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Teaching Optimization of educational expenditure

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Summary:*Countries with rapid population growth face enormous difficulties for the education of their people. This is the case of most African countries. Those aged between 2 and 24 years representthere nearly half. Therefore, these countries face a high demand for education and training. They spend a large share of their resources to cover the needs of education sector. Nevertheless, difficulties remain and young people are struggling to access higher education particularly. The policy based on the number of amphitheaters to build and that of teachers to be recruited, in relation to the potential number of applicants, is not really efficient. These two variables are often used at the expense ofteaching quality and learning outcomes. Thus, it is important to find an effective strategy to satisfy the high demand of access and efficient pedagogically at the same time.To this end, it is important to find the optimal unit cost and its parameters. Hence, we will explore by mathematical models all parameters to improve and maximize outputs training.*
Keywords*: Optimization, educational expenses, teaching, effectiveness, efficiency.*

I. Introduction

It is attributedto UNESCOthe recommendation concerning the necessity for each country to have 2% of students in its population. Although, one has to say that this ratio must be exceeded in countrieswith more than 9% of 20-24 years oldpeople. This is the case of many African countries. They face a demographic pressure and a very important need of education.Certainly,the respect of the mentioned recommendation requires significant resources and efficient management of mobilized means (Colclough, Christopher, Keith M. Lewin 1993). Different educational policies are pursued by the countries; but these are often based on the number of amphitheaters to build and professors to be recruited against the potential number of applicants for higher education. The manipulation of those two variablesto achieve that objective,hasserious consequences on the educational quality. Indeed, one considers more the policy of enrolling young people in higher education thanmaking conditions of their success.In following, we try to see if there is not a better management of high access demand to higher education. For that, it is important to find the optimal unit cost and to see how to set its key parameters.In such cases, mathematical formalization is wellindicated (JD Chesswas,1966 ; OECD 1973). One should know that in this area, the models to handle this issue are known (Poignant-Hallack, 1967; BOTTI, 1967 ; Philippe Hugon, 1972). They are in many publications of the UNESCO Institute for Statistics, Institute for Studies of the Social, Economic Development (IEDES) and the International Institute for Educational Planning (IIEP).Using these mathematical models, we will explore all of their parameters to derive the determinants of optimal cost for maximizing training outputs.

A) Econometric model of education

"*Education can be likened to an industry that receives student flows (inputs), subjected to a process of transformation aimed at achieving flow of students trained (outputs).*"(Philippe Hugon, 1972)

That is to say education is a dynamic process of production. Within this process, the products being processed can either become finished products (outgoing) or missed (excluded or drop), or semi-finished (repeaters). The process (or school cycle) consists of a series of successive ordered steps (or level of education). An outbound process becomes the inputs of the following process. The transition rate or transition ratios are essential parameters of this input-output mode. To adjust these models to the educational process in Africa, the following assumptions would bemade:

1.The enrolling capacity of the education system is governed byits budget;

2.The enrolling capacity is closely correlatedwith the population size (density) and population growth (growth rate)

3.The correlation between the volume of population (density), population growth (growth rate) and economic factors has not yet demonstrated in Africa.From these assumptions, the following indicators can be constructed:

-The **cost of student-year**; this unit is essential as analytical tool. The average cost of the student-year, for an entire cycle is a good approximation for this unit (SALL M.-Y., 2003). This cost is assumed to be independent of the number of applicants, it is based on:

- The level of qualification of trainers and their remuneration
- Professorsperstudents' ratio.

- Other non-teachingcosts.
Formally, the **cost of student-year,**noted(***C***); is estimated as follows:

$$C = a.\ b\ (1+h) \quad (1)$$

Where(***a***)represents the professors per students' ratio, **(*b*)** the average salary of professors and **(*h*)**the ratio between salary of professors and other expenses.

