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Explaining math and science achievement of public school children in the Philippines

*Stella Luz A. Quimbo**

Abstract

This paper presents estimates of an education production function which includes measures of the home learning environment and school inputs recorded at the student level. These are important variables but are often overlooked as a result of data limitations. Results suggest that minimizing teacher absenteeism and effectively providing basic learning materials in schools can improve the math and science achievement of current as well as future generations of students. The home learning environment, including parental education, was found to have a significant effect on student performance.

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1. Introduction

Student performance and its determinants have been examined extensively in the economics of schooling literature. By 1986, Hanushek [1986] estimated that about 147 studies had been done on this subject alone but noted largely inconsistent findings regarding the relationship between schooling inputs and student performance. Harbison and Hanushek [1992] made the same observation after a comprehensive review of 91 studies of education production functions.

Hanushek [1986] provides a host of reasons for the absence of systematic findings across these studies, one of them relating to the importance of using the correct measure of inputs: "...schools are quite heterogeneous institutions offering a diversity of inputs to specific students, and the exact provision for individuals is often not recorded or available". While students within the same school theoretically face the same set of learning inputs, students have varying usage levels of these inputs and therefore, varying performance levels. The use of highly aggregate rather than student-level measures of inputs in explaining individual student performance could thus introduce a potential estimation bias.

*Assistant Professor, UP School of Economics. E-mail: stella_luz.quimbo@up.edu.ph.

The unique data set employed in this study allows this important gap in the literature to be addressed. A sample of some 29,000 students in 309 public primary schools in the Philippines who took assessment tests in math and science were asked about the availability of learning materials in school and teacher characteristics. Within a school, therefore, students would have different assessments of what learning resources are available and how effective teachers are.

These subjective responses of students, arguably, point to "exact" or "effective" provisions of school inputs rather than "nominal" provisions. Students' perceptions of what resources are available in a school are likely to be a function of actual usage. Or, one may argue that such perceptions could determine potential usage. To be sure, a lack of information regarding the availability of certain types of resources in school automatically precludes a student from using these.

To determine the marginal impact of effective provisions of school inputs on student achievement, an education production function is estimated which includes input measures recorded at the student-level. By employing school fixed effects in the regression models, the impact of school-level factors that uniformly affect student performance is netted out of the estimated marginal products of school inputs. What are thus estimated are the marginal products of factors whose provisions vary across students within schools.

The education production function likewise includes home learning inputs—variables whose importance has been recognized by microeconomists but often overlooked as a result of data limitations. The notion that family background is an important determinant of student performance can be traced to the Coleman Report [1966], a study which was originally intended to assess the distribution of school resources in the United States across race and ethnical backgrounds of students. The report found that differences in student performance had less to do with school differences and more with family background and personal characteristics. While the Coleman Report has been regarded as "seriously flawed" (Hanushek [1986:11]), one of its main contributions is to highlight the importance of learning resources beyond what are available in schools in explaining cognitive achievement. Thus, omitting these variables could likewise result in potential estimation biases. Berhman et al. [2000] also pointed out that the lack of controls for learning inputs at home could be a possible explanation for the mixed estimation results across studies of education production functions.

In this study, the regression results suggest that subjective factors such as learning materials at home and in school. as well as teaching style, do matter in explaining schooling performance. In particular, students who effectively used *any* kind of learning materials at home and in school posted higher math and science scores in all grade levels than those who did not have access to any kind of resources. Moreover, students with teachers who were habitually absent or "did not teach" had among the lowest math and science scores. These findings underscore a basic requirement in the administration of the public school system, i.e., the effective delivery of basic learning inputs. For as long as learning materials—of whatever type—are provided in the facilities and actually used by students, and teachers face sufficiently strong incentives to attend class regularly, students will make the grade.

The rest of the paper is organized as follows. Section 2 briefly describes a school choice model. Section 3 presents the specification of the empirical model. Section 4 describes the data and variables used in the regression model. Section 5 provides an analysis of the regression results and Section 6 concludes the paper with some policy implications.

