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Education, Proximity to Technology Frontier, and their impact on Economic Growth in Algeria between 1991-2021

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Abstract :
The present research paper aims to study the impact of education and proximity to technologiy frontier and their interaction coefficients on economic growth in Algeria during the period from 1991 to 2021, and which educational levels are most important in relation to this proximity. The Vector Error Correction Model (VECM) was used, and the results indicated a causal relationship between all variables and proximity, especially the higher education overlap variable with proximity. However, the impact of this relationship is limited to the short and medium term. Meanwhile, the impact of primary education on proximity is highlighted in the long term. Primary and secondary education positively influence growth in the medium and long term through their interaction coefficient with proximity. The results showed that primary and secondary education are the most important educational levels in driving growth near technological frontier. Additionally, the interaction variables between education and proximity positively affect economic growth, while higher education and the rate of proximity negatively affect economic growth.
Keywords: Education - Human capital - Proximity - Technology frontier - Economic growth
JEL Classifications :I20,O30,O40

Introduction :

The contribution of human capital to economic growth has formed the core of theories of internal growth, through its direct impact on productivity and its indirect impact on technological advancement. Human capital also facilitates technology adoption ; thus it is related to the distance to technological boundaries (Nelson & Phelps, 1966; Lucas, 1988; Mankiw, Romer, and Weil, 1992; Aghnion, 1998, 2008). Consequently, numerous studies confirm that the integration of human capital, represented by education and the research and development sector, supports economic growth rates (Stadler & Manfred, 2006).

Theories of internal growth have given importance to the composition of human capital in the growth process. The impact of skilled and unskilled labor varies on

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factor productivity, especially with the integration of the technological element. Skilled labor - those with higher education attainment - have the ability to absorb technology and support innovation and creativity, while unskilled labor supports traditional technology. Results from a study by Rabiul (2010) on a sample of 87 countries for the period between 1970-2004 showed that the impact of highly educated workers on growth increases with proximity to technological boundaries only in high and medium-income countries. Conversely, workers with secondary education have a greater impact in low-income countries as they approach technological boundaries. Even for high-income countries, Aghnion, Vandenbussche, and Meghir (2006) developed a theoretical model showing that skilled labor has a stronger impact on economic growth closer to technological boundaries. The study, conducted on a sample of 19 OECD countries between 1960-2000, demonstrated that higher education is one of the factors explaining economic disparities among group countries.

Moreover ,theories of internal growth have praised the role of human capital in the economic growth process, as highlighted in the works of Shultz (1961), Becker (1964), and Romer (1990). The role of education in growth is further strengthened through its interactive relationship with the technological element and research and development (RD). The first generation of internal growth models considers human capital as a generator of innovation and growth (Romer, 1990; Aghnion, 1998). It is also seen as a factor contributing to the dissemination and absorption of technology through the external effects of knowledge (Gouranga & Drinel, 2020). This idea is also central to Nelson and Phelps (1966), who explain the role of education in transitioning to technological boundaries, where countries closer to the boundaries are better able to exploit these effects, and those with human capital capable of adapting to new technologies. Similarly, Benhabib and Spiegel (1994) illustrate that countries closer to technological boundaries accumulate human capital from higher education, which supports innovation, while countries farther from the boundaries focus more on technological diffusion.

Internal growth models have also focused on explaining the differences in productivity growth among countries worldwide, emphasizing the role of technological transformation and the capacity to absorb technology through education , research ,and development (Howitt, 2004; Keller & Acharva, 2007; Griffith, 2000). This has been corroborated by numerous studies, such as the research conducted by Madsen, Jakop, Islam, Rabiul, and Ang (2010), which analyzed a sample of 55 countries, including 23 advanced and 32 developing countries, for the period between 1970-2004. The results showed that innovation is an important factor for growth in OECD countries, while growth in developing countries is supported by imitation. Furthermore, the interaction between educational attainment and the distance to technological boundaries is identified as a determinant of growth in the overall sample.

A study by Messing and Ahmed (2008) on a sample of 70 countries worldwide for the period between 1970-2003 confirms the widening skill gap - education gap across regions of the world: Sub-Saharan Africa, South America, Eastern Europe, and more advanced OECD countries. The study developed measurements for human capital as an indicator of skills used in measuring three models of technological diffusion, to measure integration and variation between capital and skill, skilled and unskilled labor, and basic skill for technological exchange.The results indicated that skills are an important factor for innovation and technological diffusion. Many studies have sought to clarify the impact of the skilled and unskilled labor composition on production functions through their relationship with the technological element. Caselli and Coleman's model (2000) demonstrated that countries focusing on skilled labor and capital are most efficient in utilizing their inputs because they are more adaptable to technology. Each country's companies impose choices based on the content of technology, thus the interactive composition of the three production units varies. They select the factors more widely used and eliminate others. In other words, the optimal technology choice by companies is determined by the skilled and unskilled labor force in each country, and according to each country's technological boundaries due to obstacles hindering technology adoption. Poorer countries tend to be disproportionately within technological boundaries, a conclusion also supported by a similar study by Caselli and Coleman (2000). This is further elucidated by a model by Acemoglu, Aghion, and Zilibotti (2006) regarding company choices regarding the most important skills for innovation as they approach technological boundaries. It also explains their investment strategy in the short and long term.

