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Supporting economic growth through innovation: How does human capital influence the rate of growth?

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Abstract

Using VAR modeling techniques and Granger causality, this research examines the impact of innovation and human capital on economic growth in the context of the Tunisian economy during the period 1970/2015. The study found a correlation between human capital and economic growth on the one hand and innovation and completion rate of primary school on the other. Indeed, confirmed to the theory of endogenous growth based on innovation, knowledge promotes growth.

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1. Introduction

The objective of this work is to study, through econometric tools, the empirical validity of the theoretical hypothesis that knowledge has a central role in the process of growth. Since the basic models of endogenous growth based on innovation, knowledge can be produced and accumulated in a specific sector. These models distinguish two different perceptions of knowledge: technology (knowledge not incorporated or partially incorporated into equipment) and human capital (knowledge incorporated into men); whose mechanisms of production, accumulation and appropriation are quite different.

Indeed, our idea is to determine whether, in the case of Tunisia and over the period from 1970 to 2015, the production of knowledge and technology is a determining factor of economic growth. This idea was a very early concern of Guellec and Ralle (1993), Lucas (1988), Romer (1990), Barro (1991), Mankiw, Romer and Weil (1992) and Barro and Lee (1993).

We will use as a methodology the notion of autoregressive vector modeling (VAR) and the notion of Granger causality to analyze the relationship between output growth (represented by gross domestic product (GDP)), human capital represented both health (life expectancy at birth) and education (completion rate of primary school) and innovation (represented by patents and investment (GFCF))

2. Literature review

2.1. Theoretical literature

The neoclassical model of growth, in its basic version is due to Solow (1956), is considered a landmark in the history of growth theory. Thus, the new perspective of endogenous growth takes its starting point in a critique of the Solow model. The theory of endogenous growth highlights four factors that affect the rate of growth of an economy. Two of these factors lie in physical capital investment, namely, private investment and public investment in infrastructure. The other two reside in increasing knowledge, namely, technology and human capital.

Lucas (1988) proposed an endogenous growth model that relies on the accumulation of human capital. He considers that the individual educates himself by using his time and skills acquired. Thus, human capital is produced from it. The aggregate production function is deduced from the production function of each individual. It takes as input: the physical capital and the network of time spent on training. The returns of physical capital and human capital (labor) are constant. Improving the capacities of individuals causes collective effects. An employee will be more effective in a high-level work community than in a low human capital environment: it is a positive externality.

In the context of endogenous growth, Romer (1990) has made indigenous, the technical progress that is determined by the R & D activity of private companies motivated by profit-making. This model is based on the explanation of economic growth through the accumulation of knowledge and technological innovations to eliminate the hypothesis of diminishing returns of capital. It refers to learning by doing which, according to the work of Arrow (1962) and Sheshinski (1967), allows the accumulation of knowledge through the productive system of goods. The know-how acquired through experience and capitals are by-products of the productive system and constitute technological progress.

Mankiw, Romer, and Weil (1992) distinguish between the accumulation of human capital and the accumulation of physical capital. They consider that human capital encompasses a set of

capabilities, skills and knowledge of individual workers. This model has been proposed to incorporate in the Solow model, increasing the quality of the workforce to better reflect the course of economic growth. This is justified by the fact that we can increase human capital by investing in the education system, in the health system, and so on. This analysis starts from the thesis that the accumulation of physical capital is not enough (in the Solow model) to explain the disparity of economic performance.

2.2. Some empirical studies on African countries

Doudjidingao (2009) studied the socioeconomic trajectories of 33 countries to detect the reasons for their socioeconomic backwardness. He found that the impact of education is positive and significant for all the countries concerned. He concluded that the impact of education is conditioned by political, economic and social stability.

In order to correct the shortcomings identified in the literature on the usual human capital proxy, Boccanfuso and al (2009) constructed a composite human capital indicator (ACP) to integrate its qualitative aspects and decreasing returns. These indicators (proposed by Mincer (1974)) are then used to assess the contribution of human capital to the GDP level of 22 African countries; over the period 1970-2000. Using the methodology proposed by Islam (1995), the results show that taking into account the qualitative aspects and diminishing returns of human capital has made it possible to find its positive and significant impact on the economic growth process.

Altinok (2006), by introducing new indicators (constructed from international student achievement surveys that include 105 countries), has shown that education's contribution to growth is significant, both quantitatively and quantitatively. He concluded that the quality of education is an important factor of growth, and it remains, therefore, to determine the factors that can improve the quality of education and thus lead to the economic growth of countries.

Drawing on a sample of panel data relating to 83 countries and six five-year periods, Berthélemy and al (1997) shed new light on the role of human capital in growth. One of the main conclusions of the empirical tests in this work is that the accumulation of human capital can have no positive or even negative effect on growth in countries whose trade regime is closed. On the other hand, human capital has a positive influence on the growth of open economies. They concluded that the role of human capital in the growth process depends on the degree of openness of the economy.

3. Modeling and data description

3.1. Model

The mathematical equation estimated in this study, based on the Cobb-Douglas production function, is as follows:

$$Y=A_0 \exp(\lambda t)\prod_{i=1}^{p} X^{\alpha_i}, \quad (1)$$

Where Y is the output or value of income (GDP), A_0 is the level of technical progress at the base period, exp is the exponential function, λ is the parameter of technological progress (constant trend over time), t indicates the variable of time expressing the influence of technological progress, p is the number of factors of production, X is a matrix of factors of

production and α_i is the parameter of the factor of production (part of the variable X_i in the production).

