

The Impact of Institutions on the Knowledge Economy in Countries Leading the Global Knowledge Index (An Econometric Study for the Period 1996-2020)

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Abstract: This study aims to determine the impact of institutions on the knowledge economy for a sample of **18 countries** that top the Global Knowledge Index for the period **(1996-2020)**, using panel models and principal component analysis (PCA). The knowledge economy index was composed of three sub-indices: education, research and development, and information and communication technology. The institutional index was composed of six governance indicators, in addition to trade openness and per capita GDP.

The study found that the institutions index has a positive impact on the knowledge economy. It is well known that the countries under study have led the world in institutional indicators for decades, which is the main factor that has helped them build a knowledge economy. This is also evident in the positive impact of the trade openness index, which reflects the availability of a favorable environment that has contributed to the transfer of knowledge and technology and trade exchanges between countries.

Keywords: Knowledge economy, institutions, panel models, principal component analysis.

Jel classification : O30 ; C38 ; C23 ; P48

تهدف هذه الدراسة الى معرفة تأثير المؤسسات على اقتصاد المعرفة، لعينة من 18 دولة من الدول التي تصدر مؤشر المعرفة العالمي للفترة (1996-2020)، باستخدام نماذج بانل، وأسلوب تحليل المركبات الأساسية PCA. تم أخذ مؤشر لاقتصاد المعرفة مركب من ثلاث مؤشرات جزئية هي: (التعليم، البحث والتطوير، تكنولوجيا المعلومات والاتصال). ومؤشر للمؤسسات مركب من مؤشرات الحوكمة الستة. بالإضافة الى الانفتاح التجاري، ونصيب الفرد من اجمالي الناتج المحلي. توصلت الدراسة الى وجود أثر موجب لمؤشر المؤسسات على اقتصاد المعرفة. ومن المعلوم أن الدول محل الدراسة تصدر العالم في مؤشرات المؤسسات لعقود من الزمن، وهو العامل الأساسي الذي ساعدها في بناء اقتصاد المعرفة. ويتجلى ذلك أيضا من خلال الأثر الموجب لمؤشر الانفتاح التجاري الذي يعكس مدى توفر البيئة الجيدة التي ساهمت في نقل المعرفة والتكنولوجيا والتبادلات التجارية بين الدول.

الكلمات المفتاحية: اقتصاد المعرفة، المؤسسات، نماذج بانل، تحليل المركبات الأساسية.

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Introduction:

The widespread dissemination of knowledge and creativity, along with the tremendous development of information and communication technologies, have contributed to fundamental changes in the structure of economic life. Whereas the basic factors of production used to be land, capital, and labor, knowledge has emerged as the most effective and productive factor. This has given rise to a new economy called the knowledge economy, in which knowledge plays a fundamental role in creating added value. This economy has led to a rapid increase in the pace of production and exchanges between different parts of the world.

To this end, countries have rushed to enter the knowledge economy, especially after international bodies such as the World Bank adopted this economy and developed indicators to help member states understand their position in the knowledge economy. All these changes require new institutional systems that are in line with this transformation.

An enabling environment must be provided for a competitive education system, highly qualified human resources, excellent information and communications technology infrastructure, and the creation of an atmosphere conducive to creativity and innovation. This entire process of knowledge creation and dissemination depends heavily on appropriate government policies that are the result of economic incentives and institutional systems.

-Problem statement:

Based on the above, the problem statement of this study is as follows:

To what extent do institutions influence the development of a knowledge-based economy in the countries under study?

Research hypothesis:

Based on the problem statement, the following hypothesis was formulated:

- **Institutions have a positive impact on the integration of the countries under study into the knowledge economy.**

Study objective:

Through this study, we seek to determine the extent to which institutions influence the development of a knowledge economy in countries that top the Arab Knowledge Index. These countries are characterized by high institutional indicators and a favorable investment environment.

Study methodology:

To answer the question, we use econometric methods, employing panel models for a sample of 18 countries that lead the Global Knowledge Index for the period 1996-2020, using STATA17 software. We attempt to formulate a mathematical model of the relationship between institutions and the knowledge economy. We take a set of indicators that express the knowledge economy and combine them into a single indicator using the principal component analysis (PCA) method. We also take a composite indicator for institutions consisting of the six governance indicators in the same way.

Previous studies:

In a study by **Debnath, Sajit Chandra** (2011): he investigated the key determinants of economic incentives and institutional systems in East Asia to promote a knowledge-based economy in the region. The analysis showed that tariff and non-tariff barriers, business freedom, investment environment, monetary system, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption Overall, economic incentives and institutional systems play a very important role in promoting a knowledge-based economy in all East Asian countries.(Debnath, 2011)

Another study examined the role of good governance in promoting a knowledge-based economy in East Asia by investigating good governance and knowledge economy indicators and examining how they are related to each other. The analysis showed that the relationship between good governance and the creation of a knowledge-based economy in East Asia is positively correlated. Good governance also played an important role in attracting foreign direct investment, which helped develop knowledge-based economic infrastructure to create a knowledge-based economy. In the case of China, the country still lags behind other selected East Asian countries in terms of its knowledge-based economy. The same can be said for total factor productivity, which is a strong indicator of economic growth. Therefore, if China wants to be on par with other knowledge-based economies in East Asia, it must further improve its governance.(Chandra & Yokoyama, 2011)