On the other hand, models (Nelson, Phelps, 1966; Aghnion, Vandenbussche, Meghir, 2006) have clarified that growth depends on the interactive relationship between educational attainment and proximity to technological frontiers. A study by Azomahou, Diene (2009, pp. 1-5) on a sample of OECD countries for the period between 1960-2000 to analyze growth strategy when countries are close to technological frontiers, indicated that higher education is the determinant of growth. It also suggests that when a country approaches those frontiers, increased spending on research and development (R&D) is favored. This supports the findings of Aghnion, Cohen (2004, pp. 1-6), as just as countries close to technological frontiers should invest in higher education, those distant from the frontiers should invest in primary and secondary education to improve their technological levels.

Additionally, a study by Jakob Modsen (2014, p. 676) on a sample of 21 industrial countries for the period between 1870-2009 indicated that changes in educational attainment and its interaction with technological frontiers have an impact on productivity growth during this period.

In our study, we will attempt to estimate the impact of education, distance to technological frontiers, and their interaction coefficients on economic growth in Algeria during the period from 1991-2021. We will pose the following problem: What is the extent of the impact of education and distance to technological frontiers on economic growth? And which educational levels are most influential in growth when approaching technological frontiers in Algeria?

We will try to test three fundamental hypotheses:

1- Primary and secondary education have a positive impact on economic growth.

2- Higher education has a positive impact on economic growth.

3- Technological distance has a negative impact on economic growth.

4- The impact of primary and secondary education on economic growth is more significant when approaching technological frontiers.

The model assumes that the distance to technological frontiers or the rate of technological convergence negatively affects economic growth. That is, as countries approach technological frontiers - meaning a decrease in distance - the productivity of factors increases, and vice versa for countries far from those frontiers. The latter rely on traditional technology, which requires physical and human capital of lower skill levels or lesser education (Vandenbussche, Al., 2006). This is what we are attempting to test for the Algerian case. To address the posed problem, we will define the model, then analyze the variables, conduct the standard study, and analyze the results.

Introduction to the Nelson & Phelps Model (1966)

The theoretical foundation of the proposed study is based on the Nelson & Phelps model (1966), which focuses on the relationship between educational attainment and the distance to technologiy frontier. Initially, this model considers technological progress as simply an increase in labor, where the production function takes the following form: γ_t = f[K_t, A_t, L_t].

Here, Y represents output, K represents capital, L represents labor, t represents time, and A represents the technology level in practice. The technological level measures the best practices integrated into capital. As Nelson & Phelps (1966) argue, the transformation of theoretical technology into best technological practices depends not only on the educational level but also on the gap between the theoretical technology level and the technology level in practice. As a result, we write:

$$A_t = \emptyset(\mathrm{h})[\mathrm{T_t} - \mathrm{A_t}] \quad (1)$$

Or, equivalently: $$g_t = \frac{A_t}{A_t} = \emptyset(h)\frac{\mathrm{T_t - A_t}}{\mathrm{A_t}} \quad , \quad \emptyset(0)=0 \quad , \quad 0>\acute{\emptyset}(\mathrm{h}) \quad (2)$$

Where g represents total factor productivity (TFP) or knowledge growth, A represents the change in total factor productivity (TFP). According to the assumption by Nelson and Phelps (1966), the rate of technological progress in practice is an increasing function of educational attainment or human capital (h), and the percentage of the technological gap [(T_t - A_t) / A_t]. In other words, the rate of closing the technological gap depends on the level of human capital. Modern theories of internal growth have supported this idea, where Romer (1990) suggests that the direct and indirect effects of human capital on factor productivity pass through its influence on the speed of technological assimilation. Therefore, in the Benhabib and Spiegel model (1994), the direct effect of human capital is integrated into the technological assimilation model in equation (2) as follows:

$$g_A^t = \frac{A_t}{A_t} = \gamma(h) + \emptyset(h)\left[\frac{T_t - A_t}{A_t}\right] \quad (3)$$

Equation (3) indicates that education not only enhances a country's innovative capacity but also strengthens its ability to catch up with technological leadership through adaptation and application of advanced technologies (Rabiul Islam, 2010).

