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Education Quality and Economic Growth in Developing Countries: Empirical Analysis Using Non-Parametric Model

Zineb BELKHATAB[1*]
[1] Abdeljabbar ABDOUNI[2]
1. Faculty Of Economics and Management, Hassan I University, Research Laboratory in Applied and Theoretical Economics (LARETA), Settat, Private University of Marrakech (UPM), Morocco
2. Faculty Of Economics and Management, Hassan I University, Research Laboratory in Applied and Theoretical Economics (LARETA), Settat, Morocco
* E-mail : zinebbelkhatab@gmail.com

Abstract
This paper aims to analyze the impact of education quality improvement on economic growth for a sample of 27 developing countries, from 1995 to 2019. To examine this relationship, we estimated a non-parametric model on fixed-effect panel data. The results of this estimation show that the effect is positive and differs according to the economic level of countries. The findings also identified that income inequality influence the behavior of this relationship.
Keywords: Quality of education; economic growth; non-parametric model; developing countries; fixed-effect panel data.
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1. Introduction

Education has always been a key investment for the future, the people, the economy, and society at large. It can even positively impact the life expectancy of the population (Guisan and Exposito, 2016). It has long been a central focus of most empirical work on economic growth in developing countries. The results of these studies remain controversial. For most of these countries, access to the education system remains limited and the pursuit of mass education often comes at the cost of the education quality. The workforce educational level and the economic development conditions may not be sufficient to perceive the positive effects of education on economic growth.

For Becker (1964), it is more interesting to study the individual than the educational system. In other words, Becker is more interested in whether it is cost-effective to spend another year in school than in what is happening in the educational process. However, it has become important to ask more questions about the quality of education than about its quantity. Again, the empirical evidence on whether the quality of education stimulates or inhibits economic growth is mixed. This can be explained either by the choice of measures adopted, by the specification of empirical models, or by the choice of the sample and the analysis periods.

For measuring constraints, quantitative indicators, such as enrolment rates or average years of schooling, are often used in empirical work. These indicators neglect the qualitative dimension of education and are not always able to detect the positive relation between education and growth.

As for specifying the empirical model, the relationship between educational quality and economic growth has often been examined using parametric models. However, much of the existing literature has emphasized the importance of modeling heterogeneity and non-linearities in the growth process. Temple (2001) and Kalaitzidakis and al. (2001), for example, argue that there is a significant non-linear relationship between economic growth rates and education.

It is in this context that our work aims to study the relationship between the quality of education and economic growth using a non-parametric model, trying to provide an answer to the following question: Does the quality of education affect the economic growth of developing countries?

To answer this question, our work will be structured as follows. The first part will present a brief review of the literature. Then, for remainder of the paper, it will be a question of estimating a non-parametric model to test the non-linearity of the relationship between the quality of education and economic growth.

2. Literature Review

Ever since the contributions of Barro (1991, 1997) and Mankiw et al (1992), in empirical research investigating the reason nations grow faster than others, a large empirical literature has found a positive and significant relationship between quantitative measures of schooling and economic growth. Using the average number of

[1] Acknowledgements: We would like to thank Mr. Hamza CHAOURI, for his efforts to develop a program written in Python language to estimate a non-parametric and semi-parametric model for our data. (See Appendix).

years of study as a proxy for human capital, this empirical work assumes that one more year of study offers the same increase in knowledge and skills, regardless of the education system. This measure neglects the effect of variation in the quality of education on student outcomes.

As a matter of fact, although it is accepted that education promotes growth, the quality of education can undoubtedly provide better information on this sometimes-contradictory relationship. A new approach to measuring human capital is emerging. This approach was initiated by Hanushek and Kimko (2000), who measured the education quality based on pupil scores in international assessments in mathematics and science, building a database for 31 countries for the period 1960-1990. The results show the positive and very significant impact of the qualitative indicator of education on the economic growth rate.

