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Technical progress and endogenous growth: an econometric analysis using panel data on the MENA región

Yassine Elhajoui, Student
El Baouchari Nabil, PhD Candidate
Mohammed V University in Rabat, Laboratory of Economic Analysis and Modelling (LEAM), Department of Economics, Faculty of Economics, Law and Social Sciences
Adil Ez-Zetouni
PhD researcher and data science specialist at the High Commission for Planning (HCP) and division chief at the Directorate of Forecasting and Prospective Studies (DPP) within the HCP

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Abstract

From the dawn of the Christian era until the industrial revolution, the standard of living saw little to no change and remained relatively stable during this period. However, since the industrial revolution, living standards have experienced sustained growth up to the present day. The Solow model attributes this growth to technical progress, but where does this progress come from? To truly understand economic growth, we must therefore go beyond the Solow model and attempt to explain technical progress itself. The objective of this work is to identify and specify the factors that may explain technical progress (in other words, what causes growth in A?). To this end, initially, we relied on a set of theoretical works ((Romer, 1990; Lucas, 1988; Barro, 1990; Aghion, Blundell, Griffith, Howitt, & Prantl, 2009), among others) which led us to a set of recommendations. Therefore, in a second step, we proceed to an empirical analysis using panel data to test the significance of the impact of this set of recommendations on technical progress in the Middle East and North Africa (MENA) region. Our econometric results show that there is still much to be done in the MENA region to catch up with the United States, Germany, France, or Japan: the establishment of a research and innovation system based on the needs of economic and social development, an increase in the budget allocated to research, massive investment by the private sector in universities, the strengthening and creation of institutions, etc.

Keywords: Technical progress, growth, policy harmonization, panel data, MENA

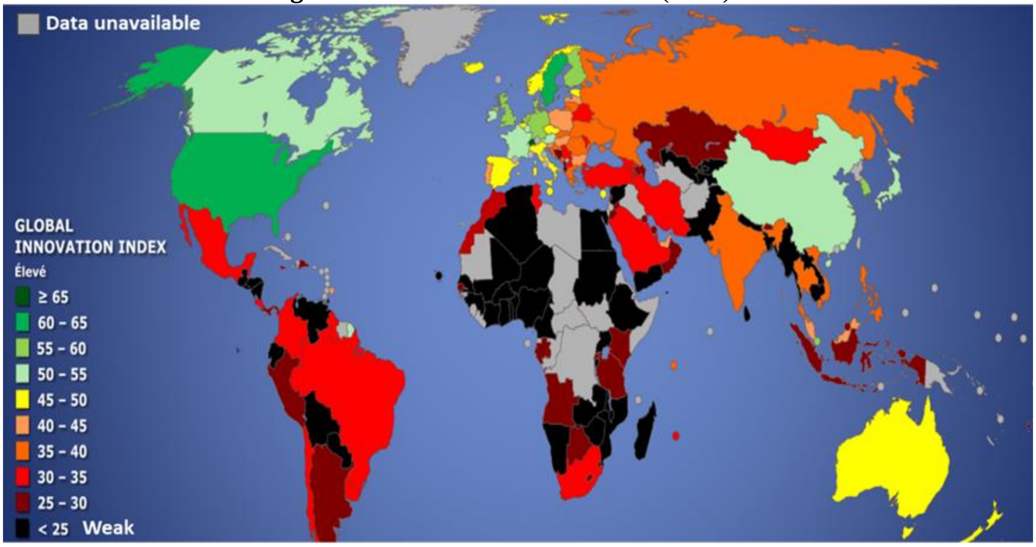
Introduction

Technical progress and endogenous growth are central concepts in contemporary economic theory, providing a powerful analytical framework for understanding the dynamics of economic development. While traditional neoclassical theory primarily emphasized the accumulation of physical capital as the driver of economic growth (Solow, 1957), endogenous growth theories have enriched this perspective by including technological progress as an essential and intrinsic element of long-term growth (Barro, 1990; Romer, 1990; Lucas, 1988). These theories have highlighted the crucial role of innovations, knowledge accumulation, and positive externalities in the economic growth process. In short, to truly understand economic growth, one must go beyond the Solow model and attempt to explain technical progress itself.

The current state of technical progress in the world reflects a diversity of trends and dynamics across different regions and economies. Figure 1 clearly illustrates this differentiation with the Global Innovation Index 2020, which shows significant disparities between countries in terms of innovation capacity. Western European countries, North America, and some parts of East Asia display high scores, indicating strong performance in innovation. In contrast, many regions in Sub-Saharan Africa and some countries in South Asia have relatively low scores, highlighting the challenges they face in integrating innovation into their economic growth models (see Fig. 1).

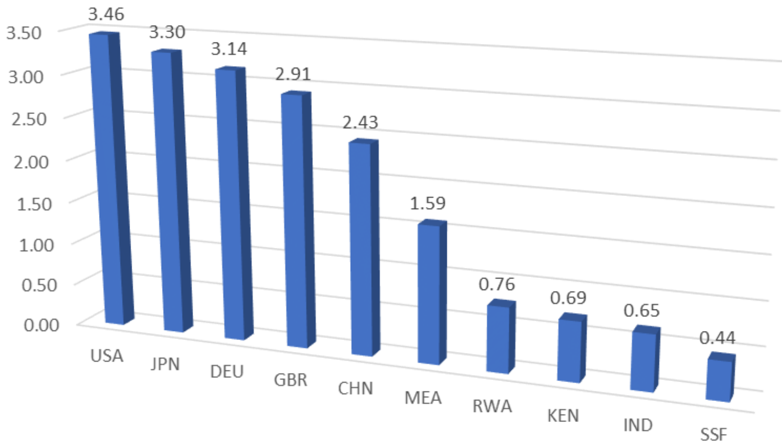
In developed countries such as the United States, Germany, and Japan, which have the highest indices, massive investments in research and development (R&D) characterize these nations, stimulating technological innovation. In 2021, R&D expenditures represented 3.46%, 3.14%, and 3.30% of their GDP, respectively, with a strong concentration in advanced sectors such as artificial intelligence, biotechnology, and renewable energy, which are considered essential drivers of economic growth in these countries. Moreover, investment in education and vocational training plays a crucial role in maintaining a highly skilled workforce capable of adopting and developing new technologies.

Fig. 1 The Global Innovation Index (2021)



Source : ATLASOCIO.COM

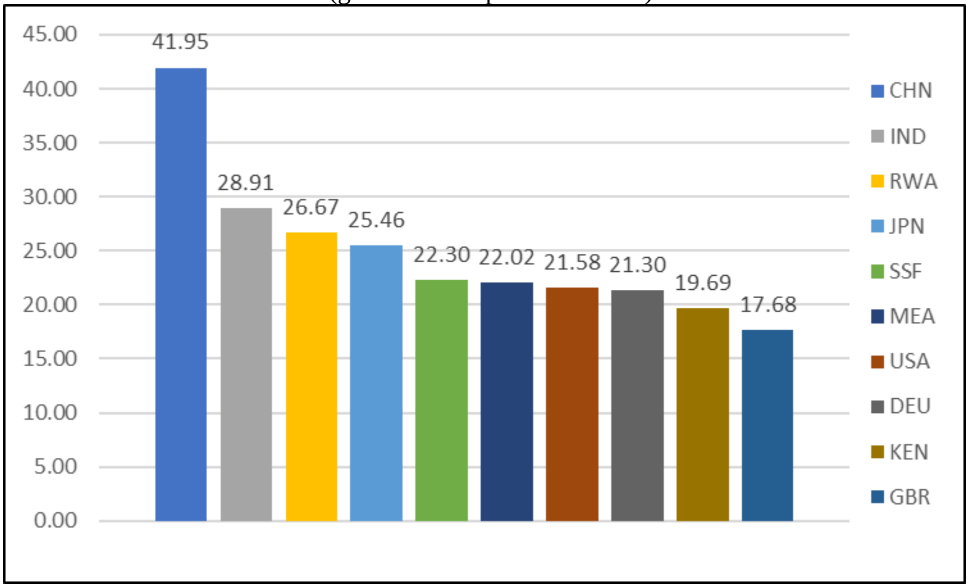
Fig. 2 R&D spending as a percentage of GDP by country (2021)



Source: World Bank Global Development Indicators

Regarding emerging countries, nations like China and South Korea have made remarkable progress in terms of technical advancement. Through government policies favoring innovation, industrialization, and infrastructure improvement, these countries have dramatically transformed their economies. Additionally, the rapid adoption of digital technologies has also contributed to accelerating economic growth in many emerging countries, facilitating access to global markets and increasing the efficiency of production processes.