Models by Vandenbussche and Al (2006) and Aghion and Al (2005, 2009) demonstrate that the impact of human capital on innovation and imitation is not equal in driving technological progress. Higher education plays a prominent role in facilitating innovation, while primary and secondary education support imitation or knowledge transfer. Therefore, according to this approach, the closer a country is to global technology frontier, the preferable investment would be in higher education to drive economic growth. Conversely, if a country is distant from these boundaries, investment in primary and secondary education is favored. In other words, as the distance to technology frontier decreases, the impact of higher education on growth increases, while the impact of primary and secondary education decreases. Thus, the Vandenbussche and Al model (2006) takes the following form:

$$g_{jt} = \Delta lnA_{jt} = \alpha_{0j} + \alpha_1 ln\left(\frac{A_{j,t-1}}{A_{t-1}^{US}}\right) + \alpha_2 f_{j,t-1} + \alpha_3 ln\left(\frac{A_{j,t-1-}}{A_{t-1}^{US}}\right) \times f_{j,t-1} + \varepsilon_{jt}$$

Whereby: g_{jt} represents total factor productivity TFP, A represents the level of TFP, $ln(A_{j,t-1}/A_{t-1}^{US})$represents the logarithm of proximity to technology frontier measured by the gap in TFP between the concerned country and the United States (technological leadership$f_{j,t-1}$ represents the proportion of the population with higher education in the previous period. It is assumed that the interaction coefficient between proximity to the boundaries and higher education, $f_{j,t-1} \times \ln(A_{j,t-1}/A_{t-1}^{US})$ is positive and significant, indicating that higher education is important for the growth of countries close to technology frontier **.**

II. Model and Study Variables

Through this research paper, we aim to study the impact of the interaction between the distance to technology frontier and education on economic growth in Algeria for the period between 1991 and 2021. We draw inspiration for the growth equation from the extended model by Vandenbussche and Al (2006). The growth equation is formulated as follows:

$$\begin{aligned} logPIB_{it=} \alpha_0 + \alpha_1\, logK_{i,t-1} + \alpha_2 PS_{i,t-1} + \alpha_3 TER_{i,t-1} \\ + \alpha_4 \log(A_i/A^{US})_{t-1} + \alpha_5(PS_{i,t-1}) \\ \times \log(A_i/A^{US})_{i,t-1} + \alpha_5(TER_{i,t-1}) \log(A_i/A^{US})_{t-1} + \varepsilon_{it} \end{aligned}$$

Where:

- $logPIB$ represents the Gross Domestic Product, taken in logarithm and adjusted for constant prices of the international dollar for the year 2011.
- PS represents the total enrollment in primary and secondary education during the previous period $(PRI_{i,t-1} + SEC_{i,t-1})$
- TER represents the enrollment rate in higher education.
- $\log(A_i/A^{US})_{t-1}$ represents the distance to technology frontier in the previous period, taken in logarithm. This is often referred to as the "proximity" index in many studies, indicating the gap in factor productivity between country i and the leading technological country. Here, $A_i$represents the labor productivity for country i, and A^{US}represents labor productivity in the United States.
- The productivity of labor is expressed through the Gross Domestic Product per worker, taken at constant prices of the international dollar for the year 2017.
- t represents time, and ε_{it}_it represents the random error term.
- The term $\log(A_i/A^{US})_{i,t-1}\ PS_{i,t-1}$ ×represents the interaction coefficient between primary and secondary education and technological distance.
- The term $\log(A_i/A^{US})_{i,t-1} \times TER_{i,t-1}$ represents the interaction coefficient between higher education and technological distance.
- $logK$ represents the accumulation of fixed capital taken in logarithm.

In summary PR represents $\log(A_i/A^{US})$, which is the distance to technology frontier. Therefore, the model can be written as follows:

$$logPIB_{it=}\ \alpha_0 + \alpha_1\, logK_{i,t-1} + \alpha_2 PS_{i,t-1} + \alpha_3 TER_{i,t-1} + \alpha_4\, \mathrm{PR}_{i,t-1} + \alpha_5 (PS_{i,t-1}) \times \mathrm{PR}_{i,t-1} + \alpha_6 (TER_{i,t-1})\, \mathrm{PR}_{i,t-1} + \varepsilon_{it}$$

I. Estimation of the Model - Standard Study

We employ the Johansen methodology to test for cointegration and to study the stability of the time series, using the Augmented Dickey-Fuller (ADF) test for unit roots. We adopted the Granger causality methodology to study the relationship between the variables.

1. Stability Study of the Model

Table (01) presents the results of the stability test using the ADF test. The results indicate that the absolute values of the statistics (TQJ) are less than the critical values, which leads us to accept the null hypothesis of the presence of unit roots and, consequently, the non-stationarity of the time series. After differencing, the series became first-order stationary, which prompts us to perform the cointegration test and verify the existence of long-term relationships between the variables.

