted has, if anything, shifted towards an even greater share of teacher compensation (although this may be due to a fiscal contraction.) We know of none, and conjecture it would be difficult to document a single instance in which an empirical study, or even a series of studies, actually affected the distribution of expenditures[18]. In contrast, a model that explains the existing spending allocation as the result

[18] There raises another, borderline ironic, sub-text to the econometric production function estimates. In order for the estimates from non-experimental data to correctly identify an underlying production function there needs to be some mechanism that causes different choices of input mix other than shifts in the production function itself. If differences in input use across the levels of the data (e.g. districts, schools, etc.) are due to differences in teacher's utility weight (α) in the objective function across policy makers then this implies the empirical estimates are correctly identifying the production function. However, while these makes the estimates technically correct it also makes them irrelevant for policy.

of a political process implies that studies of the products of various inputs may, but probably will not, influence spending which will require changing the incentives of decision makers (summarized as "α" in our simple set-up).

Caveats about the educational production function literature. We should not overstate our case as to the reliability of the educational production function literature in supporting *any* hypothesis. Many of the studies find *nothing* to be statistically significant and often find perverse patterns in the point estimates (for example negative signs on inputs like teachers or books). Moreover, even when the estimates of the individual production function coefficients are reasonable, school inputs typically have very small explanatory power. There are several additional econometric difficulties with the literature and we should at least mention four: simplistic and differing specifications[19], multi-collinearity, insufficient variation in input use, and different sensitivities among inputs.

One point on the latter two concerns. Suppose that there were a number of potential non-teaching inputs with high, but steeply declining marginal products (like algebra books). A perfectly random allocation of resources among these non-teaching inputs would produce a pattern of some very large and some small estimated marginal products with the high productivity of some of these factors due to the very low utilization. Different inputs might have

[19] The specifications in this literature use quite simple assumptions about the production function, usually that output is linear or log-linear in inputs. In particular this rules out interactive effects between inputs which are potentially important. Also, the analyses reported above may suffer from the fact that the specifications are not identical across the various results reported. Even so, World Bank (1996a) reports results from estimating the exact same functional form of an educational production function in low literacy districts in eight Indian states, for two different educational outcomes. The results clearly show that the significance (and sign) of the effects of the inputs vary widely across the different states even for exactly the same specification.

different amounts of variation in use[20]. This pattern suggests that there are inputs for which the marginal product is very high at low levels but declines very rapidly. In this case one would expect to see a very high marginal product for that input, but also observe that the input was rarely in range of low use, and hence the empirical finding is of limited usefulness. For instance, Glewwe (1996) conducts a study of the determinants of school quality in Ghana using a large scale data set and the *only* statistically significant school level effects on math and reading test scores are from the fraction of classrooms that have blackboards, and the fraction of classrooms that cannot be used when it rains. However, even in Ghana, 90 percent of schools have blackboards and only 15 percent of middle schools have leaking classrooms.

C) Direct evidence

The 10 to 100 fold divergences in marginal product per dollar across inputs, and that these are in a consistent pattern across inputs, rule out both the simple and uncertainty optimizing models. However, one could still return to the multiple output model and conjecture that the observed pattern of marginal products in producing scores corresponds to the inverse pattern in the marginal products in producing some other output. In this section we first say why we think this objection is unfounded, and then show additional evidence that bears directly on the difference between the multiple schooling output and our model, and which leans in favor of a positive model with teacher influence.

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[20] Using the results of World Bank (1996a) we perform a crude regression of the significance of the parameter estimate on the mean and standard deviation of the input. The results suggest that for score on reading test the degree of significance of the effect of an input is significantly negatively related to the mean value of the input. For the score on the math test, the estimated magnitude of the effect is significantly positively related to its standard deviation.