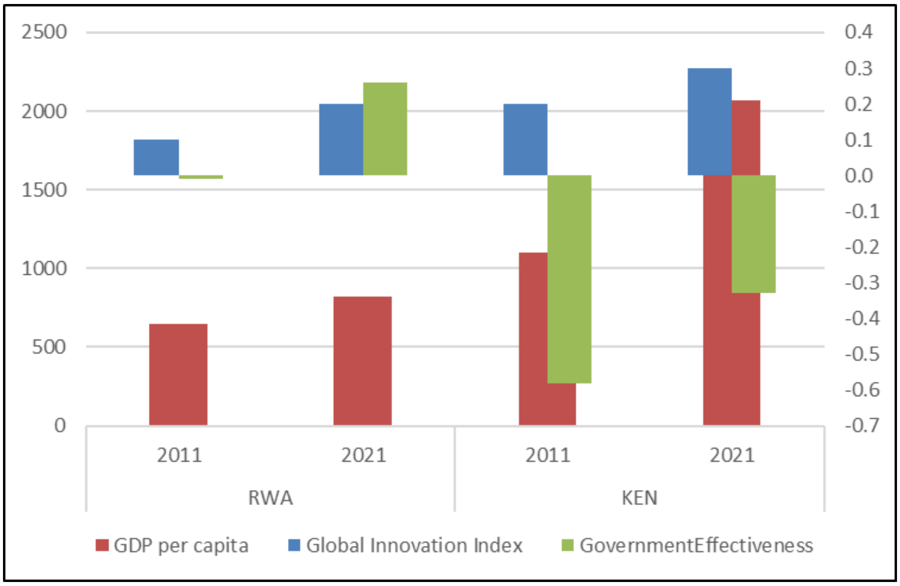
Fig. 3: Public spending on physical infrastructure as a % of GDP (gross fixed capital formation)



Source : World Bank Global Development Indicators

For developing countries, particularly in Sub-Saharan Africa, numerous structural challenges hinder technical progress. These challenges include inadequate infrastructure, limited access to quality education, and unstable economic environments. Despite these social and economic obstacles, some of these countries are beginning to see promising innovative initiatives emerge. Countries like Rwanda and Kenya are investing heavily in improving the quality of their institutions, considering this an essential factor that must be addressed before any other policy. The results of these efforts are clearly visible in both countries, especially in Rwanda (see Fig. 4).

Fig. 4 : evolution of the innovation index, Government effectiveness and GDP per capita between 2011 and 2021 for RWA and Ken



Source: World Bank Global Development Indicators and CNUCED

In the specific context of the MENA region (Middle East and North Africa), characterized by a diversity of economic structures, abundant natural resources, but also significant socio-economic challenges and large heterogeneities among its countries, the issue of technical progress is of particular importance. Understanding the determinants of technical progress in this region and their impact on long-term economic growth is crucial for guiding public policies and promoting sustainable and inclusive economic development.

The present study, conducted from this perspective, proposes an econometric analysis using panel data on the MENA region covering the period 2000-2021**, to identify the main determinants of technical progress in the region**. To this end, the remainder of the document is organized as follows: a brief review of the theoretical and empirical literature introduces the objective of the second section, while the third section highlights the results of the basic model estimation, preceded by the presentation of the model used and the description of the database. Finally, we conclude with economic policy recommendations.

Review of theoretical literature

Technological progress, as defined by (Blanchard & Cohen, 2020) as "the set of inventions applied in the form of innovations," is explained by various incentive factors. These factors can be grouped into two main categories (Agnès Bénassy-Quéré, 2017): institutions and policies.

Institutions

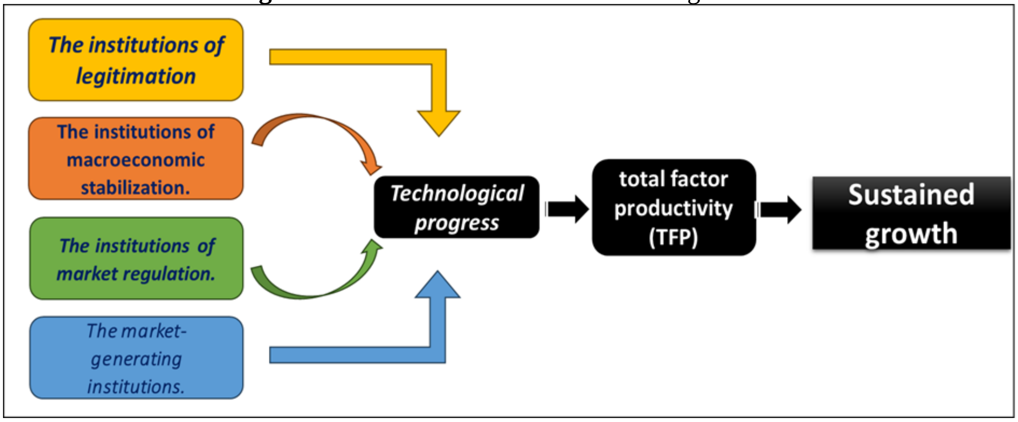
An important incentive dimension is the legal, regulatory, and social organization of productive activities, which can be grouped under the generic term of institutions. There are numerous types of institutions that influence growth. (Subramanian & Rodrik, 2003) propose four general categories of economic institutions:

- Market-generating institutions, which protect property rights, ensure contract enforcement, minimize corruption, facilitate judicial procedures, and, in general terms, uphold the rule of law. In the absence of these institutions, markets may not exist or may function poorly; conversely, strengthening them can contribute to fostering innovation and thus growth. Examples include independent judiciary, effective policing, and enforceable contracts.
- Market regulation institutions, which manage market failures such as information imperfections and economies of scale. These are institutions that limit the power of monopolies and promote competition to stimulate innovation. Examples include independent competition authorities (such as France's Autorité de la concurrence), regulatory agencies (for example, the Autorité de Régulation des Communications électroniques et des Postes - ARCEP), the European Commission, and courts of justice.
- Macroeconomic stabilization institutions, which guarantee low inflation, minimize economic instability, and prevent financial crises. They minimize macroeconomic instability, ensure fiscal stability, and prevent financial crises. Central banks, exchange rate systems, finance ministries, and fiscal and budgetary regulation all form part of market stabilization institutions.
- Legitimization institutions, which provide social protection, emphasize redistribution, and manage conflicts to encourage risk-taking and exploration of new production sectors. Examples include pension systems, unemployment insurance systems, social benefit programs, and other social funds.

Empirical studies have sought to construct indicators of institutional quality and then link them to changes in GDP per capita. (Word Bank, s.d.) maintains a governance database comprising six indicators:

- Quality of representative democracy (PSV).
- Efficiency of administration (GE).
- Quality of regulation (RQ).
- Rule of law (VA).
- Control of corruption (CC).
- Rule of law (RL).

Fig. 5 Institutions as drivers of economic growth



Source : Auteurs

Based on this data, the IMF (2003) was able to highlight a positive and robust relationship between institutional quality and GDP per capita, suggesting that institutional improvements can stimulate growth. (Cœuré 2017) also finds a very strong correlation in Europe between GDP per capita in 2015 and the ranking in 2008 in global governance indicators. Fig. 6 illustrates the correlation, for the year 2021, between GDP per capita, the quality of regulation, the rule of law, the efficiency of administration, and the quality of representative democracy.

Therefore, to ensure sustained long-term growth of technological progress and thus ensure sustainable growth, it is essential, first and foremost, to ensure that the legal and regulatory framework in which economic activities take place is conducive to private initiative (an independent legal system ensuring contract security, absence of corruption, simplicity of administrative procedures, transparency of economic information, etc.). Secondly, effective market regulation is necessary (antitrust authority, appropriate banking regulation, consumer protection). Finally, achieving macroeconomic stability is crucial (through, for example, an independent central bank and stable budgetary rules). And all of this can only be achieved through a set of institutions that ensure the fulfillment of these tasks in the best possible way.

Policies

Public policies play an essential role in fostering and stimulating productivity. They can be direct (through public financing) or indirect (through incentives given to private agents). Three main government policies stimulate productivity:

- **Infrastructure construction (Barro, 1990):**

Researchers studying the impact of infrastructure and public spending on economic growth, pioneered by (Barro, 1990), show that strong economic productivity growth requires adequate infrastructure such as schools, hospitals, roads, railways, airports, dams, electricity and telecommunication networks, water supply, waste collection, and treatment. For instance, the construction of roads and schools enables children to access education, acquire knowledge, and consequently contribute to productivity growth. Initially, these infrastructures are funded by the state or international aid and gradually, as countries become wealthier and improve their financial markets, by the private sector.

- **Increasing human capital (Lucas, 1988)** :

The knowledge and skills that workers acquire through education and training programs have a significant impact on productivity (Lucas, 1988) . For example, scientists require many years of study and laboratory experience before they can develop new technology. Countries with higher levels of education thus experience higher growth rates than those with lower levels of education. According to this approach, promoting growth involves increasing education spending, the number of teachers, literacy rates, the number of secondary and higher education graduates, etc.

At the econometric level, the link between education performance and productivity per capita has been established since the seminal study by (Nelson & Phelps, 1966). (Barro R. J., 2001) found that an additional year of education raises medium-term growth rates by 0.44 percentage points, all else being equal. Other studies, particularly those by (Aghion, Blundell, Griffith, Howitt, & Prantl, 2009), show that a one percentage point increase in the proportion of graduates in the active population increases medium-term TFP growth by around 0.1 percentage points.