A study by **Andrés, Antonio Rodriguez** (2015) examined the impact of formal institutions on the knowledge economy by assessing how intellectual property rights enforcement affects governance mechanisms. Panel models were used for a sample of 22 countries in the Middle East, North Africa, and sub-Saharan Africa during the period 1996-2010. The study used the four components of the World Bank's Knowledge Economy Index. The results showed that the application of intellectual property rights laws (treaties) for this group of countries, although necessary, is not a sufficient condition for a knowledge economy. The results also indicate that there are other factors that are more likely to determine the knowledge economies of these countries.(Andres, Asongu, & Amavilah, 2015)

The study by **Padash-Zive** and **Hamid** (2015) analyzed the impact of good governance indicators on the development of the knowledge-based economy for a sample of 33 countries. The study used the following indicators: (voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption) extracted from the World Bank's statistical databases, and Smart PLS software was used to estimate and analyze the data. The regression results indicated a significant positive effect of good governance as a key variable on the Knowledge Economy Index (KAM) in the selected countries. When using the six sub-indicators of governance, the estimated regressions showed that the components of rule of law, political stability, and control of corruption had a stronger impact on the knowledge economy than the other indicators.(Padash-Zive, 2015).

In a study by **Padash** and **Khodapanah** (2017), they investigated the impact of the institutional environment (including the business environment, legal environment, and political environment) on the knowledge-based economy in Iran. The regression results showed that political and environmental indicators have a positive and significant impact on the Knowledge Economy Index (KEI), while the impact of the business environment was relatively weak. Overall, the aggregate index of the institutional environment had a significant impact on the knowledge economy.(Padash, Khodapanah, & Ebrahimzadeh, 2017)

2. The concept and emergence of the knowledge economy:

The term "**knowledge economy**" first appeared in the **1950s**, when researchers began to notice the upward development of new sectors in developed countries, at the expense of agriculture and industry. At that time, these sectors heralded the emergence of a new economy that began to take shape at an accelerated pace, and that period was called the "**post-industrial era**." In 1962, a study by **Fritz Macklopp** appeared, in which he pointed out that the new economy was a service economy. This prompted him to study knowledge products and develop his analysis of the concept of the knowledge economy through his book, which he called "**The Production and Distribution of Knowledge in the United States**" He was largely responsible for bringing the knowledge economy to light.

Peter Drucker also touched on the terms "**knowledge economy**" and "**knowledge society**" in the twelfth chapter of his 1968 book, "**The Age of Discontinuity**". In 1977, **Mark Yuri Porat** and **Michael Rubin** made a theoretical contribution to the new economy in a book entitled "**The Information Economy**." In it, they attempted to estimate the size of the new economy and identify the nature of the economic sectors active in it. They also called it the information economy. Theoretical contributions in this field continued, with Nobel Prize-winning economist **Joseph Stiglitz** making another contribution by studying the nature of the transformation that government policies are expected to undergo in the context of the new economy in his book entitled "**Public Policy for a Knowledge Economy**". (عبد المنعم و قعلول، 2019، صفحة 9).

From this point on, humanity entered a new era of economic systems dealing with knowledge industries whose products are ideas, whose raw materials are data, and whose tools are the human mind.

The World Bank defines a knowledge economy as "an economy in which knowledge is the main driver of economic growth, through continuous investment in education, innovation, information and communication technology, and the economic and institutional environment, thereby promoting greater production and more efficient use of knowledge to support development and sustained economic growth." (جيهان، 2016، صفحة 11)

Houghton & Sheehan believe that the knowledge economy stems from two forces. The first is the increase in the intensity or density of knowledge in economic activities, which is driven by the integration of information technology and the acceleration of technological development. The second force stems from the globalization of the economy and its transformation into a global economy. (نجم عبد الله و ابراهيم علي، 2012، صفحة 366)

3. Characteristics of the knowledge economy:

- The knowledge economy has several characteristics that distinguish it from the old economy, which can be summarized in the following points: (فاضل الحياي، صفحة 147)
 - The knowledge economy is characterized by abundance, in stark contrast to the old economy, which is characterized by scarcity, because the components of this economy, namely knowledge and information, do not diminish with use but rather grow, unlike the components of production that make up the old economy.
 - The knowledge economy is not subject to the law of diminishing returns, because one of the characteristics of knowledge is that it is cumulative; the discovery of knowledge always gives us a vision for the future to discover new knowledge. For example, the

- invention of the microscope led to the discovery of microorganisms, which in turn led to knowledge of how diseases (infections) are transmitted, etc.
- In a knowledge economy, the focus is on human capital rather than physical capital, as it is responsible for the production of knowledge. While the old economy relied on physical labor and machines, with only a small amount of knowledge needed to operate these machines, the current economy relies almost entirely on intellectual effort.
 - The knowledge economy has freed the production process from time and place, as anyone can produce ideas without the need for a specific place or time.
 - The value of knowledge is determined by its use and the environment in which it exists, and varies according to different people and times. The resources used in the new economy are very few, but in return they achieve added value many times greater than that achieved by the industrial economy, especially since its material outputs sometimes disappear and are limited to intangible knowledge inputs.

4.Measuring the knowledge economy:

There are several indicators for measuring the knowledge economy, the most well-known of which are the World Bank Index (**using the Knowledge Assessment Methodology, KAM**) and the Global Knowledge Index (**GKI**), which replaced the World Bank Index when its statistics ceased in 2012. It is also considered a supplement to the Arab Knowledge Index, which was established in 2015.