There are three reasons the multiple output model is theoretically and empirically inadequate. First, it appeals to variables that are either unobserved or unobservable, which makes the model non-falsifiable. Someone with an interest in rejecting a positive model of expenditures with teacher influence could always assert that the patterns of the marginal product of inputs for the *un*observed component of educational output (e.g. citizenship) are exactly what they would have to be in order to rationalize the observed outcomes. Because the output is unobservable they could make this assertion without fear of contradiction (or confirmation). Second, related to the first, there is little or no empirical evidence of the effect of various educational inputs on anything other than achievement[21]. Third, it is hard to understand intuitively how a multiple output model could explain the existing empirical patterns, for instance of teacher salary versus class size or physical facilities versus instructional materials. In order for an appeal to multiple outputs to be satisfying, one would have to explain why is it that the *unobservable* output of education requires enormously higher teacher salaries, more teachers, but less physical facilities and less instructional materials than the *observable* output.

Parental versus educator power: Local and parental contributions, private schools and unions. Fortunately, there is a source of direct evidence which is able to distinguish the multiple output from the teacher influence models. As pointed out above, if the chooser is attempting to optimize then new information about the production function should change inputs and

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[21] Card and Krueger in various papers (e.g. Card and Krueger, 1996) have shown that budgets are related to subsequent wages of workers, but this evidence is not entirely relevant, for two reasons. First, their studies are of *aggregate* budgets and do not address the question of relative marginal products of various inputs. Second, their studies are consistent with wages being a better measure of achievement than multiple choice tests without invoking any additional assumptions that something besides achievement (e.g. “worker docility”) being produced by schooling.

outcomes. In this section we argue that the converse is also true: if the optimizing model were really correct then one should *not* see patterns of input use and outcomes respond to different degrees of incentives. Greater local financing or control of schools, differing degrees of competition, or differing amounts of union power should not affect technical efficiency. But the evidence suggests that these factors do have an important effect both on the allocation of expenditures and the efficacy of outcomes. The following section discusses three sources of evidence relating to various sources of differences in parental power: the degree of local control, teacher unions, and private schools.

Local and parental contributions.   A first source of evidence is the impact of direct parental participation and contributions. Modest amounts of direct contributions of parents should have large effects on performance only to the extent that some inputs (infrastructure, equipment, instructional materials) are so dramatically under-funded by the publicly allocated budget that their marginal products per dollar are very high. If marginal products were equalized (even according to an optimizing model with multiple outputs) then the relatively small contributions should only have a proportionately small effect. Evidence of substantial impact by parent's groups, or of local control, or of the proportion of resources from local sources is itself a sign of a failure to maximize outputs in the overall system of expenditure allocation.

Jimenez and Paqueo (1996) using data from the Philippines find that schools with a small component of local financing (under 5 percent) are incredibly less productive than schools with even a small share of public financing: their achievement score per dollar is only a third as high. More importantly, the cost savings that produce this greater cost effectiveness come disproportionately from personnel whose cost per student is 52 percent lower, with much smaller cost savings for other inputs (Table 5).

Table 5: Relative cost effectiveness and expenditures composition of locally versus non-locally financed schools

	Proportion of funds from local sources:		Percentage difference
	<5%	> 25%	
Overall score	42.46	48.25	13.6%
Total expenditures	675	265	-60.7%
Achievement score per peso	0.06	0.18	189.1%
Cost per student (Philippines pesos)			
Personnel	469	226	-51.8%
Maintenance and operating	42	35	-16.5%
Textbooks	7	5	-26.6%
Source: Adapted from Jimenez and Paqueo (1996), table 1.			

Similarly, James, King and Suryadi (1996) find that even controlling for whether schools are public or private, a greater share of funds that are locally raised compared to centrally allocated increases significantly educational output (in their model, decreases cost for a given output)[22].

