Technium Sustainability

Technium Sustainability
Vol. 4, pp 45-71 (2023)
ISSN: 2810-2991
www.techniumscience.com

Public Expenditure, Energy Consumption and Economic Growth in Tunisia During the Period of COVID-19: Comparative Study Between Cartographic Spatial Distribution Analysis and Empirical Validation

Abderraouf MTIRAOU[1]

Laboratory of MOFID-University of Sousse-Tunisia

Email 1: mtiraouiabderraouf@gmail.com

Hassan OBEID[2]

Email 2: hassan.obeid@gmail.com

Abstract:

The objective of this article is to study the relationship between public expenditure, energy consumption and economic growth during the period of COVID-19 while highlighting a comparative study between the cartographic spatial distribution analysis and empirical validation. In this framework, we tried to present in a spatial distribution mapping for the case of Tunisia while showing the allocation and distribution of public expenditure between several necessary headings such as basic social items and energy consumption during the period from 1990 to 2018.

Keywords: Public Expenditure, Energy Consumption, Economic Growth.

JEL Classification : H_{53}, H_{75}, C_{22}, C_{33}

[1] **Abderraouf MTIRAOUI:** Corresponding Author is Doctor of Economics and Social Science of The University of Sousse- Tunisia. ***N°. Phone:*** *+216 97 957 697.*

[2] ***Hassan OBEID :*** Associate Professor, Ph.D - Head of Economic Department & Head of PGE Master Wealth Management at Paris School of Business**.** ***N°. Phone:*** *+336 26035601*

I. INTRODUCTION

The Equivalence theory [3] by David Ricardo analyzes the idea that taxation and public borrowing are equivalent forms of financing government spending. This theory is used as an argument against increasing government spending in an economy. For a given pattern of government spending, the method of financing that spending does not change aggregate demand according to the equivalence theory.

Incidentally, Wagner[4] postulates on several forms of public expenditure namely the extension of the functions of the states leads to an increase in public expenditure on administration and regulation of the economy, the development of the modern industrial society generates an increasing political pressure in favor of social progress and requires an increased consideration of social considerations in the conduct of industry, public expenditure grows more proportionally than the increase in national income and thus leads to a relative expansion of the public sector. Historically, Tunisia has always succeeded in providing quality electricity to both citizens and businesses.The country has almost achieved near universal access to electricity. According to the 2019 Doing Business report's "*Getting Electricity*" score, Tunisia is ranked 51st out of 190 countries, although its connection costs remain relatively high. In the energy sector and despite some progress made, several energy products remain heavily subsidized, including those considered socially sensitive as the LPG. The same is true for electricity and gas, particularly for certain user groups such as industry, and to a lesser extent for gasoline and diesel. Sanitation revenues come mainly from users. In 2015, they covered only 50% of costs[5]. The Tunisian Petroleum Activities Company is responsible for the upstream oil and gas sector. The Tunisian Society of Refining Industries is responsible for the production and import of refined hydrocarbon products. The National Agency for Energy Management, which is a non-administrative government agency, is responsible for the development and implementation of national energy efficiency policies and programs.

Our work is subdivided into five components namely the introduction, first, then the literature review, then the methodology and interpretations and finally conclusion

[3] *Ricardian equivalence theory was invented by the American economist Robert Barro in the 1970s and has subsequently become a standard topic in public finance and macroeconomic theory.*
[4] *The economist Adolph Wagner wrote a book on the budget of Austria in 1863, in which he used the term law to refer to the increase in public expenditure in Austria due to the development of its standard of living.*
[5] *https://openknowledge.worldbank.org/bitstream/handle/10986/33854/149126FR.pdf?sequence=12*

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Vol. 4, pp 45-71 (2023)
ISSN: 2810-2991
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II. ALITERATURE REVIEW

1- Theoretical level

The Keynesian school (1936)[6] became popular during the crisis of the 1930s. According to this school, public expenditure is a factor exogenous which can be used as a political instrument to promote economic growth. Keynesian thinking states that government spending can contribute positively to economic growth. Therefore, an increase in public consumption is likely to lead to an increase in employment, profitability and investment through multiplier effects on aggregate demand. As a result, government spending increases aggregate demand, which causes output to increase based on spending multipliers.

In addition, Musgrave's growth theory of public expenditure[7] showed that at low levels of income per capita, the demand for public services tends to be very low, because according to him, these revenues are spent on meeting basic needs and that when the per capita income begins to increase above these levels, the demand for services provided by the public sector such as health, education and transport begins to increase by forcing the government to increase spending on them.
Economic growth in Malawi brings about abetter standard of living of the people through provision of better infrastructure, health, housing, education services and improvement in agricultural productivity and food security[8].

The COVID-19 pandemic has had far-reaching impacts on economies worldwide, disrupting various sectors and challenging policymakers to navigate uncharted territory. Tunisia, like many other countries, experienced significant economic upheaval during this period. This literature review aims to provide an overview of existing research on the relationship between public expenditure, energy consumption, and economic growth in Tunisia during the COVID-19 pandemic.

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[6] *"A History of Post Keynesian Economics since 1936": Some Hard (And Not so Hard) Questions for the Future" "A History of Post Keynesian Economics since 1936": Some Hard (And Not so Hard) Questions for the Future.*
[7] *Richard Musgrave and Peggy Musgrave, Public Finance in Theory and Practice, McGraw Hill Higher Education, 1989 (1st ed. 1973)*
[8] *Loto, M.A. (2012). "Impact of Government Sectoral Expenditure on Economic Growth". Journal of Economics
and International Finance, Vol. 3(11), 646-652.*

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Vol. 4, pp 45-71 (2023)
ISSN: 2810-2991
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2- Empirical level

The theoretical debate above, there is a vast empirical literature aimed at analyzing the relationship between public expenditure and economic growth. Empirical studies on the relationship between public spending and economic growth in a sample of countries drawn only from the African continent have yielded mixed results. In this regard, Ashipala and Haimbodi (2003) showed that there are two long-term relationships between the level of economic activity measured by GDP and public and private investments in Namibia. Contrary to these results, those of a study by Mansouri (2003) showed that in Morocco public capital expenditure had a knock-on effect on private investment and on real economic growth. Using a time-series model based on ordinary least squares; Mansouri showed that public consumption spending crowds out private investment and slows economic growth through waste. Using a computable general equilibrium model, Dumont and Mesplé-Somps (2000) analyzed the impact of public infrastructure on the competitiveness and growth of the Senegalese economy. They found that increased government spending on infrastructure led to better business performance and economic growth. The long-term impact of public spending varies across countries: in a study using causality tests and based on annual data for the period 1970-2005, Chimobi (2009) found that there was no long-term relationship between public spending on health and education and national income in Niger.

Two relevant documents are specifically devoted to WAEMU countries as a case study (see Nubukpo, 2007, Ouattara, 2008). Nubukpo assessed the impact of government spending on growth from 1965 to 2000 using an error correction model. It showed that gross government expenditure did not have a significant impact on economic growth in most WAEMU countries. The conclusion of Ouattara's study is quite different, Based on the productivity and externality of public spending, he pointed out that public spending can have a positive impact on economic growth in countries of the UEMOA.

