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Education Production Function in Senegal at the Primary Level: Box-Cox Transformation (1964)

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ABSTRACT

This paper proposes to estimate the educational production functions of Senegal from the PASEC 2014 data at the primary level at the beginning and end of schooling by the BOX-COX (1964) transformation. We do not impose a linear functional form a priori but propose to determine it using the BOX-COX model. The results obtained indicate that the widespread use of the linear form is not appropriate, at least with respect to the Senegalese data. On the other hand, the use of this transformation at the beginning and at the end of the schooling period yielded interesting results.

KEYWORDS: educational production function; Box-Cox transformation; Senegal; PASEC

INTRODUCTION

In most countries an interesting debate is taking place in economic policy on the issues of financing education, the transparent and efficient use of resources allocated to education. Decisions have to be made about the use of public money. Not everything is possible, the education budget is not the only budget of the nation, and within it, the different users all demand more attention.

Efficient and more effective management of these resources for education is therefore needed to meet a major challenge: improving the efficiency of the school system in order to improve the return on this investment. The efficiency of a school system can be measured in terms of individual performance (SCHULTZ, 1963; TODD and WOLPIN, 2003). In educational economics, this is generally apprehended by the score of pupils in a test, the latter being claimed to be the primary and objective selection criterion for passing from one class to another (or from one stream to another). The aim is to identify which factors have the greatest impact on the objective variables considered important. Examining this productivity relationship between pupil, family and school inputs and children's test scores would then answer the question: which inputs have the greatest impact on individual performance?

The problematic of this paper will be based on the estimation of educational production functions whose dependent variable is a measure of the output of the school system (the results of the Senegalese tests at the primary level of the Programme d'Analyse des Systèmes Educatifs de la CONFENMEN).

This output is a function of student, family and school characteristics. We assume that if the dependent variable is normally and independently distributed among individuals, then the equation is correctly specified and the estimation of this output function by maximum likelihood will give convergent estimators of the coefficients of the characteristics of the pupil, his family and his school. However, there is no way of knowing a priori whether these hypotheses are respected. We therefore propose to use the Box-Cox (1964) model to test and define the functional form considered as linear in the majority of the current literature on the subject.

The rest of this paper will be structured as follows:

Section 2 will present the literature related to the economics of education and educational production functions;

Section 3 will present the modelling of this function in the case of Senegal;

Section 4 will introduce the database and some descriptive statistics for the selected variables;

Section 5 will present the results of the estimations;

The conclusion will summarise the key findings.

LITERATURE REVIEW

The theoretical framework of the production function began with COLEMAN (1966), who was commissioned by Lindon JOHNSON, the successor to John Fitzgerald Kennedy, who was assassinated in 1963, to explain why black students achieve less than white students. This research led to the explanation that the difference was due to differences in the resources allocated to schools. This is the first time that student achievement test results have been used as an estimate of the outcome of the school process and that educational resources have been

related to outcomes at the level where education is delivered, the school. The main conclusion of this research is that ultimately the difference in performance between white and black students is not explained by the difference in financial endowments of schools.

Contrary to the expectations of researchers and politicians, COLEMAN's results were surprising, as no relationship between means and outcomes is highlighted. Family influence is more important on outcomes than school influence.

At the international level, the International Association for Educational Assessment (IEA) conducted a study in 1959-1963 in twelve countries (Belgium, France, England, Finland, Israel, FRG, Poland, Scotland, Switzerland, Sweden, the United States and Yugoslavia) on learning in mathematics, reading comprehension, geography, science and non-verbal skills. This work has enabled comparisons to be made of differences between and within countries, and has identified some individual factors that explain the differences. Subsequent studies, starting with FIMSS (First International Maths and Science Study) in 1964, did not go very far on this point.

However, nowhere in the COLEMAN report, nor in the early work of the IEA, is the concept of the production function discussed.

The use of the production function for the analysis of educational problems will only be introduced later, notably by HANUSHEK (1979). From then on, the techniques used by the economist to study production in general, i.e. the production function, were applied to education. As a production activity, education is a cumulative process that mobilises various inputs that can be grouped under three main headings: the pupil, his family and the school.

In the literature on the production function of education, these inputs are used to explain school performance. Studies that focus on the family's investment in school performance are part of the ECD (Early Childhood Development) literature, whereas those that focus on the school's investment in school performance are part of the EPF (Education Production Function) literature.

Other authors such as GOLDHABER and BREWER (1997) use variables characterising the background of the individual and his/her family, the school, the teacher and finally the class.

Among the studies of the first branch seeking to understand the role of the family and thus of the characteristics of the parents and the home environment on the production of "cognitive skills", we cite those of LEIBOWITZ (1974), HAVEMAN and WOLFE (1976), BECKER and TOMES (1976).

Studies on the cultural capital of pupils generally involve an analysis of their parents' level of education (MURAT, 2009). Numerous research studies have shown the link between parents' level of education and their children's academic success (MULLER and KERBOW, 1993; RYAN and ADAMS, 1995).

Other studies have shown the influence of the mother and father on the child's school performance. Indeed GLICK and SAHN (2000) in Guinea and WAMALA *et al* (2013) in Uganda have managed to prove that the mother's education has a great influence on the educational performance of girls. Contrary to the conclusions of TANSEL (1997) whose study on Ghana and Côte d'Ivoire shows a greater influence of the father on the performance of boys. It appears from previous studies that children's school performance is better when their parents have a certain level of education. Contradictory results are the work of HIJRI *et al* (1995) on Morocco. According to these authors, the effect of the level of education on pupils' achievements is not significant.