Higher education capacity
The training capacity is based on

- The proportion of education expenditure in GDP, noted α
- The salary of a professor expressed in GDP per capita, noted β
- The part of young people, 20-24 years old, in the total population, noted***t***

So that the **training rate** is written as follows:

$$T_S = \frac{\alpha}{a.\beta.t.(1+h)} \quad (2)$$

Graduating capacity
Assuming that
- The cost of student-year is the same at all levels of a cycle
- The number of enrolledin the system is based on resources allocated to educationestablishments only,the social expense like grants or other non-teaching services are not included, then the cost of a grade would be:

$$C_F = \theta.C \quad (3)$$

where(θ) depends on the length ofconsidered cycle (***d***) and the loss ***(p)***. It is expressed as follows:

$$\theta = f(d, p) = (1+\frac{p}{d})*d = (1+r)*d \qquad 0 \le r \le m \quad (4)$$

(***r***) is the loss coefficient. If a study-year may not be repeated more than one time, then the upper limit will be one (m = 1). But in principle, especially in the European system LMD, the length of stay in a cycle should not be limited, given that the learning outcomes are capitalized. In anyway, (***r***) constitutes a good gauge of the educational cost for a system. It can help to optimize the cost of a grade. It is a lever to be actuated formanagingbetter an educational enterprise.

But, everything suggests that the loss is not unrelated to the student population. Indeed, it is observed that the results are improved from the first to the third year of license degree (the Frenchgrade)when the number of student goes down. Furthermore, if salary is linearly related to the level of qualification, its correlation with the loss should be provable. This is to establish finally, considering that the remuneration is the main motivation of the trainer, the following functional relationship:

$$r = g(a, \beta) \quad (5)$$

Thus, the regulation of educational process depends mainly on the number of learners per professor and on the trainers' motivation. But,with available information, it is not easy to find the mathematical form of (***r***.)
From the foregoing, the graduating capacity of a system can be deduced by calculating the graduation rate (t_d).as follows:

$$t_d = \frac{\delta}{d.(1+r).a.\beta.(1+h).t_7} \quad (6)$$

Where(δ) is the proportion of education expenditure for a cohort in GDP and (t_7) the proportion of children aged 7 (population eligible in school) in the total population.

B) Application

From the previous relationships, we could get a dynamical picture of the education system. These, used in a predictive model, would also permit to have a prospective vision. The established mathematical laws may help to predictthe number of young to trainin a way better than the trend'sextrapolation for a country.

Prediction with data from Senegal in 2013

Let's start by predicting the most widely used indicator, the **training rate**. This ratio, which is the proportion of an age group at higher level, gives measure of effort the authority should madeto increasethe training capacity.The second statistic, entitled **graduating capacity**, seems more interesting for the educational planner. Indeed, it helps to see how a system can contribute to raise the education level of population.