2. Theory

The analysis takes off from the basic idea that cognitive achievement (A) is determined by individual student characteristics (P), quality indicators of the home learning environment (H), and school quality indicators (S). The achievement of child i enrolled in school j is produced according to the following education production:

$$A_{ij} = A(S_{ij}, P_i, H_i) \quad (1)$$

where S_{ij} is a vector of measures of learning materials in school j as determined by child i. S_{ij} accounts for student heterogeneity within schools, specifically, the possibility that students within a school may respond differently to the same set of inputs. For example, a student that is habitually late for class is not likely to report that the teacher is tardy even if the teacher is in fact always late. S_{ij} could thus be interpreted as a vector of effective, rather than nominal, school inputs.

Linearizing (1) yields the following regression model:

$$A_{ij} = b_0 + b_1 S_{ij} + b_2 P_i + b_3 H_i + u_i \quad (2)$$

where u_i is a measure of unobserved, child-specific components that affect achievement.

School fixed effects

Because the data set provides repeating observations for every school in the sample, school fixed effects are included as regressors. The regression model is thus re-specified as:

$$A_{ij} = b_0 + b_1 S_{ij} + b_2 P_i + b_3 H_i + \sum_{k=1}^{j-1} b_{4k} F_k + u_i \quad (2')$$

where F represents dummy variables for each school.

That is, $F_k = \begin{cases} 1 \text{ if } k = j \\ 0 \text{ otherwise} \end{cases}$

These school fixed effects control for all those factors that are invariant across students within schools. These include traditional, aggregate, measures of school quality such as teacher-student ratio and student-classroom ratio.

Arguably, school fixed effects likewise control for factors that determine school choice such as parental preferences. This point follows directly from a school choice model that is briefly described below.

School choice

In choosing a school for the i^{th} child, parents face J discrete options in the market. The i^{th} child's parents' utility level conditional on school choice is denoted as

$$U_{ij} = U\left(Z_{ij}, v_{ij}\right)$$

where Z_{ij} denotes net consumption, $Y_i - P_{ij}$. Y_i is parental income, P_{ij} is the cost of schooling, and v_{ij} represents unobserved components such as parental preferences over schools. The utility maximizing school choice, j^*, is such that:

$$U_{ij^*} = Max\left[U_{i1}, U_{i2}, \ldots, U_{iJ}\right]$$

This suggests that parents—and therefore, children—are matched with schools. That is, parents who send their children to school j are homogeneous in terms of income, the market prices they face, and school preferences.

Parental inputs

Because school choice determinants are controlled for by school fixed effects, $\hat{b}_1, \hat{b}_2$, and $\hat{b}_3$ should be interpreted as marginal effects on A of S, P, and H, respectively, through channels other than school choice.

In producing A, for example, parental inputs are considered important components of H. Parental ability, which determines the quantity and quality of inputs parents can provide, is assumed to affect student performance through two channels (Haveman and Wolfe [1995]). One is the human capital investment channel which includes school choice: better educated parents are likely to aspire for higher educational attainment by their children and would therefore choose what they deem to be better schools. They also tend to have higher incomes, thus allowing them to choose more expensive schools for their children. The other channel is the genetic transmission of ability, which implies that smarter parents tend to produce smarter children. Because the school choice channel has been netted out in the regression model, the inclusion of measures of parental ability as regressors is an attempt to take into account child ability as inherited from one's parents.

3. Data

The data used for this study are from the National Sample-based Assessment which the Department of Education, Culture, and Sports conducted in February 1999 among students in Grades 2, 4, and 6 of randomly selected public schools in the 22 poorest provinces in the Philippines. Some schools in ten other provinces were randomly selected and included in the sample. The tests covered four subject areas: math, science, English, and Filipino. Table 1 shows how students fared in math and science. If 50 percent is considered "passing," Table 1 is indicative of poor education outcomes in Philippine public primary schools.

In the Philippines, elementary education is provided by the government for free. Elementary education consists of six years. About 90 percent of all elementary schools are government-owned.