Here, the technical progress ($A=A_0 \exp(\lambda t)$) increases both and also the efficiency of all factors, so it is neutral in the sense of Hicks. We then deduce the growth rate of production:

$$\frac{\dot{Y}}{Y} = \lambda + \sum_{i=1}^{p} \alpha_i \frac{\dot{X}}{X}, \quad (2)$$

Where, $\frac{\dot{Y}}{Y}$ is the growth rate of the economy and $\frac{\dot{X}}{X}$ is the growth rate of the factor X .

3.2. Data

The data used in this study come from the World Bank database. We use a sample of annual data from 1970 to 2015, concerning the Tunisian economy. Table 1 provides definitions of variables. The data are processed through EViews software in addition to Microsoft Excel spreadsheet.

Table 1: Variable definitions and data sources

Variables	Definitions	Sources
GDP	Gross Domestic Product (2010 constant US $)	World Bank,2018
PAT	Patent Applications, Residents	World Bank,2018
PSCR	Primary School Completion Rate, total (% of relevant age group)	World Bank,2018
GFCF	Gross Fixed Capital Formation (% of GDP)	World Bank,2018
LEB	Life Expectancy at Birth, total (by years)	World Bank,2018

4. Methodology and estimation results

4.1. Methodology

Our method is to use a five variable VAR model. Considering time series of Gross Domestic Product (GDP_t), Gross fixed capital formation ($GFCF_t$), life expectancy at birth (LEB_t), primary school completion rate ($PSCR_t$) and patent applications by residents (PAT_t), which are considered, all, as endogenous. By constructing a model of simultaneous structural equations to explain the potential interactions between study variables, the idea is to assume that each variable depends on its delayed values and the delayed values of the other four variables. The VAR model proposed by Sims (1980) has the advantage of not imposing a priori restriction on the variables.

The VAR model built as following:

$$\begin{cases} GDP_t = a_{10} + a_{11}GDP_{t-1} + ... + a_{1P}GDP_{t-P} + a_{21}EVN_{t-1} + ... + a_{2P}EVN_{t-P} + a_{31}PAT_{t-1} + ... + a_{3P}PAT_{t-P} + a_{41}PSCR_{t-1} + ... + a_{4P}PSCR_{t-P} + a_{51}GFCF_{t-1} + ... + a_{5P}GFCF_{t-P} + u_{1t} & (1) \\ LEB_t = b_{10} + b_{11}GDP_{t-1} + ... + b_{1P}GDP_{t-P} + b_{21}LEB_{t-1} + ... + b_{2P}LEB_{t-P} + b_{31}PAT_{t-1} + ... + b_{3P}PAT_{t-P} + b_{41}PSCR_{t-1} + ... + b_{4P}PSCR_{t-P} + a_{51}GFCF_{t-1} + ... + a_{5P}GFCF_{t-P} + u_{2t} & (2) \\ PAT_t = c_{10} + c_{11}GDP_{t-1} + ... + c_{1P}GDP_{t-P} + c_{21}LEB_{t-1} + ... + c_{2P}LEB_{t-P} + c_{31}PAT_{t-1} + ... + c_{3P}PAT_{t-P} + c_{41}PSCR_{t-1} + ... + c_{4P}PSCR_{t-P} + a_{51}GFCF_{t-1} + ... + a_{5P}GFCF_{t-P} + u_{3t} & (3) \\ PSCR_t = d_{10} + d_{11}GDP_{t-1} + ... + d_{1P}GDP_{t-P} + d_{21}LEB_{t-1} + ... + d_{2P}LEB_{t-P} + d_{31}PAT_{t-1} + ... + d_{3P}PAT_{t-P} + d_{41}PSCR_{t-1} + ... + d_{4P}PSCR_{t-P} + a_{51}GFCF_{t-1} + ... + a_{5P}GFCF_{t-P} + u_{4t} & (4) \\ GFCF_t = d_{10} + d_{11}GDP_{t-1} + ... + d_{1P}GDP_{t-P} + d_{21}LEB_{t-1} + ... + d_{2P}LEB_{t-P} + d_{31}PAT_{t-1} + ... + d_{3P}PAT_{t-P} + d_{41}PSCR_{t-1} + ... + d_{4P}PSCR_{t-P} + a_{51}GFCF_{t-1} + ... + a_{5P}GFCF_{t-P} + u_{5t} & (5) \end{cases}$$

These equations define a VAR modeling that expresses the current values of the variables as a function of a constant and the delayed values of these same variables. The number of delays (p) determines the order of the VAR model (p). A necessary condition for estimating such a

model is the stationary of the different variables. This implies that the random vector it has a constant expectation in time (E (Y_t) = m) and the covariance matrices between Y_t and Y_{t+h} depend only on the difference (h) and not on the time (h = 0.1,...), which implies for h = 0, cov (Y_t) does not change over time.

4.2. Estimation process

The procedure adopted in this methodology goes through the following steps. First, it is necessary to study the stationary of time series using Dickey and Fuller's (1979, 1981) test strategy. Then, if all the series are stationary, we proceed to autocorrelation studies. Finally, the last step is to estimate a VAR model with p delays and apply the Granger causality test.