Therefore, it is advisable for policymakers to invest heavily in the education sector to improve the situation of technological progress (innovation) in their countries, which in turn plays a key role in growth. Recent studies by the World Bank (Patrinos & Psacharopoulos, 2018; Montenegro & Patrinos, 2014) clarify three essential points that policymakers must take into account:

- The highest social return is on primary education in developing countries and on higher education in developed countries.
- The private return on education is higher than the social return, as the latter takes into account all direct costs of education and the opportunity cost of public funding.
- The return on female education is the highest.

- **Encoding Research and Development (Romer, 1990):**

According to (Romer, 1990), technology plays a crucial role in economic growth, suggesting that countries can improve their standard of living by investing more in research and development (R&D). Governments can promote R&D in three main ways:

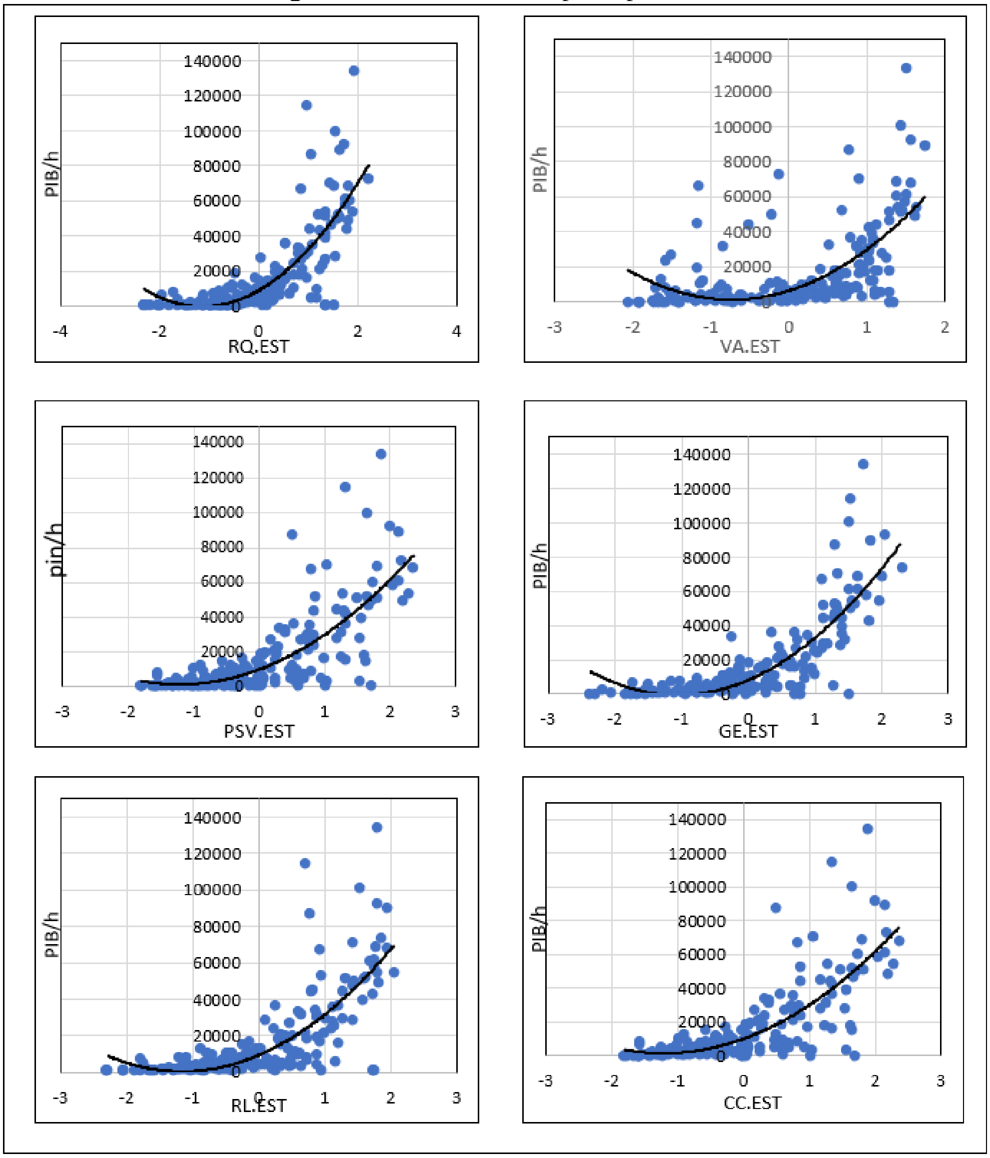
- Public spending on R&D:

Governments can directly increase R&D by engaging in research and development in government facilities. For example, many technological innovations have come from government laboratories, including nuclear energy, jet aircraft, and the electronic computer. Governments also provide grants to universities and private researchers for fundamental research through agencies such as the National Science Foundation and the National Institutes of Health. Governments recognize that research universities can be a significant source of economic growth for certain regions. For example, Boston has greatly benefited from having top research universities in its area, such as Harvard University, MIT, Tufts, Boston University, and Brandeis. Similarly, Silicon Valley has developed around Stanford University. And the high-tech center of India, Bangalore, has thrived around the prestigious Indian Institute of Science. State and local governments, as well as the U.S. federal government, provide direct grants to research universities. In recent years, Europeans have increased their support for research universities, recognizing the benefits accrued in the United States.

- Tax incentives for R&D:

Since private companies are likely to be more efficient than the government in producing practical R&D that can be immediately used in the development of new products and technologies, governments also encourage R&D by granting tax breaks to private companies for research.

Fig. 6 institution and GDP per capita 2021



Source : According to the data from the World Development Indicators (WDI) of the World Bank

- Patents:

Governments grant intellectual property rights to inventors through patents, giving them exclusive rights to use, manufacture, or sell their invention for a specified period. This encourages companies to invest in R&D by allowing them to earn higher profits and recoup their investments.

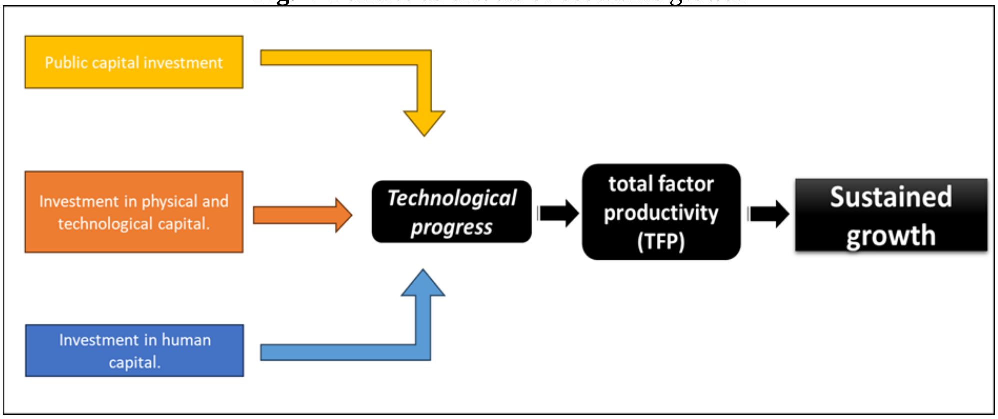
Table 1: The role of different types of government policies that stimulate productivity

Type of capital	Origin of accumulation	Effects on economic growth.
PHYSICAL and TECHNOLOGICAL (production goods and knowledge of production techniques)	(Romer, 1990) **:** Investment + Research and development expenditures	Improvement in the quality of production goods (increase in production volume or decrease in costs) Learning effect on workers Improvement in the production process Development of new products Diffusion of innovation
HUMAN (educational level, experience, health)	(Lucas, 1988) **:** Public and private expenditures on education, health, and social protection	Increase in worker productivity Greater ability to innovate Diffusion of knowledge
PUBLIC (infrastructures, recherche publique, …)	(Barro, 1990) **:** *Public expenditures*	Improvement in the productivity of physical capital or workers Spillover effect on the accumulation of other capital

Source: Authors

In summary, recent studies on economic growth, such as those by (Romer, 1990), (Lucas, 1988) and (Barro, 1990), confirm that public intervention, particularly through investment in physical, human, and public capital, plays an essential role in achieving sustained economic growth.

Fig. 7 Policies as drivers of economic growth



Source: Authors

In conclusion of this third part, it is clear that policies aimed at promoting productivity growth through innovation incentives, such as the construction of physical infrastructure (roads and ports), increasing the knowledge and skills of workers, and providing incentives to stimulate research and development, are crucial for improving the standard of living (economic growth). Similarly, the existence of a good set of basic institutions is essential for achieving strong growth in capital and productivity, thus reinforcing economic growth.

Since the foundations of these theories were laid, they have attracted the interest of many economists: (Aghion, Blundell, Griffith, Howitt, & Prantl, 2009), (Nelson & Phelps, 1966), (Barro R. J., 2001), (Sianesi & Reenen, 2002), (Acemoglu, Johnson, Robinson, & Yared, 2010), (Aghion & Howitt, 2005), and several others. The following section aims to cite the results of a sample of these works with an increased focus on those specific to the MENA region in order to construct a general overview.