In this study, A is measured by student achievement in math and science. The dependent variables, scores, were computed by dividing total number of correct answers by the total number of questions. Separate regressions were estimated for each subject area and grade level.

Besides the test proper, the school children also provided information on the kind of learning materials available in school and perceptions on the kind of teachers that they had in school. This information was used as the basis for generating S_{ij}. Students were made to choose from among a list of learning materials which best described what was available in their schools: (i) books only; (ii) books, magazines, and newspapers; (iii) TV, books, magazines, and newspapers; (iv) encyclopedia, dictionary, TV, books, and magazines; or (v) a small library, including TV and computer. Dummy variables were generated for each of the possible responses, and the left-out category is that for "no materials."

To illustrate how students' information regarding availability of school resources varies, school officials lament that students sometimes do not even realize that libraries are actually present in their schools. Actual usage is likely going to be an important basis for a student's description of what learning materials are available

Table 1. Math and science scores,[a] by grade level

	Grade 2 (11,305)[b]		*Grade 4 (10,795)*		*Grade 6 (7,625)*	
	Math	*Science*	*Math*	*Science*	*Math*	*Science*
Mean	0.38	0.42	0.34	0.35	0.37	0.41
Std. Dev.	0.13	0.16	0.14	0.13	0.13	0.15
Min	0.00	0.00	0.00	0.00	0.00	0.00
Max	0.88	0.98	0.94	0.86	0.85	0.87

[a] Raw score divided by total.

[b] Figures in parentheses refer to number of observations.

in school and ultimately, actual usage, rather than potential, determines schooling outcomes.

Furthermore, students were asked to choose which of the following would best describe their teacher: one who (i) punishes children, (ii) does not teach, (iii) gives short lessons, (iv) uses appropriate materials, (v) is frequently absent, and (vi) is frequently late for class. Because teachers are licensed professionals in the Philippines, all practicing teachers have a standard minimum amount of knowledge that, presumably, enables them to perform their teaching functions. Their effectiveness, on the other hand, is argued to be a function of teaching style. Thus, students' responses to the question on teachers were used to construct a subjective measure of teacher quality. Although it is not clear what some of these responses mean in terms of quality or teacher effectiveness, what is considered the worse types of teacher in this analysis are those who either "do not teach" or are frequently absent. These last two teacher types were used in the regression analyses as left-out categories.

Similarly, the student's description of what learning materials are available at home was used to generate H_i. Unlike S_{ij}, H_i is arguably a more accurate measure of what learning materials are truly available at home. After all, the home is a much smaller physical space than the school and therefore a child has a greater ability to give an objective description of home learning materials. As a proxy for parental inputs, dummy variables for highest level of schooling attained were generated for each parent.

Table 2 presents the means for the learning input variables. A little over half of all students reported that they had written materials at home but no TV, whereas about a third indicated that that they had written materials in addition to a TV at home. On the other hand, three-quarters of students reported having written materials and no TV in school. Lastly, an overwhelming majority of students (70 percent) gave teachers what appears to be the best possible rating—i.e., that appropriate lessons are provided.

Other student characteristics which are included in P_i are age and gender. Age plays an important role in explaining cognitive achievement. Since the assessment tests were conducted almost at the close of the school year, then each cohort of students should theoretically have the same age with the exception of repeaters or drop-outs at a previous point and those who were previously accelerated to a higher grade level due to exemplary performance. To examine the effects of age more closely, sub-sample regressions include only modal ages for each grade level. Regression samples for grades 2, 4, and 6 include ages 8-9, 10-11, and 12-13, respectively.