4.2.1. Study of stationarity

We start by applying the Augmented Dickey Fuller test on the most general model with constant and time trend. The following table represents the results of this stationary study:

Table 2: ADF Test

Variables	Level of stationarity
TGDP	Stationary in level, at the threshold of 5%, with a constant.
TPAT	Stationary in level, at the threshold of 5%, without constant or trend.
TPSCR	Stationary in level, at the threshold of 5%, without constant or trend.
TGFCF	Stationary in level, at the threshold of 5%, without constant or trend.
TLEB	Stationary in level, at the threshold of 5%, without constant or trend.

4.2.2. The choice of the number of delays

The number of delays is chosen which minimizes the values of the two AIC and SIC information criteria. The variables of the models, after the determination of the order of integration, are: TGDP, TPAT, TPSCR, TGFCF and TLEB. We note that the delay number 5 minimizes the AIC, while p = 4 minimizes SC and two other criteria (LR and FBE). We therefore adopt the least constrained model VAR (4).

Table 3: Number of delays Tests

Lag	Log L	LR	FPE	AIC	SC	HQ
0	293.4575	NA	3.75e-13	-14.42288	-14.21177	-14.34655
1	410.0980	198.2887	3.88e-15	-19.00490	-17.73824	-18.54691
2	470.4934	87.57341	7.03e-16	-20.77467	-18.45246	-19.93503
3	536.4269	79.12019	1.07e-16	-22.82135	-19.44359	-21.60005
4	583.8583	45.05983*	4.92e-17*	-23.94291	-19.50961*	-22.33997
5	622.2480	26.87276	4.93e-17	-24.61240*	-19.12354	-22.62780*

*** indicates lag order selected by the criterion**

4.2.3. Autocorrelation tests for errors

The variables are chronological variables; we say that there is autocorrelation of order q between the residues if the error terms $u_t, u_{t-1}, \ldots, u_{t-q}$ are linked by a relation of the type $u_t = \rho u_{t-1} + \ldots + \rho u_{t-q} + \eta_t$. Using here, the Breusch-Godfrey Test to test

autocorrelations, this test has the advantage that the dependent variable may be among the delayed explanatory variables in the model (autoregressive model) and the autocorrelations may be greater than the order 1.The Eviews software offers the Breusch-Godfrey test. We note that all probabilities are greater than 0.05 (Table 4); therefore we accept the null hypothesis of no autocorrelation of errors.

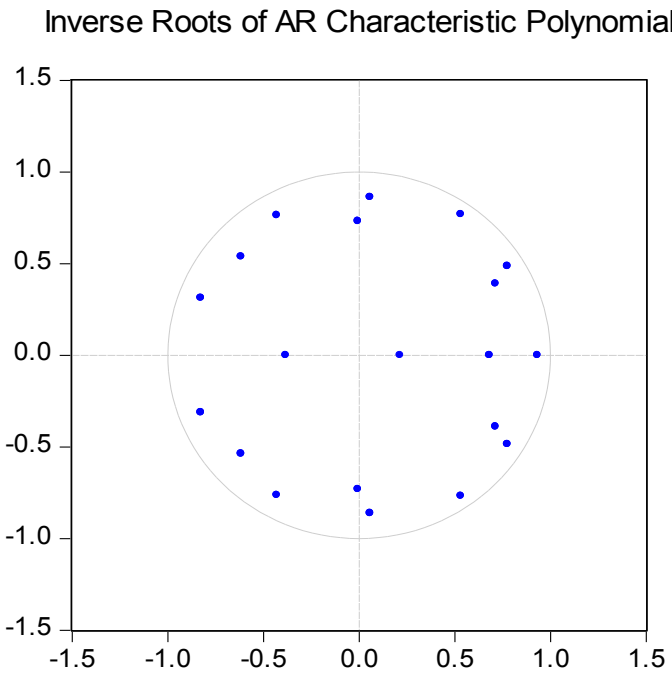
Table 4: Breusch-Godfrey Test

Lags	LM-Stat	Prob
1	25.33513	0.4437
2	19.04258	0.7951
3	38.21026	0.0641
4	23.68313	0.5377
5	25.76884	0.4200
6	16.32477	0.9048
7	34.96009	0.0889
8	31.57998	0.1705
9	22.02228	0.6345
10	27.60305	0.3264
11	22.78435	0.5902
12	32.53789	0.1430

4.2.4. Stationarity of the VAR

A VAR (p) process is stationary (stable) if all the roots of the characteristic polynomial are outside the unit circle. That is to say that all the Eigen6values of the matrix are in module less than 1. For that one draws the circle of the Eigen-values. We note that the two Eigen-values are within the unit circle (graph 1).

Graph 1: Eigen-values of the characteristic polynomial



4.3. Interpretation and discussion of the results

We estimate the VAR model (4) by the MCO equation method independently of each other. The result of the estimation is given in Table 5.