According to PASEC (2007), in Grade 2, in both French and mathematics, students from wealthy families perform at a higher level than those from poor families in both assessment years. However, in grade 5, the difference is only noticeable in mathematics in both 1996 and 2007.

On the other hand, DUNGA (2013) in a study on Malawi shows that the sex of the pupil, socio- economic status, language spoken at home, have a positive impact on pupils' reading performance. On the other hand, the effect of the variables age of the pupil and absenteeism is negative.

If we look at the 'teacher' variable, it also plays a crucial role. Indeed, the level of student performance is often more related to the quality of teaching than to the level of resources available at school and in the classroom (HANUSHEK and RIVKIN, 2006). HANUSHEK et al (2005), using a database of Texas schools, show that good teachers will make significant progress in students. BRESSOUX, KRAMARZ and PROST (2005) analyse the impact of teacher training in French schools. Their results show that teacher training substantially improves performance in mathematics. In the case of reading, training is most beneficial for the best classes.

According to DIENG (2017), teacher experience plays an important role on students' performance in Mozambique, Swaziland, Uganda and Zimbabwe, which means that the more experienced the teacher the higher the student's score in these countries. In Kenya, NGWARE *et al* (2015) conclude that students' performance varies from teacher to teacher or group of teachers.

The SACMEQ III and PASEC studies conducted in Africa between 2004 and 2012 showed a significant and positive relationship between student performance and the availability of textbooks in the classroom. The PASEC2014 assessment confirms these trends. In low-income countries, the availability and use of textbooks improves student achievement (KEEVES, 1995), while no such effect was observed in high-income countries. In contrast, according to ZUZE and REDDY (2014) the relationship between reading achievement and educational facilities is significant for both girls and boys in South Africa.

Class size and pupil-teacher ratios are important factors in the cost of education. All observed effects of class size on performance, whether positive or negative, are quite small. This observation had already been made by MICHAELOWA (2003): "the effect of class size on the quality of learning is variable and

in general very modest, even sometimes insignificant in the African context". DIENG (2017) shows that having a large number of pupils in classes has a negative effect on school results in Kenya, Malawi, Namibia, South Africa and Zimbabwe.

METHODOLOGY

The functional forms proposed by the BOX-COX model have received little interest when estimating educational production functions. In most PASEC and SACMEQ works, we find traditional linear specifications to estimate the impact of educational factors on student learning. The downside is that there might appear some restriction, as the non-linear effects of production factors might not be captured potentially. The results obtained could be characterized by an underestimation of the school inputs on the pupils' achievements. This is why we proposed to estimate the production function of education in Senegal and above all we note a significant presence of dummy variables. The objective is to improve the fit of the model to the data using the BOX-COX transformation (1964) and to obtain a normal distribution of the data.

The particularity of the use of this transformation is the fact that a linear functional form is not imposed.

Our problem is to estimate the educational production functions in Senegal at the primary level, whose dependent variable is school performance according to the characteristics of the student, his family and his school.

That is :

- A, the measure of the output of the school system (for example, the score obtained on a test);
- the letter i is a clue for individuals;
- the vector X_i the variables relating to the student's characteristics;
- the vector F_i those relating to the characteristics of its family
- and the vector S_i those relating to the characteristics of its school.

In general, the following educational production function can be modeled as follows:

$$A_i = f(X_i, F_i, S_i) \quad (1)$$

In this equation, we start from the basic assumption that the function is linear and that X_i, F_i and S_i are exogenous. If we assume that in the model $A_i = \beta_1 + \beta_2' X_i + \beta_3' F_i + \beta_4' S_i + \varepsilon_i$, the A_i are normally and independently distributed with the expectation $= \beta_1 + \beta_2' X_i + \beta_3' F_i + \beta_4' S_i$ and the variance $= \sigma^2$. BOX and COX (1964) then propose to "work with a parametric family of transformations from A to $A^{(\theta)}$, the parameter θ, (…) defining a particular transformation". What we now find in the literature under the name of Box-Cox transformation which therefore proposes to estimate the following model:

$$A^{(\theta)}{}_i = \beta_1' + \beta_2' X_i + \beta_3' F_i + \beta_4' S_i + \varepsilon_i \quad (2)$$

With :

$$A^{(\theta)} = \frac{A^{\theta} - 1}{\theta} si 0 \le \theta \le 1 = \ln(A) si \theta = 0 \quad (3)$$

The transformation holds for A > 0. Since the majority of the explanatory variables are dummy variables, we keep the linear form to the right of the equalizer sign.

Now suppose that for θ Nope known, the observations transformed $A^{(\theta)}{}_i = (i = 1,..,n)$ satisfy all the normal theoretical assumptions. The probability density for untransformed observations is obtained by multiplying the normal density by the transformation Jacobian (BOX-COX, pp. 215). We then obtain the likelihood function of the Box-Cox model:

$$\ln L_c = -\frac{n}{2}\left[\ln(\tilde{\sigma}^2) + \ln(2\pi) + 1\right] + (\theta - 1)\sum_{i=1}^{n} \ln(A_i) \quad (4)$$

Where $\tilde{\theta}^2 = \frac{1}{n}\sum_{i=1}^{n} \varepsilon_i{}^2$

In order to be able to interpret the coefficients obtained, we use the procedure commonly called the delta method derived from Taylor's theorem. This transformation allows us to obtain two distinct qualitative effects, namely:

the relative difference: $\frac{A_1 - A_0}{A_0} \cong \beta_k A_0^{-\theta}$ (5)

the absolute difference: $A_1 - A_0 \cong \beta_k A_0^{1-\theta}$ (6)

where A_0 is the average score in one of the two disciplines and β_k the estimated coefficient of the kth variable.