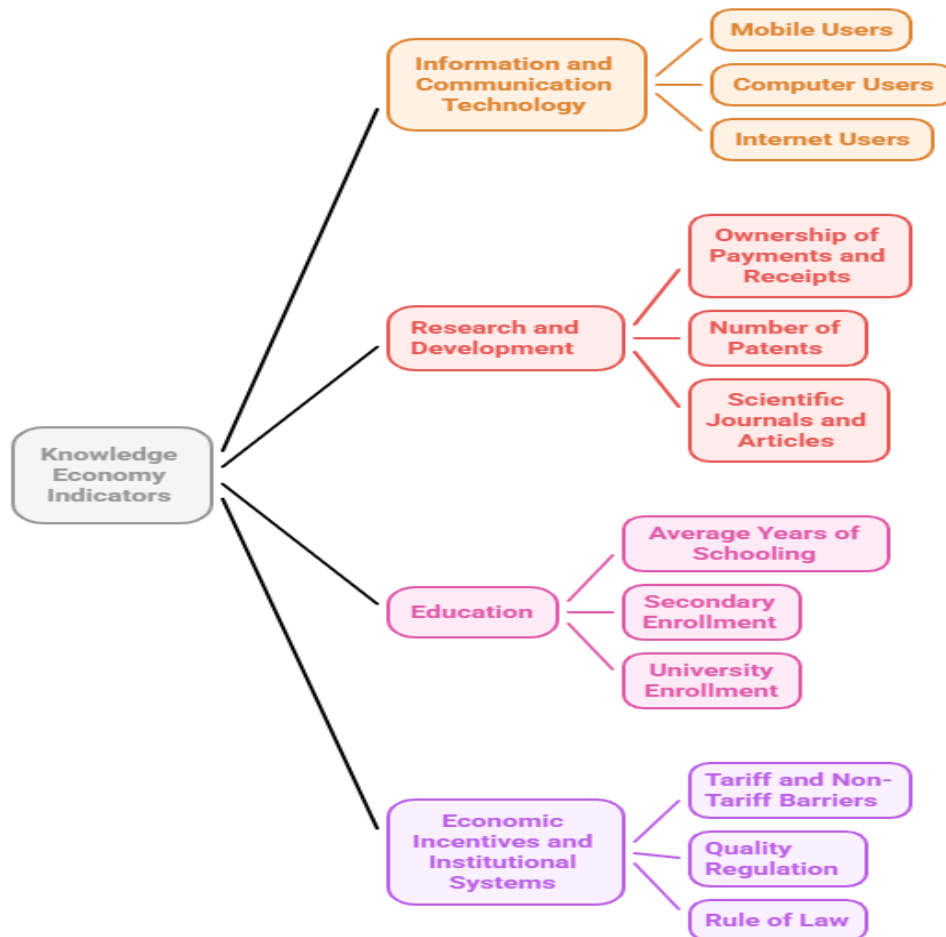
1.4 World Bank Index (Knowledge Assessment Methodology, KAM):

To determine the position of countries in the knowledge economy, the World Bank has developed a tool to assist the countries it works with, called the Knowledge Assessment Methodology (**KAM**), which covers 146 countries. This tool allows countries to identify their strengths and weaknesses by comparing themselves with member countries or any other country. This methodology is based on the four pillars of the knowledge economy, which are: education, research and development, information and communication technology, economic incentives, and institutional systems. These pillars include a set of indicators that are calculated based on the average performance of each country. (Drek & Dahlman, 2006, p. 9)

According to the first pillar of the knowledge economy, which relates to the economic and institutional system, a country interested in transforming its economy into a knowledge economy must provide incentives for the effective use of existing and new knowledge and the flourishing of entrepreneurship. According to the second pillar, the state must ensure that its people have access to education and skills that will enable them to create, apply, and share acquired knowledge. According to the third pillar, a dynamic information infrastructure is critical to facilitating effective communication and the dissemination and processing of information. According to the fourth pillar, innovation systems in any country, such as companies, research centers, and universities, must be able to leverage the growing stock of global knowledge, absorb it, and adapt it to local needs in order to create new tools and technologies. (stamou, 2017, p. 3)

Figure 01 represents the knowledge economy indicators according to the World Bank methodology:

Figure 1: Knowledge Economy Indicators (KEI)



Source: Kaur, M., & Singh, L. (2015). Knowledge in Economic Growth of Developing Economies P2