4. Estimation and results

Tables 3-4 present the regression results. These show that the male dummy variable is statistically significant and negatively correlated with both math and

Table 2. Proportion of children, by type of learning material or teacher

Indicator variables for learning inputs	*Mean*	*Std. Dev.*
Books only at home	0.338	0.473
Books, magazines, newspapers at home	0.191	0.393
TV, books, magazines, newspapers at home	0.208	0.406
Encyclopedia, dictionary, TV, books, and magazines at home	0.083	0.275
Small library including TV and computer at home	0.020	0.141
No materials at home	0.161	0.367
Books only in school	0.299	0.458
Books, magazines, newspapers in school	0.454	0.498
TV, books, magazines, newspapers in school	0.066	0.248
Encyclopedia, dictionary, TV, books, and magazines in school	0.087	0.282
Small library including TV and computer in school	0.055	0.228
No materials in school	0.039	0.194
Teacher punishes children	0.063	0.243
Teacher does not teach	0.019	0.138
Teacher gives short lessons	0.153	0.360
Teacher gives appropriate materials	0.700	0.458
Teacher is absent	0.036	0.185
Teacher comes late to class	0.029	0.167

science scores in all grade levels. The finding that girls tend to outperform boys is consistent with the results of the 1999 Third International Math and Science Study in which selected students from 38 countries, including the Philippines, took achievement tests in math and science (Gonzales et al.[2000]). Regression results also indicate that younger children posted higher scores in all grade levels, supporting the hypothesis that older students in each cohort tend to be those who repeated or dropped out from a previous grade level.

Joint tests of significance show that the presence of school and home learning materials, regardless of type and combinations, as well as the "effective" presence of teacher (i.e., not being absent or being present but not teaching) generally have an impact on scores in all grade levels. Individual tests of significance, however, indicate that the specific impacts of combinations of school and home inputs as well as teacher types vary widely across subjects and grade levels.

For younger children (Grade 2), none of the combinations of school learning materials positively contributes to math achievement. For older children (Grades 4 and 6), combinations of materials that include computers are positively correlated with math and science scores. Some school input combinations that include television (TV) help improve math and science scores for older children. Having books only in school increases science scores for all grade levels.

Table 3. Math scores regressions

Independent variable	*Grade 2*	*Grade 4*	*Grade 6*
	Coef. *(t)*	*Coef.* *(t)*	*Coef.* *(z)*
Age	-0.0026 (-0.82)	-0.0071 (-2.13)	-0.0144 (-4.66)
Male	-0.0173 (-6.05)	-0.0300 (-9.73)	-0.0288 (-9.61)
Mother is a high school graduate	0.0097 (2.44)	0.0112 (2.89)	0.0032 (0.86)
Father is a high school graduate	0.0027 0.65)	0.0071 (1.78)	0.0138 (3.62)
Mother is a college graduate	0.0280 (5.21)	0.0148 (2.93)	0.0319 (6.39)
Father is a college graduate	0.0173 (3.18)	0.0136 (2.61)	0.0107 (2.04)
Books only at home	0.0053 (0.97)	-0.0008 (-0.13)	-0.0003 (-0.05)
Books, magazines, newspapers at home	0.0096 (1.47)	0.0124 (1.85)	0.0143 (2.18)
TV, books, magazines, newspapers at home	0.0154 (2.68)	0.0230 (3.39)	0.0230 (3.38)
Encyclopedia, dictionary, TV, books, and magazines at home	0.0112 (1.39)	0.0346 (4.49)	0.0403 (5.37)
Small library including TV and computer at home	0.0042 (0.37)	0.0071 (0.60)	-0.0009 (-0.07)
Books only in school	0.0165 (1.49)	0:0279 (2.51)	0.0341 (3.12)

Table 3. Math scores regressions (continued)