This modeling is little used in economics of education, even to our knowledge in the context of PASEC data from Senegal, it has never been used. The only study in the field which is devoted to this and which has greatly inspired us is that of MURIEL MEUNIER (2006) on Switzerland. On the other hand, it has been used in other fields (BUCHINSKY (1995) or MACHADO and MATA (2000)).

It is therefore this modeling that we will apply in the context of Senegal on PASEC 2014 data.

DATA

The data used come from the 2014 evaluation of the CONFENMEN Education Systems Analysis Programme. They are collected from a representative sample of the school population; from students, teachers, headmasters and ministries of education, both at the beginning and at the end of schooling, to better understand the relationship between students' home and school environments and their performance. These student

achievement results or performances measure competencies in French and mathematics. Pupils are assessed in grade 2 and grade 6 (at the beginning and end of the year).

In year 6e , after data collection, 160 of the 180 sampled schools were actually surveyed and 2,905 students tested.

In 2e year, after data collection, 83 schools out of the 90 sampled were actually surveyed and 807 pupils tested.

The aim of the study, based on a certain methodological framework, is to assess the levels of pupils in the first and second grades and to investigate the factors influencing pupils' learning.

Table 1: Description of variables

The variables	Description
Student performance	Student test scores, average student scores in grade two and grade six: these are the variables explained
Student's age	The student is old or not
Student gender	The student is male or female
The student attended preschool	The student attended preschool yes or no
The student has repeated at least once	The student has repeated at least once yes or no
The language spoken at home is the mother tongue	The language spoken at home is the mother tongue or the language of instruction
Does the student have a textbook for reading in class?	Does the student have a textbook for reading in class? Yes or no
A classroom math textbook	A math textbook in the classroom? Yes or no
Lack of student motivation for studies	Lack of student motivation for studies
Parents' lack of interest in school	Parents' lack of interest in school
Household poverty	The student's parents are poor
Availability of books at home	The student has the books at home
parent education	The student's parents are educated
Teacher	The characteristic variables of the teacher are the gender of the teacher (male or female), the secondary level, the university level, his level of training (no year of training Six months of training, one year of training), absenteeism from teacher and his experience as a teacher
School facilities and resources	This variable includes: Class pedagogical resource index[1] Index of perception (by the master) of working conditions School pedagogical resource index School infrastructure index[2] Textbooks: number of textbooks Availability of school supplies: yes or no
School methods and school organization	Do you have students work in small groups? Yes or no Overcrowded class sizes: number of students School programs The use of the competency-based approach (APC): yes or no The use of the situational approach (APS): Yes or no Pedagogy by objectives (PPO): Yes or no The pedagogy of large groups (PGG): Yes or no Support lessons, tutoring: Yes or no

Source: PASEC 2014

[1] The class equipment index is constructed from questions asked to the teacher concerning the availability of textbooks for pupils, educational documents and materials for teachers and classroom furniture: number of mathematics and reading textbooks available per student; availability of textbooks, teaching guides and programs for reading and mathematics for the teacher; availability of teaching materials (blackboard, chalk, dictionary, maps of the world, Africa and the country, measuring equipment such as square, compass and ruler, and clock) and availability of classroom furniture (desk and chair for the master bedroom, cupboard and storage shelves for books, reading corner and sufficient bench tables) **,** PASEC 2014 **.**

[2] Built through a series of questions concerning the availability of equipment, the possibilities of welcoming pupils in the classes and the existence of sanitary facilities: ratio between the number of functional classrooms and the total number of pupils, availability of some equipment (a separate office for the director, a place to store equipment, a master room, a playground, an independent sports field, a fully fenced perimeter, a medicine box, accommodation(s) for teachers or directors, running water, a source of drinking water other than running water, and electricity) and the existence of latrines or toilets.

Table 2 below summarises the skills in French and mathematics.

Table 2: Senegal's average scores in language and mathematics at the beginning and end of primary school

Performance	Obs.	Average		Standard deviation	
		Start	End	Start	End
Reading Mathematics		501,9	548,4	9,5	6,8
		521,4	546,6	8,9	6,7

Source: PASEC 2014

The average of the national sample is 501.9 at the beginning of schooling and 548.4 at the end of schooling in reading and 521.4 and 546.6 in mathematics, respectively at the beginning and end of schooling. In international comparison, Senegal is a good performer in terms of these scores in language and mathematics at the beginning of schooling.

Indeed, only Burundi has higher scores than Senegal in these two subjects (PASEC 2014).

After the description of the descriptive statistics of the performances, those of some inputs are specified in the following table 3.

Table 3: Characteristics of some inputs

Input variables	Average		Standard deviation	
	Start	End	Start	End
Average level of the socio- economic index of the student's Family		55,1		0,6
Percentage of pupils who report	20,2	84,6	2,6	1,7
using the language of instruction at home				
Percentage of pupils who report having attended pre-school	31,3	43,7	3	2,5
Percentage of pupils having repeated at least once	9,8	36,8	1,3	2,2
Average level of the equipment index of the class	53,9	53,1	1,2	1
Percentage of students by number of students per textbook Reading	61,7	42,3	5,4	4,8
Percentage of pupils with a mathematics textbook in class	37,1	51,6	5,3	4,7
Distribution of students by secondary level	59,2	52,8	8,9	4,8
Distribution of students by university level	40,8	47,2	8,9	4,8
Distribution of students for No Training	5,9	4,2	3,4	2,3
Distribution of students by less than six months of training	29,6	31,9	6,4	5
Distribution of students by year of Training	58	57,5	7,2	5,1
Distribution of students by two or more years of training	6,5	6,3	3,7	2,2
Average level of school infrastructure index	58,5	58	1,3	0,7

Source: PASEC 2014

At the end of their schooling in Senegal, 84.6% of pupils declare that they practice French outside of school. At the beginning of their schooling, almost 20% of pupils say they speak the language of instruction at home. Conversely, at the beginning of their schooling, almost 80% of pupils say they do not speak French at home.