Table 01. Results of Variables' Stationarity Test

VARIABLES	ADF STAT		DIC
	I(1)	I(0)	
LOG_K	0.0074	0.1976	I(1)
PSPR	0 ,0014	0.8887	I(1)
TRPR	0,0100	0,8103	I(1)
PR	0,0000	0,6777	I(1)
PS	0,0686	0,7580	I(1)
TR	0,0293	0,4456	I(1)
LOGPIB	0,0293	0,9716	I(1)

Source: Prepared by the researcher based on Eviews outputs

The results of the stationarity test indicate that the absolute values of the (TQJ) statistic are lower than the critical values, which leads us to accept the null hypothesis of unit roots and thus the non-stationarity of the time series. After differencing, the series became first-order stationary, which prompts us to conduct the cointegration test and confirm the existence of long-term relationships between the variables.

2- Determination of Optimal Lag Length for Slowdown Periods: VAR Lag Order Selection Criteria:

After studying the stability, we proceed to study the slowdown periods as shown in Table (02). The results indicate that the degree of delay is estimated to be 2.

Table 02. Study of Lag Lengths

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-6.898316	NA	6.15e-09	0.958505	1.288541	1.061868
1	215.7010	322.3852	4.31e-14	-11.01386	-8.373566*	-10.18695
2	291.0645	72.76476*	1.37e-14*	-12.83203*	-7.881480	-11.28158*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Prepared by the researcher based on Eviews outputs

3- Cointegration

Table (03) shows the results of the cointegration test between the variables. Through the Johansen cointegration test, it is evident that the statistical probability of the Trace test is lower than the critical values at 1, hence we accept the null hypothesis of cointegration, indicating the presence of simultaneous integration relationships between the variables at a significance level of 5%. This implies that the variables do not deviate significantly from each other in the long run, as they exhibit similar behavior. Since the model is stable at first differences and there is cointegration among the variables, we can utilize the Vector Error Correction Model (VECM).

Table 03. Results of Cointegration Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value 0.05	Prob.**
None *	0.860502	199.9545	125.6154	0.0000
At most 1 *	0.852676	142.8331	95.75366	0.0000
At most 2 *	0.605547	87.29462	69.81889	0.0011
At most 3 *	0.595136	60.31721	47.85613	0.0022
At most 4 *	0.504014	34.09528	29.79707	0.0150
At most 5	0.371902	13.76027	15.49471	0.0898
At most 6	0.009388	0.273532	3.841466	0.6010

Trace test indicates 4 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Source: Prepared by the researcher based on Eviews outputs

4- Estimation of the Vector Error Correction Model (VECM):

After confirming the presence of cointegration among the variables, the next step is to estimate the Vector Error Correction Model (VECM), as shown in Table (04).The results of the Vector Error Correction Model (VECM) indicate that the error correction term (ECT(-1)) is negative and statistically significant at the 5% level, confirming the statistical validity of the estimated error correction model. The adjustment speed in the model is approximately 25.10%, implying that economic growth takes a very long time to converge to its equilibrium value in the long run following any shock to its determinants. Additionally, the coefficient of determination is estimated to be 0.4666, meaning that 46.66% of the variation in the dependent variable is explained by the independent variables, while the remaining percentage is attributed to other variables not included in the model.

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Review MECAS V° 20/ N°1 / June 2024