Many countries have adopted locally run community schools as a mechanism to accommodate the demand for schooling in remote and rural areas that are not reached by the "official" school system. One common feature of these schools is that the teachers are hired by the local community and are not education ministry employees and are not subject to the usual

[22] Both of these papers use econometric estimation of the dual, that is, cost per student controlling for quality, rather than estimate a production function. However, their results on local financing indicate that the primal problem is not maximization of output subject to a budget constraint, but rather some more complicated objective function involving teacher utility of the type we explore here.

qualification requirements. While there is little direct evaluation of these schools that can compare costs and outcomes, the existing evidence suggests that community managed schools user fewer “teacher wage” inputs and achieve essentially the same or better academic results.

Results on local financing and the experience with community schools are consistent with more centrally controlled resources being allocated by an optimizer with a high concern for teacher welfare (high α) principally to teacher inputs, while locally raised funds being subject to a greater degree of parental control and hence high concern for educational output (low α) and are allocated principally to non-wage inputs with high marginal product.

Private schools. The evidence from five developing countries marshaled by Jimenez and Lockheed (1995) shows that, even controlling for selection effects, private schools are significantly more cost effective than public schools. This fact alone is inconsistent with the simple or uncertainty optimizing model of the allocation of the public budget. However, it is possible that the improvement in efficiency is due to pure X-inefficiency of public schools, that is public and private schools do not differ in the allocation of inputs but simply that private schools are uniformly more productive for all inputs. An alternative explanation, consistent with a model of teacher influence, is that private schools, if they are more subject to competition for enrollments, are more directly controlled by parents. By being more subject to parental pressure and less susceptible to teacher power the managers of private schools (or private school systems) will have a lower “α” than public school system managers and these differences in parental control should produce both higher effectiveness of the budget overall and also different ratios of inputs. Importantly, since evidence from private schools is based on parental willingness to pay for schooling it does not depend on test scores as the measure, as it incorporates parent’s concerns about the all schooling outputs. If the observed difference in marginal products per dollar of inputs were the result of optimizing over multiple outputs and public and private schools were optimizing over the same set of outputs, then one should not observe systematic differences across the marginal products of various inputs between private and public schools.

Fortunately there is a recent study that provides almost exactly this test. Alderman, Orazem and Paterno (1996) examine how the characteristics of schools (like instructional expenditure per student and class sizes) affect parental decisions between private and public schools in Lahore, Pakistan, an urban area where 58 percent of students are enrolled in private schools even though private school fees are 5 times higher. They find, controlling for class sizes and instructional expenditures, that achievement scores were 60 percent higher in private schools.

Since school level instructional expenditure represents almost entirely teacher salaries we can compare how much parents are willing to pay to increase salaries versus decrease class sizes. As shown in table 6, parental willingness to pay to increase salaries in the private sector was almost six times larger than in the public sector, suggesting that the marginal product of additional teacher wages in terms of *all* parental valued outputs (not just scores) in the public sector was already quite low. Conversely, class sizes were so high in the public sector that parents were willing to pay substantial amounts to reduce them, and were substantially more willing to pay for class size reductions than wage increases, the opposite of the private sector.

Table 6:	**Parental willingness to pay for teacher salary increases versus class size reductions in private and public schools in Pakistan.**		
	Private school	Public School	Ratio Private to public
Expenditures per teacher (rupees per month)	7711	8406	.92
Parental willingness to pay to increase instructional expenditure per pupil (a proxy for teacher salaries of Rp 200)	40.4	7.05	5.7
Average class size	25.2	42.5	.59
Parental willingness to pay to decrease class size by 10 students	-35.7	7.10	--
Ratio of willingness to pay an additional rupee to teacher salaries versus class size reductions	∞	.47	--
Notes: Adapted from tables 2 and 5, using willingness to pay of parents with monthly household income of Rp. 3000 (Alderman, Ozarem, and Paterno, 1996).			

Unions. Caroline Minter-Hoxby has two recent pieces of research, which although they are on the US and not developing countries, are relevant to the issue at hand[23]. In one (1994) she shows that the larger the number of school districts within a given metropolitan area the better the performance of the schools. She argues this is evidence that greater competition among public school districts substitutes for school choice and increases performance. Another paper (1996) shows that even after controlling for the endogeneity of unionization, school districts that are unionized are less effective than the non-union school districts. She shows that in districts with unions, spending on schools is higher but a larger proportion goes to teachers.