Home schooling language by pupils is more practised at the end of schooling than at the beginning of primary schooling. This is because pupils have spent more time in the education system at the end of their schooling than at the beginning, when they are taking their first steps in school.

At the beginning of schooling, at the national level, 31.3% of pupils declared having attended pre- school compared to 68.7% of pupils who did not attend.

At the end of the school year, the proportion of pupils who declare having attended pre-school is 43.7%. At this level, the percentage of pupils (56.3%) who have not attended pre-school is higher.

The percentage of students who have repeated at least one grade is 9.8% at the beginning of school. More students (more than 90%) pass their compositions at the beginning of the school year.

At the end of schooling, 36.8% of pupils have repeated at least once, compared to 63.2% of those who pass. It should be noted that there are more repeaters at the end of school (36.8%) than at the beginning (9.8%).

The average level of equipment in the class is 53.9 at the beginning of school and 53.1 at the end. In both cases, this index exceeds 50%.

At the beginning of school at national level, the proportion of pupils who have a reading textbook is higher (61.7%) than the international average (35.4%). In mathematics, the national average (37.1%) is lower than the international average (39.5%).

The percentage of students who have a textbook in reading (42.3%) and mathematics (51.6%) at the end of school is higher than the international average (36.4% in reading and 41.9% in mathematics).

Senegal is one of the countries with the highest proportion of students who have teachers with a university degree (40.8% at the beginning of schooling and 47.2% at the end). However, it should be noted that more than 50% of students have secondary school teachers at the beginning and at the end of their schooling.

In international comparison, more than 60% of pupils are taught by teachers with one to two years of training. However, there is a very small share of teachers with no years of training and two or more years of professional training.

The average level of the school infrastructure index is 58.5 at the beginning of schooling and 58% at the end. Senegal is among the countries in the PASEC2014 assessment that have the highest average level of school infrastructure.

EMPIRICAL RESULTS

The production functions of education in Senegal at the primary level were estimated using the BOX- COX transformation at the beginning of schooling and at the end of schooling (sixth grade). We obtain the effects of the explanatory variables on the performance of pupils in terms of absolute value (numerical data) and relative value. The relative values that we will analyse are expressed as percentages in the different results tables.

Estimation of the primary education production function in the second stage by the BOX- COX transformation

The following three tables show the results of these estimates.

Table 4 below shows the results of the estimation of reading and mathematics performance according to student characteristics.

Table 4: Estimation of the production function of education at the primary level in the second year of operation

Performance	**French**		**Mathematics**	
Inputs : Characteristics of the student	**Relative (%)**	**Absolute**	**Relative (%)**	**Absolute**
Age of the student	-0,01*	-0,72	0,10***	0,14
The student is a girl	4,51***	8,42	-0,94***	-2.67
The student is a boy	-0,03*	-4,87	1,24	4.93
The student attended pre-school	1,99*	19,02	-1,37*	-1,89
The student has repeated at least one year	1,44*	9,07	4,32*	16,74
The score at the beginning of School	0,005***	0,12	0,03***	0,12
The language spoken at home is the mother tongue	-8,93*	-19,75	-2,28***	-6,03
Does the pupil have a reading book in class?	8,66***	17,24	Nd	Nd
A mathematics textbook in the Classroom	Nd	Nd	3,49***	9,38
Lack of motivation of the student to study	-14,04***	-22,23	-2,41***	17,52

Source: Author's estimate from PASEC 2014 Senegal

Notes: * (chi2 < 10%, ** (chi2 < 5%, *** (chi2 < 1%. Observations: 800 in reading and mathematics

Table 4 above presents the estimation results for all students. The results clearly indicate that age and nursery school attendance are important explanatory variables. Indeed, in the second year of reading, the effects of the variables age of the pupil (-0.1%), the fact of the pupil's male gender (-0.03%), the fact that the language spoken at home is a mother tongue (-8.93%) and lack of motivation (-14.04%) on performance are negative. For the lack of motivation and the availability of a mathematics textbook, the result is significant. On the other hand, if the pupil has a reading textbook, is female, has attended pre-school and is repeating a year, the results are good. Indeed, the impacts on student performance are 8.66% for the availability of a reading textbook, 1.99%, 1.4% for repeating a year, and 4.51% for the female

gender of the student. The effects are significant according to the initial score at the beginning of the pupil's schooling and according to the female gender.

In mathematics, the age of the student (0.10%), the fact of being male (1.24%), repetition (4.32%) and the availability of a mathematics textbook (3.49) are positively correlated with performance.

The impact is negative for the other variables (the fact that the pupil is female, the fact that the language spoken at home is a mother tongue, lack of motivation). The results on student achievement are -0.94, -2.28 and -2.41% respectively.The interesting result for pre-school attendance could be due to a growing demand for education in this

sector with the continuous growth of the school-age population and the multiplication of pre- school institutions. In 2014, the Senegalese education system recorded a gross preschool enrolment rate (GPR) of 16.4 per cent, according to data from the last population census, compared to 6.1 per cent in 2004, a gain of 10.3 percentage points (PASEC, 2014).

Repetition is a pedagogical practice put in place to help students with learning difficulties to catch up with educational objectives. From 2009 to 2014, the repetition rate was relatively stable. Only in 2010 did it peak at 6.4% with the long strike by teachers. In 2014, the rate dropped to 2.8%, which is well below the 5% threshold set by the education system authorities (PASEC 2014). Even if it involves costs and contrary to what many studies have proven, notably the PASEC 2014 study on Senegal, repetition has a positive effect on learning in second grade reading and mathematics. But this result does not corroborate the qualitative findings obtained by DIENG (2017) in twelve Eastern and Southern African countries, as both pupil age and repetition have significantly negative effects on pupil performance in all countries in his database.