Barro (2001), joining the idea of Hanushek and Kimko (2000), produced indicators representing three different skill areas: mathematics, science and reading, for a limited sample of 43 countries. The author concluded that the quality of education, as measured by the indicators used, is more important than its quantity as measured by educational attainment.

Lee and Barro (2001) used the results of international student performance tests without any specific methodology to adjust for potential differences between different series. Instead, they used a regression technique to obtain different constants between each test, and thus to account for potential differences between tests over several years and on the skills.

As part of the confirmation of the positive and significant role of quality in education, Lee and Lee (1995) found an effect of the same size as that of Hanushek and Kimko (2000) for a sample of 17 countries between 1970 and 1985. The results showed that qualitative indicators have a positive and significant effect (Coulombe and al. (2004); Coulombe and Tremblay (2006); Jamison and al (2007)). Quantitative indicators can have a positive, negative, and non-significant effect. Bosworth and Collins (2003) and Ciccone and Papaioannou (2005) found the same results: the effect of the quality of education is more significant than that of the quantity of education.

In line with the work of Hanushek and Kimko (2000) and Barro (2001), Altinok and Murseli (2007) have done very interesting work on the importance of taking the qualitative dimension of education into account in empirical analyses of economic growth. They proposed a database of 105 countries in instant section. They were based on three areas of expertise: mathematics, science and reading, between 1998 and 2005. The authors used almost all the IEA surveys on the 3 areas to construct 3 indicators of human capital quality in 3 areas, the objective being to obtain several dimensions to education quality. They then constructed a general quality indicator by calculating the arithmetic average of the three qualitative indicators.

Hanushek and Wöessmann (2008) build new human capital indicators. They conclude that the quality of education, as measured by cognitive skills, explains more the differences in economic growth between countries than the quantity of education, often measured by the rate of enrolment or the average number of years of study. The measures developed by Hanushek and wossmann (2012) extend those developed in Hanushek and Kimko (2000) by using an approach that assumes the stability overtime of the variance in the quality of student outcomes for a limited number of OECD countries. Their main measure of cognitive competence is a simple average of all standardized test scores in math and science.

Altinok (2015) conducted a first comparative analysis of the quality of education in sub-Saharan Africa, using the method of Altinok et al (2014). It has built a database of 29 sub-Saharan African countries for the period 1996-2010, combining the two existing assessments in sub-Saharan Africa (SACMEQ and PASEC). The results of this work show that some countries are interested in improving and increasing the school access rate at the expense of the quality of their education systems. While other studies have shown that the quality of primary and secondary education improves the economic development of countries (Gorzek et al. 2021). Thus, a major change in the skills of the population and improving the quality of schools strongly impact the economic growth rate (Hanushek and Woessmann 2021).

However, empirical research often shows that the sign and importance of education depends on the sample of observations or the specification of the model or the proxy used to measure human capital. The literature shows that it is not clear which econometric specification is appropriate to properly capture the fundamental aspects of the growth process. Thus, the exact relationship between economic growth rates and education is not known.

Our contribution in this work, consists in analyzing the relationship between the education quality and economic growth through a non-parametric model and a semi-parametric model in panel data, while showing that the behavior of this relationship differs according to the level of economic development of the countries. The proxy indicator is the Mathematics and Science score from the TIMSS database. This choice is based on the reliability of the results provided by all these series of surveys.

3. The non-linear model specification

To analyze the non-linearity of the relationship between education quality and economic growth, we use non-

parametric and semi-parametric models in panel data for 27 developing countries observed over the period 1995-2019. These models allow data to express the relationship between explained variables and the explanatory variables without first defining a hypothesis on the distribution of population to generate a model. Therefore, the non-parametric approach avoids errors that can be caused by the wrong choice of this hypothesis.
Based on the specification proposed by Henderson and al. (2008), our non-parametric model and the semi-parametric fixed-effect panel model are as follows:

$$y_{it} = g(z_{it}) + \mu_i + \varepsilon_{it} \quad \text{(Non-parametric model)}$$