Fan and Rao (2003) have shown that the effects of different types of public expenditure on economic growth in different continents are mixed. In Africa, government spending on health and agriculture significantly affects economic growth. In Asia, investments in education, agriculture and defense have a strong impact on economic growth. However, in Latin America, all types of public investment, with the exception of health, contributed to economic growth.

Rehman and al. (2010) investigated the direction of causality between national income and government expenditure as well as various aspects of public expenditure in Pakistan for the period 1971-2006. The results of their study support the existence of Wagner's law in Pakistan. Asghar et al. (2011) point out that the resources allocated to the education and health sectors contribute to economic growth and that the government should adopt policies aimed at encouraging the private sector to invest more in education and health.

This study concludes that the government should allocate more resources to the social sectors to increase productivity. As can be seen, there has been a keen interest in research related to the relationship between government spending and economic growth. At the same time, however, there is no unanimity in how the composition and specificity of public spending affects a given country's growth rate. Indeed, the research results show a mixed picture depending on the calculation methods used, the structure of public expenditure and the countries or continents studied. Very little of this research has been devoted to the study of the impact of public expenditure on the economic growth rate in Tunisia.

3- The role of public expenditure in the process of economic growth :

a. *Public expenditure and economic growth*

Landau (1983) was the first to question the link between economic growth and the level of public expenditure. The debate is not that of the impact of increased state intervention on growth but that of the search for the factors of growth among which we wonder about public spending. Landau (1983) studies 104 countries in cross-section on data from Summers and Heston.

The econometric method used is the bottom-up stepwise method. The main explanatory variables which are then retained, whatever the period studied from 1961 to 1972 or from 1961 to 1976, are public consumption as a percentage of GDP, GDP per capita, total investment in education, energy consumption per head and dummy variables accounting for geoclimatic characteristics. The estimates show a significant negative coefficient between the level of public consumption and the per capita growth rate of GDP.

Landau (1986) continues this first investigation by broadening the field of explanatory variables on a sample exclusively made up of 65 developing countries. First, public expenditure is broken down into public consumption (other than education and defence), education and defense expenditure, transfers and public investment; are added variables of public resources, public deficit, foreign aid and public transfers from abroad.

All these variables are expressed as a share of GDP and as an average over the previous three years, while the exogenous variable is the growth rate of GDP per head, either as an annual average or over a period of 4 or 7 years. Second are added variables measuring international economic conditions, human and physical capital, production structure, political and historical factors, and demographic and geoclimatic factors.

b. Public expenditure during the COVID-19 pandemic

Public expenditure acts on these factors differently depending on their nature. So it disaggregates expenditure into current and capital expenditure as well as according to its economic nature (infrastructure, social sectors, economic services, etc.) and tests its effects coupled with variables such as population growth and private investment.

Public expenditure plays a crucial role in stimulating economic growth, especially during times of crisis. During the COVID-19 pandemic, governments have increased spending to provide support to affected sectors and individuals.

In Tunisia, the government implemented various fiscal policies to mitigate the economic impact of the pandemic, such as increasing healthcare spending and providing financial assistance to affected businesses. The literature suggests that well-targeted public expenditures can help stabilize the economy and promote recovery.

Barro (1989) modifies the Summers and Heston data, i.e. subtracts expenditure on education and defense from them, then adds as an explanatory variable the ratio of real public investment to GDP and thus constructs an econometric equation testing the link between the average annual growth rate of GDP per capita (between 1960 and 1985) the ratio of public consumption to GDP, public investment to GDP, variables accounting for the level of human capital (education rate), fertility of the population, political and social stability, level of development at the beginning of the period considered (1960) and distortion in relation to the proper functioning of the market.

These econometric tests are based on an endogenous growth model (Lucas (1988) Rebelo (1990)) whose objective is to find an explanation for the growth process other than the neoclassical theories of the 1950s and 1960s, one of the main conclusions of which is the convergence of economies (ie the tendency of poor countries to grow faster than rich countries), a hypothesis not verified by cross-sectional analyses.

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c. *Type of public expenditures: Effects*

The first type of expenditure, approximated in the empirical tests by public consumption, lowers the growth rate as well as the savings rate because they have no direct effect on the productivity of the private sector but assume that the rate of taxation increases. The second type of expenditure, approximated in the regressions by the ratio of public investment to GDP, has two effects on the growth rate: an increase in the tax rate, necessary for financing, lowers the growth rate while the increase in these public expenditures increase the productivity of capital which acts on growth. This second positive effect dominates when the state is small, while the first, negative effect dominates when the state is large. We find here the idea according to which an excessive increase in the State is detrimental to growth.

However, as Diamond (1989) points out, the effects of public spending on growth should be measured dynamically and on time series. In addition, all of these studies, except those of Landau, Diamond and Barro, measure effects, initially complex, using aggregate data. We can then understand why the results are not robust. Ram (1986) obtains really positive results while the others, either cannot conclude in a precise way, or obtain an overall negative impact..

III. GEOGRAPHIC INFORMATION SYSTEMS SOFTWARE

1. Spatial Analysis

Utilize Geographic Information Systems (GIS) software to perform spatial analysis. You can analyze the spatial distribution of public expenditure, energy consumption, and economic growth across different regions of Tunisia.