Table 5 below shows the results of the estimation of reading and mathematics performance according to family characteristics.

Table 5: Estimation of the production function of education at the primary level in the second year of schooling

Performance	**French**		**Mathematics**	
Inputs : **Characteristics of the family**	**Relative (%)**	**Absolute**	**Relative (%)**	**Absolute**
Lack of interest in school on the part of families	-1,17**	-3,26	-2.36*	-13,38
Household poverty	-3,95***	-16 ,54	-9,53***	-20,53
Availability of books at home	-.024**	-8.04	-4,29**	-54,42
Parent education	0,21***	29.85	4,24***	24,26

Source: Author's estimate from PASEC 2014 Senegal

Notes: * (chi2 < 10%, ** (chi2 < 5%, *** (chi2 < 1%. Observations: 800 in reading and mathematics

With regard to family characteristics in both reading and mathematics, household poverty, lack of interest in school and availability of textbooks have negative effects on pupils' learning. In reading, the results are -1.17% for lack of interest from the family, household poverty -3.95% and availability of books at home -0.24%. In mathematics we have -9.53% for household poverty, -4.29% for availability of books at home and -2.36% for lack of family interest. This result differs from that found by WILLIAMS and SOMERS (2001) who found that academic achievement in several Latin American countries is strongly related to the number of books owned by the child's family home. The negative impact of household poverty on scores is highly significant. This result corroborates with The lack of interest of the family, in addition to having a negative effect on school results, could compromise other quality indicators (success rate in the CEP exam, primary school completion rate, repetition, dropout and exclusion rates). To avoid negative effects due to the lack of interest of the family, a strong link should be established between the family and the school to allow both environments to collaborate well, to work together so that performance improves.

With regard to the education of pupils' parents, the result is more interesting, as its impact on reading and mathematics scores is significant with 0.21% and 4.24% respectively. This result is in line with DIENG's (2017) finding that parental literacy has a positive influence on students' academic performance in almost all the 12 countries except Kenya, Zambia and Zimbabwe. These results could be explained by the fact that parents are more likely to support and supervise their children.

For the availability of books at home, the negative sign could be interpreted as the pupil not being able to use them at home due to either incapacity, lack of interest on the part of the family, or lack of parental education or support and supervision.

Table 6 below shows the results of the estimation of performance in reading and mathematics according to school characteristics.

Table 6: Estimation of the production function of education at the primary level in the second year

Performance / Inputs: School Features		French		Math	
		Relative (%)	**Absolute**	**Relative (%)**	**Absolute**
Master	Kind of the master	3.31	25.75	19.14	11.27
	Secondary level	0.12*	5.13	3.56	16.48
	University level	9.68***	12.35	0.89***	2.41
	No year of training	-0.002*	-2.1	-0.12*	-12.56
	Six months of training	0.001**	2.1	0.14**	5.23
	One year of training	2.1***	17.5	6.23***	5.79
	Teacher absenteeism	-3.78***	-9.54	-1.73***	-10
	The teacher's experience	0.02*	14.21	1.08***	1.812
School facilities and resources	Class pedagogical resource index	0.45*	34.90	1.92**	20.57
	Index of perception (by the master) of working conditions	-0.09*	-7.31	7.15*	12.48
	School pedagogical resource index	2.76*	11.6	14.26***	18.4
	Textbooks	0.52***	10.2	5.6***	21.46
	School infrastructure index	0.05**	15.84	2.57**	17.97
	Availability of school supplies	4.07***	15.46	19.17***	34.94
School methods and school organization	Do you have students work in small groups?	0.04**	11.44	5.26***	19.7
	Overcrowded class sizes	-0.01***	8.22	-1.39***	10.60
	School programs	-12.32*	-23.74	-2.78*	-14.13
	The use of the competency-based approach (APC)	6.45**	23.9	4.47***	21.38
	The use of the situational approach (APS)	-0.07*	-7.86	-10.22*	-55.93
	Pedagogy by objectives (PPO)	0.01*	1.69	5.54***	9.19
	The pedagogy of large groups (PGG)	4.69**	12.73	4.44***	14.91
	Support lessons, tutoring	0.03*	8.76	6.38*	28.53

Source: Author's estimate based on the PASEC 2014 Senegal database

Notes: * (chi2 < 10%, ** (chi2 < 5%, *** (chi2 < 1%). Observations: 800 in reading and mathematics

For school characteristics, the variables are grouped into teachers, school equipment and school methods and organisation.

With regard to the characteristics of the teacher, in the second year, absenteeism and the lack of teacher training have a negative impact on student achievement with respective results equal to - 0.002% and -0.12% for the second variable and -3.78% and -1.73% in reading and mathematics respectively. On the other hand, the level of education, training and experience of the teacher had very significant positive effects in both mathematics and reading. For example, for a university-level teacher, the impact on learning in reading is significant at 9.68% and in mathematics at 0.89%. One year of training is equivalent to 2.1% and 6.23% of significant scores. The significant results could be interpreted by the fact that a higher level of education plus allows the teacher to acquire more advanced knowledge and skills and that the training in turn gives him/her the pedagogical tools to carry out his/her teaching properly.

The positive result on teacher experience is in line with that found by (MOURJI and ABBAIA, 2013) on Morocco with professional teacher experience, measured by seniority having a fairly significant positive effect on student achievement.