[23] Since we believe that there are *qualitative* differences between the US case and that in developing countries, we are reluctant to use any evidence at all from the US, as this raises a whole host of US specific issues. However, the evidence provided here is too unique and too directly related to the question at hand to pass up.

III) Implications of a positive theory for educational policy

We have shown that the educational output optimizing model of expenditure allocation, in all its variants is inconsistent with the evidence and that a simple model in which teacher utility receives direct concern in expenditure choices is consistent with the stylized facts. Having a positive model of educational spending is important for the analysis of policy options. As mentioned in the introduction, there are two kinds of educational policies currently proposed: more of the same (higher enrollments, higher expenditures, better teacher training, etc.) and fundamental reform of incentives (decentralization, community involvement, school choice, etc.). Guidance on the choice between these requires modeling the underlying public sector decision and control mechanisms as fundamental reforms are about changing the incentives within the sector.

A) More budget versus reform

As mentioned above, one of the puzzles in the literature on educational production functions is that it is often difficult to demonstrate a positive impact of increased spending on educational outcomes[24]. The literature is criticized precisely because the results seem so implausible to educators and educated alike: of course "money matters" and on some level

[24] The two best arguments against this are the meta-analysis of studies in the US (Hedges, Laine and Greenwald, 1994) and the studies of the impact on subsequent wages of budgetary resources while in school (Card and Krueger, 1996), also done exclusively in the US. Both of these are reasonably convincing that there is *some*, but small, connection between expenditures and outcomes, which of course under a positive maximizing model must have been the case. But neither of these methods speak to the question of whether a different budgetary allocation could have had a larger impact.

everyone knows that[25]. But the implication of our positive model is that while “money matters” to educational outcomes, money also matters to those who receive it as income and that “mattering” will have implications for publicly determined outcomes, like the allocation of expenditures.

Budgets and educational outcomes when objectives differ. If non-experimental data are taken from jurisdictions (or time periods within the same jurisdiction) that differ in either the degree of educational output concern (1-α) or in the degree of professionalism (δ) of the teachers then equal budgets could produce very unequal outcomes due to the allocation across inputs[26]. For any given level of α, higher budgets lead to better outcomes (the sense in which money matters). But a higher α implies worse outcomes for any given budget. Any estimation of the relationship between expenditures and budgets from non-experimental data that differ in α which do not control for these differences can produce any relationship at all: positive, zero, or negative. For instance, Hanushek and Kim (1996) estimate the relationship between the internationally comparable test scores of achievement in math and science derived from the various IEA and IEAP studies and expenditures. They find that both public expenditure per student and the ratio of total educational expenditure to GDP are significantly *negatively* related

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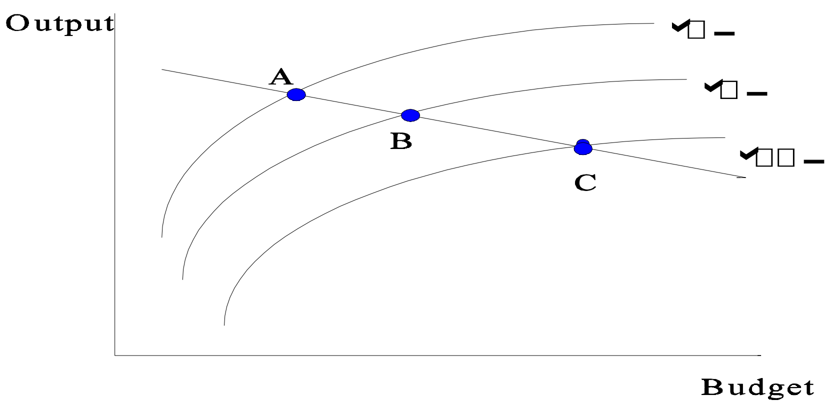
[25] There has been a vociferous debate in the US around the question “does money matter?” In this political debate the rejoinder "the only ones who say resources do not matter have their children in schools with adequate resources" carries a good deal of common sense appeal.