$$y_{it} = g(z_{it}) + \gamma X_{it} + \mu_i + \varepsilon_{it} \quad \text{(Semi-parametric model)}$$

y_{it} : is the variable to be explained. It represents the logarithm of GDP per capita in constant 2011 PPP from the World Bank, where i represents the different developing countries considered and t the periods between 1995 and 2019.
z_{it} : is the explanatory variable. In our work, we used the score in Mathematics and Science as two measures of the education quality. To assess the contribution of each variable to economic growth, we have separately analyzed the impact of these variables on GDP per capita.
$g(z_{it})$: is the unspecified function that links the variable to be explained (y_{it}) with the explanatory variable (z_{it}).
X_{it} : represents the control variables (Governance (Gov it), Foreign Direct Investment (FDI it), Openness (Open it), Government Expenditures (GE it)).

4. Developing a nonlinear relationship between education quality and economic growth.

4.1 Polynomial nonlinear model

Before estimating a non-parametric model, a polynomial nonlinear model must be estimated in order to clearly identify the behavior and shape of the relationship between quality of education and economic growth.
Or the following polynomial model of degree k:

$$y_{it} = \sum_{k=0}^{k+1} \beta_k \, (\text{QualityEdu}_{it})^k + \gamma X_{it} + \mu_i + \varepsilon_{it}$$

Which: i = 1, … 27 et t = 1995, …. , 2019
Three parametric models are derived from this model, in particular:

$$y_{it} = \beta_0 + \beta_1 \text{QualityEdu}_{it} + \gamma X_{it} + \mu_i + \varepsilon_{it}$$

$$y_{it} = \beta_0 + \beta_1 \text{QualityEdu}_{it} + \beta_2 \text{QualityEdu}_{it}^2 + \gamma X_{it} + \mu_i + \varepsilon_{it}$$

$$y_{it} = \beta_0 + \beta_1 \text{QualityEdu}_{it} + \beta_2 \text{QualityEdu}_{it}^2 + \beta_3 \text{QualityEdu}_{it}^3 + \gamma X_{it} + \mu_i + \varepsilon_{it}$$

For which: i = 1, … 27 ; t = 1995, …., 2019 ; $X_{it} = (Gov, \text{Open, FDI, GE})$
The results of estimating these three parameter models are presented in the following table:

Table 1: Parametric Fixed Effect Estimation

	Dependent variable: Logarithm of GDP per capita					
Explanatory variables	Linear (1)	Quadratic (2)	Cubic (3)	Linear (4)	Quadratic (5)	Cubic (6)
	QualityEdu corresponds to the score in Maths.			QualityEdu is the score in science.		
Constant	7.643 (17.87)***[1]	10.152 (9.92)***	-0.0191 (-0.01)	7.809 (19.54)***	9.772 (10.75)***	1.861 (0.55)
QualityEdu	0.00218 (3.05)***	-0.01055 (-2.20)**	0 .0662 (2.38)**	0.0019 (2.88)***	-0.00862 (-1.94)**	0.0549 (2.07)**
QualityEdu²	-	0.0000152 (2.69)***	-0.0001698 (-2.56)**	-	0.000013 (2.39)**	-0.000150 (-2.23)**
QualityEdu³	-	-	1.45e-07 (2.80)***	-	-	1.35e-07 (2.43)***
Gov	0.104 (0.99)	0.0512 (0.49)	0.109 (1.05)	0.125 (1.19)	0.0695 (0.66)	0.0865 (0.83)
Open	0.00189 (1.16)	0.00172 (1.08)	0.00162 (1.04)	0.00189 (1.16)	0.00183 (1.14)	0.00194 (1.23)
FDI	0.02284 (2.62)**	0.02586 (3.01)***	0.0254 (3.03)***	0.0215 (2.46)**	0.0232 (2.70)***	0.0234 (2.77)***
GE	0.0193 (1.71)*	0.0231 (2.08)**	0.0179 (1.62)*	0.0172 (1.53)*	0.0208 (1.86)*	0.0181 (1.64)*
R²	0.83	0.84	**0.85**	0.83	0.84	**0.85**

[1] The values in brackets represent the Student statistic. ***, ** and * indicate the significance level of 1%, 5% and 10% respectively.

