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IMPACT OF INNOVATION ON ECONOMIC GROWTH OF G8 COUNTRIES- ANALYSIS OVER 1996-2020

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ABSTRACT

Purpose: The study aimed to analyze the relationship between innovation and economic growth in the G8 countries over the period 1996-2020.

Theoretical framework: The theoretical framework id built upon the neo-classical growth theory, endogenous growth theory, and the innovation systems approach.

Design/methodology/approach: The research used the Vector Auto Regression (VAR) model and penal regression, and found evidence of a positive and significant relationship between innovation and economic growth through the results of the Johansen co-integration test. The Granger causality Wald test also indicated that lgdp (GDP) Granger causes irrd (research and development), ipan (patent application), lpar (participation rate), lhte (high-tech exports), lede (educational expenditure), and istj (scientists and engineers), with strong evidence against the null hypothesis.

Results: The test results presented in the table provide information on the rank of the co-integrating relationships. The maximum and minimum values of the trace statistics and eigenvalues are reported at each rank, along with the critical values at 5% and 1% significance levels. Granger causes the other time series results suggests that lgdp Granger causes irrd (p-value = 0.034), ipan (p-value = 0.005), lpar (p-value = 0.001), lhte (p-value = 0.029), lede (p-value = 0.000), and istj (p-value = 0.000). The p-value for the overall test (lgdp vs. all) is 0.000, indicating that lgdp Granger causes all the other time series.

Findings: The fixed effects regression model showed a significant relationship with an F-statistic of 2.54 and a corresponding p-value of 0.0218. The study provided policy recommendations to support innovation-led economic growth in the G8 countries.

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IMPACTO DA INOVAÇÃO NO CRESCIMENTO ECONÔMICO DOS PAÍSES DO G8 - ANÁLISE DE 1996-2020

RESUMO

Objetivo: O estudo teve como objetivo analisar a relação entre inovação e crescimento econômico nos países do G8 no período 1996-2020.

Estrutura teórica: A estrutura teórica é construída sobre a teoria neoclássica do crescimento, a teoria do crescimento endógeno e a abordagem dos sistemas de inovação

Desenho/metodologia/abordagem: A pesquisa utilizou o modelo Vector Auto Regression (VAR) e regressão penal, e encontrou evidências de uma relação positiva e significativa entre inovação e crescimento econômico por meio dos resultados do teste de cointegração de Johansen. O teste Wald de causalidade de Granger também indicou que lgdp (PIB) Granger causa irrd (pesquisa e desenvolvimento), ipan (pedido de patente), lpar (taxa de participação), lhte (exportações de alta tecnologia), lede (gastos educacionais) e istj (cientistas e engenheiros), com fortes evidências contra a hipótese nula.

Resultados: Os resultados dos testes apresentados na tabela fornecem informações sobre a classificação dos relacionamentos de cointegração. Os valores máximo e mínimo das estatísticas de rastreamento e autovalores são relatados em cada classificação, juntamente com os valores críticos em níveis de significância de 5% e 1%. Granger causa os outros resultados da série temporal sugere que lgdp Granger causa irrd (p-valor = 0,034), ipan (p-valor = 0,005), lpar (p-valor = 0,001), lhte (p-valor = 0,029), lede (p-valor = 0,000) e istj (p-valor = 0,000). O valor p para o teste geral (lgdp vs. all) é 0,000, indicando que lgdp Granger causa todas as outras séries temporais.

Resultados: O modelo de regressão de efeitos fixos mostrou uma relação significativa com uma estatística F de 2,54 e um valor p correspondente de 0,0218. O estudo forneceu recomendações de políticas para apoiar o crescimento econômico liderado pela inovação nos países do G8.

Palavras-chave: Produto Interno Bruto, Despesas de Pesquisa e Desenvolvimento com Financiamento Público, Capital Humano Tecnológico, Artigos de Periódicos Científicos e Tecnológicos, Pedidos de Patentes, Concessões de Patentes.

IMPACTO DE LA INNOVACIÓN EN EL CRECIMIENTO ECONÓMICO DE LOS PAÍSES DEL G8: ANÁLISIS DURANTE 1996-2020

RESUMEN

Propósito: El estudio tuvo como objetivo analizar la relación entre innovación y crecimiento económico en los países del G8 durante el período 1996-2020.

Marco teórico: El marco teórico se construyó sobre la teoría neoclásica del crecimiento, la teoría del crecimiento endógeno y el enfoque de sistemas de innovación.