Table 04. Results of Vector Error Correction Model (VECM) Estimation

Error Correction:	D(LOG_PIB)	D(LOG_K)	D(PR)	D(PS)	D(TER)	D(PSPR)	D(TERPR)
CointEq1	-0.251006	-0.874612	-0.957002	8.696005	-3.464361	-171.8069	-16.60050
	(0.16113)	(0.31657)	(0.16327)	(87.1536)	(20.4027)	(61.3993)	(11.2639)
	[-1.55783]	[-2.76278]	[-5.86135]	[0.09978]	[-0.16980]	[-2.79819]	[-1.47377]
D(LOG_PIB(-1))	-0.018449	-0.852141	0.028427	91.02772	-45.82968	-22.27560	31.11892
	(0.26891)	(0.52834)	(0.27250)	(145.456)	(34.0512)	(102.473)	(18.7990)
	[-0.06861]	[-1.61287]	[0.10432]	[0.62581]	[-1.34591]	[-0.21738]	[1.65535]
D(LOG_K(-1))	0.011571	-0.218961	-0.391980	37.76162	20.45061	-89.18336	-18.12338
	(0.14740)	(0.28961)	(0.14937)	(79.7307)	(18.6650)	(56.1699)	(10.3046)
	[0.07850]	[-0.75606]	[-2.62426]	[0.47361]	[1.09567]	[-1.58774]	[-1.75877]
D(PR(-1))	0.919043	4.247193	-8.216387	-624.9586	462.1263	-1061.438	-305.2350
	(2.34081)	(4.59906)	(2.37201)	(1266.15)	(296.406)	(891.998)	(163.641)
	[0.39262]	[0.92349]	[-3.46390]	[-0.49359]	[1.55910]	[-1.18996]	[-1.86528]
D(PS(-1))	-0.003498	-0.017271	0.027467	2.282758	-1.658187	3.441023	1.067365
	(0.00788)	(0.01549)	(0.00799)	(4.26373)	(0.99814)	(3.00378)	(0.55105)
	[-0.44376]	[-1.11515]	[3.43866]	[0.53539]	[-1.66128]	[1.14557]	[1.93695]
D(TER(-1))	0.008790	0.049382	-0.091211	-4.163133	4.579412	-13.62768	-3.399598
	(0.02205)	(0.04332)	(0.02234)	(11.9259)	(2.79186)	(8.40177)	(1.54134)
	[0.39867]	[1.13997]	[-4.08248]	[-0.34908]	[1.64027]	[-1.62200]	[-2.20562]
D(PSPR(-1))	-0.007530	-0.035584	0.066942	4.336689	-3.445979	9.064361	2.385502
	(0.01802)	(0.03540)	(0.01826)	(9.74634)	(2.28162)	(6.86625)	(1.25964)
	[-0.41789]	[-1.00514]	[3.66628]	[0.44496]	[-1.51032]	[1.32013]	[1.89380]
D(TERPR(-1))	0.021552	0.105979	-0.212927	-9.930964	9.402673	-31.52905	-7.297703
	(0.05096)	(0.10012)	(0.05164)	(27.5646)	(6.45288)	(19.4191)	(3.56252)
	[0.42292]	[1.05849]	[-4.12334]	[-0.36028]	[1.45713]	[-1.62361]	[-2.04847]
C	0.013231	0.033166	-0.004478	-1.270344	1.671883	-0.002753	-0.815793
	(0.00448)	(0.00880)	(0.00454)	(2.42326)	(0.56728)	(1.70717)	(0.31319)
	[2.95335]	[3.76796]	[-0.98645]	[-0.52423]	[2.94717]	[-0.00161]	[-2.60481]
R-squared	0.466677	0.611142	0.741790	0.228582	0.597565	0.413437	0.515306
Adj. R-squared	0.253348	0.455598	0.638506	-0.079985	0.436591	0.178812	0.321428
Sum sq. resids	0.001627	0.006280	0.001671	475.9920	26.08570	236.2411	7.950780
S.E. equation	0.009019	0.017720	0.009139	4.878483	1.142053	3.436867	0.630507
F-statistic	2.187590	3.929078	7.182051	0.740785	3.712184	1.762118	2.657890
Log likelihood	100.7823	81.19695	100.3983	-81.72174	-39.61355	-71.56380	-22.38584
Akaike AIC	-6.329811	-4.979100	-6.303331	6.256672	3.352658	5.556124	2.164541
Schwarz SC	-5.905478	-4.554767	-5.878998	6.681005	3.776992	5.980457	2.588874
Mean dependent	0.011465	0.018825	-0.006113	2.005764	1.468840	-1.893772	-0.765329
S.D. dependent	0.010438	0.024016	0.015201	4.694355	1.521509	3.792639	0.765406

Source: Prepared by the researcher based on Eviews outputs

5- Granger Causality Test

Table (05) presents the results of the Granger causality test between the variables. Through the results of estimating the Granger causality relationship, it becomes evident that there is a significant causal relationship:

Table 05. Results of Granger Causality Test between VECM Variables

VEC Granger Causality/Block Exogeneity Wald Tests					
D(PR)		D(TER)		D(TERPR)	
Excluded	Prob.	Excluded	Prob.	Excluded	Prob.
D(LOG_PIB)	0.9169	D(LOG_PIB)	0.1783	D(LOG_PIB)	0.0979
D(LOG_K)	0.0087	D(LOG_K)	0.2732	D(LOG_K)	0.0786
D(PS)	0.0006	D(PR)	0.1190	D(PR)	0.0621
D(TER)	0.0000	D(PS)	0.0967	D(PS)	0.0528
D(PSPR)	0.0002	D(PSPR)	0.1310	D(TER)	0.0274
D(TERPR)	0.0000	D(TERPR)	0.1451	D(PSPR)	0.0583

Source: Prepared by the researcher based on Eviews outputs

A unidirectional causality relationship from the total enrollment in primary and secondary education towards the enrollment coefficient in higher education.This result is logical considering that the outputs of the earlier stages of general education (both quantitatively and qualitatively) serve as inputs to higher education.