The results of the linear model show that the parameters of the two indicators of education quality used are positive and significant at 1%. This implies that the education quality can stimulate economic growth. However, if a country has a quality education system, this can help improve the country's economic growth.

The parameters $\gamma_1, \gamma_2, \gamma_3$ *and* γ_4 correspond respectively to the four control variables: Governance (Gov), Degree of Openness (Open), Foreign Direct Investment (FDI) and Government Expenditures (GE). The coefficients γ_1 and γ_2 are positive and statistically insignificant, implying that for our data, governance and the degree of openness have a positive but not significant effect on economic growth. The γ_3 *and* γ_4 results were positive and statistically significant. Indeed, for government spending, some studies have found controversial results. In his work, Gupta (1988) shows that the effect of government consumption expenditure on economic growth differs between a developed country (negative effect) and an undeveloped country (positive effect). However, Devarajan et al. (1996) find an opposite result. The work of Grier and Tullock (1989) shows a positive correlation between government spending and growth in Asian countries while it becomes negative for other groups of countries. Concerning FDI, the results show that its effect on economic growth is positive confirming the statements.

The results of the quadratic polynomial model estimation for our two quality indicators (see column 2 and 5) show that the coefficients are positive and significant. Concerning estimation results of the cubic polynomial model which are presented in columns 3 and 6. We note that the coefficients attached to the scores in Mathematics and Science, are still significant. This implies that for these two indicators the relationship is assumed to be nonlinear between the education quality and economic growth.

Thus, for the two indicators of the quality of education we find that the explanatory power (R^2) of the cubic model is more important than those of the linear and quadratic models, this further confirms that the relationship between education quality and growth is nonlinear.

4.2 Non-parametric and semi-parametric models

We note the following non-parametric and semi-parametric models:

$$y_{it} = g(\text{QualityEdu}_{it}) + \mu_i + \varepsilon_{it} \quad \text{(Non-parametric model)}$$

$$y_{it} = g(\text{QualityEdu}_{it}) + \gamma X_{it} + \mu_i + \varepsilon_{it} \quad \text{(Semi-parametric model)}$$

For which: i = 1, … 27 et t = 1995, …., 2019

The results of the estimation of the non-parametric model for the two indicators of the education quality used in our analysis (Score in Math and Score in Science) within a 95% confidence interval are presented in the following graph:

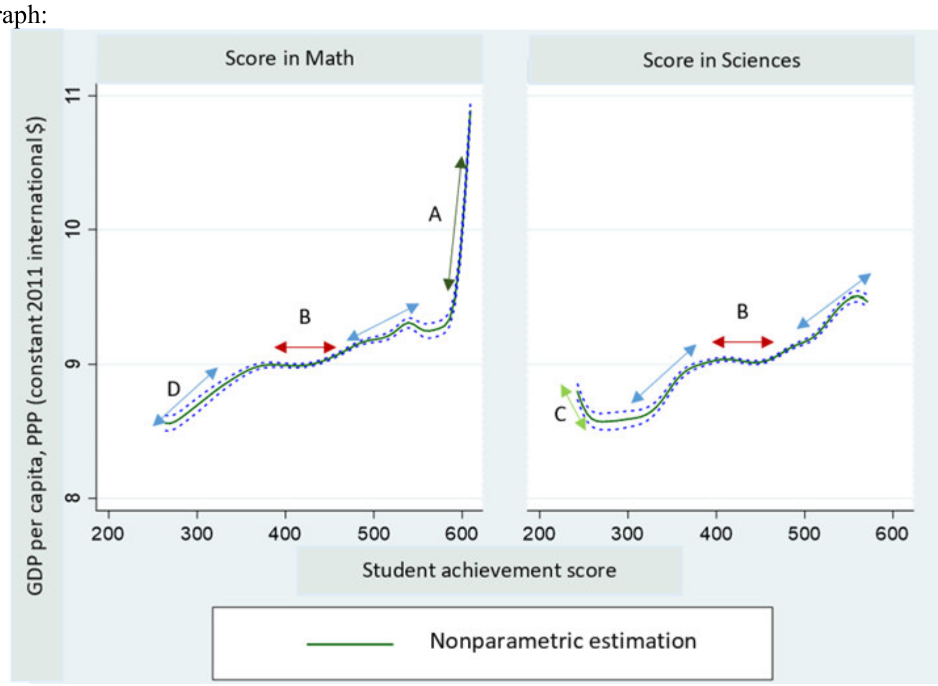

Figure 1: Estimated non-parametric function for the LDC panel according to the education quality indicator

Estimates are acceptable although the estimation has edge effects. Overall, we see a positive relationship for both quality indicators. This relationship is changing while following the same upward trend.

Thus, we find that the speed of the two curves of the estimated non-parametric functions is the same for both indicators (between 260 and 560). When the score indicator in Mathematics reaches a very high threshold of 600, we notice that the curve shows a different trend than the one that represents the score in science. When

Math scores reach a level between 260 and 450 and Science scores reach a level between 270 and 460, the curve of the two estimated functions presents an increasing function with a positive and increasing slope throughout the increase in the quality of education. This increase becomes even more significant for the mathematics score indicator when the score reaches a threshold of 600 and above (Phase A). This indicates that the effect of improving the quality of education on economic growth is much greater when the initial level is higher.

The non-parametric function in this phase (phase B) is almost horizontal, with almost no slope, indicating that the improvement in the quality of education in the interval [360; 460] is almost without any effect on economic growth.

Unlike the other phases of the relationship, this phase (phase C), for the Science score index, no longer appears to be dominated by an upward trend in the quality of education. The estimated function, with a negative slope, indicates that the relationship is not stable, and that the quality of education could negatively affect economic growth. This implies that the impact of the quality of education on growth changes from country to country.

By analyzing the thresholds of the quality of education, we can determine the corresponding levels of growth. Two thresholds of GDP per capita are identified. The following figure summarizes the different stages of growth as the quality of education increases:

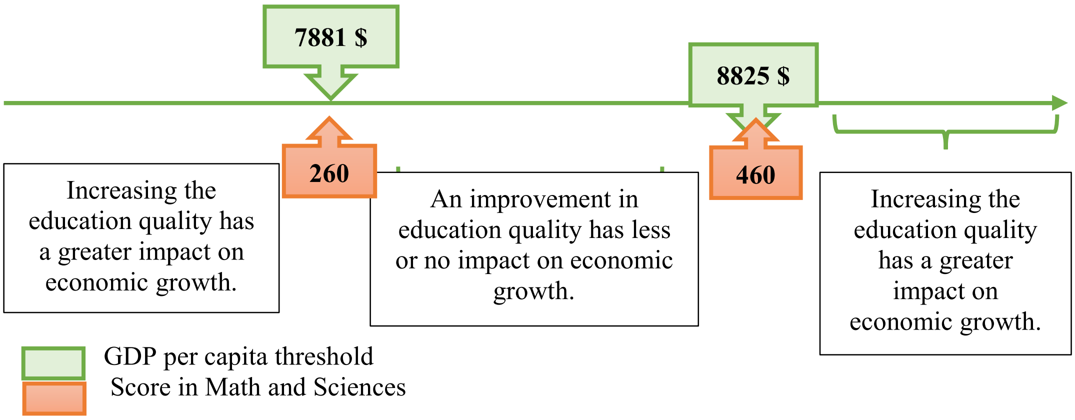

Figure 2: Authors' representation of GDP per capita thresholds and corresponding pupil achievement scores

To test the robustness of our two estimated non-parametric functions, we first compare the curve of the non-parametric function with that of the semi-parametric function, to check if the allure of the non-parametric function parametric changes with the addition of control variables. In a second step, we compare the parametric part of the semi-parametric model with the results from the polynomial parametric model, in order to test the robustness of the coefficients of the control variables.