2.4 Global Knowledge Index (GKI):

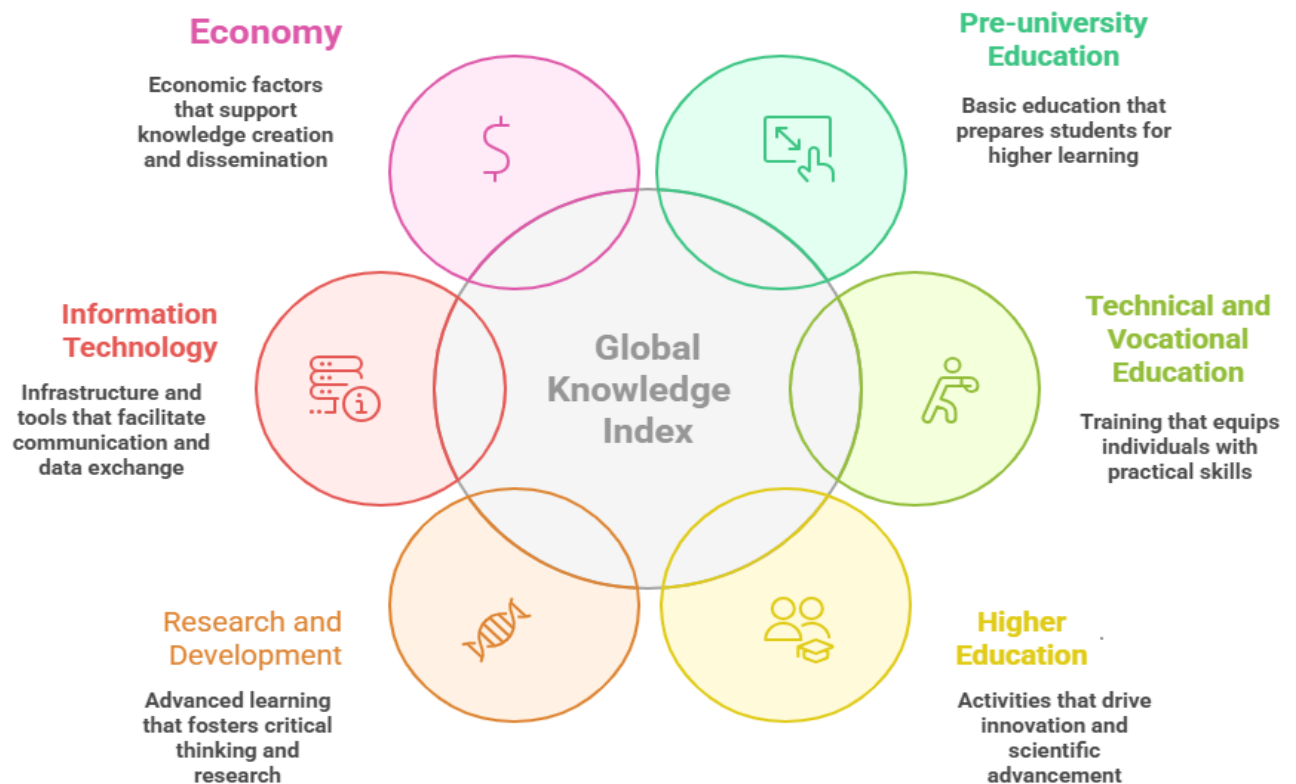
The Global Knowledge Index was established in 2017 as an initiative of the United Nations Development Programme and the Mohammed bin Rashid Al Maktoum Knowledge Foundation. This index measures knowledge in all its dimensions by assessing the performance of 138 countries in seven sectors. The index is based on the fundamental concept of a knowledge society, which relies on tremendous advances in information and communication technology and human capital that contributes to creativity and innovation.

A team of multidisciplinary academic researchers contributed to the development of this index in consultation with an expanded advisory team consisting of independent experts or experts affiliated with specialized international bodies. This index complements the Arab Knowledge Index. It provides an overview of each country's knowledge infrastructure to guide policymakers,

researchers, civil society, and the private sector to collaborate on various aspects of policy, promote knowledge-based societies, and bridge knowledge gaps. (المعرفة والثورة الصناعية الرابعة، تحليل مؤشر المعرفة العالمي 2017، صفحة 5)

The Global Knowledge Index consists of seven sub-indices that are strongly interrelated. The relationship between the quality of knowledge capital and the ability to build robust knowledge economies capable of achieving equitable and sustainable development requires greater attention to human resource development systems. It also requires developing and improving the efficiency of outputs in terms of pre-university education, technical education and vocational training, higher education, investment in research, development, and innovation, maximizing economic returns, developing information and communications technology infrastructure, stimulating economic openness, and increasing competitiveness. This requires a supportive social and political environment and a healthy and safe enabling environment so that these sectors can contribute to knowledge-based development. (سامر، 2021، صفحة 7).

Figure 2: Global Knowledge Index (GKI)



Source : <https://knoema.com/WBKEI2013/knowledge-economy-index-world-bank->

Figure 2 shows the basic indicators for the global knowledge economy according to the 2021 edition and beyond. The structure of the index is divided into five levels, from top to bottom, as follows: The general index is divided into sub-indices, each of which is linked to a set of themes that are in turn divided into sub-themes formed by a selected set of variables. A weighting of 15% has been assigned to each of the six sectoral indices and 10% to the enabling environment index. The Following is a breakdown of these indices : (المعرفة والثورة الصناعية الرابعة، تحليل مؤشر المعرفة العالمي 2017، صفحة 24).

- **Pre-university education Index:** consists of two axes, namely knowledge capital and the enabling educational environment.
- **Technical education and vocational training Index:** covers two axes, namely the components of technical education and vocational training, and the technical education and vocational training labor market.
- **Higher education Index:** Consists of three components: inputs, learning environment, and outputs.
- **Research development and innovation Index:** Consists of three components: inputs, outputs, and impact.
- **Information and Communication Technology Index:** Consists of three pillars, infrastructure, availability of information and communication technology, and usage.
- **Economy Index:** Consists of three areas: economic competitiveness, economic openness, and financing and local value added.
- **Enabling Environment Index:** Consists of three pillars: governance, social and economic environment, and health and environment.