Table 5: Estimation of VAR

	TGDP	TLEB	TPAT	TPSCR	TGFCF
TGDP(-1)	-0.352512	-0.000206	-3.230201	-0.075735	-3.17E+08
	(0.18285)	(0.00068)	(6.16982)	(0.58331)	(2.0E+09)
	[-1.92784]	[-0.30437]	[-0.52355]	[-0.12984]	[-0.15802]
TGDP(-2)	0.189106	-0.000297	5.002467	-0.435318	1.35E+09
	(0.15927)	(0.00059)	(5.37395)	(0.50806)	(1.7E+09)
	[1.18736]	[-0.50328]	[0.93087]	[-0.85682]	[0.77334]
TGDP(-3)	0.116791	7.08E-07	13.71692	-0.134684	1.71E+09
	(0.13906)	(0.00052)	(4.69209)	(0.44360)	(1.5E+09)
	[0.83987]	[0.00137]	**[2.92342]**	[-0.30362]	[1.12145]
TGDP(-4)	0.070518	1.52E-05	-1.101266	-0.727824	1.70E+09
	(0.13338)	(0.00049)	(4.50047)	(0.42548)	(1.5E+09)
	[0.52870]	[0.03068]	[-0.24470]	[-1.71059]	[1.16243]
TLEB(-1)	-94.67496	3.202079	-1998.135	268.0117	-7.70E+11
	(51.0306)	(0.18914)	(1721.87)	(162.789)	(5.6E+11)
	[-1.85526]	**[16.9295]**	[-1.16044]	[1.64638]	[-1.37443]
TLEB(-2)	256.3278	-4.041990	6349.731	-797.4393	2.26E+12
	(141.986)	(0.52626)	(4790.87)	(452.937)	(1.6E+12)
	[1.80531]	[-7.68055]	[1.32538]	[-1.76060]	[1.45185]
TLEB(-3)	-243.5739	2.361232	-6535.747	843.4022	-2.20E+12
	(146.046)	(0.54131)	(4927.89)	(465.891)	(1.6E+12)
	[-1.66778]	**[4.36203]**	[-1.32628]	[1.81030]	[-1.37232]
TLEB(-4)	82.49320	-0.526752	2255.913	-313.9148	6.87E+11
	(54.9071)	(0.20351)	(1852.67)	(175.155)	(6.0E+11)
	[1.50241]	**[-2.58832]**	[1.21765]	[-1.79221]	[1.14117]
TPAT(-1)	0.008104	5.63E-06	-0.569924	0.023967	17868007
	(0.00483)	(1.8E-05)	(0.16312)	(0.01542)	(5.3E+07)
	[1.67642]	[0.31396]	**[-3.49392]**	[1.55413]	[0.33686]
TPAT(-2)	0.003329	9.86E-06	-0.391340	0.049784	67448322
	(0.00465)	(1.7E-05)	(0.15693)	(0.01484)	(5.1E+07)
	[0.71576]	[0.57200]	[**-2.49371**]	**[3.35550]**	[1.32173]
TPAT(-3)	-0.014171	-3.61E-06	-0.546919	0.016826	89411829
	(0.00517)	(1.9E-05)	(0.17453)	(0.01650)	(5.7E+07)
	[-2.73971]	[-0.18816]	**[-3.13371]**	[1.01972]	[1.57548]
TPAT(-4)	-0.009526	1.54E-05	-0.712776	0.049883	9305595.
	(0.00559)	(2.1E-05)	(0.18873)	(0.01784)	(6.1E+07)
	[-1.70308]	[0.74348]	**[-3.77662]**	[**2.79563**]	[0.15163]
TPSCR(-1)	0.092163	0.000136	0.302209	-0.537344	-5.90E+08
	(0.06131)	(0.00023)	(2.06862)	(0.19557)	(6.7E+08)
	[1.50331]	[0.59644]	[0.14609]	**[-2.74757]**	[-0.87679]
TPSCR(-2)	0.263847	-7.62E-05	4.186609	-0.971944	3.33E+08
	(0.07149)	(0.00026)	(2.41228)	(0.22806)	(7.8E+08)
	[**3.69058**]	[-0.28755]	[1.73554]	[-4.26178]	[0.42468]
TPSCR(-3)	0.275277	-0.000163	0.761994	-0.495278	1.06E+09
	(0.06387)	(0.00024)	(2.15504)	(0.20374)	(7.0E+08)
	[**4.31008**]	[-0.68940]	[0.35359]	**[-2.43092**]	[1.51495]
TPSCR(-4)	0.226631	-2.23E-05	0.458135	-0.238506	8.94E+08
	(0.05127)	(0.00019)	(1.72988)	(0.16355)	(5.6E+08)
	[**4.42052**]	[-0.11732]	[0.26484]	[-1.45835]	[1.58915]
TGFCF(-1)	2.03E-11	6.27E-14	7.08E-10	-1.48E-10	-0.074051
	(2.3E-11)	(8.4E-14)	(7.7E-10)	(7.2E-11)	(0.24923)
	[0.89334]	[0.74467]	[0.92394]	[-2.03564]	[-0.29712]
TGFCF(-2)	2.17E-11	-3.33E-14	3.74E-10	-9.55E-11	0.002144
	(2.1E-11)	(7.9E-14)	(7.2E-10)	(6.8E-11)	(0.23462)
	[1.01642]	[-0.42018]	[0.51805]	[-1.40056]	[0.00914]
TGFCF(-3)	2.72E-11	-3.40E-15	-3.63E-10	-8.08E-11	0.138371
	(1.7E-11)	(6.5E-14)	(5.9E-10)	(5.6E-11)	(0.19178)
	[1.55768]	[-0.05241]	[-0.61602]	[-1.44838]	[0.72151]
TGFCF(-4)	-5.20E-12	1.71E-14	9.48E-10	2.80E-11	-0.115633
	(1.7E-11)	(6.4E-14)	(5.8E-10)	(5.5E-11)	(0.18875)
	[-0.30254]	[0.26796]	[1.63329]	[0.51044]	[-0.61263]
C	0.009856	1.25E-05	-0.773821	0.140847	34800922
	(0.01429)	(5.3E-05)	(0.48228)	(0.04560)	(1.6E+08)
	[0.68956]	[0.23674]	[-1.60452]	**[3.08908**]	[0.22191]