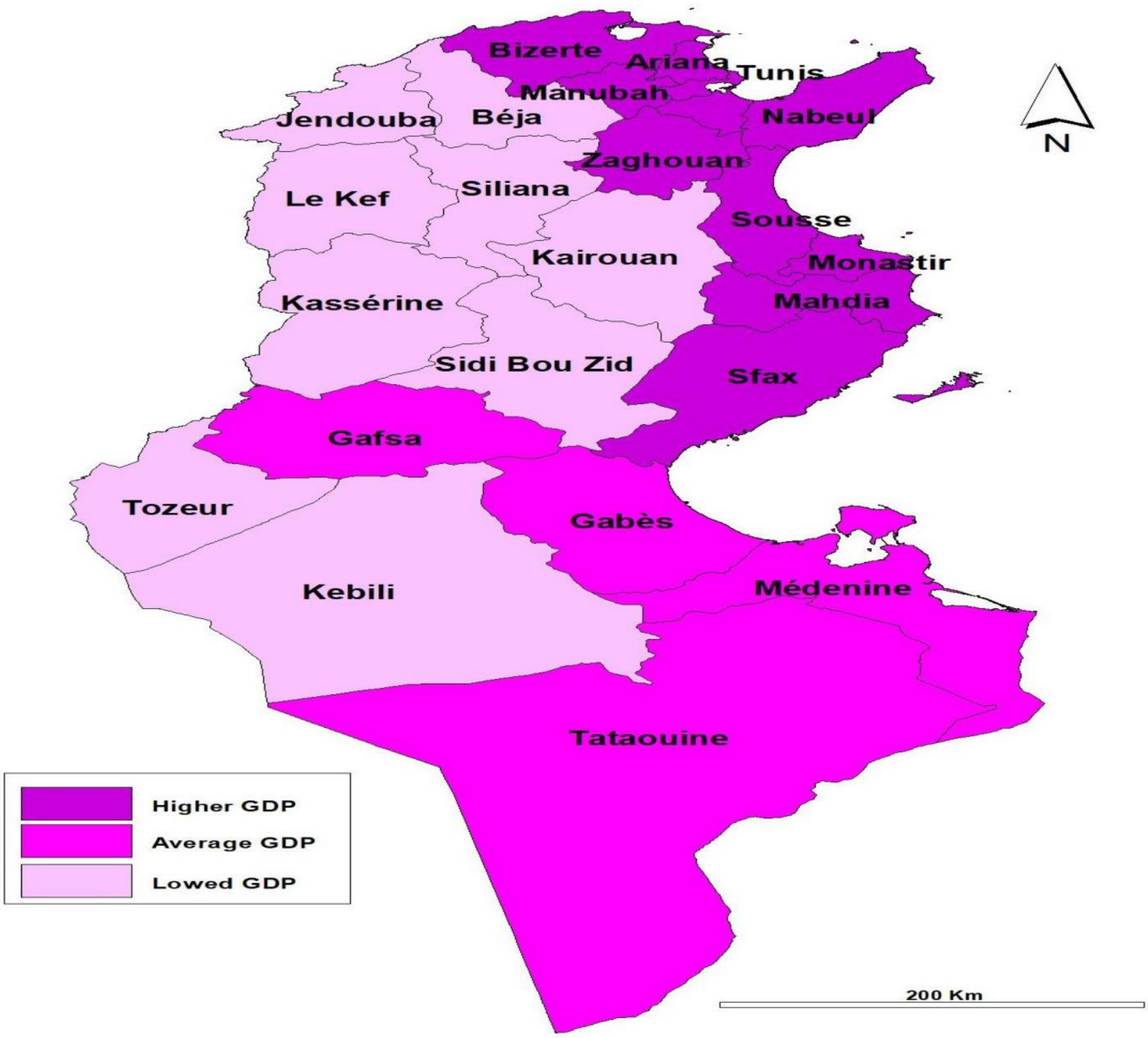
2. Statistical Analysis

Employ appropriate statistical techniques to analyze the relationships between the variables. You might use regression analysis to quantify the impact of changes in public expenditure and energy consumption on economic growth.

3. *Cartographic Visualization:*

Create maps and visualizations to communicate your findings. These could include choropleth maps to show regional variations, time series maps to demonstrate changes over time, and spatial patterns that emerge from your analysis.

Figure N°1: Distribution according to GDP per capita



Source: *software output*

Figure N°2 : Distribution according to energy consumption in Tunisia

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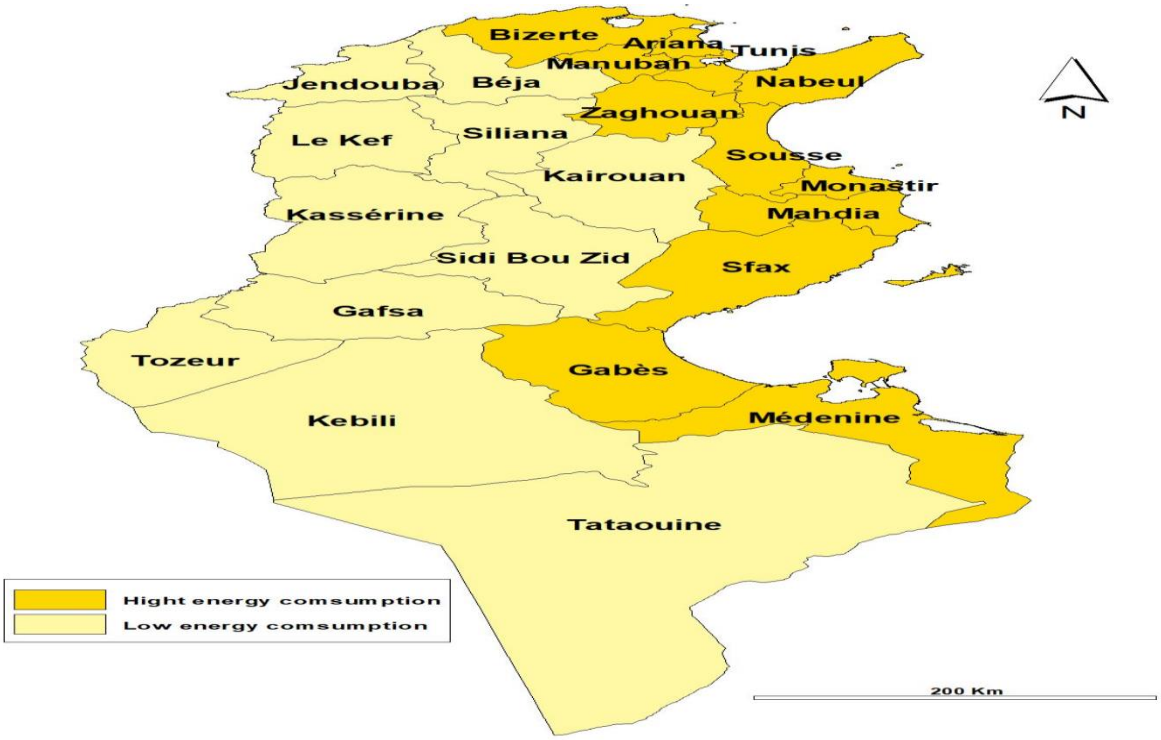
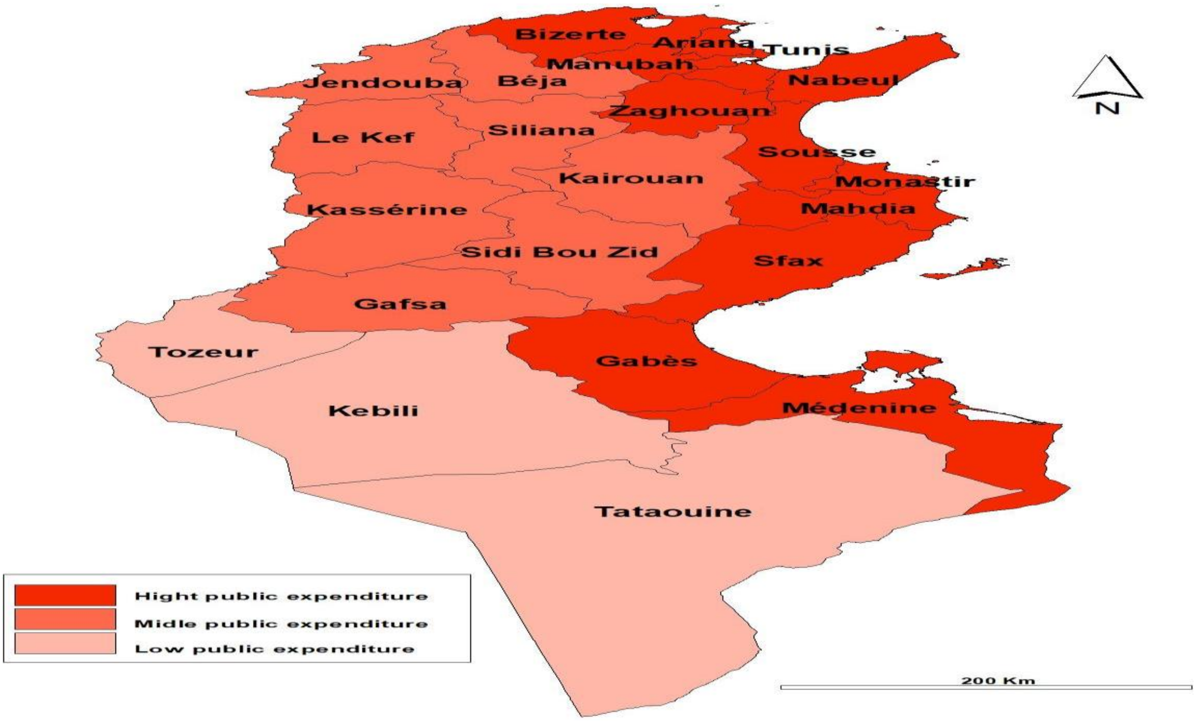