5. The role of institutions in the knowledge economy:

Institutions are defined as established laws, customs, or practices. **Jepperson** defines them as a set of socially constructed rules and programs that are routinely reconfigured and function as relatively restrictive pillars. They are theoretical strategies that seek to apply and develop methods that enable the interpretation and study of the influences that shape institutions and practices within them. **North** defines it as "the rules of the game in society, or more formally, the constraints imposed by humans that regulate human interaction. It consists of formal rules (constitutions, laws, regulations) and informal rules (customs, traditions, social values) (تشيكو و عيود، 2022، صفحة 4).

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To understand and measure the knowledge economy, many international organizations and bodies have developed indicators to gauge the extent to which countries are integrated into this economy. Among the pillars they have adopted in constructing these indicators are economic incentives and institutional systems.

Numerous theoretical studies and empirical evidence have demonstrated the role of institutions in building the knowledge economy. According to North, institutions continuously invest in skills and knowledge in order to survive in competitive environments. Many factors can play a role in the achievement or failure of a knowledge economy. Through the interaction

between actors and institutions, and through the relationship between the production system, government agencies, universities, and educational centers that are influenced by the innovative performance of establishments, organizations, and economies, the technical and institutional dimensions of knowledge-based economy are intertwined. Institutions that facilitate the use of knowledge can also be responsible for promoting competition within the industry. In this way, they stimulate innovation, which is the cornerstone of the knowledge-based economy.

From Sheehan's point of view, promoting a knowledge-based economy requires not only the existence of institutions, but also that these institutions be strong and credible in practice. The development of knowledge-based economies is founded on an effective institutional framework and human capital, and the establishment of credible institutions is a fundamental prerequisite for building such an economy (Padash-Zive, 2015, p. 7)

Institutions are closely interrelated and create an environment conducive to human interaction. They reduce uncertainty while fostering stability and security for both organizations and individuals.

Furthermore, the creation and dissemination of knowledge in a knowledge-based economy depends heavily on appropriate government policies, which are usually the result of economic incentives and institutional arrangements. Governments therefore play a crucial role, as the creation and dissemination of knowledge cannot rely on market mechanisms alone. An appropriate framework of economic incentives and institutional arrangements is necessary to facilitate interaction between different sectors in the knowledge-based economy. Institutions also help generate and use new technologies that facilitate the task, especially those designed to protect and promote competition within the industry, the existence of agencies that set standards and develop new technologies, military orders that reduce uncertainty about demand for a new technology or product, and communication between organizations specializing in generating new knowledge, such as universities and research institutes, and intellectual property. (Schiliro, 2012, p. 4)

6. Econometric Study:

This study aims to examine the role of institutions in the knowledge economy, based on a sample of 18 countries that are considered leaders in the field of the knowledge economy, namely: Switzerland, the United States, Finland, Sweden, the Netherlands, Luxembourg, Singapore, Denmark, the United Kingdom, Germany, Japan, Norway, Austria, Belgium, Iceland, the Republic of Korea, France, and Canada. The study covers the period from 1996 to 2020, depending on data availability.

A composite index of several knowledge economy indicators was used as the dependent variable, while a composite institutional index based on the six governance indicators provided by the World Bank, GDP per capita, and trade openness were employed as independent variables. The analysis was conducted using panel data models and principal component analysis (PCA), with the application of Stata 17 software.

6.1 Study Model Specification:

The study model is formulated according to the following equation:

$$KE = \beta_0 + \beta_1 INST + \beta_2 GDPP + \beta_3 TO + \varepsilon \dots \dots \dots (01)$$

Where:

KE: Knowledge Economy Index, composed of five indicators as follows:

EDC: Expenditure on education (% of Gross National Income).

PRT: Total patent applications (by residents and non-residents).

INT: Percentage of Internet users per 100 inhabitants.

FT: Percentage of fixed telephone subscriptions per 100 inhabitants.

MT: Percentage of mobile phone subscriptions per 100 inhabitants.

INST: Institutional Index, composed of six indicators:

CC: Control of Corruption

RL: Rule of Law

GE: Government Effectiveness

PS: Political Stability

RQ: Regulatory Quality

VA: Voice and Accountability

GDPP: GDP per capita.

TO: Trade openness, measured as (Exports + Imports) / GDP.

β : Model parameters.

ε : Random error term

6.2. Principal Component Analysis (PCA) of Knowledge Economy Variables (KE)

According to the World Bank methodology, the Knowledge Economy Index consists of four main pillars: education and training, the economic and institutional regime, research and development, and the information and communication infrastructure. Each pillar includes several sub-indicators. However, since the official data for this composite index are not available, this study constructs a general index based on data availability using the Principal Component Analysis (PCA) method. Initially, the correlation matrix among the variables is computed, followed by the KMO test to evaluate the adequacy of applying this method.