For school facilities and resources, the variables retained are the index of pedagogical resources of the class, the index of

perception (by the teacher) of working conditions, the index of pedagogical resources of the school, the index of school infrastructure, the availability of school supplies and the availability of textbooks. Except for the index of perception (by the teacher) of working conditions in reading, all the other variables play a positive role on students' performance in reading and mathematics. The results for the availability of school supplies, the index of classroom and school resources are more significant with respectively 4.07% and 19.17% in reading and mathematics respectively, 1.92% and 14.26% in mathematics. Textbooks also have a positive and significant impact on students' results (0.52% and 5.6%). These results are in line with those of DIENG (2017). Indeed, according to this author, pupils whose schools have adequate equipment record higher scores in Kenya, Lesotho, Mozambique, Namibia, Tanzania and Zimbabwe.

School methods and organisation, on the other hand, cover a multitude of specific factors: working with students in small groups, large class sizes, school curricula, the use of the competency-based approach, the use of the situation-based approach, objective-based pedagogy, large-group pedagogy, and support courses. Only the variables: large class size, curriculum and situation-based approach have negative percentage scores with in reading -0.01% (highly significant result), 12.32% and -.07% and in mathematics -1.39, -2.78 and -10.22%. Our findings are in line with the work of (BOURDON *et al.*, 2010; BIRCHLER and MICHAELOWA, 2016; LEE *et al.* , 2014; BRAULT *et al.* , 2014) who show that school performance is also strongly dependent on the quality of school organisation and teaching. With regard to class size, the negative effect is in line with those found by several researchers, notably HANUSHEK (1994) and HOXBY (2000) who worked on American data.

Working with students in small groups, the use of the competency-based approach, objective-based teaching, large group teaching and tutoring have a positive influence on students' achievement in reading and mathematics at the beginning of school. Indeed, in mathematics, for example, the scores are 5.26%, 4.47%, 5.54%, 4.44% and 6.38% respectively for these variables. The only impact on performance in mathematics that is not significant is that of tutoring.

Estimating the production function of education at the primary level in grade 6 by the BOX- COX transformation

The following three tables show the results of the sixth grade estimates.

Table 7 below shows the results of the estimation of reading and mathematics performance according to student characteristics.

Table 7: Estimated production function of education at primary level in grade 6

Performance	**French**		**Mathematics**	
Inputs : **Characteristics of the student**	**Relative (%)**	**Absolute**	**Relative (%)**	**Absolute**
Age of the student	2,25*	9,91	0,23*	10,62
The student is a girl	5,08*	20,44	-1,76***	-20,45
The student is a boy	6,18*	21,10	10,16***	18,23
Attendance at pre-school	5,14**	14,90	-1,86*	-17,71
The score at the beginning of school	0,12***	0,53	0,3***	0,56
The student has repeated at least one year	4,72*	58,7*	11,32***	27,99
The language spoken at home is mother tongue	-10,74*	-12,96	-1,01*	-21,98
The student has a reading manual	22,91***	30,25		
Does the student have a mathematics textbook in class?			7,59***	12,01
Lack of motivation of the student to study	-17,71**	-39,54	-3,95***	-23,16

Source: Author's estimate from PASEC 2014 Senegal

Notes: * (chi2 < 10%, ** (chi2 < 5%, *** (chi2 < 1%. Observations: 2770 in reading and mathematics

In the sixth grade, the results of the above table show that in mathematics and reading, depending on whether the pupil is a boy or a girl, repetition, the age of the pupil and the availability of a mathematics textbook have a positive impact on the pupils' results. Indeed, for these variables the effect is significant in mathematics with 10.16%, 11.32% and 7.59% respectively. In reading, the availability of a reading textbook is significant with 22.91%, while for repetition and the male gender of the pupil, the effect is not very significant with 6.18% and 4.72% respectively.

The effect on performance was negative for the other variables, the fact that the pupil was female (- 1.76), the fact that the language spoken at home was a mother tongue (-1.01), the fact that the pupil attended a nursery school (-1.83), as well as his or her lack of motivation in mathematics (-3.95).

In sixth grade French, the language spoken at home is a mother tongue (-10.74) and lack of motivation (-17.71) are variables with negative effects. At this level, only the male and female gender of the pupil, age, repetition, attendance at pre-school and the availability of a reading textbook have a positive effect on performance.

Age at school entry in mathematics and at school leaving in both subjects has interesting results. It can be hypothesised that older students will have more developed cognitive abilities that will allow them to make faster progress in mathematics in grade 2 and grade 6 in both subjects.

In both grades, the results for gender are interesting and show a difference between girls and boys. While being a girl has a positive impact on reading, this effect is negative for mathematics. This result can be explained by differences in students' abilities in the different domains. Indeed, girls would be "predisposed" to more literary subjects, while boys to more scientific subjects.

Table 8 below shows the results of the estimation of reading and mathematical performance according to family characteristics.

Table 8: Estimated production function of education at primary level in grade 6

Performance	**French**		**Mathematics**	
Teuhdfc **Inputs :** **Characteristics of the family**	**Relative (%)**	**Absolute**	**Relative (%)**	**Absolute**
Lack of interest in school on the part of families	-17,23***	-23,26	-34.25***	-53,04
Household poverty	-3,95***	-16 ,54	-9,53***	-20,53
Availability of books at home	0,98**	2,04	16,55**	34,62
Parent education	2,19***	17,8	1,39**	7,81

Source: Author's estimate from PASEC 2014 Senegal

Notes: * (chi2 < 10%, ** (chi2 < 5%, *** (chi2 < 1%. Observations: 2770 in reading and mathematics

At the end of schooling in both subjects, the education of the pupils' parents and the availability of textbooks at home have positive impacts on performance scores of 2.19% and 0.98% respectively. The effect is significant for the parental education variable. This result was observed at the beginning of schooling. This variable is important because it provides information, among other things, on the capacity of the family environment to transmit basic language that is appropriate for school, as well as on its capacity to support pupils in their learning and schoolwork.