[26] Differences in the relative weight of teachers also happen over time within a given jurisdiction as across jurisdictions. For instance, in Paraguay after the end of a long period of dictatorship teacher wages more than tripled in a six year period, with an almost complete lack of complementary reforms either in the school system or even in the structure of teacher pay. Given the total lack of objective comparable testing it is impossible to say for sure, but many doubt this increase led to commensurate increases in student performance.

to achievement. While this obviously cannot represent the impact of the relaxation of the budget constraint, if higher α values are associated with higher budgets then the data across jurisdictions on budgets and outcomes could show a negative relationship, as in figure 2 with a line fitted to hypothetical outcomes A, B and C, even though for any given α a budget increase would improve scores[27].

Figure 2: Budgets and educational outcomes



Given that both budgets and their allocation matter, what should be the focus of improving school performance? The answer that will be guaranteed vocal support is "increase budgets" as this generates support among parents, the general public who have an interest in promoting better education, and teachers (for both professional and self-interested reasons).

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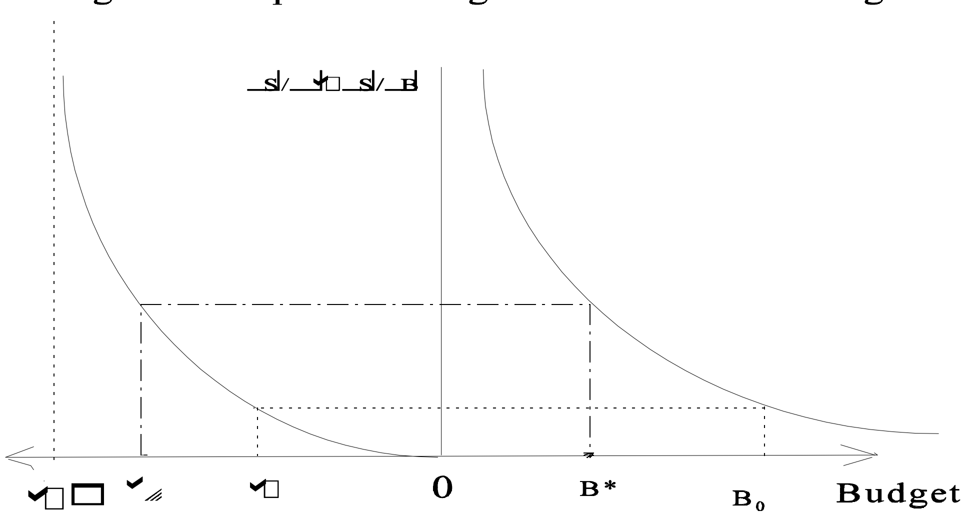
[27] Differences in misallocation relative to the optimum is only one possible explanation of the empirically small impacts of budgets on outcomes. The other is that educators are systematically ignorant of the true pedagogical function, and ideological blinders, not self-interest prevents them from acknowledging the truth. This is essentially the controversial argument E.D. Hirsch (1996) makes about schooling in the US. In this case more resources do not produce greater output because of ignorance about the production function.

However, if the existing allocation of inputs is not optimal, school performance can also be improved by a reallocation of expenditures with no increases in the overall budget. These proposals will tend to split the above coalition and pit educators against all others. Which type of reform will be the most effective if implemented? The answer is, not surprisingly (and even reassuringly), it all depends. If the budget is high and α is high then fundamental reforms are more pressing. If on the other hand the budget is low and α is low then budgetary reform should receive priority.