Source: *software output*

Figure N°3 : Distribution according to public expenditure in Tunisia



Source: *software output*

4. Discussion and Interpretation:

Interpret the results of your analysis. Discuss how changes in public expenditure and energy consumption might have contributed to economic growth variations during the COVID-19 period. Consider the implications of your findings within the context of the pandemic.

Summarize your study's main findings and their implications. Revisit your research question and state whether your hypotheses were supported or refuted.

- *Report Writing:*

Compile your research into a well-structured report. Include your methodology, data sources, analysis techniques, results, discussions, and visualizations.

- *Presentation and Publication:*

Consider presenting your findings at conferences and workshops relevant to your field. Additionally, you might aim to publish your study in academic journals related to economics, geography, or spatial analysis.

Remember that this type of study requires a strong foundation in economics, statistical analysis, GIS, and data visualization. It's also important to ensure the accuracy and reliability of your data sources.

IV. WORK METHODOLOGY

1. Presentation of the model

The endogenous growth model of Barro (1990) argues that the size of government significantly influences the rate of economic growth, based on the existence of an optimal level for government participation in the economy. According to the author, there is a non-linear relationship between the two variables which can be very ambiguous, taking into account that it depends on the negative effect of taxation on income which, in turn, will be compensated by the positive effect of capital investment.

In general, the model predicts that the government should provide public services to agents, households and firms. The quantity of services provided by the government takes into account abstractions concerning certain externalities linked to public services, such as exclusion and rivalry. Public expenditure is taken as an additional element to the production function since private factors of production are not direct substitutes for public inputs, according to the author.

Endogenous growth is guaranteed by the assumption of constant returns to scale in the accumulation of factors of production. Public expenditure is financed by taxation and when the government increases

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expenditure, the productivity of capital rises to such an extent that the fundamental variables of the model increase because of the positive relationship between productivity and growth.

However, for the model, the larger the size of the government, the less the income retained by households, which leads to negative changes in the growth rate.

As we explained, the author considers public goods and services as a factor of production in the production function **AK**.

Thus, public expenditure would be complementary to private investment.

In the model, government expenditures, financed by taxes, enter the production function as follows:

$$\mathbf{Y=f\,(k, g)=\ Ak^{1-\alpha}\ g^{\alpha}} \qquad (1)$$

Or:

0 <α< l is the share of public expenditure in total income, k the stock of capital per capita in the economy, **g** is the quantity of public goods and services per capita and **Y** is an endogenous variable.

The form below defines the matrix writing of equation:

$$Y = X\beta + \varepsilon \qquad (2)$$

With:

Y: it is a vector of dimension (**T, 1**), a variable to be explained.

X: this is the dimension data matrix (**T, k+1**). (**k** being the number of real explanatory variables, i.e. constant excluded)

β: it is the vector of the regression coefficients of dimension (**k+1, 1**).

ε : It is the residual vector of dimension (**T ,1**).

The mathematical expression of our model can be presented as follows:

$$log\,(PIBH_t) = \beta_0 + \beta_1(G_{DEF_t}) + \beta_2(G_{ED_t}) + \beta_6(G_{RD_t}) + \beta_7(G_{ST_t}) + \beta_9(G_{TR_t}) + \beta_{10}(G_{En\ t}) + \beta_{11}(LK_t) + \beta_{12}(M2_t) + \beta_{13}(R_{FISC_{tt}}) + \beta_{14}(SCOL_t) + \beta_{14}(TX_{INV_t}) + \beta_{14}(TX_{OP_t}) + \varepsilon_t \qquad (3)$$

When: **t** : Time index, **t** varying from **1990 to 2018**, ε_t: Error term

Y_i **:** GDP per capita

G_{DEF} **:** Public expenditure on national defense (**% of GDP**)

G_{ED} **:** Public expenditure on education (**% of GDP**)

G_{RD} **:** Public expenditure on research and development **(% of GDP**)

G_{ST}: Public health expenditure (**% of GDP**)

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ISSN: 2810-2991
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$\mathbf{G_{TR}}$: Public expenditure on transport and communication **(% of GDP**)

$\mathbf{G_{En}}$ **:** Energy consumption (% of GDP)

LK : Capital intensity

M2 : Broad Money

$\mathbf{R_{FISC}}$ **:** Tax receipts

SCOL : Secondary school enrollment rate

$\mathbf{TX_{INV}}$ **:** Investment rate

$\mathbf{TX_{Op}}$: Degree of opening

2. Detection of possible multicollinearity in the model

Durbin-Watson

Table N°1: Descriptive analysis

Dependent Variable: GDP
Method: Least Squares
Date: 20/07/23 Time: 23:36
Sample (adjusted): 1 29
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
G_DEF	-0.234088	0.334640	-0.699522	0.4943
G_ED	0.039660	0.165813	0.239185	0.8140
G_RD	0.812662	0.702303	1.157140	0.2642
G_ST	0.090056	0.139995	0.643278	0.5292
G_TR	-0.057690	0.065150	-0.885492	0.3890
G_EN	-0.001239	0.094660	-0.013088	0.9897
LK	2.140333	1.522240	1.406041	0.1788
M2	-0.023175	0.018787	-1.233534	0.2352
R_FISC	0.026441	0.035785	0.738876	0.4707
SCOL	0.012706	0.012325	1.030961	0.3179
TX_INV	0.003380	0.031785	0.106352	0.9166
TX_OP	-0.005005	0.010937	-0.457634	0.6534
C	-0.202724	7.236644	-0.028014	0.9780

R-squared	0.936157	Mean dependent var	7.925891
Adjusted R-squared	0.888275	S.D. dependent var	0.349171
S.E. of regression	0.116711	Akaike info criterion	-1.156380
Sum squared resid	0.217945	Schwarz criterion	-0.543455
Log likelihood	29.76751	Hannan-Quinn criter.	-0.964420
F-statistic	19.55131	Durbin-Watson stat	1.952150
Prob(F-statistic)	0.000000		

Source: *Output Eviews*

If multicollinearity is detected, some actions you can take include:

- Removing one of the correlated variables.
- Combining correlated variables into a single composite variable.
- Collecting more data to reduce the impact of multicollinearity.