Review of empirical literature

Numerous empirical studies have been conducted in this context to evaluate the significance of the impact of these factors on technical progress:

The (Asian Development Bank, 2019), used a fixed effects panel model and regression models on a sample covering all Southeast Asian countries. This study showed that improving the quality of institutions significantly boosted innovation and sustainable economic growth in the region. Similarly, the (World Bank, 2018), using dynamic panel models applied to a study covering all Sub-Saharan African countries, found that investments in education, appropriate industrial policies, and modern infrastructure are crucial for promoting innovation and stimulating economic growth. Furthermore, the (European Commission, 2017), using a fixed effects panel model, demonstrated that public and private investments in R&D can improve economic competitiveness and innovation, thereby driving long-term growth. Additionally, a study conducted in Asia by the (Asian Development Bank , 2017), based on a panel covering emerging economies in Asia, revealed that targeted policies promoting R&D and investments in infrastructure are key factors for boosting competitiveness and innovation in the region. Similarly, the (International Monetary Fund , 2016), on a sample including Latin American and Caribbean countries, demonstrated with a fixed and dynamic panel model that financial reforms and macroeconomic stability are crucial for attracting foreign direct investment (FDI) and stimulating innovation and economic growth. Using the same model, the (Organization for Economic Co-operation and Development, 2021), on a sample comprising OECD member countries, found that structural reforms, particularly those focused on the labor market and education, are essential for fostering innovation and supporting long-term economic growth. More recently, the (African Development Bank, 2021), on a sample encompassing North African countries and with a fixed effects panel model, found that investments in information and communication technologies (ICT) and regional integration policies are essential for accelerating innovation and economic growth in this region.

For the MENA region, studies are still very scarce. Research such as that by (Acemoglu, Johnson, Robinson, & Yared, 2010) has examined the institutional determinants of technological progress in developing countries, including the MENA region, highlighting the importance of political and economic institutions in promoting innovation and productivity. Similarly, the work of (Aghion & Howitt, 2005) has emphasized the crucial role of competition and industrial policies in accelerating technological progress and thus in the process of endogenous growth, offering valuable insights for development policies in the MENA region. Additionally, (Hall & Jones, 1999), using regression models, have examined how the protection of intellectual property rights can encourage innovation and technological progress.

However, despite these advances, the literature on technological progress and endogenous growth in the MENA region remains relatively limited. Empirical studies specific to this region are rare, and there is an urgent need for in-depth research to better understand the determinants of technological progress and its impact on economic growth in the region.

In this perspective, the following section aims to fill this gap by providing a comprehensive econometric analysis to assess the significance of the impact of the aforementioned factors on technological progress in the MENA region, thereby offering valuable insights to policymakers and researchers interested in the economic development of the region.

Econometric Model

Methodology

Our objective is to test the significance of the impact of the cocktail of recommendations announced in the previous chapter on technological progress in the Middle East and North African (MENA) region. Therefore, it is necessary to choose an adequate and appropriate model to achieve this objective.

To begin, we start with the key equation in the Romer model[1], which measures the pace of technological progress.

$$\frac{\Delta A_{i,t}}{A_{i,t}} = (\chi_{i,t} * \alpha_{i,t} * N_{i,t}) \quad (1)$$

With:

- $\frac{\Delta A_{i,t}}{A_{i,t}}$: the growth rate of technology (= pace of technological progress).

[1] This relationship is extensively explained in the book (Mishkin, 2010), page 189-191.

- $\chi_{i,t}$: the productivity of research and development.
- $\alpha_{i,t}$: the fraction of the population devoted to research and development.
- $N_{i,t}$: the total population of the economy.

To econometrically study this model, we add a few essential elements:

$$g_{A_{i,t}} = \left(\chi_{i,t}^{\beta_1} * \alpha_{i,t}^{\beta_2} * N_{i,t}^{\beta_3}\right)$$

With:

- β_1 : The elasticity of g_A with respect to research and development productivity χ,
- β_2 : The elasticity of g_A with respect to the fraction of the population engaged in research and development, α.
- β_3 : The elasticity of g_A with respect to the total population in the economy, N.

Furthermore, it is necessary to introduce a constant in the econometric model to avoid the risk of biasing the estimator of the coefficient β and that of the variance of the residuals. Moreover, the variance decomposition and the interpretation of the determination coefficient (R) only make sense in the presence of a constant term in the econometric model. Therefore, we pose the following multiple linear model to estimate the equilibrium relationship of g_A :

$$g_{A_{i,t}} = \beta_0\left(\chi_{i,t}^{\beta_1} * \alpha_{i,t}^{\beta_2} * N_{i,t}^{\beta_3}\right)$$

$$\ln\left(g_{A_{i,t}}\right) = \ln(\beta_0) + \beta_1 \ln\left(\chi_{i,t}\right) + \beta_2 \ln\left(\alpha_{i,t}\right) + \beta_3 \ln\,(N_{i,t})$$

The quality of institutions is considered one of the key elements that accelerates the pace of technological progress (g_A). We focus on four indicators of institutions that have been highlighted in the literature:

- FF : **Ease of Doing Business**, which is an average ranking of countries based on the ease of conducting the following ten actions : starting a business, dealing with permits, hiring workers, transferring property, accessing credit, protecting investors, paying taxes, trading across borders, enforcing contracts, and closing a business (BanqueMondiale, 2008).
- QE : **Quality of Higher Education**, which is a composite measure of the extent to which tertiary institutions have : freedom to manage resources, including student selection, autonomy to decide on funding sources and structure, and personnel policies, freedom to set objectives, including setting course content and leaders, including various types of assessment (Oliveira, Borini, Struss, Maisonneuve, & Saadi, 2009).

- DP : **Intellectual Property Rights**, which are measured by a patent protection index (Park & Lippoldt, 2005);
- PSJ : **The origin of legal systems in French**, German, Scandinavian, or English law (Porta, Silanes, Lopez, Shleifer, & Vishny, 1999; Porta, Lopez-De-Silanes, & Shleifer, 2008).

So the model is presented as follows :

$$\ln\left(g_{A_{i,t}}\right) = \ln(\beta_0) + \beta_1 \ln(\chi_{i,t}) + \beta_2 \ln(\alpha_{i,t}) + \beta_3 \ln(N_{i,t}) + \beta_4 FF_{i,t} + \beta_5 QE_{i,t} + \beta_6 DP_{i,t} + \beta_7 PSJ_{i,t}$$

Finally, as is customary in all econometric models, we add the term $\varepsilon_{i,t}$ which encompasses all other variables that may influence g_A:

$$\ln\left(g_{A_{i,t}}\right) = \ln(\beta_0) + \beta_1 \ln(\chi_{i,t}) + \beta_2 \ln(\alpha_{i,t}) + \beta_3 \ln(N_{i,t}) + \beta_4 FF_{i,t} + \beta_5 QE_{i,t} + \beta_6 DP_{i,t} + \beta_7 PSJ_{i,t} + \varepsilon_{i,t} \quad (2)$$

Presentation of the variables and their sources

The variables to be presented are collected over the period 2000–2021. The variables included in our study are total factor productivity (TFP), the fraction of the population engaged in R&D (α), the total population in the economy (N), and R&D productivity, χ.

- **The dependent variable**

TFP is measured using the growth accounting method in which TFP is synonymous with technological progress. In other words, TFP is the portion of growth not explained by the physical quantities of the two traditional factors (capital and labor). For each country in the sample, TFP is calculated from a Cobb-Douglas production function with constant returns to scale as follows:

$$PGF_t = \frac{Y_t}{K_t^{\beta} * L_t^{(1-\beta)}}$$

With Y_t K_t and L_t representing respectively the real gross domestic product, the stock of physical capital, and the active labor force at time t. Since the contribution of TFP depends on the production elasticity with respect to physical capital, we calculated TFP assuming a value of 0.4 for β, which is often used in empirical studies (Mankiw, Romer, & Weil, 1992; Coe, Helpmae, & Hoffmaister, 1997; Senhadji, 2000)[2].

Thus, the stock of physical capital is calculated using the perpetual inventory method:

[2] In studying the sources of growth during the period 1960-1994, (Senhadji, 2000) considers a share of capital equal to 0.4 for different regions of the world. (Mankiw, Romer, & Weil, 1992) assume that the share of physical capital in income is equal to 1/3. For (Coe, Helpmae, & Hoffmaister, 1997), this elasticity is also assumed to be equal to 0.4.

$$K_t = Inv_t + (1-\delta)K_{t-1}$$

Where Inv_t is the gross fixed capital formation (GFCF)[3], and δ is the depreciation rate of physical capital ($\delta = 6\%$)[4]. $A_{t=0}$ the initial stock of physical capital is:

$$K_0 = \frac{Inv_0}{g+\delta}$$

Where Inv_0 is the initial investment, and g is the annual growth rate of investment.