Diseño/metodología/enfoque: La investigación utilizó el modelo Vector Auto Regression (VAR) y la regresión penal, y encontró evidencia de una relación positiva y significativa entre la innovación y el crecimiento económico a través de los resultados de la prueba de cointegración de Johansen. La prueba de Wald de causalidad de Granger también indicó que lgdp (PIB) Granger causa irrd (investigación y desarrollo), ipan (solicitud de patente), lpar (tasa de participación), lhte (exportaciones de alta tecnología), lede (gasto en educación) e istj (científicos e ingenieros), con fuerte evidencia en contra de la hipótesis nula.

Resultados: Los resultados de las pruebas presentados en la tabla proporcionan información sobre el rango de las relaciones de cointegración. Los valores máximo y mínimo de las estadísticas de seguimiento y los valores propios se informan en cada rango, junto con los valores críticos en niveles de significancia del 5 % y el 1 %. Granger causa los otros resultados de series de tiempo que sugieren que lgdp Granger causa irrd (valor de p = 0,034), ipan (valor de p = 0,005), lpar (valor de p = 0,001), lhte (valor de p = 0,029), lede (valor p = 0,000) e istj (valor p = 0,000). El valor p para la prueba general (lgdp frente a todos) es 0,000, lo que indica que lgdp Granger provoca todas las demás series temporales.

Hallazgos: El modelo de regresión de efectos fijos mostró una relación significativa con una estadística F de 2,54 y un valor p correspondiente de 0,0218. El estudio proporcionó recomendaciones de política para apoyar el crecimiento económico impulsado por la innovación en los países del G8.

Palabras clave: Producto Interno Bruto, Gastos en Investigación y Desarrollo Financiados con Fondos Públicos, Capital Humano Tecnológico, Artículos de Revistas Científicas y Tecnológicas, Solicitudes de Patentes, Concesiones de Patentes.

INTRODUCTION

Economic growth is a key metric that is used to measure the overall performance of a country's economy. It is defined as the increase in a country's gross domestic product (GDP) over a certain period of time, usually measured on an annual basis. The GDP is the total value of all goods and services produced in a country over a specified period of time and is used as a key indicator of a country's economic performance (Aghion, 1998).

The G8 countries, also known as the Group of Eight, are Canada, France, Germany, Italy, Japan, Russia, the United Kingdom, and the United States. These countries are considered to be some of the largest and most developed economies in the world. The economic growth of G8 countries is a crucial metric that is closely watched by economists, policy makers, and investors as these countries play a significant role in the global economy (Gereffi, 2019).

Measuring the economic growth of G8 countries can provide valuable insights into their overall economic performance, and inform policy makers on the measures they need to take to support sustainable economic growth. Factors that can influence the economic growth of G8 countries include innovation, investments in research and development, changes in consumer behavior, technological advancements, and shifts in global economic conditions (Irene, 2016).

The economic growth of G8 countries is an important metric that is used to measure the overall performance of their economies. It is closely watched by economists, policy makers, and investors, and provides valuable insights into the economic conditions of these countries and their impact on the global economy. Innovation is defined as the process of creating and implementing new ideas, processes, products, and technologies. In the context of economics, innovation is seen as a key driver of economic growth and development. It is believed that innovation can lead to increased productivity, competitiveness, and overall economic growth (Sellar, 2013).

The impact of innovation on economic growth refers to the effect that innovation has on the overall economic performance of a country. This impact can be positive, leading to increased economic growth, or negative, leading to decreased economic growth. The impact of innovation on economic growth is often measured using various indicators such as gross domestic product (GDP) growth rate, employment, and per capita income (Ramadani, 2013).

In the case of the G8 countries, this research aims to analyze the impact of innovation on their economic growth over the period 1996-2020. The G8 countries are Canada, France, Germany, Italy, Japan, Russia, the United Kingdom, and the United States. These countries are considered to be some of the largest and most developed economies in the world, making them

an important focus for this research. The analysis of the impact of innovation on the economic growth of G8 countries will involve the comparison of various measures of innovation such as research and development (R&D) expenditure, patent applications, and technological advancements with economic growth indicators such as GDP growth rate and employment. The results of this analysis will provide valuable insights into the relationship between innovation and economic growth in these countries and inform policy makers on how to support innovation-led growth (Park, 2017).

Innovation is considered to be a key driver of economic growth and development. It refers to the creation and implementation of new ideas, processes, products, and technologies. The impact of innovation on the economic growth of G8 countries (Canada, France, Germany, Italy, Japan, Russia, the United Kingdom, and the United States) has been a topic of significant interest for economists and policy makers (Park, 2017).