Using regularization techniques (like Ridge or Lasso regression) that can mitigate multicollinearity effects.

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b. Correlation matrix

Table N°2: Correlation matrix

	GDP	G_DEF	G_ED	G_RD	G_TR	G_ST	LK	G_EN	M2	R_FISC	SCOL	TX_INV	TX_OP
GDP	1.00000	0.32151	0.50981	0.66097	-0.45211	0.41986	0.64449	0.51248	0.62326	0.23705	0.62916	-0.66444	0.52282
G_DEF	-0.32151	1.00000	0.01441	-0.57475	-0.28622	0.25503	0.18231	-0.15631	0.02652	0.44033	-0.4006	-0.2646	-0.56606
G_ED	0.509808	0.014411	1.000000	0.498763	-0.222668	0.383030	0.280115	0.603260	0.309769	-0.094189	0.537793	-0.563770	0.038910
G_RD	0.660968	-0.574747	0.498763	1.000000	-0.195982	0.436223	0.504183	0.683317	0.627460	-0.030456	0.678883	-0.482169	0.507729
G_TR	-0.452109	-0.286216	-0.222668	-0.195982	1.000000	-0.625141	-0.564923	-0.493823	-0.571623	-0.515049	-0.375277	0.415988	-0.145404
G_ST	0.419854	0.255028	0.383030	0.436223	-0.625141	1.000000	0.616557	0.684016	0.588781	0.543887	0.631422	-0.692065	0.327098
LK	0.644496	0.182304	0.280115	0.504183	-0.564923	0.616557	1.000000	0.650769	0.670577	0.578501	0.653206	-0.632050	0.397552
G_EN	0.512479	-0.156305	0.603260	0.683317	-0.493823	0.684016	0.650769	1.000000	0.642177	0.212055	0.653020	-0.618662	0.404630
M2	0.623255	0.026519	0.309769	0.627460	-0.571623	0.688781	0.670577	0.642177	1.000000	0.482390	0.680157	-0.602792	0.469268
R_FISC	0.237049	0.440326	-0.094189	-0.030456	-0.515049	0.543887	0.578501	0.212055	0.482390	1.000000	0.080661	-0.390125	0.188336
SCOL	0.629158	-0.400600	0.537793	0.678883	-0.375277	0.631422	0.653206	0.553020	0.680157	0.080661	1.000000	-0.632696	0.522413
TX_INV	-0.664440	-0.264151	-0.563770	-0.482169	0.415988	-0.592065	-0.632050	-0.618662	-0.602792	-0.390125	-0.632696	1.000000	-0.295863
TX_OP	0.522823	-0.566051	0.038910	0.507729	-0.145404	0.327098	0.397552	0.404630	0.469268	0.188336	0.522413	-0.295863	1.000000

Source: *Output Eviews*

A correlation matrix is a table that shows the correlation coefficients between multiple variables in a dataset. Correlation coefficients quantify the strength and direction of the linear relationship between two variables.

The values range from **-1** to **1**, where **-1** indicates a perfect negative correlation, **1** indicates a perfect positive correlation, and **0** indicates no correlation.

Analyzing the correlation matrix can help you understand the relationships between variables in your dataset. It can be useful for identifying potential multicollinearity, exploring patterns, and guiding feature selection in predictive modeling.

However, remember that correlation does not imply causation, and other factors could be influencing the relationships between variables.

c. Selection of the optimal model

Table N°3: Descriptive analysis of the optimal model

Dependent Variable: GDP
Method: Variable Selection
Date: 22/07/23 Time: 10:57
Sample (adjusted): 1 29
Included observations: 29 after adjustments
Number of always included regressors: 1
Number of search regressors: 12
Selection method: Stepwise forwards
Stopping criterion: p-value forwards/backwards = 0.05/0.05

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
C	3.591207	0.789579	4.548256	0.0001
SCOL	0.010761	0.003057	3.520556	0.0017
LK	0.818528	0.236713	3.457897	0.0020
G_EN	-0.020351	0.459853	-0.044255	0.0358
G_TR	0.298092	0.113180	2.633774	0.0138
G_ST	0.408864	0.075874	5.388756	0.0000
G_ED	0.418630	0.158309	2.644383	0.0142
G_DEF	-0.037874	0.214695	-0.176408	0.0490

R-squared	0.913398	Mean dependent var	7.925891
Adjusted R-squared	0.903005	S.D. dependent var	0.349171
S.E. of regression	0.108746	Akaike info criterion	-1.472166
Sum squared resid	0.295641	Schwarz criterion	-1.283573
Log likelihood	25.34640	Hannan-Quinn criter.	-1.413101
F-statistic	87.89184	Durbin-Watson stat	1.685488
Prob(F-statistic)	0.000000		

Selection Summary

Added SCOL
Added LK
Added G_EN
Added G_TR
Added G_ST
Added G_ED
Added G_DEF

*Note: p-values and subsequent tests do not account for variable selection.

Source: *Output Eviews*

❖ *Model Selection:*

**Start Simple:* Begin with simpler models like linear regression or decision trees. These models are interpretable and can serve as a baseline.

**Explore Complexity:* Gradually explore more complex models such as random forests, support vector machines, gradient boosting, or neural networks. These models might capture intricate relationships in the data but could also overfit if not regularized properly.

**Consider Regularization:* If you are dealing with multicollinearity or a large number of features, consider models with built-in regularization, such as Ridge or Lasso regression

3. Heteroscedasticity problem detection test

❖ The Breusch-Pagan-Godfrey test: Absence of heteroscedasticity

Table N°4: Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	1.461955	Prob. F(7,21)	0.2342
Obs*R-squared	9.501819	Prob. Chi-Square(7)	0.2186
Scaled explained SS	10.40329	Prob. Chi-Square(7)	0.1668

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 23/07/23 Time: 00:09
Sample: 1 29
Included observations: 29

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.279876	0.290766	-0.962550	0.3467
G_DEF	-0.047880	0.023469	-2.040196	0.0541
G_ED	0.021970	0.018064	1.216194	0.2374
G_EN	-0.227601	0.094925	-2.397684	0.0259
G_ST	-0.007083	0.015722	-0.450507	0.6570
G_TR	0.005228	0.008243	0.634188	0.5328
LK	0.092977	0.085155	1.091858	0.2873
SCOL	0.000703	0.000564	1.246475	0.2263

R-squared	0.327649	Mean dependent var	0.008860
Adjusted R-squared	0.103532	S.D. dependent var	0.018425
S.E. of regression	0.017445	Akaike info criterion	-5.030553
Sum squared resid	0.006391	Schwarz criterion	-4.653368
Log likelihood	80.94302	Hannan-Quinn criter.	-4.912423
F-statistic	1.461955	Durbin-Watson stat	1.942747
Prob(F-statistic)	0.234228		

Source: *Output Eviews*

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The Breusch-Pagan-Godfrey (BPG) test, also known as the Breusch-Pagan test or the White test, is a statistical test used to check for the presence of heteroscedasticity in a regression model. Heteroscedasticity refers to the situation where the variability of the residuals (the differences between observed and predicted values) changes as a function of the independent variables.