Furthermore, for the calculation of TFP, we used real GDP, GFCF, and the employed labor force. The data for these variables, for the 17 countries in our representative sample, are extracted from the World Bank's World Development Indicators CD-ROM, version 2021

- **Independent Variables**

✓ For the fraction of the population engaged in R&D (α), based on the work of (Mankiw, Romer, & Weil, 1992), we use the Researcher-to-Labor Force Ratio (as a percentage of the employed labor force) as a proxy for this variable[5]:

$$\alpha_t = \frac{Chercheurs\ en\ R\&D\ (par\ million\ d'habitants) * million\ d'habitants}{population\ active\ occupée}$$

The data are extracted from the World Bank Indicators (2021) and the UNESCO Institute of Statistics (2021).

✓ For the productivity in terms of scientific research (χ), we use the number of scientific articles published per million inhabitants as representative variables. The data are extracted from the UNESCO databas.

✓ For the total population in the economy (N), we replace it with the total employed labor force. The data are extracted from the World Bank Indicators (2021).

✓ Governance is defined as "the traditions and institutions by which authority is exercised in a country for the common good. This includes the process by which governments are chosen, monitored, and replaced, the capacity of the government to develop and implement sound policies, and the respect of citizens and the state for the institutions that govern their economic and social interactions" (Kaufmann, D, KRAAY, A, & ZOIDO-LOBATON, 1999). This

[3] The data on Gross Fixed Capital Formation (GFCF) are extracted from the World Bank indicators (2009).

[4] According to (Hall & Jones, 1999)

[5] Although the use of this indicator is contested in the literature, it nevertheless provides a measure of the effort made by a country to improve its stock of human capital.

definition covers several aspects of governance: the democratic nature of political institutions, political instability and violence, the effectiveness of public authorities, the weight of regulations, the rule of law, and finally, the fight against corruption.

We preferred this definition over the one provided by the World Bank because it takes into account the nature of political regimes. In our study, based on this definition, we consider three indicators of governance:

- **"Quality of Regulation" (QR)** is focused on policies in the strict sense. This criterion includes measures of anti-liberal policies such as price controls or inadequate banking supervision, as well as the burden imposed by excessive regulation in areas such as foreign trade and business development.
- **"Rule of Law" (ED)** determines the success of a state in establishing an environment in which fair and equitable rules form the basis of economic and social relations.
- **"Government Effectiveness" (EG)** is focused on the inputs required for the government to be able to produce and implement good policies and ensure good public service. The data for these variables, for the 17 countries in our representative sample, are extracted from the World Bank's CD-ROM, Worldwide Governance Indicators (WGI), in its 2021 version.

The model is as follows:

$$\ln\left(g_{A_{i,t}}\right) = \ln(\beta_0) + \beta_1 \ln(\chi_{i,t}) + \beta_2 \ln(\alpha_{i,t}) + \beta_3 \ln(L_{i,t}) + \beta_4 QR_{i,t} + \beta_5 ED_{i,t} + \beta_6 EG_{i,t} + \varepsilon_{i,t} \quad (3)$$

Estimation Methods

Before proceeding with the estimation, it is necessary to determine the appropriate estimation method for each model. To find the most suitable estimation method for each model, follow the steps outlined in the diagram in Appendix 2.

We apply the Honda test on the model datasets and obtain the results described in the following table :

Table 2: Test of Honda for the existence of individual specific effects

	the statistic Calculate	**The value Critiqued**	**p-val**	**conclusion**
$Modele\_\ln(g_A)$	LM = 7,207	$\chi^2_6 = 12{,}592$	2.85×10^{-13}	$H_0 Rejet$

Source: Authors, RSudio (appendix 3 Fig. 13)

According to the results of Table 2, H0 is rejected since the calculated LM statistic, 7.207, is strictly inferior than the theoretical chi-square, χ_6^2 = 12.592, **confirming the existence of individual-specific effects.**

Similarly, we apply the Hausman test to the model data and obtain the results described in the following table :

Table 3: Results of the Hausman specification test

	$\boldsymbol{Le\ modele\ de\ ln}(\boldsymbol{g_A})$				
Fixed	**Randam**	**the statistic Calculate**	**The value Critiqued**	**p-val**	**conclusion**
$\breve{\boldsymbol{\beta}}_{1;\boldsymbol{Within}} = 0{,}208$	$\boldsymbol{\beta}_{1\boldsymbol{MCG}} = -0{,}071$	$H = 12{,}64 \gg$	$\chi_6^2 = 12{,}59$	0.0490	$H_0 Reffuse$
$\breve{\beta}_{2;Within} = -0{,}372$	$\beta_{2MCG} = -0{,}383$				
$\breve{\beta}_{3;Within} = -0{,}938$	$\beta_{3MCG} = 0{,}299$				
$\breve{\beta}_{4;Within} = 0{,}119$	$\beta_{4MCG} = -0{,}015$				
$\breve{\beta}_{5;Within} = 0{,}018$	$\beta_{5MCG} = -0{,}204$				
$\breve{\beta}_{6;Within} = 0{,}124$	$\beta_{6MCG} = 0{,}087$				

Source: Authors, RSudio (appendix 3 Fig. 14)

With these elements, we obtain the calculated statistic value H, which is 12.64, exceeding the theoretical Chi-Square value at 6 degrees of freedom with a 5% significance level, which is 12.59. Thus, we reject the null hypothesis of no correlation between the random individual specific effects and the explanatory variables of the model. The estimator of the GLS with composite errors model is biased and non-convergent. However, the within estimator is unbiased and convergent. This estimator is none other than that of the **model with individual fixed effects**.

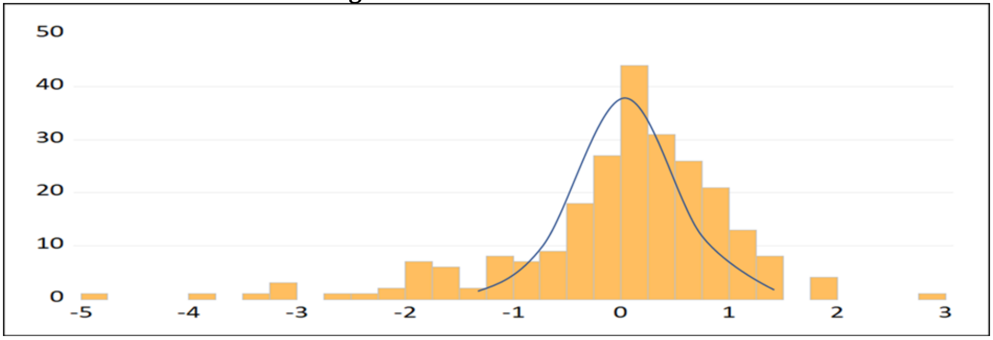
For the tests on the residuals of the fixed effects model, the Jarque Bera test yielded the following result:

Table 4: Results of the Jarque-Bera normality test

	the statistic Calculate	**The value Critiqued**	**p-val**	**conclusion**
$\boldsymbol{Modele\_\ln}\ (\boldsymbol{g_A})$	$JB = 189{,}25 \gg$	$\chi_2^2 = 5{,}99$	0.00000	$H_0 Rejet$

Source: Authors, RSudio (appendix 3 Fig. 15)

Fig. 8: Distribution of residuals



Source: Authors, RSudio (appendix 3 Fig. 15)

According to the result described above, it is observed that the residuals of both models do not follow a normal distribution (see Table 4 and Fig. 8) :
Similarly, the Breusch-Pagan test for heteroskedasticity yields the following result :

Table 5: The results of the homoscedasticity test

	the statistic Calculate	**The value Critiqued**	**p-val**	**conclusion**
$Modele\_\ln\ (g_A)$	$BP = 9{,}46 \gg$	$F(6; 1047) = 3{,}67$	0.1491	$H_0 Rejet$

Source: Authors, RSudio (appendix 3 Fig. 16)

According to the results in **Error! Reference source not found.**, the null hypothesis (H0) is rejected since the calculated statistic BP=9.46 is strictly greater than the theoretical Fisher F(6; 1047)=3.67: indicating heteroskedasticity.

Table 6: The results of the autocorrelation test (intra-individual correlation)

	the statistic Calculate	**The value Critiqued**	**p-val**	**conclusion**
$modéle\_\ln\ (g_A)$	$BG = 0{,}0046 \ll$	$F(6; 1047) = 3{,}67$	0.9455	$H_0 Rejet$

Source: Authors, RSudio (appendix 3 Fig. 17)

According to the results in Table 6, the null hypothesis (H0) is rejected since the calculated statistic BG=0.0046 is strictly lower than the theoretical Fisher F(6; 1047)=3.67: indicating the errors are not autocorrelated.
We apply the Pesaran test (CD) on the model dataset and obtain the results described in the following table :

Table 7: The results of the autocorrelation test (intra-individual correlation)

	the statistic Calculate	**The value Critiqued**	**p-val**	**conclusion**
modéle_ln (g_A)	$CD = 3{,}69 \gg$	$t_{c(5\%)} = 1{,}96$	0.0002162	$H_0 Rejet$

Source: Authors, RSudio (appendix 3 Fig. 18)

According to the results in **Error! Reference source not found.**, we reject the null hypothesis (H0) since the calculated statistic CD=3.69 is significantly greater than the critical t-value $t_{c(5\%)} = 1{,}96$. This indicates individual error dependence in the model.