To say more, we can make specific (and very limiting) assumptions about the functional forms of the production function and teacher utility (Cobb-Douglas) and assume no teacher professionalism. Under these assumptions we can solve explicitly for the relationship between scores, budgets and α. In this case, the score improvement from budget increases approaches infinity as the budget tends to zero and approaches zero as the budget tends to infinity for any

Figure 3: Impact of budget reform versus changes in α



given α. The incremental impact of changes in α on scores approaches zero as α goes to zero and approaches infinity as it approaches one[28]. As can be seen in figure 3, this situation implies that for any given level of the budget, B_0 there is a critical level, α^*, such that for all levels of α above α^* the increment to changing α will have a greater impact than changing the budget. Similarly, for any level of teacher power, α_0, there is some level of the budget low enough (B^*) such that increasing the budget will have more impact on scores than changing teacher power.

B) Three possible models behind the model

The model we have specified is *ad hoc*, in that it is not derived from underlying behavior by actors, and hence is more of a description of a class of models that might be derived from different structural assumptions. That is, we have not articulated a complete model which specifies which person or entity controls the allocation of spending (a school board? a legislature? the ministry of education?) nor why exactly that person or entity cares directly about teacher welfare. For many of our conclusions the exact model is not important. However, to move to the predictions about outcomes of more specific reforms one needs to specify a more complete model. There are three prototype models: *principal-agent*, *teacher power*, and *patronage*, each of which has different implications for policy.

Principal-agent. In this model the decision maker can be either the parents themselves or a manager that faithfully represents parent interests. The source of teacher weight in the objective function is superior knowledge by teachers about the production function. In this case,

[28] Both of these results are illustrative only as they follow quite mechanically from the Cobb-Douglas assumptions, which implies that each input is “essential” in the sense its marginal product goes to infinity as the level of input approaches zero.

teachers will systematically misrepresent the production function so as to lead the chooser of budgets to choose greater spending on those inputs that teachers prefer. In this model, empirical studies actually might have some impact by revealing the true production function. This particular model predicts a systematic tendency of educators to resist quantitative evaluation of their output, as this allows checking the reported production function against the actual.

Teacher power. The second possibility is that teachers as a group are powerful enough to affect the allocation of education expenditures. In this case, there is a third party (e.g. minister of education) or institution (e.g. legislature or school board) that controls budgetary allocations and has to choose between pleasing a concentrated group of educators and a diffuse group of parents. Given that on issues like teacher wages educators have a very clear and direct interest, they may be more successful at organizing to influence public decisions than are parents. In this case, the problem is not that parents are systematically under informed about the production function, but that parents have greater difficulty overcoming the free rider problem inherent in collective action than do teachers (Olson, 1965).

In our model greater teacher professionalism helps output. However, the mechanisms that foster greater teacher professionalism are precisely those that tend to create greater teacher power by making cooperation in lobbying easier. A common recommendation of education professionals is to get teachers to work together, to share experience, give support, etc. However, teachers are no different than any other group and Adam Smith's adage applies[29].

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[29] "People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices."

Patronage. Another possible model is that teachers are not particularly powerful but the chooser of expenditures is powerful. Suppose that the Minister of Education can allocate all jobs and each job creates a favor. In this case the chooser would want teacher salaries to be relatively low (but a slight premium so that the job is a "favor") but would want to maximize the employment of teachers. In this case teachers would be poorly paid individually but there would far too many teachers. This might explain those cases in which the marginal product of teacher salary was greater than that of class size as the total wage bill to the chooser is more important than the wage.

C) The analytical base for fundamental school reforms

A positive model of educational expenditures will also provide guidance to the actions or reforms that are likely to improve outcomes. In particular, there are three commonly proposed actions that are unlikely to lead to significant changes in performance: more research into the technical pedagogical processes behind the production function, more school choice without true competition, and greater parental involvement without control or choice.

Ignorance or incentives? Even though, as in all fields that involve human behavior, there are enormous areas of ignorance, the fundamental problem is typically not teacher or technocrat ignorance that could be resolved by more research. Our positive model implies several things about education research. First, since some types of research are inimical to furthering certain interests this implies that one should expect there to be relatively little research into cost effectiveness of various inputs from educational production functions. The amount of ignorance is endogenous, and sometimes it pays to be ignorant[30]. Second, only well disseminated and widely understood studies that foment deep public dissatisfaction with the schools would be likely to change the incentives of the actors within the system and hence have any influence on outcomes. Merely documenting the differences, as has been done in many times and many places, will typically have no effect.