Standard errors in ( ) & t-statistics in [ ]

While the third equation shows that the number of patents filed is positively correlated with GDP, the first equation indicates that the growth rate of GDP depends, negatively, on a patent growth rate delayed by 3 periods. The coefficient -0.014171 (Table 5) is statistically significant at the 5% level. This implies that a 10% increase in patent growth rate delayed by 3 years results in a 0.1% economic growth rate decrease. Also, the third equation shows that the number of patents filed negatively responds by itself.

This contradicts the predictions of endogenous growth theories based on innovation. Indeed, most endogenous growth models (Romer (1990), Aghion and Howitt (1992) and Grossman and Helpman (1991)) state that increased competition, or imitation rate, has a negative effect on productivity growth, by reducing the monopoly rent that rewards the cost of research and development. According to these models, a competition policy has adverse effects on economic growth. Thus, the establishment of industrial property protection, such as a patent, protects the monopoly rent and encourages innovation and hence promotes growth. However, contrary to the traditional view of economic analysis, which considers the patent as the most appropriate tool for guaranteeing protection, in exchange for the dissemination of information, Anton and Yao (2004), Kultti and al (2005), Boldrin and Levine (2008), Henry and Ponce (2011) and Henry and Ruiz-Aliseda (2016)) underline the patent's preference for secrecy by companies. Stiglitz (2008) argues that encouraging people to engage in research projects is not really reflected in the intellectual property regime. Some other economists, including Boldrin and Levine (2002, 2005, 2008, and 2011), Henry and Ponce (2011) and Picron (2017), go even further in criticizing the protection of intellectual property rights and propose the removal of such rights by promoting a world without patents.

In practical terms and in the context of our study, this negative effect can be explained by a specific point in the Tunisian economy. In fact, the climate of innovation in Tunisia is hampered by weaknesses in the key elements of knowledge. This weakness of the national research system and national inventors is essentially due to the virtual absence of the private sector in the sphere of R&D. In 2000, only 9% of R&D expenditure came from private funds, while the rest came from public sources (91%). Also, the expenditure ratio to R&D / GDP represents less than 1% until 2004, which does not favor the technological modernization and, therefore, the obtaining of the patents. The analysis of patent filings by origin shows that the share of patents held by residents is low, averaging 18.79% over the period 1990 - 2010. This problem is all the more serious as some foreign companies have the status of residents in Tunisia.

This weakness of the national research system and national innovators is also marked by a study by Hammami and Hammami (1999). By comparing a set of Mediterranean countries and European countries over the period 1996-2005, this study showed that Tunisia files the least number of patents: 10 patents only against 42464, 19334 and 3651 filed respectively by France, Italy and Spain and 26.31 and 91 patents filed respectively by Jordan, Morocco and Egypt.

This weakness persists for a long time, despite the strategy adopted by the Tunisian authority in favor of a sector of scientific and technological research that has undergone a remarkable development during the last 30 years. This strategy has been manifested in the introduction of structural reforms and the taking of a series of measures aimed at promoting this sector:

The creation in 1978 of the Ministry of Higher Education and Scientific Research (before the Ministry of Higher Education) marked a turning point in the construction of the system of scientific research in Tunisia. During the period 1978 -1990, the public authorities through this ministry, were interested in the research sector by:

- ✓ Creation of the Scientific and Technical Research Council in 1982.
- ✓ Establishment of the National Institute of Standardization and Industrial Property (INNORPI), by Law No. 82-66 of August 6, 1982, which is responsible for the protection of industrial property in Tunisia.
- ✓ Creation of the National Institute for Scientific and Technical Research (INRST) in 1983.
- ✓ Creation of a special fund for the financing of research: the Fund for Scientific Research and Mastery of Technology (FORESMAT) in 1984.
- ✓ Development of national research programs in 1985.
- ✓ Creation of the National Foundation for Scientific Research in 1889.

Also, we notice the increased place of research policy in the Tunisian state, through the orientations of the V Plan in this area:

- ✓ Promote research on national development priorities.
- ✓ Establish and regulate coordination between the different ministries involved in research and development and technology.
- ✓ Encourage cooperation between higher education institutions and research centers on the one hand and the productive sector on the other.

The period after 1990 is marked by the establishment of an action program for scientific research, which has resulted in the creation of various institutions such as:

- ✓ The State Secretariat for Scientific Research and Technology (SERST) in 1991. It is attached directly to the first ministry to play a maestro and ensure effective coordination between the different ministries responsible for research.
- ✓ The Higher Council for Scientific Research and Technology: was created by the law of orientation and regulated by the decree n ° 97-940 of May 19th, 1997. The objective of this council is to take care of the achievement of the objectives set, involving all the ministries concerned by the activities of scientific research.
- ✓ The National Committee for the Evaluation of Scientific Research Activities (CNEARS): was created under Article 5 of the 1996 Orientation Law and regulated by Decree No. 97-941 of 19 May 1997. The mission of CNEARS is to evaluate the scientific research activities carried out by public institutions and research laboratories as well as private research projects that receive state funding. This committee is attached to the Prime Ministry.
- ✓ The Technical Committee for Scientific Research and Technology: was created under Article 6 of the 1996 Orientation Law and regulated by Decree No. 97-941 of 19 May 1997. It is attached to the Minister scientific research, technology and skills development. This committee brings together representatives of the various ministries involved in research and development and has the mission of monitoring the execution of research projects and ensuring their funding.