The following figure represents the overlay, on the same graph, of the curves of the estimated non-parametric and semi-parametric functions. This overlay allows us to identify the existence of a change in the trend of the estimated function following the addition of the control variables.

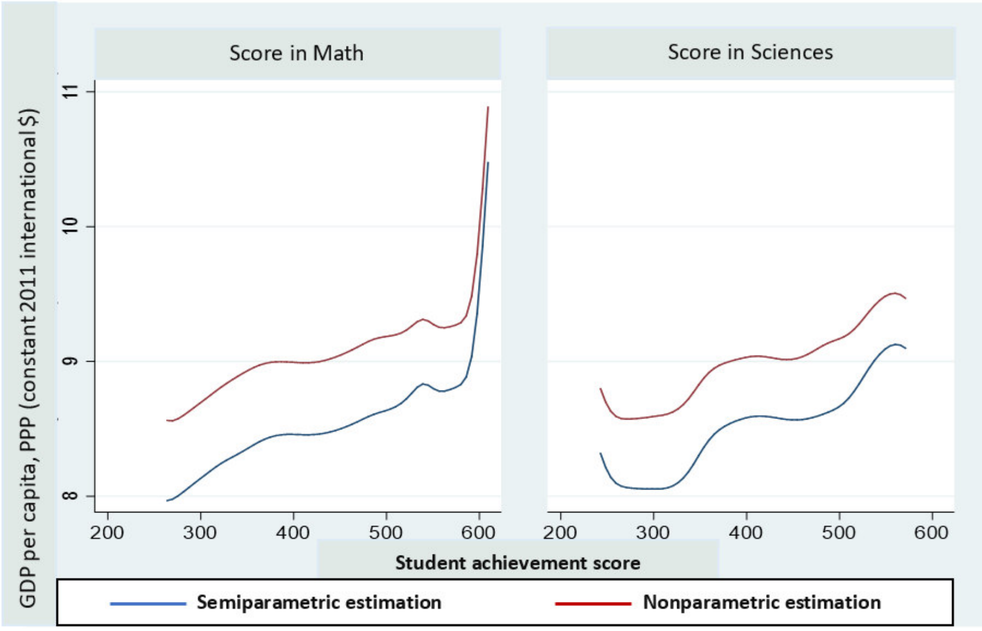

Figure 3: Estimated semi-parametric function for the LDC panel according to the education quality indicator

Indeed, it appears that the non-parametric and semi-parametric curves show identical trends. This leads us to conclude that the relationship between the quality of education and growth remains stable with the introduction of the control variables, and that the latter, although having an overall impact, play little role in the estimation of the non-linear form of g (·).

In addition, the vertical difference between the two curves shows the overall contribution of the control variables. This contribution varies according to the level of development of the countries. In general, the greater the vertical difference, the more economically significant the integrated effect of control variables on growth. On the other hand, the effect becomes insignificant when the difference is reduced.

The following table presents the results of the parametric part of the semi-parametric estimation according to the two indicators of the quality of education used in our analysis. We conclude that the coefficients of the control variables show the same signs as those derived from the estimation of the polynomial model.

Table 2: The parametric part of the semi-parametric modelling according to the education quality indicator used

Explanatory variables	**Dependent variable: Logarithm of GDP per capita**			
	(1) Maths score		(2) Science score	
	Ceof.	Std.err.	Ceof.	Std.err.
Gov	0.0881	0.1122	0.1180	0.1124
Open	0.0021	0.0016	0.0023	0.0017
FDI	0.0244	0.0089	0.0199	0.0088
GE	0.0222	0.0121	0.0188	0.0119

In the next two tables (3 and 4), the nonparametric function g (·) is estimated at certain quantile points of both the Math score and the Science score using the nonparametric model and the semi-parametric model. Overall, the non-parametric estimates are almost identical to their semi-parametric counterparts, which implies, confirming the results obtained in Figure (2), that the introduced control variables do not affect the results of the non-parametric model.