Finally, an implication similar to the lack of new studies in influencing expenditure allocations is that educational innovations that are labor saving will be under adopted. That is, when technological advance shifts the production function such that more of some other input and less of teaching input is now optimal, one can expect to see resistance and see that the adoption rate is very slow, or occurs without any labor saving[31]. In almost complete ignorance, we would predict very slow and patchy adoption of innovations like rural radio based instruction, shown almost twenty years ago to be extraordinarily cost effective (Lockheed and Hnaushek, 1988), even when this technology is appropriate. Even more speculatively, we guess new technologies will only make headway as an input *in addition* to teacher inputs and hence will be

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[30] This point is not lost on legislators or policy makers. In Horn's (1995) terminology the "enacting coalition" of interests have incentives to prevent future legislators or policy makers from undoing their agreement. In the US for instance, certain types of regulatory legislation explicitly forbid the implementing agency from considering costs. During certain periods Department of Agriculture economists were forbidden from doing any research on the economic losses from existing agricultural policies. A recent example is the Clinton administration's refusal to redo a study of the impact of welfare reform which had been influential in scuttling earlier legislation (The Washinton Post, July 26, 1996).

[31] Again, teachers are not alone in this as capital intensive innovations have always brought resistance from those with specific human capital. In fairness, labor intensive innovations have also met staunch resistance, such as the persistent opposition to land reform from large land owners in Latin America (Binswanger et al, 1993).

adopted only when the new technology is used as an output (and budget increasing) device, and not for cost savings.

School choice with and without competition. Since teacher welfare increases directly with their weight in the decision maker's objectives, teachers as a group will rightly oppose any reform efforts that would reduce that power. Changes that provide more school choice to satisfy "taste heterogeneity" but that do not create true supply competition on input use will be unlikely to change input expenditure outcomes significantly. This is clearly consistent with teacher's opposition to private school choice and their lesser concern with choice entirely within a controlled public sector.

Exceptions to the widespread predominance of public schools perhaps prove the rule. In some school systems, such as those in the Netherlands and Argentina, "private" schools are subsidized by direct government payments and private schools account for a large fraction of enrollment. However, these payments in Argentina are structured such that it creates no incentive at all for the private schools to economize on teaching inputs. First, the teacher's union covers both private and public teachers and private schools hire only union teachers. Second, the government subsidy is not a per student payment that can be used for any input but rather goes directly to pay the wages of teachers. A simple model of teacher power would predict that a teacher input subsidy to private schools is the political outcome in the situation where teachers are powerful and parents demand school heterogeneity (on "taste" grounds, such as ideological or religious) as this allows schools to compete in parental tastes without jeopardizing teacher's welfare by competing in costs or input mix (James, 1987).

Decentralization/localization/parental participation. In implicit recognition of the incentive problems inherent in centrally controlled public provision of schooling there have been a number of moves to increase local control over schools. These range from "decentralization" type reforms which shift the governmental authority with control over the provision of schooling, from federal to state (provincial), or state (provincial) to municipal, to "localization" or "school autonomy" initiatives to move more control over schools from whatever level to the schools themselves.

Within the context of our model the impact of jurisdictional decentralization on average performance depends entirely on how much it alters power between educators and parents. First, merely moving from federal to state control seems unlikely to change much as moving to a quite low level would seem to be necessary to bring about real shifts in relative strengths. Second, much depends on how and how well teachers are organized. If teachers are organized effectively at a geographic level higher than that of the school administration (e.g. national unions versus local school boards) then some of the most crucial decisions (e.g. level and structure of teacher wages, class sizes, work conditions) may be outside the scope of control of the local school authorities.