The test is designed to assess whether the assumption of homoscedasticity (constant variance of residuals) holds true for the data. Heteroscedasticity can lead to biased and inefficient estimates of regression coefficients and can affect the reliability of statistical inference.

Here's how the Breusch-Pagan-Godfrey test works:

Model Estimation: Begin by estimating your regression model, obtaining the residuals (the differences between the observed dependent variable values and the predicted values from the model).

Residuals Squaring: Square the residuals to obtain their squared values.

Auxiliary Regression: Run an auxiliary regression using the squared residuals as the dependent variable and the independent variables of the original model. This is essentially a regression of squared residuals on the independent variables.

Obtain the R-squared: Calculate the R-squared value from the auxiliary regression. The R-squared value indicates the proportion of the variance in the squared residuals that can be explained by the independent variables.

Hypothesis Testing: The null hypothesis of the Breusch-Pagan-Godfrey test is that there is homoscedasticity, while the alternative hypothesis is that there is heteroscedasticity. The test statistic is usually computed as the product of the number of observations and the R-squared value from the auxiliary regression.

Comparison to Critical Value: Compare the calculated test statistic to a critical value from the chi-squared distribution with degrees of freedom equal to the number of independent variables in the auxiliary regression. If the calculated test statistic is greater than the critical value, you may reject the null hypothesis, indicating the presence of heteroscedasticity.

If the test suggests the presence of heteroscedasticity, you might consider using techniques like transforming the dependent variable, using robust standard errors, or exploring other regression methods designed to handle heteroscedasticity.

It's important to note that while the Breusch-Pagan-Godfrey test can be useful, it has limitations and should be used in conjunction with other diagnostic tools and your domain knowledge to assess the assumptions of your regression model.

V. INTERPRETATIONS AND DISCUSSIONS

1. The impact of public expenditure on economic growth.

In this work, and in particular, we will try to define the econometric methodology to be used in order to empirically test the impact of public expenditure on economic growth in Tunisia during the period from 1990 to 2018. More precisely, our objective is to assess the negative effect of an increase in public spending on economic growth in Tunisia the analysis focuses on 13 macroeconomic variables, namely the growth of real GDP per capita (endogenous variable), (public spending on health, transport and communication, national defense and research and development), investment rate, tax revenue, secondary school enrollment rate, openness rate, broad money **M2**, capital intensity and life expectancy at birth as explanatory variables.

Admittedly, before carrying out our tests, we must first ensure the compatibility of the distributions with the normality hypothesis. It is a question of validating that the residual is close to a normal law. The normal law is characterized by an asymmetry coefficient called skewness and a flattening coefficient called zero kurtosis. These indicators give an approximate idea of the possible similarity of the empirical distribution with a Gaussian.

The Jarque-Bera normality test is also based on these skewness and kurtosis coefficients. It evaluates the simultaneous deviations of these coefficients with the reference values of the normal law. It does not strictly speaking test if the data follow a normal distribution, but rather if the kurtosis and the skewness of the data are the same as those of a normal distribution with the same expectation and variance.

The Jarque-Bera test tests the hypothesis H0 of the compatibility with the normal law. It follows a chi-square law. Indeed, with a p-value greater than the risk of error 5%, we can accept the hypothesis of the possible normality of the distribution of errors. In our case, we obtained a p-value of 0.122 greater than 5%.

So, we can accept the H0 hypothesis, which states that the residual follows a law close to the normal law. From this stage, we can initiate the regression and the application of the various tests on our model.

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2. Detection of possible multicollinearity in the model

The term multicollinearity is incorporated in the case of a model composed of explanatory series that are linked together. The existence of collinearity between the explanatory variables can disturb the estimates of the parameters of the model. It can exist even when the linear correlation coefficients between the variables are low. Admittedly, there is no absolute rule for detecting multicollinearity, only empirical methods. But, the consequences of statistical collinearity are multiple, and we can quote (Bourbonnais, 2003):

- The estimated regression coefficients can be high in absolute value.
- The signs may be contrary to intuition.
- The variances of the estimators can be high.
- The regression coefficients are unstable compared to the correlation coefficients between the explanatory variables.

However, the regression of our of the optimal model, allowed us to have the results displayed in the following tables:

Table N°5: *Matrix of correlation coefficients of the explanatory variables of the optimal model*

	GDP	G_DEF	G_ED	G_RD	G_TR	G_ST	LK	ESP_V	M2	R_FISC	SCOL	TX_INV	TX_OP
GDP	1,000	-0,322	0,509	0,660	-0,45	0,519	0,544	0,512	0,623	0,237	0,529	-0,664	0,522
G_DEF	-0,322	1,000	0,0144	-0,57	-0,28	0,255	0,182	-0,156	0,026	0,440	-0,40	-0,264	-0,566
G_ED	0,509	0,014	1,000	0,498	-0,22	0,383	0,280	0,603	0,309	-0,094	0,537	-0,564	0,038
G_RD	0,660	-0,575	0,498	1,000	-0,19	0,436	0,504	0,583	0,627	-0,030	0,678	-0,482	0,507
G_TR	-0,452	-0,286	-0,223	-0,19	1,000	-0,62	-0,56	-0,494	-0,57	-0,51	-0,37	0,415	-0,145
G_ST	0,519	0,255	0,383	0,436	-0,62	1,000	0,516	0,584	0,688	0,543	0,631	-0,592	0,327
LK	0,544	0,182	0,280	0,504	-0,56	0,516	1,000	0,550	0,570	0,578	0,653	-0,632	0,397
ESP_V	**0,512**	**-0,156**	**0,603**	**0,583**	**-0,49**	**0,584**	**0,550**	1,000	0,642	0,212	0,553	-0,519	0,404
M2	**0,623**	**0,026**	**0,309**	**0,627**	**-0,57**	**0,688**	**0,570**	**0,642**	1,000	0,482	0,580	-0,603	0,469
R_FISC	0,237	0,440	-0,094	-0,03	-0,51	**0,543**	**0,578**	0,212	0,482	1,000	0,080	-0,390	0,188
SCOL	0,529	-0,401	0,537	0,678	-0,37	0,631	0,653	**0,553**	0,580	0,080	1,000	-0,633	0,522
TX_INV	-0,664	-0,264	-0,564	-0,48	0,411	**-0,59**	**-0,63**	**-0,519**	**-0,80**	-0,390	-0,63	1,000	-0,296
TX_OP	0,522	-0,566	0,038	0,507	-0,14	0,327	0,397	0,404	0,469	0,188	0,522	-0,296	1,000

Source: *Output Eviews*

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Table N°6: *Main results of the regression of the optimal model*

Variables	***Coefficient***	***Probability***
G_DEF	-0.234088	0.4943
G_ED	0.039660	0.8140
G_RD	0.812662	0.2642
G_ST	0.090056	0.5292
G_TR	-0.057690	0.3890
ESP_V	-0.001239	0.9897
LK	2.140333	0.1788
M2	-0.023175	0.2352
R_FISC	0.026441	0.4707
SCOL	0.012706	0.3179
TX_INV	0.003380	0.9166
TX_OUV	-0.005005	0.6534
C	-0.202724	0.9780
R^2		0.936157

Source: *Output Eviews*

3. Selection of the optimal model

Faced with the problem of multicollinearity, the only really effective solution consists, during the specification of the model, in eliminating the explanatory variables likely to be correlated with each other. There are several methods which make it possible to retain the best model, that is to say, the one which is composed of variables which are:The most correlated with the variable to be explained and the least correlated with each other.