In reading and mathematics we have the same results as at the beginning of school for inputs lack of interest in school and household poverty. Indeed, in reading the effects are negatively significant (- 17.23% for lack of interest from the family and -3.95% for household poverty). The same is true for mathematics (-34.25% for lack of family interest and -9.53% for household poverty).

The results concerning parental education and family poverty at the beginning and end of schooling are in perfect harmony with those found in the literature on the production function of education such as that of MULERA et al. (2017) which shows that low socio-economic status of students negatively affects student performance in Malawi. Moreover, for the level of education of parents, our results are in line with the work of SUCHAUT (2006) and DURU-BELLAT (2003). The pupil whose parents are educated and wealthy is more likely to succeed.

Table 9 below shows the results of the estimation of reading and mathematics performance according to school characteristics.

Table 9: Estimation of the production function of education at the primary level in sixth grade

Performance / Inputs: School Features		French		Math	
		Relative (%)	**Absolute**	**Relative (%)**	**Absolute**
Teacher	Gender of the teacher	0.012*	5.75	9.14**	11.27
	Secondary level	-0.04*	-10.25	-8.14*	-21.38
	University level	0.19***	2.51	2.14***	10.83
	No year of training	-0.18*	-11.4	-2.45***	-22.09
	Six months of training	0.16**	9.16	0.85**	10.8
	One year of training	18.1**	31.1	24.67***	46.18
	Teacher absenteeism	-24.89**	-41.34	-12.50***	-23.5
	The teacher's experience	2.6**	21.7	4.76***	12.35
School facilities and resources	Class pedagogical resource index	1.98*	9.01	0.58**	7.32
	Index of perception (by the master) of working conditions	1.01*	6.71	9.23*	32.84
	School pedagogical resource index	3.14**	8.37	5.28**	14.75
	School infrastructure index	0.12*	8.8	1.6**	9.7
	Textbooks	1.23***	7.51	10.35***	8.69
	Availability of school supplies	0.7***	6.8	04.17***	4.55
School methods and school organization	Do you have students work in small groups?	12.59**	21.23	18.65***	23.68
	Overcrowded class sizes	-26.66***	-56.16	-36.48***	-44.13
	School programs	-2.78***	-10.70	-13.91**	-23.16
	The use of the competency-based approach (APC)	0.64***	18.16	8.61**	22.29
	The use of the situational approach (APS)	0.12**	6.16	0.06***	1.50
	Pedagogy by objectives (PPO)	-0.95*	-2.78	-9.54*	-15.62
	Pedagogy of large groups (PGG)	0.89***	23.67	6.1**	22.64
	Support lessons, tutoring	15.81***	32.14	25.64***	46.74

Source: Author's estimate based on the PASEC 2014 Senegal database

Notes: * (chi2 < 10%, ** (chi2 < 5%, *** (chi2 < 1%). Observations: 2770 in reading and mathematics

We have the same results as in the second year of schooling for the inputs relating to the practical training, the level of study and the experience of the teacher for their positive impact and absenteeism for its negative effect on learning in mathematics and reading. But when the teacher has a secondary level, the impact on student performance is negative and not very significant with -0.04 and -8.14% respectively in reading and mathematics.

Secondary level has a positive impact at the beginning of schooling, but a negative impact at the end. This would suggest that as one progresses through the grades, the teacher's secondary education cannot positively impact student performance. In other words, the higher the grade, the higher the teacher's level of education needs to be in order to have a positive effect. This is confirmed when the teacher has a university degree.

The positive effect of teacher training at the beginning and end of schooling supports the importance and necessity of training.

In the sixth grade, all the variables concerning the school's facilities and resources play an important role in students' achievement in reading and mathematics, even for the index of perception (by the teacher) of working conditions, which has a negative effect at the beginning of the school year. The reading scores for this variable are 1.01% and 9.23% in reading and mathematics respectively.

The material and pedagogical resources of the school are essential supports and play a crucial role in the acquisition of knowledge and skills. This could explain the positive and significant results observed in reading and mathematics at the beginning and end of schooling.

On the availability of textbooks, our result is in line with that at the beginning of schooling and with the SACMEQ III and PASEC studies conducted in Africa between 2004 and 2012 and PASEC 2014 which showed a significant and positive impact on student performance, as well as the study by KEEVES, 1995) on low-income countries. Several international evaluations have shown the importance of these resources, when provided in sufficient quantity and of an appropriate nature, in creating favourable learning conditions (HUNGI et al., 2011; MULLIS et al., 2012a; MULLIS et al., 2012b) and its consistency with our findings.

As in the second year, the variables: large class size and curriculum have a negative effect on students' performance, but the situation approach has a positive and significant effect in the sixth year with 0.12% and 0.06%. The difference for the situation approach could be explained by the fact that in the sixth grade students have more situational awareness skills.

In contrast, when the teacher uses the goal-oriented approach, the performance results are negative in grade 6 with -0.95 and -9.54% in reading and mathematics respectively.

The negative result for the curriculum on learning is confirmed again in grade 6. It could be interpreted by the fact that the curricula are inappropriate and too heavy.