Independent variable	*Grade 2*	*Grade 4*	*Grade 6*
	Coef. *(t)*	*Coef.* *(t)*	*Coef.* *(z)*
Books, magazines, newspapers in school	-0.0086 (-0.77)	0.0206 (1.83)	0.0459 (4.25)
TV, books, magazines, newspapers in school	-0.0234 (-1.86)	0.0028 (0.22)	0.0044 (0.33)
Encyclopedia, dictionary, TV, books, and magazines in school	0.0087 (0.70)	0.0152 (1.24)	0.0462 (3.87)
Small library including TV and computer in school	-0.0042 (-0.31)	0.0313 (2.51)	0.0307 (2.39)
Teacher punishes children	0.0307 (2.93)	0.0594 (6.18)	0.0170 (1.92)
Teacher gives short lessons	0.0174 (2.04)	0.0538 (6.29)	0.0388 (4.66)
Teacher gives appropriate materials	0.0275 (3.62)	0.0607 (7.81)	0.0494 (6.17)
Teacher comes late to class	0.0078 (0.63)	0.0169 (1.53)	0.0278 (2.2)
Constant	0.3714 (12.66)	0.3452 (9.31)	0.4635 (11.14)
R-squared	0.0412	0.0807	0.0696
Number of observations	6469	5748	5202
Hausman test statistic (H_0: Random effects is the true model)	69.49	160.75	18.72
p-value for test of joint significance of H	0.14	0.00	0.00
p-value for test of joint significance of B	0.00	0.01	0.00
p-value for test of joint significance of T	0.00	0.00	0.00

Table 4. Science scores regressions

Independent variable	*Grade 2*	*Grade 4*	*Grade 6*
	Coef. (*t*)	*Coef.* (*t*)	*Coef.* (*z*)
Age	-0.0065 (-1.74)	-0.0122 (-3.75)	-0.0202 (-6.11)
Male	-0.0241 (-7.17)	-0.0242 (-7.97)	-0.0335 (-10.5)
Mother is a high school graduate	0.0188 (3.98)	0.0043 (1.14)	0.0033 (0.82)
Father is a high school graduate	0.0038 (0.77)	0.0151 (3.83)	0.0181 (4.43)
Mother is a college graduate	0.0467 (7.37)	0.0294 (5.92)	0.0419 (7.87)
Father is a college graduate	0.0358 (5.59)	0.0133 (2.62)	-0.0014 (-0.24)
Books only at home	0.0211 (3.28)	0.0007 (0.10)	0.0130 (1.80)
Books, magazines, newspapers at home	0.0232 (3.02)	0.0138 (2.10)	0.0266 (3.76)
TV, books, magazines, newspapers at home	0.0334 (4.92)	0.0260 (3.89)	0.0346 (4.71)
Encyclopedia, dictionary, TV, books, and magazines at home	0.0474 (4.95)	0.0460 (6.08)	0.0542 (6.72)
Small library including TV and computer at home	0.0068 (0.5)	0.009 (0.77)	0.0200 (1.44)
Books only in school	0.0365 (2.79)	0.0312 (2.86)	0.0415 (3.52)

Table 4. Science scores regressions (continued)

Independent variable	*Grade 2*	*Grade 4*	*Grade 6*
	Coef. (*t*)	*Coef.* (*t*)	*Coef.* (*z*)
Books, magazines, newspapers in school	0.0053 (0.40)	0.0292 (2.63)	0.0610 (5.24)
TV, books, magazines, newspapers in school	-0.0068 (-0.46)	0.0126 (0.99)	0.0182 (1.26)
Encyclopedia, dictionary, TV, books, and magazines in school	0.0019 (0.13)	0.0152 (1.25)	0.0455 (3.53)
Small library including TV and computer in school	-0.0164 (-1.04)	0.0311 (2.54)	0.0450 (3.24)
Teacher punishes children	0.0354 (2.86)	0.0682 (7.22)	0.0274 (2.88)
Teacher gives short lessons	0.0295 (2.93)	0.0496 (5.90)	0.0406 (4.53)
Teacher gives appropriate materials	0.0296 (3.31)	0.0574 (7.52)	0.0618 (7.16)
Teacher comes late to class	0.0231 (1.58)	0.0119 (1.10)	0.0263 (1.94)
Constant	0.4184 (12.07)	0.3892 (10.68)	0.5588 (12.65)
R-squared	0.0602	0.1143	0.1123
Number of observations	6469	5748	5202
Hausman test statistic (H_0: Random effects is the true model)	115.32	77.21	95.28
p-value for test of joint significance of H	0.00	0.00	0.00
p-value for test of joint significance of B	0.00	0.01	0.00
p-value for test of joint significance of T	0.01	0.00	0.00

In general, however, the following important observation can be made: the availability of *basic* learning materials—e.g., books only, or books, magazines, and newspapers—in school produces a significant and sizeable impact on both math and science scores, an impact which is sometimes larger than what a more expensive set of resources (e.g., small library with TV and computer) can produce.