Table 3: Nonparametric and semi-parametric estimation of g (·) at different points in the Math Score

	Quantile z = Maths score		**Nonparametric model**		**Semiparametric model**	
	%	z	g(z)	Std.err.	g(z)	Std.err.
Maths score	2.5%	274,0696	8,5696	0,0541	8,0212	0,046
	25%	378,8615	8,9958	0,019	8,4576	0,0129
	50%	433,62	9,0073	0,0137	8,4675	0,0118
	75%	472,194	9,1187	0,0152	8,5638	0,013
	95%	525,7825	9,2541	0,0299	8,754	0,0257
	97.5%	582,8099	9,3043	0,0528	8,8481	0,0453

Table 4: Non-parametric and semi-parametric estimation of g (·) at different points in the Science Score

	Quantile z = Sciences Score		Nonparametric model		Semiparametric model	
	%	z	g(z)	Std.err.	g(z)	Std.err.
Score en Sciences	2.5%	243,6232	8,7788	0,0585	8,0746	0,0513
	25%	385,0311	9,006	0,0198	8,5924	0,0136
	50%	445,308	9,0135	0,0134	8,5678	0,0117
	75%	473,9605	9,0844	0,0141	8,5895	0,0123
	95%	529,535	9,3497	0,0291	8,9255	0,0254
	97.5%	560,1586	9,5052	0,0386	9,125	0,0338

5. Discussion of results

The results we have obtained from our analysis show, confirming the theoretical arguments, that the quality of education has a positive impact on the economic growth of developing countries. The scale of this impact differs according to the level of economic development of these countries.

Such a result clearly shows the effects of income inequality on the behavior of the relationship between the quality of education and economic growth. Indeed, we have grasped three phases of the relationship:

- The first phase: in this phase, which mainly concerns low-income countries, the quality of education has a positive and significant effect. This implies that it contributes to improving the economic growth of these countries.
- The second phase is characterized by fluctuations in the education quality index, implying that the quality of education may have no effect on economic growth, as in the case of some African countries. For the latter, the quality of education is far from being a factor in stimulating growth, despite the efforts made by governments to increase the access to education rate, it still presents a source of inequality and inefficiencies.
- The third phase: at a certain level, quality positively affects economic growth regardless of the level of economic growth of the countries.

Overall, improving the education quality indicator can contribute to improving economic growth in countries. In fact, to ensure long-term economic growth in countries, it is necessary to improve the quality of schools and progress towards the achievement of the 17 SDGs (Hanushek 2020). However, this contribution to increased growth differs according to the level of development of the countries. This impact can even be negative, by joining the results of Dessus (2000) which showed that education can have a negative impact on economic growth. This result is explained by the fact that education has not been able to reduce socio-economic inequalities, which could result in low growth. Thus, this negative relationship can be explained by the increase in spending on education in parallel with the rate of enrolment, which leads to budget waste.

6. Conclusion

The objective of this work was to test the non-linearity of the relationship between the quality of education and economic growth for a sample of 27 developing countries between 1995 and 2019, by estimating non-parametric and semi-linear models parametric, while showing the effect of income inequality on the behavior of this relationship.

First, we cited the most important empirical work that examined the relationship between the quality of education and economic growth. The results of this work are controversial, which may be justified by the choice of data, the education measures used, the sample and period of analysis used, and the non-linear behavior of the relationship.

Second, we estimated a polynomial nonlinear model. The results showed that the relationship between the quality of education and economic growth can be non-linear. Thirdly, we estimated a non-parametric model for our sample of developing countries. This estimate allowed us to identify the nature of the link between the quality of education and economic growth. Indeed, the model shows that the relationship is non-linear, and that the quality of education positively affects economic growth. This effect differs according to the level of development of these countries, implying that income inequality has an impact on the effect of improving the quality of education on economic growth.