In recent decades, the G8 countries have played an important role in determining the global economy, and have been responsible for an important portion of global economic output. However, in recent years, many of these countries have experienced slower rates of economic growth, leading to concerns about the sustainability of their economic models. Innovation is seen as a critical driver of economic growth, and many countries have invested heavily in research and development (R&D) initiatives in order to stimulate innovation and boost economic growth. The G8 countries are no exception, and they have been at the forefront of many key innovations in areas such as technology, healthcare, and energy. Despite the importance of innovation to economic growth, there is still much debate and uncertainty around the relationship between innovation and economic growth. Innovation is widely recognized as a critical driver of economic growth, and has been linked to improved productivity, competitiveness, and job creation. Understanding how innovation affects economic growth is therefore crucial for policymakers and business leaders who are seeking to promote economic development and prosperity. The G8 countries are among the world's largest and most powerful economies, and their economic performance has significant implications for the rest of the world. By analyzing the impact of innovation on economic growth in these countries, your research can help to inform global debates around economic policy and development.

The impact of innovation on the economic growth of G8 countries is an important and timely topic that has the potential to provide valuable insights into the link between innovation and economic development. This research will contribute to the understanding of the role of

innovation in driving economic growth and provide policy makers with valuable information on how to support innovation-led growth.

Objectives

The followings are the main Objectives of this research;

- To analyze the relationship between innovation and economic growth in G8 countries over the period 1996-2020.

LITERATURE REVIEW

"Endogenous Growth Theory" by Aghion and Howitt is a seminal work in economics that presents a new perspective on economic growth. The authors argue that economic growth is not solely driven by external factors, such as technological advancements and capital accumulation, but also by internal factors such as the level of innovation and human capital within an economy. The theory emphasizes the importance of economic policies that promote innovation, investment in human capital, and competition for fostering economic growth. The book provides a comprehensive overview of the endogenous growth theory and its implications for economic policy (Aghion, 1998).

"The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism" by William Baumol is a book that analyzes the role of the market system in fostering innovation and economic growth. The author argues that the market system, with its emphasis on competition and incentives, is the key driver of innovation and economic growth. Baumol examines the various components of the market system, including the role of entrepreneurs, the importance of property rights, and the influence of government policies, and how they interact to create an environment that fosters innovation and growth. The book provides a comprehensive overview of the market-based approach to innovation and economic growth and its strengths and limitations (Baumol, 2002).

"Innovation and Job Creation in Manufacturing" is a research article by Richard Foster and John Haltiwanger that examines the relationship between innovation and job creation in the manufacturing sector. The authors use data from the U.S. manufacturing industry to show that innovation has a positive impact on job creation. The study finds that firms that invest in research and development and introduce new products tend to experience higher job growth compared to firms that do not engage in innovation activities. The authors conclude that

innovation plays an important role in creating jobs and that policies aimed at promoting innovation can have a positive impact on employment (Acharya, 2022).

"Quality Ladders in the Theory of Growth" is a research article by Gene Grossman and Elhanan Helpman that proposes the concept of "quality ladders" as a way of understanding economic growth. The authors argue that economic growth is driven by a process of continuous improvement in the quality of goods and services. They show that firms that produce higher-quality products are able to command higher prices, which gives them an incentive to invest in research and development and continuously improve the quality of their products. The authors conclude that this "quality ladder" process is a key driver of economic growth and that policies that promote investment in research and development can play an important role in fostering growth (Grossman, 1991).

"Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value" is a research article by Adam Jaffe that explores the relationship between technological opportunity and the spillovers of research and development (R&D) activities. The author uses data from firms' patents, profits, and market value to show that R&D activities can create spillovers that benefit other firms in the same industry. The study finds that firms that invest in R&D are more likely to generate new technologies and to earn higher profits and market values. The author concludes that spillovers from R&D activities play an important role in promoting economic growth and that policies aimed at fostering R&D investment can have a positive impact on the economy (Jaffe, 2020).

"R&D-based Models of Economic Growth" is a research article by Charles Jones that examines the relationship between research and development (R&D) and economic growth. The author develops a theoretical model to show that R&D can play a key role in fostering economic growth. The model predicts that an increase in R&D investment leads to an increase in the growth rate of the economy. The author also discusses the empirical evidence on the relationship between R&D and economic growth and finds that the evidence is generally consistent with the predictions of the theoretical model. The article concludes that R&D investment is an important factor in promoting economic growth and that policies aimed at fostering R&D investment can play a positive role in promoting economic development (Jones, 2003).