Bidirectional causality between the proximity index and the interaction coefficient between higher education and proximity to technology frontiers.

All variables have a causal direction towards the proximity index as well as towards the interaction coefficient between higher education and proximity to technology frontiers.

These results indicate that both physical and human capital variables are related to the process of proximity. However, concerning human capital variables, it becomes evident that higher education plays a more significant role in the process of proximity. Considering the causal relationship between economic growth and the interaction variable between higher education and proximity to technological frontiers, as well as the bidirectional relationship between the interaction variable specific to higher education and the proximity variable, elementary and secondary education does not show this relationship.

6. Statistical Analysis of the Model

6.1 Autocorrelation Test for Errors

We test the autocorrelation of errors using the Breusch-Godfrey test. Autocorrelation Test for Errors: Based on the table, it is evident that the probability value (LM) is greater than 5%. Therefore, we conclude that the calculated value is less than the tabulated value, indicating no autocorrelation of errors.

Table 06. Autocorrelation Test for Errors

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.505570	Prob. F(2,22)	0.2439
Obs*R-squared	3.732150	Prob. Chi-Square(2)	0.1547

Source: Prepared by the researcher based on Eviews outputs

6.2 Heteroskedasticity Test

Next, we proceed to test for the heteroskedasticity of errors using the ARCH test.

Table 07. Heteroskedasticity Test

Heteroskedasticity Test : ARCH			
F-statistic	0.207239	Prob. F(1,28)	0.6525
Obs*R-squared	0.220411	Prob. Chi-Square(1)	0.6387

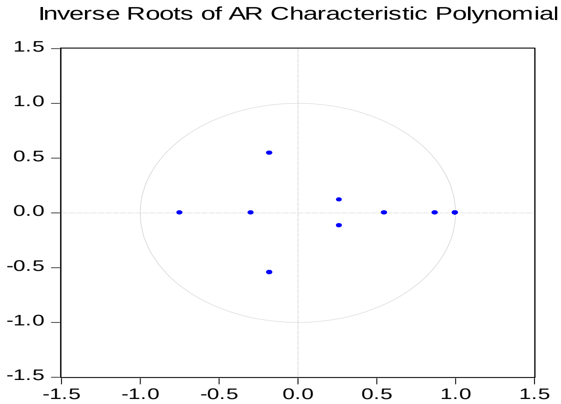
Source: Prepared by the researcher based on Eviews outputs

We notice that the probability values are greater than 5%. Thus, the tabulated values are smaller than the calculated values. Therefore, we accept the null hypothesis, indicating no heteroskedasticity issue. Hence, we can conclude that the model does not suffer from heteroskedasticity.

6.3. One-Step Ahead Predictive Ability Test for Model Validity

As illustrated in Figure 01, the estimated model meets the stability conditions (VAR satisfies the stability condition). This is because all coefficients are less than one, and all roots lie within the unit circle. This implies that the model does not suffer from errors correlation or heteroskedasticity issues.

Figure 01. One-Step Ahead Predictive Ability Test for Model Validity



Source: Prepared by the researcher based on Eviews outputs

7. Variance Component Analysis

The importance of variance component analysis for each variable lies in providing the relative importance of the effect of any sudden change in each variable on the other variables of the model. Through conducting a test of error variance component analysis as illustrated in Table 08, it is evident that the transitory fluctuations of the variables PIB, K, PR, PS, and TER in the short term are highly related to shocks in the variables themselves.

In the medium term, we find that 23.64% of economic growth fluctuations are caused by shocks in the primary education enrollment rate, while 13.29% are explained by shocks in higher education. As for the long term, economic growth fluctuations, estimated at 33.70%, 19.64%, 14.94%, and 12.13% respectively, are attributed to shocks in higher education, physical capital, the interaction rate between primary and secondary education and proximity, and proximity, respectively.

Table 08. Analysis of Variance Components

Percentage of the forecast error of:	Explained by shocks in:							
	Years	LogPIB	Log k	PR	PS	TER	PSPR	TERPR
Log PIB	2	91.04917	2.803667	0.096718	0.568360	2.197817	2.520041	0.764230
	6	34.62757	9.690177	3.224760	23.64087	13.29521	8.383566	7.137853
	10	0.066196	19.64191	12.13563	4.850417	33.70686	14.91814	8.015673
Log k	2	14.03127	74.61553	0.157389	0.043500	0.092412	7.505903	3.553994
	6	2.518093	39.37234	2.460310	15.63683	7.282741	14.28717	18.44251
	10	0.819662	28.86626	4.426878	28.80114	11.08942	12.08321	13.91343
PR	2	7.938622	6.257133	36.80114	12.79823	0.083746	1.255135	34.86600