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Appendix

NP & SP Estimations

For the estimation of our models, we developed a program written in Python to estimate a non-parametric and semi-parametric model in panel data with fixed effects. The program is written based on Henderson's original simulation code.

This first version: January 20, 2019, written by: Hamza CHAOURI & Zineb BELKHATAB.

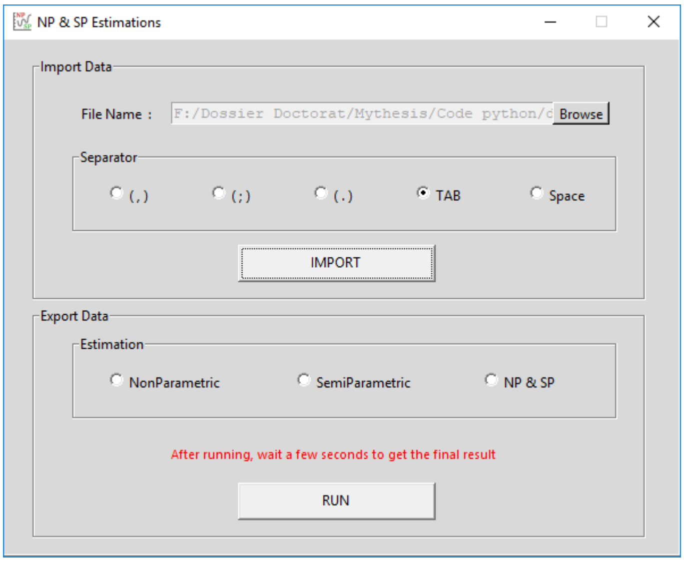
The nonparametric model: $y_{it} = g(\mathrm{z}_{it}) + \mu_i + \varepsilon_{it}$

The semiparametric model: $y_{it} = g(\mathrm{z}_{it}) + \gamma X_{it} + \mu_i + \varepsilon_{it}$

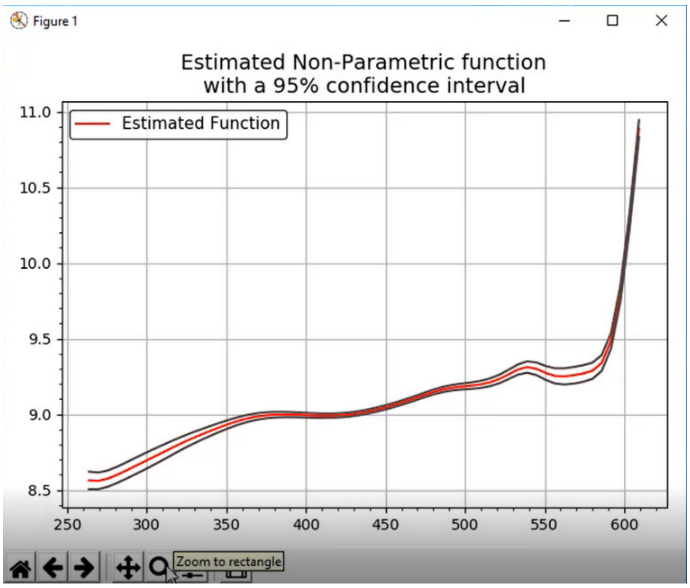
Or:

y_{it} : represents the dependent variable.
z_{it} : represents the explanatory variable.
$g(z_{it})$: represents the link function that links the z vector with the y variable. It is an unspecified function to estimate.
X_{it} : represents the control variables.

After the installation of the program, a window will show which will allow import the database that must already be prepared according to the standards we have indicated in the guide, furthermore we must choose the appropriate separator and the model which will help estimate, and that's the step when we are supposed to run the program after.



Giving it one minute as a waiting time, you will happen to get two files as outcomes from this operation: an excel file with the estimated data and the following graph:



This program is used to estimate a fixed-effect model and we intend to develop it to estimate a random-effect model.