Table 1: Correlation Matrix of the Variables

Variables	(1) INT	(2) FT	(3) MT	(4) EDC	(5) PRT
(1) INT	1.000				
(2) FT	-0.426	1.000			
(3) MT	0.873	-0.471	1.000		
(4) EDC	0.230	-0.087	0.110	1.000	
(5) PRT	-0.001	0.015	-0.054	-0.376	1.000

Source: Prepared by the researchers based on STATA 17 software

Table 2: KMO Test for the Variables

Variable	Kmo
(1) INT	0.527
(2) FT	0.884
(3) MT	0.529
(4) EDC	0.375
(5) PRT	0.352
Overall	0.529

Source: Prepared by the researchers based on STATA 17 software

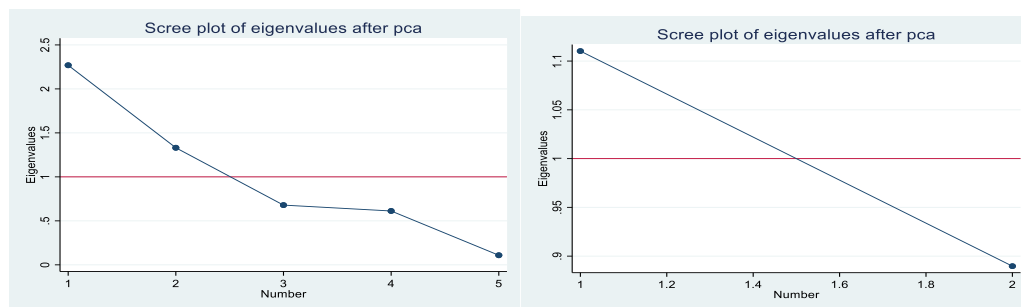
From the correlation matrix, it can be observed that most of the indicators are interrelated. Furthermore, the KMO test value exceeds 50%, indicating that all conditions are satisfied for applying the Principal Component Analysis (PCA) method

Table 3: Variance-Covariance Matrix

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.269	0.938	0.454	0.454
Comp2	1.331	0.652	0.266	0.720
Comp3	0.679	0.067	0.136	0.856
Comp4	0.612	0.503	0.122	0.978
Comp5	0.109	.	0.022	1.000

Source: Prepared by the researchers based on STATA 17 software

Figure 3: Scree Plot of Principal Components



Source: Prepared by the researchers based on STATA 17 software

Table 4: Determination of the Number of Components Using the Kassiar Method

First Stage				
Component	Variance	Difference	Proportion	Cumulative
Comp1	2.224	0.848	0.445	0.445
Comp2	1.376	.	0.275	0.720
Second Stage				
Component	Variance	Difference	Proportion	Cumulative
Comp3	1.110	.	0.555	0.555

Source: Prepared by the researchers based on STATA 17 software

Table 5: Component Matrix of Variables After Rotation

First Stage			
Variable	Comp1	Comp2	Unexplained
INT	0.618	0.029	0.143
FT	-0.467	0.039	0.521
MT	0.626	-0.009	0.132
EDC	0.073	0.690	0.312
PRT	0.062	-0.722	0.293
Second Stage			
Variable	Comp1	Unexplained	
pca1	0.707	0.445	
pca2	0.707	0.445	

Source: Prepared by the researchers based on STATA 17 software

The Principal Component Analysis (PCA) was conducted in two stages. In the first stage, two components, Comp1 and Comp2, were extracted. Comp1 included the number of Internet users, fixed telephone subscriptions, and mobile phone subscriptions, while Comp2 comprised education expenditure and the number of patent applications. In the second stage, a composite index, Comp3, was created by combining the two components. This is evident from the Scree Plot and Kaiser's method. Accordingly, all indicators can be represented by a single principal component, which accounts for the largest proportion of variance, estimated at 55.5%.

6.3. Principal Component Analysis (PCA) of Institutional Variables

Table 6: Correlation Matrix of Institutional Variables

Variables	(1) CC	(2) GE	(3) RQ	(4) RL	(5) PS	(6) VA
(1) CC	1.000					
(2) GE	0.850	1.000				
(3) RQ	0.768	0.763	1.000			
(4) RL	0.855	0.729	0.692	1.000		
(5) PS	0.639	0.606	0.370	0.588	1.000	
(6) VA	0.355	0.175	0.110	0.529	0.227	1.000

Source: Prepared by the researchers based on STATA 17 software

Table 7: KMO Test for Institutional Variables

Variable	Kmo
(1) CC	0.834
(2) GE	0.859
(3) RQ	0.787
(4) RL	0.807
(5) PS	0.818
(6) VA	0.533
Overall	0.802

Source: Prepared by the researchers based on STATA 17 software

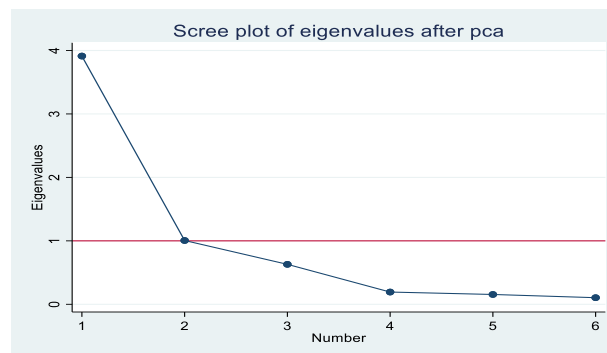
From the correlation matrix, it can be observed that all indicators are positively correlated with each other. Furthermore, the KMO test value is approximately 80%, indicating that all conditions are satisfied for applying the Principal Component Analysis (PCA) method.