Finally, we observe that all assumptions are violated (except for within-individual correlation). To address the issues of heteroscedasticity and inter-individual and within-individual correlation, we resort to estimating the fixed-effects model using the Generalized Least Squares (GLS) method. The abnormality of errors is automatically corrected during the correction of other assumptions by GLS.

Results and Interpretation

The results of the estimated model are presented in **Error! Reference source not found.** Several insights can be drawn from these results. Firstly, the estimation using GLS produces overall comparable and consistent results with the literature. Indeed, the fraction of the population engaged in R&D (α) has a positive and significant impact on the total factor productivity. The estimated coefficient of (α) is substantially greater than 1/2. The associated elasticity is $\beta_2 = expo\,(-0.321) = 0.72$. This indicates that a one percentage point increase in the proportion of researchers in R&D in the active population increases g_A in the medium term by approximately 0.72 percentage points. These coefficients are close to those estimated by (Aghion & Howitt, 2005). This strong significant relationship is explained by the efforts made by most Arab countries in the field of R&D; over the past two decades, public spending on R&D in Arab states has seen a considerable increase, averaging $5 billion in 2000 to $15 billion in 2017 (see Fig. 9).

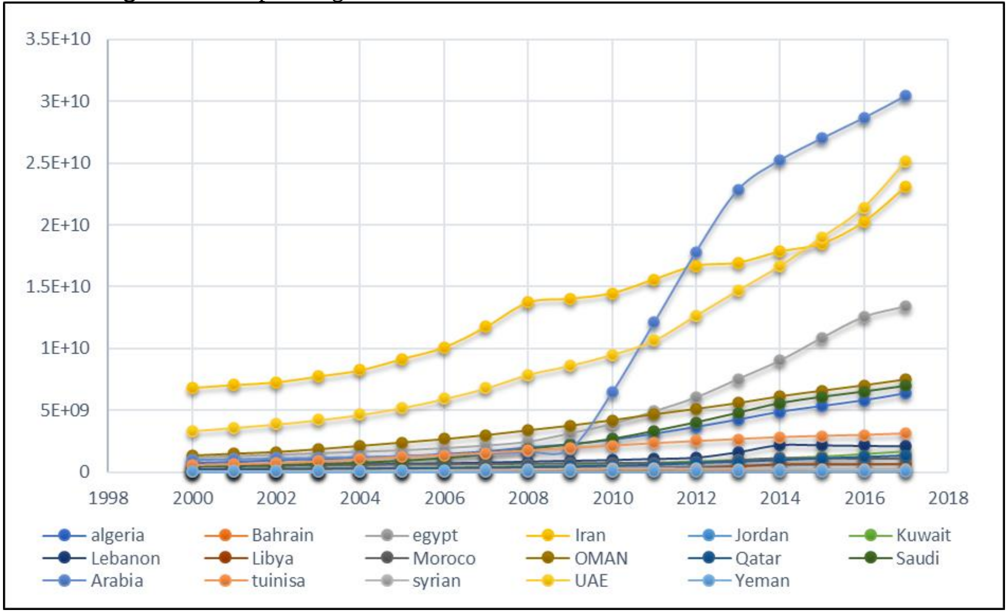
Table 8: Result of model estimation by GLS

	$ln(\chi_{t,i})$	$ln(\alpha_{i,t})$	$ln(L_{i,t})$	$EG_{i,t}$	$QR_{i,t}$	$ED_{i,t}$	$cost$
Coefficients (t statistic)	0,505 (0,73)	-0,321 (-2,05)*	-0,332 (-1,44)	0,096 (0,36)	0,33 (1,21)	0,035 (0,10)	0,34 (0,222)

Source: Authors, RSudio (appendix 3 Fig. 19)

It is widely accepted today that productivity in terms of scientific research, measured by the number of scientific articles, is closely linked to notable growth in Total Factor Productivity (TFP). According to UNESCO data (Fig. 10), Arab countries have experienced significant growth in the publication of scientific articles over the past decade, particularly Saudi Arabia, Egypt, Tunisia, and Qatar, which positively reflects on scientific productivity in the Arab world. However, these encouraging figures unfortunately mask a less favorable reality, contrary to the UNESCO report on science in these countries. The distribution of these figures at the sectoral level shows that the sectors considered most important in studies have very few scientific outputs. Even if some of them have fortunately been successful, they owe their success to clear external cooperation, which explains the insignificance of the coefficient relative to scientific productivity at traditional confidence levels (the statistic $t = -0.61 < tc(1\%) = 2.58$; $tc(5\%) = 1.96$; $tc(10\%) = 1.64$). This result confirms the necessity for certain Arab countries to find the right balance aiming for a qualitative and quantitative increase in article publications to improve their impact on g_A.

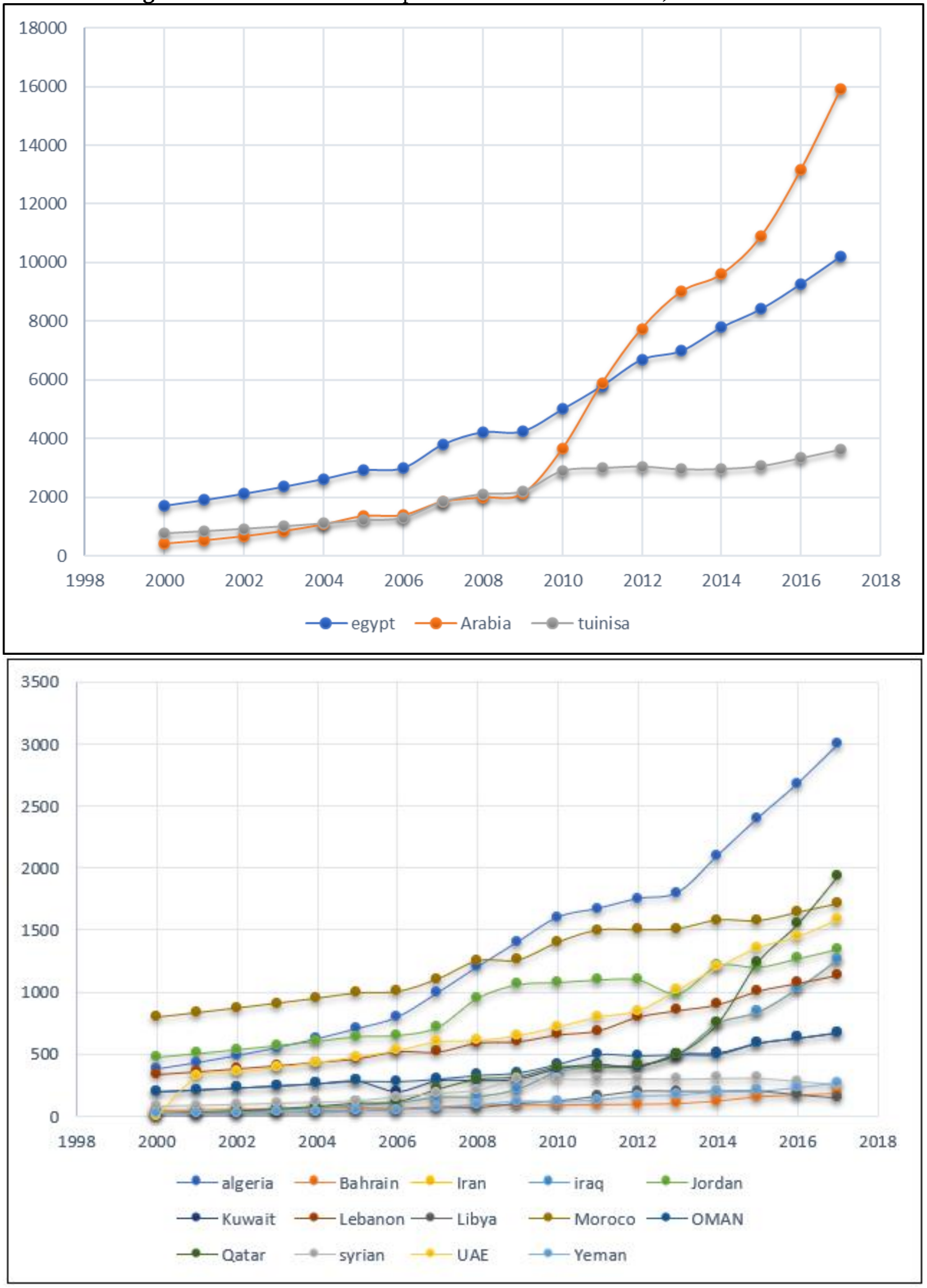
Fig. 9: Total spending on R&D in the Arab world between 2000 and 2017



Source: World Bank World Development Indicators

The general underinvestment in research, the lack of correlation between DIRD and R&D (GDP %), the significant weakness in private funding, the shortage of researchers in host institutions, and the high emigration of graduates all work against this governance and clearly demonstrate its weakness in terms of efficiency and organization. The institutional coefficients are non-significant at traditional confidence levels (the statistic $t = -0.61 < tc(1\%) = 2.58$; $tc(5\%) = 1.96$; $tc(10\%) = 1.64$).