Thanks to the aforementioned institutional reforms, the National Research System (SNR) has undergone a profound restructuring. Thus, the creation of laboratories and research units at the level of Public Research Establishments (EPR), higher education and research institutions and public health establishments (EPS) are the result of such a restructuring.

Most of the public power intervention in the national R&D system has focused on promoting innovation and technological development, notably through support for businesses:

- ✓ The establishment of the Federated Research Programs (FRP): their objectives are the organization of research and development activities, through the mobilization of

human skills and the foundation of synergies between research and development organizations and their partners' socioeconomic sectors, public or private.

- ✓ The establishment of a National Program for Research and Innovation (PNRI): its objective is to develop the potential of human skills and technological resources to develop applied research and consolidate cooperation between the fabric industry and the research sector to meet the technological innovation needs of Tunisian companies.
- ✓ The granting of an investment premium in research and development (PIRD): its objective is to encourage companies to invest in technological innovation.
- ✓ The establishment of a program to promote research results (VRR): it aims to encourage companies to invest more in the context of national research priorities. Funding for VRR projects depends on the degree of project relevance and its integration into national research priorities.

The introduction of structural reforms at the level of the sector of scientific research and technology is reflected in a large change in the budget allocations allocated to research and development. These come mainly from the state budget, companies and resources from international cooperation.

Table 6 shows that the budgetary expenditure allocated to the R&D sector increased by more than 1028% during the period 1992-2009. This development has been fairly rapid since 2000. Given that over the whole period more than 80% of the total expenditure was financed by the government and most of the funding was intended to subsidize research mainly in public centers, to train and mobilize technical expertise and link the research system to the productive sphere in order to increase the national knowledge base. The equivalent figures were 43% in OECD countries, 36% for tigers and 35% for CEECs.

For the purpose of national comparison, the expenditure ratio to R&D/GDP is determined, which rose from 0.43% in 1992 to 1% in 2004 and 1.25% in 2009, with a slight decrease in 1996 which increased in 1997 to stabilize over the next two years and then recovered. It is clear that one of the essential characteristics of the Tunisian research sector is its weakness, since the R&D/GDP expenditure ratio represents less than 1% (until 2004), which does not favor technological modernization. However, we note that Tunisia has become fully aware of the importance of the positive impact of research on growth and development, which appears very clearly from the evolution of the share of investment in R&D in GDP, which jumped 1% from 2004 and reached 1.25 in 2009.

Table 6: Evolution of Budgetary Expenditures Allocated to the Scientific and Technological Research Sector: 1992 – 2009

(In Millions of Dinars)

	1992	**2004**	**2009**
Expenditure In R& D	57,5	350	649
DR&D/GDP in %	0,43	1%	1,25

Source: MESRST (31 July 2010)

According to the Ministry of Higher Education and Scientific Research, the human capital of the research sector is made up of researchers and technicians from public research institutions, who is assigned full-time to carry out research activities and teacher researchers from higher education institutions who contribute, in addition to their teaching activity, to the research programs implemented by laboratories and research units.

The development of the national research system requires, in addition to the mobilization of internal human and material resources, the strengthening of cooperation links with the rest of the world, particularly with the most technologically advanced countries. This is why Tunisia has given importance to international cooperation in research and development. The objectives assigned to scientific cooperation, concern:

- ✓ Strengthening the upgrading of the national research system at all levels (structures, organization, working methods,
- ✓ The development of the human resources which constitute the main factor of consolidation of the national system of research,
- ✓ The development of a strategic partnership with foreign operators with high technological qualifications,
- ✓ The maximum attraction of external financing in favor of the national research system in order to lighten the burden borne by the state budget.

Our study also shows that patents positively affect the completion rate of primary school. In addition, the latter (at t-2, t-3 and t-4) has a positive effect on today's growth rate. In addition, we find that patents cause in the Granger sense the completion rate of primary school {prob = 0.025 (Table 7)}; the latter in turn Granger causes {prob = 0.0045 (Table 7)} the growth rate of GDP. The results also show a statistically significant positive effect of life expectancy at birth on it. Thus, confirmed to the predictions of the endogenous growth theory, the human capital plays a determining role in the process of economic growth {Mincer (1958), Schultz (1963), Becker (1964) and Lucas (1988)}.

Our results confirm and complement those of previous research {Mabrouki (2017)} which focused on the link between economic growth and development in the case of the Tunisian economy. These positive effects of human capital on growth reflect the fruits of Tunisia's special efforts to promote the education and health sectors. Indeed, since the dependence, the Tunisian government has allocated a significant percentage of the state budget for improving infrastructure, education and health. Thus, Tunisia was ranked by the 2010 Human Development Report as one of the top 10 performers in terms of non-monetary HDI and GDP between 1970 and 2010.