Table 8: Variance-Covariance Matrix

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	3.912	2.907	0.652	0.652
Comp2	1.006	0.376	0.168	0.820
Comp3	0.630	0.437	0.105	0.925
Comp4	0.193	0.038	0.032	0.957
Comp5	0.155	0.051	0.026	0.983
Comp6	0.104	.	0.017	1.000

Source: Prepared by the researchers based on STATA 17 software

Figure 4: Scree Plot of Principal Components



Source: Prepared by the researchers based on STATA 17 software

Table 9: Determination of the Number of Components Using the Kassiar Method

Component	Variance	Difference	Proportion	Cumulative
Comp1	1.424		0.712	0.712

Source: Prepared by the researchers based on STATA 17 software

Table 10: Component Matrix of Variables After Rotation

Variable	Comp1	Unexplained
CC	0.479	0.087
GE	0.505	0.129
RQ	0.485	0.224
RL	0.398	0.117
PS	0.349	0.485
VA	-0.022	0.041

Source: Prepared by the researchers based on STATA 17 software

Based on the Scree Plot and Kaiser's method, it can be observed that the six indicators- Control of Corruption, Government Effectiveness, Regulatory Quality, Rule of Law, Political Stability, and Voice and Accountability-can be represented by a single principal component, which accounts for the largest proportion of variance, estimated at 71.2%.

1. Model Estimation

The model is estimated using panel data in STATA 17. Initially, three models are estimated: the pooled regression model, the fixed effects model, and the random effects model. The most appropriate model is then selected by comparing these three models through a series of statistical tests.

Table 11: Estimation Results of the Pooled Regression, Fixed Effects, and Random Effects Models

Dependent variable: KE (Knowledge Economy)			Number of countries: 18			
Study period: 1996-2020			Total observations: 450			
Explanatory Variables	Pooled Regression Model		Fixed Effects Model		Random Effects Model	
	P-value	Coef	P-value	Coef	P-value	Coef
INST	0.000	0.241	0.037	0.0622	0.241	-0.0773
GDPP	0.000	0.000	0.000	0.0531	0.000	0.0471
TO	0.000	0.000	0.000	1.0199	0.000	0.9439
Constant	0.000	0.000	0.000	-4.6109	0.000	-4.1182
R-squared	0.3000		0.7111		0.7077	
F-test	63.698		351.92		788.94	
Prob> F	0.000		0.000		0.000	

Source: Prepared by the researchers based on STATA 17 software

Table 12: Tests for Selecting the Appropriate Model

Appropriate	Calculated	Probability	Test
Fixed effects	0.0000	108.60	Ficher
Random effects	0.0000	924.88	Breusch and
Fixed effects	0.0000	31.99	Hausman

Source: Prepared by the researchers based on STATA 17 software

To select the appropriate model, we first compare the Pooled Regression Model with the Fixed Effects Model using the Ficher test. We observe that the p-value corresponding to its statistic is less than 5%, indicating that the Fixed Effects Model is preferable.

We also compare the Pooled Regression Model with the Random Effects Model using the Breusch and Pagan test. Given that the p-value of this statistic is below 5%, we conclude that the Random Effects Model is more appropriate.

Finally, we differentiate between the Fixed Effects Model and the Random Effects Model using the Hausman test. The p-value of this test is less than 5%, which indicates that the Fixed Effects Model is the most suitable for this study, as presented in Table 11.

2. Model Validity Tests:

To assess the validity of the model, several tests were conducted, as follows

2.1. Wooldridge Test for Autocorrelation:

The results indicate that the p-value of this test is less than 5%, implying that the studied model suffers from autocorrelation (see Appendix 04)

2.2. Test for Groupwise Heteroskedasticity

As shown in Appendix 05, the p-value of this test is less than 5%, indicating the presence of heteroskedasticity

2.3. Pesaran's Test of Cross-Sectional Independence:

According to Appendix 06, the p-value of this test is greater than 5%, suggesting no cross-sectional dependence problem.

2.4. Panel Corrected Errors (PCE) Model:

Based on the previous tests, the estimated model (Fixed Effects Model) suffers from autocorrelation and heteroskedasticity. Therefore, these issues are addressed by applying the Panel Corrected Errors (VCE) method, which accounts for heteroskedasticity and corrects the standard errors of the parameters to resolve estimation problems. Consequently, the final model is obtained as follows:

$$KE = -4.611 + 0.062 INST + 0.531 GDPP + 1.019 TO \dots \dots (02)$$

From Appendix (07), which presents the Panel Corrected Errors Model, we observe that the probability corresponding to the F-statistic is (0.0000), which is less than 5%. Therefore, the model is statistically significant. Moreover, the coefficient of determination (R^2) equals (0.7111), indicating that the independent variables explain 71.11% of the variation in the dependent variable, while the remaining percentage is explained by other factors not included in the model. We also note that the probability values associated with the F-statistics of the independent variables are less than 5%, which means that all the independent variables are statistically significant.

7. Interpretation of the Results:

The model obtained (Equation No. 02) shows the following results:

- ✓ A positive relationship between the Institutional Index and the Knowledge Economy Index.

An increase of one unit in the Institutional Index leads to an increase of 0.062 units in the Knowledge Economy. This finding is consistent with theoretical studies and empirical evidence. The countries under study are among the top performers in institutional indicators, having successfully created, over the past decades, a favorable environment for building strong economies based on knowledge and innovation. As a result, they have consistently ranked among the leading nations in the Global Knowledge Index

- ✓ A positive relationship between GDP per capita and the Knowledge Economy Index.