	6	40.01640	2.397088	30.86399	7.690196	0.896520	3.323585	14.81223
	10	0.039577	43.94401	1.646062	30.16758	5.424602	2.135868	5.063815
PS	**2**	1.950098	15.70489	15.63313	66.31568	0.045594	0.037435	0.313180
	6	0.880466	17.29978	15.53057	65.27229	0.051491	0.601091	0.364314
	10	0.449160	17.42400	14.84447	64.86378	0.345438	1.247782	0.825380
TER	**2**	0.520232	7.292066	1.672431	7.232508	78.76108	0.058596	4.463092
	6	2.421888	9.956615	0.501898	12.97358	52.14792	4.896809	17.10129
	10	1.678000	5.876541	2.130284	11.25874	32.33869	14.74441	31.97332
PSPR	**2**	1.575370	12.93469	35.37293	42.44720	0.350348	1.188645	6.130817
	6	5.317931	12.18665	33.91317	42.74098	1.050426	1.027166	3.763684
	10	5.228123	12.28276	33.10991	44.06895	0.847301	0.722660	3.740297
TERPR	**2**	0.334042	1.565034	12.95802	2.846233	71.55811	2.892234	7.846325
	6	1.147465	5.494750	3.778712	13.69503	61.22812	1.064329	13.59160
	10	0.922515	3.734624	6.190096	9.620527	48.88368	4.212817	26.43574

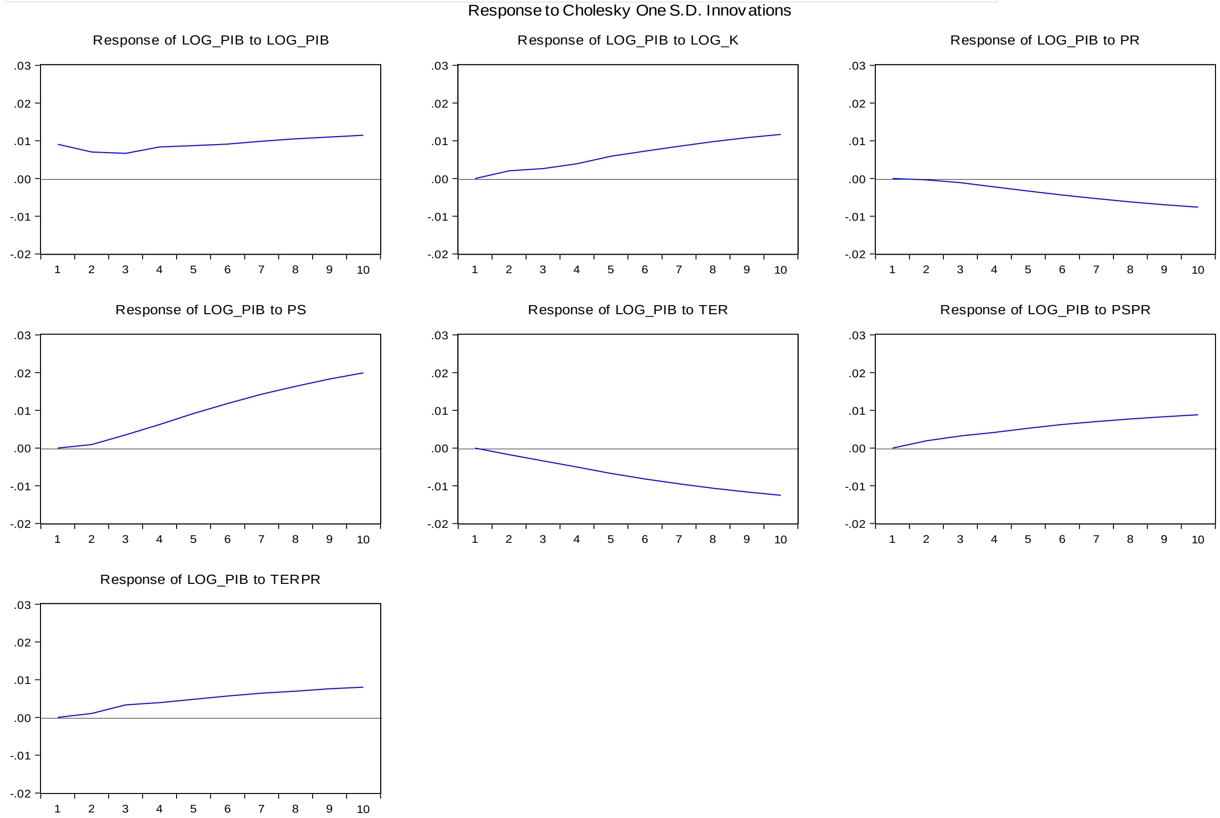
Source: Prepared by the researcher based on Eviews outputs