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Table 7: Granger Causality Test

Null Hypothesis:	F-Statistic	Prob.
TLEB does not Granger Cause TGDP	1.14644	0.3526
TGDP does not Granger Cause TLEB	0.62509	0.6480
TPAT does not Granger Cause TGDP	1.45468	0.2390
TGDP does not Granger Cause TPAT	2.15904	0.0962
TPSCR does not Granger Cause TGDP	4.64871	**0.0045**
TGDP does not Granger Cause TPSCR	0.54129	0.7065
TGFCF does not Granger Cause TGDP	0.95466	0.4456
TGDP does not Granger Cause TGFCF	0.07766	0.9886
TPAT does not Granger Cause TLEB	0.41944	0.7934
TLEB does not Granger Cause TPAT	2.57391	0.0564
TPSCR does not Granger Cause TLEB	0.55559	0.6964
TLEB does not Granger Cause TPSCR	0.43523	0.7821
TGFCF does not Granger Cause TLEB	0.59398	0.6695
TLEB does not Granger Cause TGFCF	1.75420	0.1625
TPSCR does not Granger Cause TPAT	0.55032	0.7001
TPAT does not Granger Cause TPSCR	3.21954	**0.0250**
TGFCF does not Granger Cause TPAT	0.06745	0.9913
TPAT does not Granger Cause TGFCF	0.16058	0.9567
TGFCF does not Granger Cause TPSCR	1.24498	0.3118
TPSCR does not Granger Cause TGFCF	1.00924	0.4173

4.4. Variance decomposition and impulse analysis

The purpose of this section is to do a residue analysis: variance decomposition and impulse analysis.

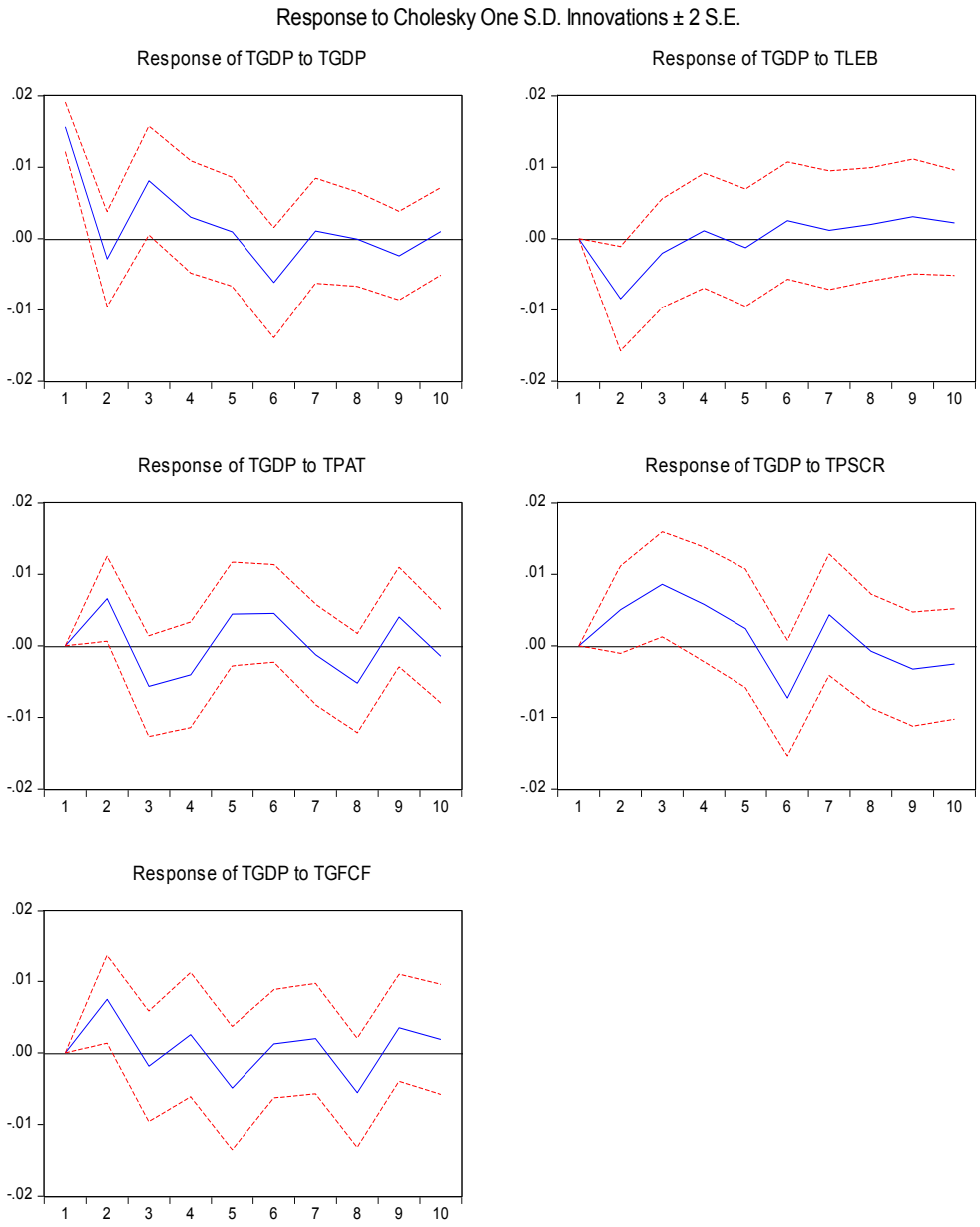
- ✓ **Impulse response analysis**

Since there is a dynamic structure in the VAR modeling, the objective of this analysis is to show the impact of a shock to a variable on the other variables of the system. In order to provide a graphical representation that is consistent with our study, the following graph shows how GDP responds to shock produced to other variables.