Fig. 10: Trends in scientific publications in Arab States, 2000-2017



Source: UNESCO Institute for Statistics

Conclusion

Revisiting the initial question of which factors can explain technological progress (In other words, what causes growth in A?) in region Mena, we find that a sound set of primary institutions is essential. These institutions ensure a sound legal and regulatory framework for economic activities, fostering private initiative and promoting efficient and stable economic activity conditions.

All of this contributes in one way or another to accelerating technological progress, which is recognized as the main engine driving the increase in total factor productivity, or in other words, growth in A. Beyond the institutional dimension, the political dimension also plays an equally important role; with some public intervention to encourage research and development (Romer, 1990), increase human capital (Lucas, 1988), and improve and strengthen infrastructure (Romer, 1990), the state promotes and stimulates innovative activities that play a crucial role in increasing total factor productivity and thus economic growth.

Unfortunately, the state of technological progress in the MENA region is very dismal, as has been clearly confirmed by the econometric model :

- Institutional fragility is evident (non-significant institutional coefficients at traditional confidence levels $(t - statistic = -0.61 < critical\ t - values\ (1\%) = 2.58;\ (5\%) = 1.96;\ (10\%) = 1.64))$: legal system dependency and corruption not ensuring contract security, presence of corruption, complexity of administrative procedures, lack of transparency in economic information, unstable economic environment, etc.
- Quasi-phantasmagorical interventionist policies (the non-significance of the coefficient related to scientific productivity and that of (L) at traditional confidence levels $(t - statistic = -0.61 < critical\ t - values\ (1\%) = 2.58;\ (5\%) = 1.96;\ (10\%) = 1.64\ )$: share of public spending on research and development does not exceed 1% of GDP, lack of correlation between DIRD and R&D, Education spending that could make R&D sector workers more productive (thus increasing χ) is almost negligible, etc.

Much remains to be done in the MENA region to embark on a substantial project following the example of the United States, Germany, France, or Japan: building a research and innovation system based on the needs of economic and social development, increasing the budget dedicated to research, massive investment from the private sector in universities, strengthening and creating institutions, etc.

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Data Availability: All data are included in the content of the paper.

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References:

1. Acemoglu, Johnson, Robinson, & Yared. (2010). Income and Democracy. *American Economic Review, 98(3)*, 808-842.
2. African Development Bank. (2021). Information and Communication Technology Investments and Regional Integration Policies for Innovation and Economic Growth in North Africa. *AfDB Policy Research Paper.*
3. Aghion, & Howitt. (2005). *Handbook of economic growth*, 67-110.
4. Aghion, Blundell, Griffith, Howitt, & Prantl, S. (2009). The effects of entry on incumbent innovation and productivity. *The review of economics and statistics,91(1)*, 20-32.
5. Agnès Bénassy-Quéré, B. C.-F. (2017). *Politique économique,4 edition.* DE BOECK SUPERIEUR.
6. Asian Development Bank . (2017). Infrastructure Investments and Trade Liberalization as Key Drivers of Competitiveness and Innovation in Emerging Asian Economies. *ADB Economic Research Series.*
7. Asian Development Bank. (2019). Improving Institutional Quality and Industrial Policies for Sustainable Economic Growth in Southeast Asia: A Panel Data Analysis. *ADB Economic Working Paper Series*.
8. BanqueMondiale. (2008). *Pratique des affaires dans le monde 2008.* http://francais.doingbusiness.org/documents/fullreport/2008/DB_08_Full_Report_French.pdf.
9. Barro. (1990). Les dépenses publiques dans un modèle simple de croissance endogène. *Journal of political economy, 98(5, Part 2),*, S103-S125.
10. Barro, R. J. (2001). Human capital and growth. *American economic review, 91(2)*, 12-17.

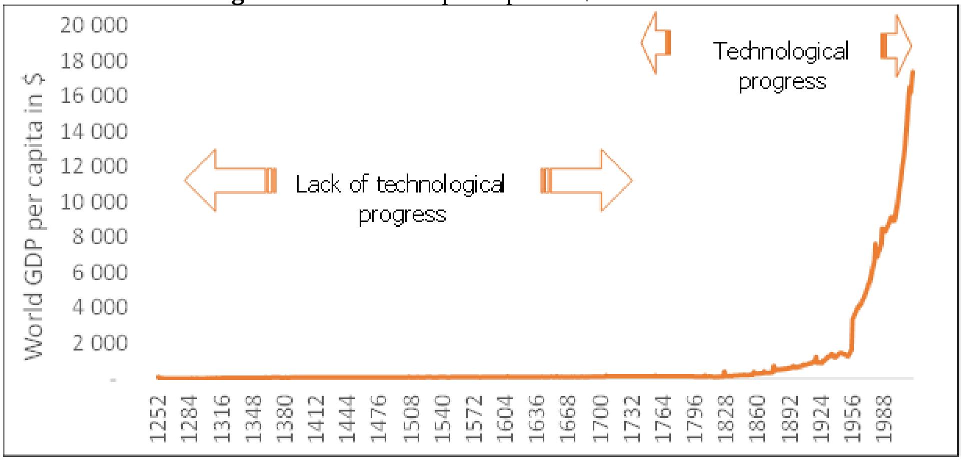
11. Blanchard, O., & Cohen, D. (2020). *Macroéconomie, 8e édition.* Paris: Pearson.
12. Coe, Helpmae, & Hoffmaister. (1997). North-South R&D Spillovers. *TheEconomic Journal,107 (440)*, 134-149.
13. European Commission. (2017). *Science, Research and Innovation Performance of the EU 2017.* European Union Publications.
14. Hall, & Jones. (1999). Why Do Some Countries Produce So Much More Output per Worker than Others? *The Quarterly Journal of Economics, 114(1)*, 83-116.
15. Inter-American Development Bank (BID). (Various Years). *Institutions, Policies, and Economic Performance in Latin America.* BID Research Publications.
16. International Monetary Fund . (2016). Financial Reforms, Macroeconomic Stability, and Foreign Direct Investment: Evidence from Latin America and the Caribbean. *IMF Working Paper*.
17. Kaufmann, D, KRAAY, A, & ZOIDO-LOBATON. (1999). Governance matters, Policy Research. *The World Bank, Working Paper Series 2196*.
18. Korea Institute for Industrial Economics and Trade (KIET). (Various Years). *Industrial Policies and Economic Growth in East Asia.* KIET Research Papers.
19. Lucas, R. (1988). On the Mechanisms of Economics Development. *Journal of Monetary Economics,22, 3, July*, p. 3-42.
20. Mankiw, Romer, & Weil. (1992). A Contribution to the Empirics of Economic Growth,. *Quarterly Journal of Economics, 107 (2)*, 407-437.
21. Mishkin, F. S. (2010). *Macroeconomics Policy and Practice.* Boston: PEARSON.
22. Montenegro, & Patrinos. (2014). Comparable estimates of returns to schooling around the world. *Policy Research Working Paper No. 7020, The World Bank.*
23. Nelson, R., & Phelps, E. S. (1966). Investment in Humans, Technological Diffusion and Economic Growth. *American Economic Review 56, 2 (May),*, 69-75.
24. Oliveira, Borini, Struss, Maisonneuve, & Saadi. (2009). The Policy Determinants of Investment in Tertiary Education. *OECD Journal: Economic Studies, 1,*, 111-148.
25. Organization for Economic Co-operation and Development. (2021). Structural Reforms for Long-Term Growth: Dynamic Panel Data Analysis. *OECD Economic Studies.*

26. Park, & Lippoldt. (2005). International licensing and the strengthening of intellectual property rights in developing countries during the 1990s. *OECD Economic Studies,n°40*, 7-48.
27. Patrinos, & Psacharopoulos. (2018). Returns to investment in education: A decennial review of the global literature. *Education Economics, 26(5)*, 445-458.
28. Porta, L., Silanes, Lopez, Shleifer, & Vishny. (1999). The quality of government. *Journal of Law, Economics and Organization*, 222-279.
29. Porta, Lopez-De-Silanes, & Shleifer. (2008). The Economic Consequences of Legal Origins. *Journal of Economic Literature, 46 (2)*, 285–332.
30. Rivera-Batiz, & RomerI. (1991). Economic Integration and Endogenous Growth. *The Quarterly Journal of Economics, 106 (2)*, 531-555.
31. RODRIK, D. R. (2005). *Economics of Transition, The European Bank for Reconstruction and Development, 13 (3)*, 533-564.
32. Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy*, pp. S71-S102 (32 pages).
33. Senhadji. (2000). Sources of Economic Growth: An Extensive Growth Accounting Exercise. *International Monetary Fund Staff Papers, 47 (1)*, 129-157.
34. Senhadji. (2000). Sources of Economic Growth: An Extensive Growth Accounting Exercise, . *International Monetary Fund Staff Papers, 47 (1),*, 129-157.
35. Sianesi, & Reenen, V. (2002). The returns to education: a review of the empirical macro-economic literature.
36. SOLOW. (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics, 39 (3)*, 312-320.
37. Solow, R. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*.
38. Subramanian, & Rodrik. (2003, 2003). La primauté des institutions (ce que cela veut dire et ce que cela ne veut pas dire). *Finances & Développement*, 31-34.
39. Word Bank. (s.d.). *Worldwide Governance Indicators*. Récupéré sur The World Bank: https://www.worldbank.org/en/publication/worldwide-governance-indicators
40. World Bank. (2018). *Accelerating Poverty Reduction in Africa: In Five Charts.* World Bank Group Publications.
41. Young. (1991). Learning by doing and the dynamics effects of International trade,. *Quarterly Journal of Economics*, *106 (2),*, 369-405.