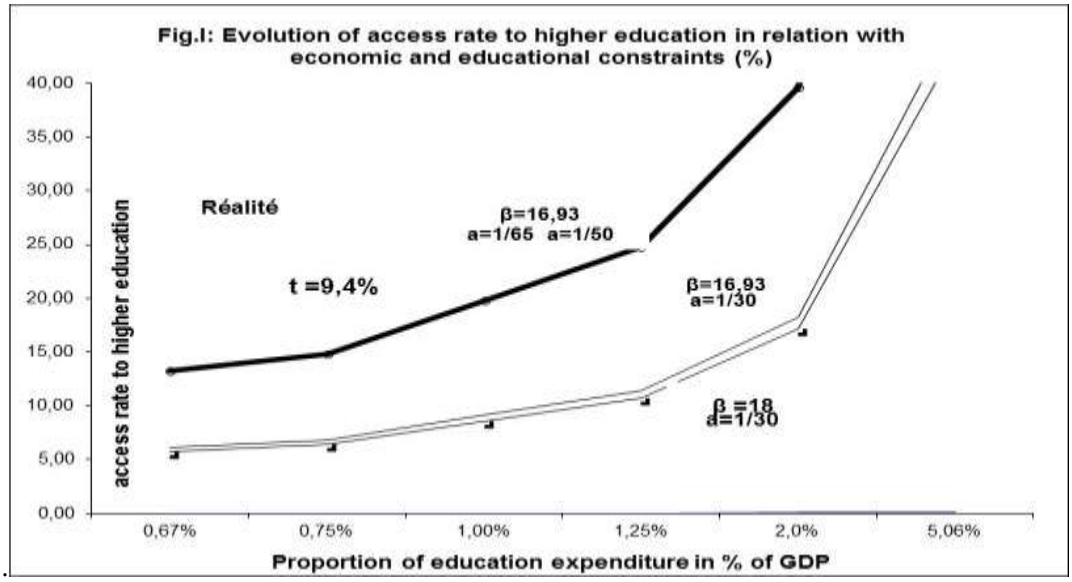
II. Training Capacity

Knowing the three explanatory factors of training,which areGDP, number of population to train and Cost of student-year, it is possible to provide the estimated training capacity by training rate (see Table I, Figure I).With 9.4% asproportion of population eligible to higher education, Senegal devotes the equivalent of 0.67% of GDP to educational expenditures in higher education, allowingto accommodate 13,20% of the (20-24) age group population.With the following data : one professor for 65 students on average,salary of professor about 16.93 GDP per head, one could enroll 19,77% of the population aged 20-24, or 1.86% of the total population, by spending the equivalent of 1% of GDP.

T.1 : Rate of access to higher education relating to expenditure and educational parameters

Professors per students ratio (a)	Professor remuneration (β)	Educational expenditure in % of GDP : (α)					
		0,67%	**0,75%**	**1,0%**	**1,25%**	**2,0%**	**5,06%**
		Rate of accessto university					
1/65	***16,93***	***13,20***	***14,83***	***19,77***	***24,71***	***39,54***	***100,00***
1/50	*16,93*	*10,15*	*11,41*	*15,21*	*19,01*	*30,42*	*76,92*
1/30	*16,93*	*6,09*	*6,84*	*9,13*	*11,41*	*18,25*	*46,15*
1/30	*18,00*	*5,73*	*6,44*	*8,58*	*10,73*	*17,16*	*43,40*

Reading: The current spent forhigher education is now about 0.67% of GDP, which serves to pay an equivalent of **16.93**GDP per head for each professor, to host **13.20%** of target age group (20-24 years), corresponding to 1.24% of total population. In this case, with a ratio of one professor for 65 students, one has to spend the equivalent of 2% of GDP to enroll 39.54% of this age group in higher education. But by acting on teaching rate, with one professor for 30 students, one can reach**18.25%** of students (1.72% of the population) with a budget equivalent to 2% of GDP.



III. Graduation Capacity

This capacity is estimated by graduation rate (t_d).It isa measure of educational system impact on thepopulation training level. With the following data (Table II & Figure II) :

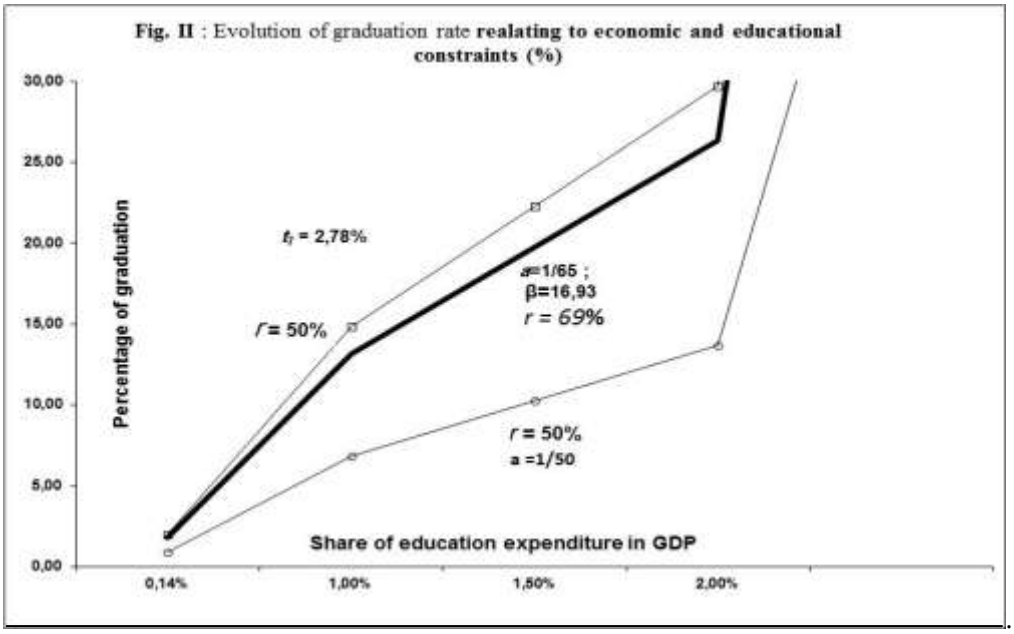
-Proportion of 7 years old children in the total population = 2.78%
-Average remuneration of professor = 16.93 GDP per head,
-Loss coefficient = 69%

1.80% per age groupis graduatedby spending 0.14% of GDP. This result would mean that, to raise higher the level of training for the entire target group, onemust pay the equivalent of 7.6% of GDP. However, if we increase the teaching efficiency by reducing the loss from 69% to 50%, we arrive at 2.03% of graduates with the same amount of expenditure.