The shock on GDP has instantaneous repercussions on itself, which explains why the TGDP curve starts from a value well above zero. The consequences of this shock spread and disappear slowly from the eighth period.

Shocks on LEB, PAT, PSCR and GFCF have no instant influence on GDP. We note that the impact of shocks on PAT and GFCF takes a cyclical form. The magnitude of LEB and PSCR shocks is gradually diminishing.

Graph 2: Impulse response functions of the GDP response to positive shocks on LEB, PAT, PSCR and GFCF



We can complete this study based on the impulse response functions by an analysis of the variance decomposition of the forecast error. The interest is to know how to calculate the contribution of each innovation to the total variance of the forecast error.

- ✓ **Variance decomposition**

The following table shows the percentage contribution of the residues of each study variable to the variance of the forecast error of the variable under consideration. The variance of the prediction error of TGDP is due for 36.41% to its own innovations and for 10.12%, 17.4%, 22.2% and 13.9% of those of TLEB, TPAT, TPSCR and TGFCF respectively.

Table 8: Variance decomposition

Period	S.E.	TGDP	TLEB	TPAT	TPSCR	TGFCF
1	0.015659	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.021211	56.31412	15.80607	9.682525	5.685979	12.51131
3	0.025091	50.71826	11.95596	11.96820	15.86160	9.495979
4	0.026395	47.15617	10.98481	13.18104	19.15155	9.526432
5	0.027367	43.98658	10.43428	14.89373	18.59716	12.08824
6	0.029476	42.28793	9.731472	15.22167	22.15043	10.60850
7	0.029931	41.14413	9.588568	14.92942	23.59471	10.74318
8	0.030961	38.45408	9.379081	16.80222	22.10969	13.25494
9	0.031829	36.95073	9.818845	17.50878	21.96652	13.75514
10	0.032110	36.40905	10.12499	17.40491	22.20152	13.85954

5. Conclusion

This research examines the impact of innovation and human capital on economic growth in the context of the Tunisian economy during the period 1970-2015. Using the VAR and Granger causality modeling techniques, the study found a correlation between human capital (the completion rate of primary school) and economic growth, and the existence of a correlation between innovation and the completion rate of primary school. Indeed, confirmed to the theory of endogenous growth based on innovation, knowledge promotes growth.

However, it is essential to point out that the climate of innovation in Tunisia is hampered by weaknesses in the key elements of knowledge. Due to reasons for economic risks and the costs of innovation, some companies are forced to delay their innovation projects. The business environment can also be a barrier to innovation "some also reduce the attractiveness and feasibility of innovation compared to other business strategies: a financial sector unable to appreciate innovative projects; weak intellectual property protection that reduces the rewards of responsiveness; regulations that increase the risks and costs of marketing innovative products or processes, etc. "(OECD Report (1999)).This weakness of the national research system and national inventors is essentially due to the virtual absence of the private sector in the sphere of R&D. In 2000, only 9% of R&D expenditure came from private funds, while the rest came from public sources (91%). Also, the expenditure ratio to R&D / GDP represents less than 1% until 2004, which does not favor the technological modernization and, therefore, the obtaining of the patents.

To encourage innovation on the one hand and ensure the dissemination of knowledge on the other hand, the State imposes a legal framework on the patent holder through the system of protection of industrial property. This legal framework serves two purposes:

- ✓ On the one hand, it encourages companies to invest in research; the fact that the patent gives the inventor a monopoly right,
- ✓ On the other hand, it plays the role of a tool for the publication of knowledge, so that the innovator in exchange for the monopoly right conferred on him by obtaining the patent must publish his invention.

In order to promote innovation and stimulate investment in research and development, the Tunisian public authorities are asked to rethink the Tunisian patent system. A simple, fast, cooperative and accessible system must be established. We must take advantage of the experiences of developed countries such as France and Germany.

As J. Aubert (2005) points out, in a World Bank research paper, the climate of innovation in developing countries, such as Tunisia, is hampered by weaknesses in the key elements of knowledge. It focuses on three elements: education level, business environment, and information infrastructure.

- ✓ Education levels are low in developing countries, and this is a major impediment to the development and diffusion of innovation in these countries. In fact, a clear relationship can be established between educational needs and the different phases of industrialization.
- ✓ The business environment, linked to governance conditions, has a great influence on innovation performance. To judge the quality of a business environment, it is of paramount importance to go beyond the formal aspect of laws and to examine how these laws are applied in practice, taking into account the more or less informal governing relations between economic agents.
- ✓ Finally, there is the question of a lack of infrastructure. Infrastructure needs for innovation in developing countries are not limited to, telecommunications, roads and other transport infrastructure. Indeed, innovation systems in developing countries are poorly constructed and highly fragmented. On the business side, generally a large number of micro-enterprises operate in the informal economy.

In terms of knowledge, there is usually a limited research community, usually operating in an ivory tower, and a university system that is poorly connected to local realities, particularly market needs.

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