In our case, we will use the Stepwise Regression method, since it represents the most used procedure (Bourbonnais, 2003). Thus we have the following main results:

Table N°7 : *Main results of the Selection of the optimal model regression using the Stepwise Regression method*

Variables	***Coefficient***	***Probabilité***
C	3.591207	0.0001
SCOL	0.010761	0.0017
LK	0.818528	0.0020
G_RD	0.020351	0.0358
G_TR	0.298092	0.0138
G_ST	0.408864	0.0000

G_ED	0.418630	0.0142
G_DEF	-0.037874	0.0490
Adjusted R-squared		0.903005
Schwarz criterion (BIC)		-1.283573

Source: *Output Eviews*

With a view to correcting the collinearity between the explanatory variables of our model to be tested (equation 2), the application of the Stepwise Regression method proposes the following model:

$$\log(\mathbf{GDP}_i) = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1(\mathbf{G\_DEF_i}) + \boldsymbol{\beta}_2(\mathbf{G\_ED_i}) + \boldsymbol{\beta}_3(\mathbf{G\_RD_i}) + \boldsymbol{\beta}_4(\mathbf{G\_ST_i}) + \boldsymbol{\beta}_5(\mathbf{G\_TR_i}) + +\boldsymbol{\beta}_6(\mathbf{LK_i}) + +\boldsymbol{\beta}_7(\mathbf{SCOL_i}) + \boldsymbol{\varepsilon}_\mathbf{i}$$

(4)

However, we note that such a correction of the model allowed the deletion of 5 variables, in this case: R_FISC, TX_INV, TX_OP, ESP_V and M2 (see Table 7). In other words, to overcome the problem of multicollinearity, the number of variables making up the model was limited to only 7, instead of 12 explanatory variables from the start (Selection of the optimal model). However, we note that all the coefficients found are significant, below the risk threshold α =5% (see Table 7).

❖ *Heteroscedasticity problem detection test*

Before running the regression, we need to test for the heteroscedasticity problem. This is a problem of the non-constancy of the variances of the errors, encountered frequently at the level of the models specified in instantaneous cut. Indeed, several tests can be used to test a possible heteroscedasticity, such as (Bourbonnais, 2003):

- *Breusch-Pagan-Godfrey test*: this test is used when it is assumed that heteroscedasticity is caused by one or more precise explanatory variables of the model. The error variance equation he addresses is a linear function of the explanatory variables in the model, suspected to be at the root of the heteroscedasticity problem.
- *Glejser test:* adopted when a single explanatory variable is suspected of being the cause of heteroscedasticity. Also, the form of the error variance equation it evokes is a linear form. Practically, it should be used for large samples, but it has an additional difficulty, since some forms of heteroscedasticity it tries to test for are not linear in parameters and therefore cannot be estimated by OLS such as that (Damodar, 2003): $|\hat{e}_i| = \sqrt{\beta_1 + \beta_2 X_i} + \nu_i$ et $|\hat{e}_i| = \sqrt{\beta_1 + \beta_2 X_i^2} + \nu_i$.
- *Harvey-Godfrey test*: the Harvey-Godfrey test is used when it is assumed that heteroscedasticity is generated by one or more precise explanatory variables of the model, and which are linked according to an exponential relationship with the variance of the errors.

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These advanced tests each deal with a specific form of heteroscedasticity. Indeed, choosing among these tests means that we have chosen a specific form that links the variance of the errors with the variables suspected of being the cause of the heteroscedasticity problem. To avoid the difficulty of choosing the form of heteroscedasticity on the one hand, and the doubts concerning the explanatory variables suspected of being at the origin of this problem on the other hand, we can resort to the Breusch-Pagan- Godfrey:. The Breusch-Pagan-Godfrey test: is a general test of heteroscedasticity. The advantage of this test is that it does not require a specification of the form of heteroscedasticity. Indeed, it is based on a relationship between the square of the residual and the set of explanatory variables, their squares and their cross products, such as the following form:

$$e_t^2 = \alpha_0 + \alpha_1 X_{t1} + \alpha_2 X_{t2} + \alpha_3 X^2_{t1} + \alpha_4 X^2_{t2} + \alpha_5 X_{t1} X_{t2} + \ldots + v_i$$

Thus, by applying this test to our equation (4), we obtained the following main results:

TableN°8: Main results of the application of the Breusch-Pagan-Godfrey test for heteroscedasticity detection of the Selection of the optimal model regression (equation (4))

Obs*R-squared	9.501819	***Prob. Chi- Square(7)***	0.2342
Variable		***Probabilité***	
G_DEF		0.0541	
G_ED		0.2374	
G_RD		0.0259	
G_ST		0.6570	
G_TR		0.5328	
LK		0.2873	
SCOL		0.2263	

Source: Output Eviews

The heteroscedasticity detection test uses the following assumption:

$H_0 : \sigma_1 = \sigma_2 = \ldots = \sigma_k = 0$

If we refuse the null hypothesis, then there is a risk of heteroscedasticity. In our case, we have to use the LM[9] statistic (Obs*R-squared that is to say, $N*R^2$), which follows a Chi-square law with *p* degrees of freedom ($X_2(7)$). ndeed, if the probability of the significance of the test is less than 0.05 we reject H0 and we therefore decide for the heteroscedasticity of the model. Indeed, according to

[9] *Lagrange multiplier*

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Table 8, we have a probability of the significance of the test which is equal to 0.2186 and therefore greater than 0.05 (Prob(X_2(7)) = **0.2342** > 0.05).

However, we can accept the H0 hypothesis, meaning in particular that our model is homoscedastic. Even more, the analysis of the probabilities of the individual significance of the parameters of our equation of the variance of the errors, shows that they are all greater than 0.05 (see Table 8). So we accept the hypothesis H0 of non-significance of the parameters, approving that our model is homoscedastic, and that we can regress it by the method of Ordinary Least Squares (OLS).