T.2: Graduation rate relating to expenditures and educational parameters

Professor to students Ratio (a)	Professor Remuneration(β)	Loss coefficient (*r*)	Education expenditure in% of GDP: (*δ*)				
			0,14%	1,00%	1,50%	2,00%	7,6%
			Percentage of graduates				
1/65	*16,93*	*69,0%*	*1,80*	*13,19*	*19,78*	*26,37*	*100,00*
1/65	*16,93*	*50,0%*	*2,03*	*14,86*	*22,28*	*29,71*	*112,67*
1/30	*16,93*	*50,0%*	*0,94*	*6,86*	*10,29*	*13,71*	*52,00*
1/30	*16,93*	*33,3%*	*1,05*	*7,71*	*11,57*	*15,43*	*58,50*

Reading: Now, producing 1.80% of graduate per age group costs about 0.14% of GDP, which serves to pay each professor the equivalent of 16.93 GDP per capita. That is to say,we have to pay 2% of GDP to produce 26.37% of graduate per cohort. But,reducing the loss coefficient from 69% to 50%, the proportion of graduates increases to **29.71%** (i.e. 8 graduates for 1000 inhabitants) by spending 2% of the GDP



In summary, it appears that in the field of education, the **unit cost** should be handled with caution. The results showed that the student-year cost is based on remuneration or level of qualification of professors and on educators per students' ratio. These factors are conditions of educationalquality.Hence, it is evident that the qualification of the professors should not be lowered.Undoubtedly, we increase the educational difficulties if we let thestudents over professor's ratio be above 25. In addition, remuneration is one of the most important motivations of eacheducator;reducingthis onewillalter the training quality.For all these reasons, it would be better to act on the teaching performance.That is to increase the educational productivity by reducingmuch the system waste.

IV. Conclusion

We have tried in this article to identify simple mathematical relationships in order to describe an educational process and predict its evolution. There are probably a number of factors determining the costs of education. We can only use some of them to improve the management of education budget. From the simulation carried out above, it seemed obvious that acting on the levers of educational performance is far more efficient than intervening on any other factors. Intensifying the work of professor will give less important educational results thanfinding educational resources to enhance the level of students' knowledge in order to reduce wastage. The average duration of students stay at university can be limited without limiting learning time.So, the best adjusting variables in the field of training are those related to internal educational effectiveness. Funding on teaching performance gives higher results than continuing to invest on other factors such as recruiting number of cheaper professors (contractual or temporary staff) or increasing the ratio of students per professors.

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Annex

Matrix of UGBeducational process									
	Study Level	**I**	**II**	**License**	**IV**	**V**	**Master**		Totalyears
School Year					**License**				
1		700							700
2		310	390						700
3			320	243					563
4			65	250	193				508
5				82	250	141			472
6				17	118	215	107	27,5%	351
7					31	129	165	42,2%	160
8					4	43	99	25,3%	47
9						8	33	8,4%	8
10						1	6	1,6%	1
Total		*1 010*	*775*	*592*	*596*	*537*	*411*		**3 510**
Outgoing		*137*	*80*	*14*	*37*	*42*	*390*		
Progression of the cohort		700	563	483	469	432	390		**3510**
Teaching results									

	License		**Master**	
The number of net useful student years:	578		537	
The number of useful student-years:	2356		2541	
The number of student-years provided :	2 377		3510	
Graduate return:	66,99%		55,77%	
Net graduate return	27,51%		15,35%	
Graduation Duration	5,08		6,51	
Average delay of graduates	1,47529		1,61	
Graduate unit cost in student-years	5,07		8,991	
Average level without a diploma	1,46798		2,24	
Average length of stay at the University	3,3958		5,014	
Loss coefficient	69%		79,81%	