On the other hand, short-term fluctuations in proximity rate are attributed to shocks in the same variable (36.8%) and to the interaction rate between higher education and proximity (34.86%). In the medium term, shocks in GDP explain about 40% of the fluctuations in the proximity rate. Meanwhile, the remaining fluctuations, estimated at 30.86% and 14.81%, are attributed to shocks in the same variable and to the interaction coefficient between higher education and proximity, respectively. In the long term, approximately 43.94% of the fluctuations in the proximity rate are due to shocks in physical capital, and around 30.16% are attributed to primary and secondary education. As for the interaction coefficients, fluctuations in the interaction rate between primary and secondary education and proximity are related to primary education and proximity. Conversely, fluctuations in the interaction rate between higher education and proximity are associated with higher education and the same variable, both in the short, medium, and long term.

8. Estimation of Impulse-Response Functions

Through Figure 02, the response of economic growth (GDP) to a one-standard-deviation shock in each of the following: physical capital, primary and secondary education, higher education, proximity, and variables representing the interaction between education and proximity, is demonstrated over a period of 10 time periods.

Figure 02. Results of estimating impulse response functions.



Source: Prepared by the researcher based on Eviews outputs

Through the graphical representation in Figure 02 of the estimated impulse response functions, we can draw the following key observations:

- Impact of shock in physical capital: A positive shock in physical capital estimated at one standard deviation will have a significant positive effect on economic growth throughout the response period up to the tenth year, with an increase of 1.1672%.
- Impact of shock in proximity: A positive shock in the rate of proximity estimated at one standard deviation will have a significant negative effect on economic growth, persisting throughout the response period up to the tenth year, with a decrease of 0.7654%.
- Impact of shock in primary and secondary education: A positive shock in primary and secondary education estimated at one standard deviation will have a significant positive effect on economic growth throughout the response period up to the tenth year, with an increase of 1.9939%.
- Impact of shock in higher education: A positive shock in the rate of higher education estimated at one standard deviation will have a significant negative

effect on economic growth, persisting throughout the response period up to the tenth year, with a decrease of 1.2573%.

- Impact of shock in the interaction rate between primary-secondary education and proximity: A positive shock in the interaction rate between primary-secondary education and proximity, estimated at one standard deviation, will have a significant positive effect on economic growth throughout the response period up to the tenth year, with an increase of 0.8823%.
- Impact of shock in the interaction rate between higher education and proximity: A positive shock in the interaction rate between higher education and proximity, estimated at one standard deviation, will have a significant positive effect on economic growth throughout the response period up to the tenth year, with an increase of 0.803%.

Conclusion :

The study results indicate that both physical and human capital variables are related to the process of proximity to technology frontier. However, concerning human capital variables, the causal relationship between economic growth and the interaction variable between higher education and distance to technological frontiers, as well as the bidirectional relationship between the interaction variable between higher education and proximity, clarifies that higher education plays an important role in the process of technological convergence but its impact is limited to the short and medium term. On the other hand, the impact of primary education on proximity over the long term is highlighted according to the results of variance analysis.

Regarding the nature of the impact of these educational variables, the estimated response functions reveal that primary and secondary education positively influence economic growth, both in the medium and long term, through their interaction coefficient with proximity. Hence, we conclude that primary and secondary education are more important in driving economic growth as technological frontiers are approached, thus supporting the first and fourth hypotheses. On the other hand, higher education negatively impacts growth, thereby rejecting the second hypothesis.

Additionally, the results demonstrate the positive impact of fixed capital and the interaction variables between education and proximity on economic growth. Conversely, the results show the negative impact of the rate of proximity on growth, thus accepting the third hypothesis. An increase in the rate of proximity implies widening the gap or distance to technological frontiers, implicitly reflecting a decline in factor productivity in the country and consequently negatively affecting economic growth.

These results align with the analysis of models (Vandenbussche, Al., 2006) and (Aghnion, Al., Benhabib, Spiegel, 1994), where countries distant from technological frontiers focus on technological diffusion and knowledge transfer through a less

ASJP
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Review MECAS **V° 20/ N°1 / June 2024**

skilled workforce, namely individuals with primary and secondary education. The negative impact of higher education on growth and the absence of its interaction effect with proximity indicate a distance from technological frontiers. Higher education is associated with innovation and creativity, which are the missing link in the growth function in the Algerian case.

Applying the theoretical model to the Algerian case remains limited because it lacks the technological link in the growth function, especially given the shortage of data on research and development during the study period. Additionally, factors such as labor market imbalances in employing educational outputs in productive sectors, alongside the reality of the research and development sector, and the issues faced by the private sector and the overall business environment, contribute to mitigating the impact of education, especially higher education, and its role in technological catch-up to support economic growth.

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