Appendix

Appendix 1: The evolution of GDP per capita from the dawn of the Christian era to the present

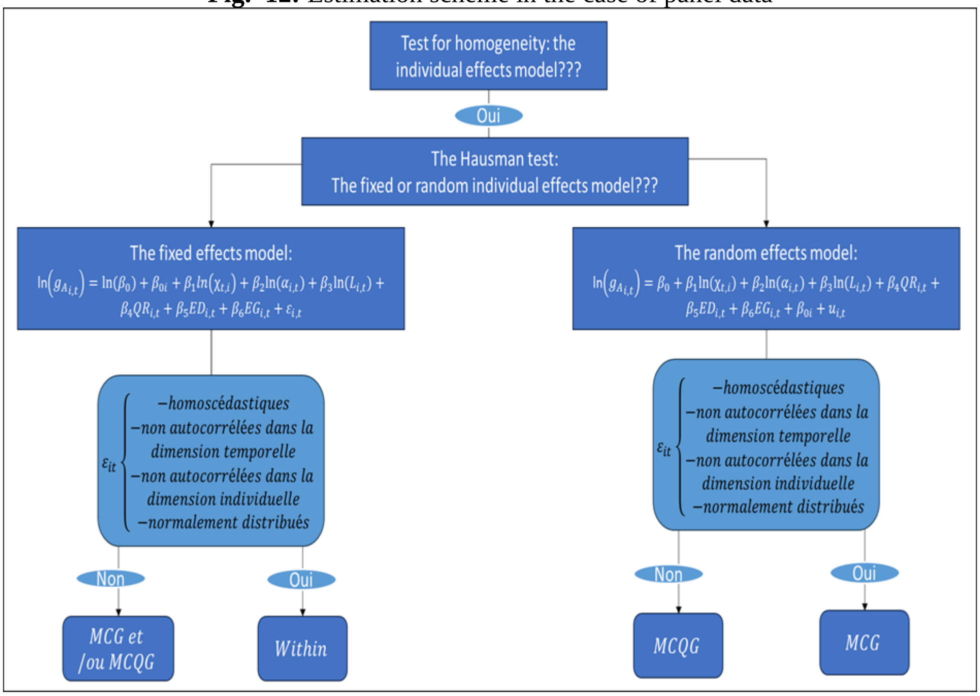
Fig. 11: World GDP per capita in $ and innovation



Source: *Maddison, Angus. Historical statistics, population and per capita GDP levels,* 1–2006. *www .ggdc.net/maddison/*

Appendix 2: The process used in panel econometrics to determine the estimation method

Fig. 12: Estimation scheme in the case of panel data



Appendix 3 : software output

Fig. 13 : The results of Honda's specification tests

```
> library("zoo")
> library("lmtest")
> library("collapse")
> library("plm")
> library("readxl")
> library(readxl)
> modéle_finale <- read_excel("D:/livre Macro/excelle/modéle finale.xlsx",
+     sheet = "Feuil2")
New names:
• `` -> `...11`
> View(modéle_finale)
> pdata=pdata.frame(modéle_finale,index=c("i","t"))
> RF=plm(ln_ga~ln_alpha+ln_pro+ln_L+EG_+QR_+ED_,data=pdata,model1="within")
> plmtest(RF,effect="individual",type="honda")

        Lagrange Multiplier Test - (Honda)

data:  ln_ga ~ ln_alpha + ln_pro + ln_L + EG_ + QR_ + ED_
normal = 7.2074, p-value = 2.851e-13
alternative hypothesis: significant effects
```

Fig. 14: Specification test by Hausman

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	12.646153	6	0.0490

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
LN_L_	-0.938135	0.299597	0.178389	0.0034
LN_PRO_	0.208033	-0.071049	0.007923	0.0017
LN_ALPHA_	-0.372695	-0.383380	0.017422	0.9355
EG_	0.124408	0.087871	0.028102	0.8275
ED_	0.018903	-0.204761	0.042739	0.2793
QR_	0.199233	-0.015496	0.054016	0.3555

Fig. 15: Jarque Bera test on Eviews

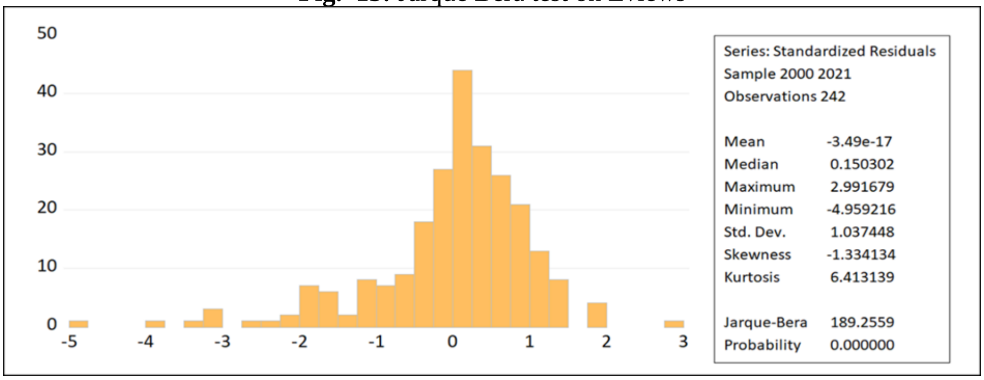


Fig. 16: Autocorrelation test (intra-individual correlation)

```
> library("dplyr")
> pdata=pdata.frame(modéle_finale,index=c("i","t"))
> RF=plm(ln_ga~ln_alpha+ln_pro+ln_L+EG_+QR_+ED_,data=pdata,model1="within")
> pbgtest(RF,order=1)

	Breusch-Godfrey/Wooldridge test for serial correlation in panel models

data:  ln_ga ~ ln_alpha + ln_pro + ln_L + EG_ + QR_ + ED_
chisq = 0.0046757, df = 1, p-value = 0.9455
alternative hypothesis: serial correlation in idiosyncratic errors
```

Fig. 17 : Breusch-Pagan homoscedasticity test

```
> library("zoo")
> library("lmtest")
> library("collapse")
> library("plm")
> library("readxl")
> library(readxl)
> modéle_finale <- read_excel("D:/livre Macro/excelle/modéle finale.xlsx",
+     sheet = "Feuil2")
New names:
• `` -> `...11`
> View(modéle_finale)
> pdata=pdata.frame(modéle_finale,index=c("i","t"))
> bptest(ln_ga~ln_alpha+ln_pro+ln_L+EG_+QR_+ED_,data=pdata,studentize = F)

	Breusch-Pagan test

data:  ln_ga ~ ln_alpha + ln_pro + ln_L + EG_ + QR_ + ED_
BP = 9.4643, df = 6, p-value = 0.1491
```

Fig. 18 : Inter-individual correlation test

```
> pdata=pdata.frame(modéle_finale,index=c("i","t"))
> RF=plm(ln_ga~ln_alpha+ln_pro+ln_L+EG_+QR_+ED_,data=pdata,model1="within")
> pcdtest(RF,test="cd")

	Pesaran CD test for cross-sectional dependence in panels

data:  ln_ga ~ ln_alpha + ln_pro + ln_L + EG_ + QR_ + ED_
z = 3.6992, p-value = 0.0002162
alternative hypothesis: cross-sectional dependence
```

Fig. 19 : Regression model estimation results by OLS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LN_L_	-0.332191	0.229391	-1.448145	0.1490
LN_PRO_	0.055460	0.075144	0.738055	0.4613
LN_ALPHA_	-0.321730	0.156381	-2.057356	0.0408
EG_	0.096021	0.265680	0.361416	0.7181
ED_	0.035058	0.331508	0.105752	0.9159
QR_	0.334367	0.276159	1.210775	0.2273
C	0.349481	1.571394	0.222402	0.8242
Effects Specification				
Cross-section fixed (dummy variables)				
Weighted Statistics				
R-squared	0.798213	Mean dependent var		-5.101206
Adjusted R-squared	0.777942	S.D. dependent var		7.400509
S.E. of regression	1.042749	Sum squared resid		238.1241
F-statistic	39.37740	Durbin-Watson stat		1.638546
Prob(F-statistic)	0.000000			
Unweighted Statistics				
R-squared	0.373727	Mean dependent var		-2.881509
Sum squared resid	262.2560	Durbin-Watson stat		1.529618