The impact of school "localization" or direct parental participation will depend to a large extent on the degree to which this shift fundamentally changes the balance between teacher and parent interests. Most decentralizations are of the type in which parent groups are given specific responsibilities (like mobilizing additional expenditures) but do not have managerial control, particularly over monitoring teachers, teacher hiring and firing, teacher wages, etc. This is the level of decentralization most often observed, perhaps precisely because teachers resist coming under the authority of parents, either in instruction which is naturally thought to be their professional prerogative, but also in wages and work conditions, where they would prefer to negotiate a centrally bargained solution. In this case one would expect the experience of decentralization to have mixed results, as it will have some, but modest, impacts on school performance.

There is another kind of reform sometimes called "decentralization" which is more about the autonomy of the individual school from a larger administrative or political unit. Some versions even propose "teacher autonomy" implying a greater control of individual teachers over classroom practices and instructional method. Here it is obvious that "control" over different aspects of the overall educational process are being discussed. Suggesting that individuals should be able to choose their own health care provider to increase patient power to discipline suppling health markets does not imply a loss of professional autonomy of surgeons over what happens on the operating room. In fact, in an environment with greater consumer power, institutions which provide greater autonomy at the organizational (e.g. school, hospital) and professional (e.g. doctor, teacher) level may do even better than institutions with centralized controlling bureaucracies. Greater parental power might not increase or decrease teacher and school power, but rather change its dimensions.

Conclusion

Even though it is shockingly simplistic, there are enormous advantages to thinking through the implications of positive models of the allocation of expenditures. In particular, these models have strong implications for the expected results from the estimation of an educational production function: in any optimizing model marginal product per dollar of all inputs in increasing the value of output should be equalized at the point chosen. However, no study that we know of *ever* tested that hypothesis and did not reject it. Nearly every study finds that the "cost effectiveness" of educational inputs differs by almost an order of magnitude, or more. These results are too strong and the pattern of the relative cost-effectiveness among inputs too consistent to be happenstance. Spending on educational inputs is systematically affected by how much weight teacher related inputs have in determining the allocation of spending across inputs, independent of their impact on outputs.

Given the evidence, we think the correct model that describes the actual allocation of educational expenditures must include the fact that educators have enormous influence over the allocation of spending and that spending is biased towards those educational inputs that also directly increase the welfare of teachers. Crudely put, teachers lobby (and form unions, and strike, and write) and books and desks do not. Parents generally have been insufficiently strong on behalf of books. This implies that the main role of the estimation of educational production functions is not to inform an optimizing policy maker of the "true" technical production function but rather to provide the information necessary to encourage deeper educational reforms that change the structure of decision making power.

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Appendix 1: Two other reviews of the literature.

Table A.1:	**Confirmation ratios of the significance of various inputs sorted by direct impact on educator welfare from 96 studies in developing countries**				
Input	Number of studies	Positive (significant)	Negative (significant)	Insignificant	Confirmation Percentage
Teacher's salary	13	4	2	7	30.8
School teacher-pupil ratio	30	8	8	14	26.7
Teacher's education	63	35	2	26	55.6
Teacher's experience	46	16	2	28	34.8
School facilities	34	22	3	9	64.7
Source: Harbison and Hanushek, 1992.					

Table A.2:	**Confirmation ratios of the significance of various educational inputs sorted by their direct utility to educators, from studies in Latin America.**				
Characteristic	Number of studies	Positive relation	Negative relation	No relation	Confirmation Percentage
Teacher's satisfaction	43	4	2	37	9.3
School student/teacher ratio	21	2	9	10	9.5
Teacher's years of schooling	68	31	4	33	45.6
Teacher's years of experience	62	25	2	35	40.3
Teacher's subject knowledge	19	9	1	9	47.4
School infrastructure	70	23	2	45	32.9
Access to textbooks and other reading materials	17	13	0	4	76.5
School access to other instructional materials	34	14	3	17	41.2
Source: Velez, Scheifilbein, and Valenzuela, 1993.					