An increase of one unit in GDP per capita leads to an increase of 0.531 units in the Knowledge Economy. This indicator reflects the extent to which individuals contribute to the development of the knowledge economy through spending on education, research and development, and the use of modern technologies in daily life

- ✓ A positive relationship between Trade Openness and the Knowledge Economy Index.

An increase of one unit in Trade Openness leads to an increase of 1.019 units in the Knowledge Economy. This indicator has significantly contributed to the advancement of the knowledge economy through technology transfer, exchange of expertise among countries, and the creation of a favorable environment for investment and trade exchange.

Conclusion

Most studies have indicated that institutions play a major role in strengthening and building the knowledge economy, as they provide an appropriate environment for interaction among various sectors, reduce uncertainty, and bring stability and security to organizations and individuals. Governments also play a crucial role, since the creation and dissemination of knowledge cannot rely solely on market mechanisms. Therefore, the existence of a proper framework of economic incentives and institutional systems is essential

International organizations and institutions that have developed indicators for the knowledge economy -such as the World Bank Index and the Global Knowledge Index - have emphasized the institutional dimension. In this study, we aimed to examine the role of institutions in building the knowledge economy for a sample of 18 countries that top the Global Knowledge Index, covering the period (1996-2020). Panel data models were applied using STATA17 software.

A composite index for the knowledge economy was constructed from a set of sub-indicators, along with an institutional index composed of the six governance indicators. The results showed that the institutional index plays a significant role in building the knowledge economy. It is well known that the countries under study have led the world in institutional

indicators for decades, and this factor has been fundamental to their position in the Knowledge Economy Index. This is also reflected in the Trade Openness Index, which has contributed to the transfer of technology and the expansion of trade and knowledge exchanges among nations.

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Appendices:

Appendix 1: Estimation of the Fixed Effects Model

```
. xtreg KE INST GDPP TO, fe
```

Fixed-effects (within) regression	Number of obs	=	450
Group variable: pays	Number of groups	=	18
R-squared:	Obs per group:		
Within = 0.7111	min =		25
Between = 0.1514	avg =		25.0
Overall = 0.2103	max =		25
corr(u_i, Xb) = -0.8430	F(3,429)	=	351.92
	Prob > F	=	0.0000

KE	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
INST	.0622398	.0697126	0.89	0.372	-.0747809	.1992605
GDPP	.0531837	.0017097	31.11	0.000	.0498233	.056544
TO	1.019927	.0967981	10.54	0.000	.8296695	1.210185
_cons	-4.610915	.1495292	-30.84	0.000	-4.904816	-4.317014
sigma_u	1.6325799					
sigma_e	.39164567					
rho	.94558266	(fraction of variance due to u_i)				

F test that all u_i=0: F(17, 429) = 108.60 Prob > F = 0.0000

Appendix 2: Breusch and Pagan Lagrangian Multiplier Test

```
. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

      KE[pays,t] = Xb + u[pays] + e[pays,t]

Estimated results:
      _____
      |          Var      SD = sqrt(Var)
      |_____
      | KE      1.110265    1.053691
      |  e      .1533863    .3916457
      |  u      .317837     .5637703
      |_____

Test: Var(u) = 0
      chibar2(01) =    924.88
      Prob > chibar2 =    0.0000
```

Appendix 3: Hausman Test

```
. hausman fixed_model random_model

      _____ Coefficients _____
      |          (b)          (B)          (b-B)          sqrt(diag(V_b-V_B))
      | fixed_model random_model Difference          Std. err.
      |_____
INST  | .0622398   -.0773242    .139564    .0226716
GDPP  | .0531837    .0471563    .0060273    .
TO    | 1.019927    .9439825    .0759445    .

      b = Consistent under H0 and Ha; obtained from xtreg.
      B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

      chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)
              = 31.99
      Prob > chi2 = 0.0000
      (V_b-V_B is not positive definite)
```

Appendix:4 Wooldridge Test for Autocorrelation

```
. xtserial KE INST GDPP TO

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
      F( 1,      17) =    132.610
      Prob > F =    0.0000
```

Appendix 5: Heteroskedasticity Test

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (18) =      473.90
Prob>chi2 =      0.0000
```

Appendix 6: Pesaran's Test of Cross-Sectional Independence

```
. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =      21.991, Pr = 0.0000

Average absolute value of the off-diagonal elements =      0.506
```

Appendix 7: Results of the Panel Corrected Errors Model Estimation

```
. xtreg KE INST GDPP TO, fe vce(robust)

Fixed-effects (within) regression           Number of obs   =      450
Group variable: pays                       Number of groups =      18

R-squared:                                Obs per group:
   Within = 0.7111                          min =          25
   Between = 0.1514                         avg =          25.0
   Overall = 0.2103                         max =          25

                                F(3,17)           =      43.01
corr(u_i, Xb) = -0.8430              Prob > F        =      0.0000

                                (Std. err. adjusted for 18 clusters in pays)
```

KE	Coefficient	Robust std. err.	t	P> t	[95% conf. interval]	
INST	.0622398	.1911335	0.33	0.749	-.3410166	.4654962
GDPP	.0531837	.0059133	8.99	0.000	.0407078	.0656596
TO	1.019927	.1471655	6.93	0.000	.7094349	1.330419
_cons	-4.610915	.4413893	-10.45	0.000	-5.542165	-3.679665
sigma_u	1.6325799					
sigma_e	.39164567					
rho	.94558266	(fraction of variance due to u_i)				

Source: Outputs of STATA 17 Software