Teacher effects, on the other hand, appear to be uniformly large across grade levels and subject areas. Among all inputs examined in this study, teachers appear to have the most sizeable impact on scores. In particular, mere teacher presence seems to be a significant contributor to math and science achievement. Students with any type of teacher, with the exception of those who are not punctual, tend to have higher scores than those who said teachers were always absent or "did not teach." Among Grades 2 and 4 students, those having teachers who were always late did not perform any better or worse than those with absentee teachers. Punctuality perhaps matters more to younger children whose attention spans are shorter then their older peers. Thus, being late for class could be equally harmful as not coming at all to class. These results collectively underscore the huge importance of teacher presence in student performance.

At home, having TV, books, magazines and newspapers is positively correlated with both math and science scores in all grade levels. Having computers at home, along with a small library, is not a significant factor in explaining student achievement for all grade levels.

Students whose parents completed college education performed better than those whose parents had not. Interestingly, the marginal impacts of having a college diploma on children's scores are larger for mothers than fathers. While this result is indeed not inconsistent with the finding that female students performed better in all the tests, this could also reflect the traditional role played by women in Filipino society. Mothers typically "make the home," a task which includes directly supervising the children's homework assigned by teachers.

A Hausman test was performed to determine whether a fixed-effects or a random-effects model was appropriate. The tests indicate that the fixed-effects model is the correct specification for all regressions with the exception of math scores for Grade 6 students. The Hausman test statistics are presented in Tables 3-5.

5. Conclusion

To explain student performance, this paper focused on two important variables—student-level measures of inputs, and family and home characteristics—the lack of data on which has handicapped previous studies on the determinants of cognitive achievement. Moreover, by incorporating a school choice mechanism in the behavioral framework, parental characteristics are interpreted as proxy measures for child ability. While a number of researchers had been able to devise ways to control for unobserved child ability, they had been able to do so often as a result of costly data collection efforts such as the use of data on twin siblings. The estimation strategy employed in this paper showed that the same could be done with standard data from nationally-administered tests.

The findings of the paper can be summarized as follows.

Teachers play an important role in improving the math and science performance of public elementary school children in the Philippines. Moreover, what is required from teachers is minimal, i.e., presence. However, it appears that dealing with teacher absenteeism requires more than minimal efforts. Although the administration of the education system has been devolved, teachers (at least at the time of data collection) are hired at the regional level and often deployed in areas that are too distant from their places of residence. Designing sufficiently strong incentives—possibly in the form of bonuses, housing benefits, or transportation allowances—for teachers to attend class needs to be given priority by school administrators.

Estimation results also suggest that encouraging the use of learning materials in school and at home can play an important factor in improving student achievement. Basic learning materials such as books, magazines, and newspapers appear to be sufficient performance enhancers for both math and science. More expensive resources like the TV and computer, in combination with basic materials, seem to be more useful in boosting math performance among older children.

Moreover, because the marginal impacts of specific combinations of school inputs vary considerably across subjects and grade levels, it can be argued that giving school managers some autonomy, at least in resource allocation, can result in better student performance. When the provision of school resources is done uniformly via a centralized procurement system, student performance will be affected in a non-uniform fashion. Some amount of fiscal autonomy given to school managers can result in the achievement of uniformly good schooling outcomes with the employment of fewer resources.

Lastly, the paper underscores the intergenerational benefits of investing in education. Parents who attain higher levels of schooling also tend to produce children who perform better in school. The finding that completion of tertiary education by mothers contributes more than that by fathers to children's school achievements, coupled with the result that girls posted higher math and science scores than boys, emphasizes the importance of not only ensuring that women have access to schooling but more importantly that they face strong incentives to remain in school, e.g., equal opportunities in the labor market.

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