The ratio of enrolment to the number of classes gives the class size. The negative result of overcrowding at the end of school (-26.66 and -36.48% in reading and mathematics respectively) is in line with that found at the beginning and with those found in the literature concerning class size. Notably the work of (SHIN and RAUDENBUSH, 2011; ALTINOK and KINGDON, 2012; NANDRUP, 2016), it is commonly accepted that smaller class sizes positively impact student learning, and thus student performance. Large class sizes are sometimes difficult for teachers to manage, which may lead them to adopt less effective teaching methods, and this limits the time spent with each student. On the other hand, according to DIAMBOMBA *et al* (1996), in these countries, large class sizes are not synonymous with a drop in student results. The work of DIENG (2017) confirms this thesis in countries like Lesotho, Uganda and Zimbabwe. According to the author, school success is rather linked to the way teachers manage large classes.

When the teacher uses small-group work, the competency-based approach, large-group pedagogy and tutoring, it has a positive effect on students' performance in reading and mathematics at the end of school. For example, the scores are 0.64 and 0.89% and significant in reading, respectively, for the competency-based approach and large group pedagogy. In the context of African countries characterised by overcrowding in the levels of education due to the issue of the poverty trap, large group pedagogy is a good teaching tool to use to improve student learning. This positive result on teaching methods is in line with the findings of Moses W. NGWARE, Moses OKETCH and Maurice MUTISYA (2015) who use data from 72 mathematics lessons in 72 primary schools in Kenya. The authors demonstrate the extent to which teaching practice explains differences in performance between students and schools

FUNCTIONAL FORMS

The following tables 10 and 11 present the thetas estimated by the BOX-COX model and provide information on the functional form in reading and mathematics at the beginning and end of school.

Table 10: Box-Cox estimate of functional form at school entry

Early school reading				
Test H0:		Restricted log likelihood	LR statistic chi2	P-value Prob> chi2
theta =	-1	-4623,743	129,38	0,000
theta =	0	-4569,1331	20,16	0,000
theta =	1	-4561,3489	64,59	0,032
Mathematics at the beginning of school				
Test H0:		Restricted log likelihood	LR statistic chi2	P-value Prob> chi2
theta =	-1	- 4506,1168	36,47	0,000

theta =	0	-4488,8495	81,94	0,164
theta =	1	-4524,9771	74,19	0,000

Source: Author's calculations based on PASEC 2014 Senegal

Table 11: Box-Cox estimate of functional form at the end of school

In early reading				
Test H0:		Restricted loglikelihood	LR statistic chi2	P-value Prob> chi2
theta =	-1	-4715,3774	32,73	0,000
theta =	0	-4701,0198	24,02	0,045
theta =	1	-4743,4351	88,85	0,000
In early mathematics				
Test H0:		Restricted log likelihood	LR statistic chi2	P-value Prob> chi2
theta =	-1	-4743,4913	42,63	0,000
theta =	0	-4722,6622	97,55	0,324
theta =	1	-4756,1702	67,99	0,000

Source: Author's calculations based on PASEC 2014 Senegal

At the beginning of schooling in reading and mathematics, we note that the LR statistic ch2 is higher than the theta values and significantly different. For example, for theta equal to zero in reading, the statistic is 20.16. Therefore, in both subjects at the beginning of schooling, the linear (theta= 1), log linear (theta= 0) and inverse (theta= -1) specifications do not fit our data. The use of the functional form proposed by the BOX-COX model is justified for the PASEC Senegal data.

However, it should be noted that the rejection of traditional forms does not necessarily imply that the functional form proposed by BOX-COX must necessarily be adopted.

We find the same results as at the beginning of the school year concerning the rejection of specifications and the adoption of the functional forms proposed by the BOX-COX model.

CONCLUSION

The contribution of the paper is that, compared to the traditional literature, we have made the estimation using the BOX-COX model, without a priori imposing a linear functional form.

The results indicate that the widespread use of traditional forms is not appropriate, at least with respect to the Senegalese data, and that the use of BOX-COX transformation is justified.

Moreover, the use of this transformation at the beginning and end of schooling has produced interesting results and has highlighted certain characteristics of the pupil, the family and the school. We will only mention here some of the main results. Indeed, the student-specific inputs that have a strong impact on student learning are the male gender of the student, repetition and the use of a reading or mathematics textbook. The results by gender indicate that boys are more sensitive to mathematics than girls.

One unsurprising result regarding family characteristics is the positive influence that parental education has on students' achievement, in contrast to the lack of interest in family poverty.

School variables related to school characteristics that are important and on which the decision-maker can rely to improve student learning include the teacher's level of education, professional training, school and classroom facilities and resources, competency-based pedagogy, and large group pedagogy. Given the resource constraints in the education system, if there is a need to reallocate, it should be to the characteristics of the school (teacher, teaching equipment and resources, and pedagogical organisation and method), as these are key elements for improving performance. Indeed, if the objective of decision-makers is to improve the quality of learning, policies aimed at :

- to further develop pre-school and to ensure articulation ;
- focus on the physical and pedagogical environment in schools;
- extend initial and in-service teacher training
- and provide and distribute textbooks in all subjects.

Among other actions that follow from our results and that can improve school performance we can mention

- a reduction in the number of classes. This requires the construction of classrooms and the recruitment of

additional teachers trained for at least two years to fill them;

- Strict control of teachers' attendance; the government, for its part, must ensure that the commitments made with the teachers' unions are respected in order to reduce the strike movements that explain their repeated absences;
- require that teachers who take the competitive examination for student teachers have a university degree plus two years of training;
- keep experienced teachers at primary level for as long as possible, as some are often reassigned to inspectorates and secondary schools to provide supervision.

These actions are important to improve school performance, which is now at the heart of the debates in schools. The Senegalese education system must demonstrate its capacity to provide quality training capable of meeting the demands of productivity, innovation and technological change. From this observation results the need to evaluate and measure performance, but above all to be able to identify the levers of performance, i.e. the factors likely to lead to an improvement in the results of schools and institutions.

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