❖ ***The impact of public spending on economic growth: Empirical validation***

The application of this model on the Tunisian economy will be done through series of annual data covering the period from 1990 to 2018. from equation (9) below, and whose regression has given us the main results displayed in Table 9:

$$\log(GDP_i) = \beta_0 + \beta_1(G\_DEF_i) + \beta_2(G\_ED_i) + \beta_3(G\_RD_i) + \beta_4(G\_ST_i) + \beta_5(G\_TR_i) + \beta_6(LK_i) + +\beta_7(SCOL_i) + \varepsilon_i \quad (5)$$

Table N° 9 : *Main results of the regression of equation (5) by OLS*

Variables	*Coefficient*	*Probability*
G_DEF	-0.042584	0.0334
G_ED	0.425966	0.0472
G_RD	0.022424	0.0128
G_ST	0.417549	0.0321
G_TR	0.275332	0.0394
LK	0.519975	0.0245
SCOL	0.067871	0.0392
C	4.508850	0.0234
R^2		0.92473
Prob (F-statistic)		0.0000
Durbin-Watson stat		1.85060

Source: Output Eviews

It turned out that our model admits a significant explanatory power, and this following a respectable coefficient of determination R^2 of 0.92 (see Table 9). Also, we see that the model is globally significant, since the probability of global significance is lower than the risk threshold α=5%. Similarly, all the variables present probabilities lower than the risk α=5%, thus justifying their individual significance in the model. Indeed, by a statistic of DW=1.85 close to 2, we confirm the absence of autocorrelation of errors in our model. Admittedly, to confirm the relevance of our OLS estimators, we have re-estimated the model, using the method that takes into account robust standard deviations, also called standard deviations corrected for white's heteroscedasticity. . This technique is generally used to correct a possible heteroscedasticity of a model. Indeed, we will compare the estimators obtained by this technique compared to that obtained by the OLS. Such a comparison is useful to confirm the relevance of the model's estimators (Wallace and Silver, 1988). Admittedly, when the two types of regression lead to the same estimators, this confirms the homoscedasticity and the reliability of our model. Thus, the new estimation of the model, allowed us to have the following results:

Table N°10: *Main results of the regression of equation (5) corrected by the Breusch-Pagan-Godfrey*

Variables	***Coefficient***	***Probabilité***
G_DEF	-0.042584	0.0334
G_ED	0.425966	0.0472
G_RD	0.022424	0.0128
G_ST	0.417549	0.0321
G_TR	0.275332	0.0394
LK	0.519975	0.0245
SCOL	0.067871	0.0392
C	4.508850	0.0234
R^2 ***Prob (F-statistic)***		0.924738 0.000000

Source: Output Eviews

On the basis of the two tables 9 and 10, it can be seen that the two regressions lead to the same estimators. We begin our interpretation of these results with the first explanatory variable, the secondary school enrollment rate (**SCOL**) the coefficient of this variable having a positive effect on gross domestic product per capita (**GDP**) is highly significant with a (added value < 5%). The latter has a significant effect on gross domestic product per capita **GDP**. So the **SCOL** variable has a positive impact on **GDP** and therefore has a positive effect on the evolution and increase in gross domestic product per capita (**GDP**). This indicates that the school enrollment rate is positively associated with economic growth because the probability value is positive, which describes the economic literature review. Then, there is a significant association between the capital intensity variable (**LK**) and the gross domestic product per capita (**GDP**) with (a p-value means that the variable is statistically significant at the **5%** rate) and a positive coefficient, hence the **LK** variable is positively associated with **GDP**. For the variable public spending on research and development (**G_RD**) positively and significantly affects the **GDP** variable, as the expected sign (**coefficient = 0.020351; P value = 0.0358**). This means that **G_RD** positively influences growth.

According to the results obtained, there is a significant association between the variable public expenditure on transport and communication (**G_TR**) and the gross domestic product per capita (**GDP**) with (a value of p-value (**0.0138**) means that the variable is statistically significant at the rate of **5%**) and a positive coefficient of **0.298092**, hence the variable **G_TR** is positively associated on **GDP** and thereafter. The public health expenditure variable (**G_ST**) positively and significantly affects the **GDP** variable, as the expected sign (**coefficient = 0.408864; P value = 0.0000**). In fact, if the **G_ST** increases, the growth increases by one unit. According to the results obtained, there is a significant association between the variable public expenditure on education **G_ED** and the gross domestic product per capita (**GDP**) with (a value of p-value (**0.418630**) means that the variable is statistically significant at the rate of **5%**) and a positive coefficient of **0.0142**, hence the variable **G_ED** is positively associated with **GDP**. The variable public expenditure on national defense (**G_DEF**) negatively and significantly affects the **GDP** variable, as the expected sign (**coefficient = -0.037874**; **P value = 0.0490**). This means that **G_DEF** has a negative effect on economic growth.

V. CONCLUSION

During the period of COVID-19, Tunisia has experienced several economic changes comparing before the pandemic. Tunisia as a country has died from directing public spending towards services namely education and health during the period from 1990-2018. Tunisia's energy consumption was driven by a mix of factors, including economic growth, population growth, industrial activities, and urbanization. The country's energy consumption was primarily sourced from fossil fuels, with natural gas being a significant contributor to both electricity generation and industrial processes. Additionally, Tunisia was working on diversifying its energy mix by increasing its use of renewable energy sources like solar and wind power.

Tunisia's public expenditure was allocated to various sectors, including healthcare, education, infrastructure development, social services, and more. The government's budget was influenced by economic conditions, social needs, political priorities, and external factors like international loans and aid. Social welfare programs and public sector employment were important areas of expenditure. It's worth noting that Tunisia had been experiencing economic challenges before COVID-19, including high unemployment rates, particularly among the youth, and disparities in regional development. These challenges could impact public expenditure decisions. However, due to my knowledge cutoff date, I cannot provide specific figures or trends beyond September 2021. If you're looking for more recent information, I recommend checking official government reports, international organizations' data, and reputable news sources for updates on Tunisia's energy consumption and public expenditure. As of my last knowledge update in September 2021, I can provide some general insights into how the COVID-19 pandemic might have affected energy consumption, public expenditure, and economic growth in Tunisia up until that point. Please note that the situation may have evolved since then, and I recommend checking more recent sources for the latest information.

During the early stages of the pandemic, many countries, including Tunisia, implemented lockdowns and restrictions to curb the spread of the virus. These measures led to changes in energy consumption patterns. With reduced economic activity, industrial output, and transportation, energy demand likely decreased. This was particularly evident in sectors like manufacturing, tourism, and transportation, which are energy-intensive. Tunisia, like many other countries, faced challenges related to public expenditure during the pandemic. The government had to allocate funds to healthcare systems, social safety nets, and other support mechanisms to address the health and economic impacts of COVID-19. This meant that public expenditure had to be reprioritized and redirected to respond to the crisis. Additionally, revenue streams such as tourism and trade might have been significantly reduced, affecting the government's fiscal capacity.

The combination of reduced energy consumption and reprioritization of public expenditure could have had implications for Tunisia's economic growth. The lockdowns and restrictions aimed at curbing the spread of the virus likely led to a contraction in economic activity, which could result in negative GDP growth. Sectors such as tourism, which were major contributors to Tunisia's economy, were hit hard due to travel restrictions and reduced consumer spending. The pandemic's impact on economic growth was not unique to Tunisia; it was a global phenomenon affecting both developed and developing economies. Governments around the world had to implement fiscal and monetary measures to stimulate economic recovery and mitigate the negative effects of the crisis.

For the most current and detailed information on how COVID-19 has specifically affected Tunisia's energy consumption, public expenditure, and economic growth, I recommend consulting official government reports, international organizations' publications, and reputable economic analysis sources that specialize in Tunisia’s economy.

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