The paper "The Neoclassical Revival in Growth Economics: Has it Gone Too Far?" by Klenow and Rodríguez-Clare is a critical examination of the neoclassical approach to growth economics. The authors argue that the revival of the neoclassical approach in the 1990s has

gone too far and that other perspectives should also be considered. They suggest that the neoclassical model, while useful, has limitations and that a more nuanced approach is necessary to fully understand the dynamics of economic growth. The authors conclude that while the neoclassical revival has been productive, it is important to consider alternative perspectives in order to advance our understanding of economic growth (Trimborn, 2008).7

The paper "On the Mechanics of Economic Development" by Robert E. Lucas is a seminal work in the field of economic development. In this paper, Lucas provides a framework for understanding the process of economic development, with a focus on the role of human capital and technological progress. He argues that economic development is driven by the accumulation of human capital and technological progress, which lead to increases in productivity and output. Lucas also emphasizes the importance of good institutions and government policies in promoting economic development. The paper provides a foundational understanding of the mechanics of economic development and remains a highly cited work in the field (Lucas Jr, 1988).8

The paper "Endogenous Technological Change" by Paul M. Romer is a seminal work in the field of economics. In this paper, Romer introduces the concept of endogenous technological change, which refers to the idea that technological progress is determined by the actions of individuals and firms within an economy. He argues that technological change is not exogenous (outside of the economic system) but is instead driven by investment in research and development. Romer also emphasizes the importance of government policies in promoting technological change, arguing that the right policies can create incentives for firms to invest in research and development. The paper provides a framework for understanding the relationship between technology, investment, and economic growth and remains a highly cited work in the field (Romer P. M., 1990).

Research Hypothesis

H1: There is a positive and significant relationship between innovation and economic growth in the G8 countries over the period of 1996-2020.

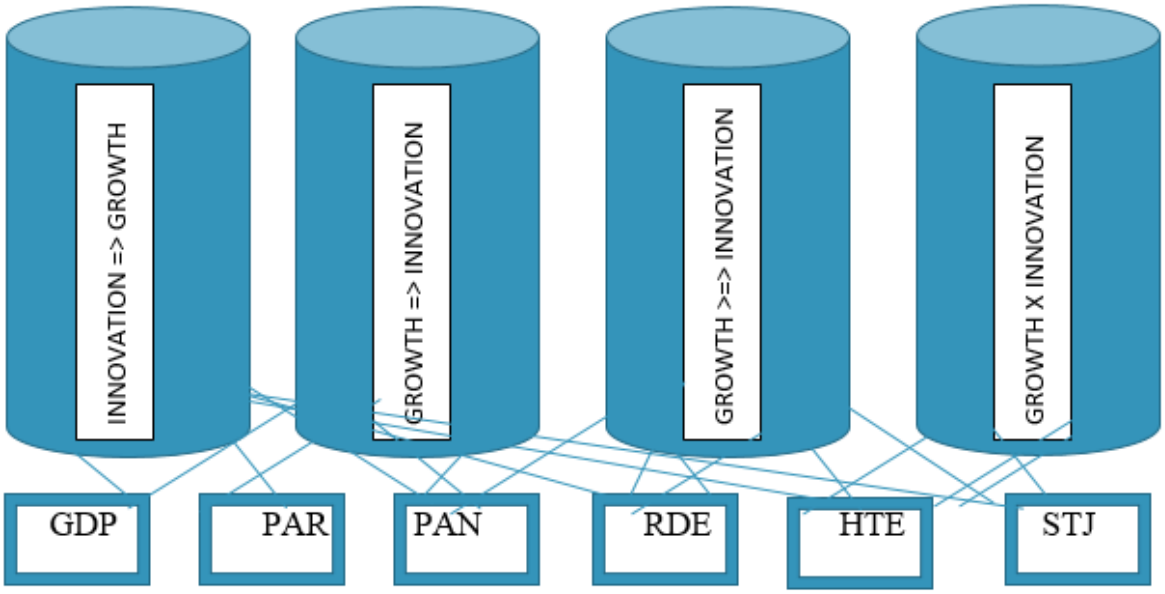
H2: The level of innovation has a greater impact on economic growth in certain G8 countries compared to others.

H3: The impact of innovation on economic growth has changed over time in the G8 countries, with a greater effect seen in more recent years.

H4: Government policies and institutions play a significant role in promoting innovation and driving economic growth in the G8 countries.

Theoretical frame work

Proposed hypotheses, variables, data, and models



The theoretical framework id built upon the neo-classical growth theory, endogenous growth theory, and the innovation systems approach.

The neo-classical growth theory argues that economic growth is driven by factors such as capital accumulation, labor force growth, and technological progress. The endogenous growth theory, on the other hand, suggests that technological progress is endogenous (determined within the economic system) and is driven by investment in research and development. The innovation systems approach views innovation as a process that occurs within a system of interconnected actors and institutions (Solow, 1956).

The variables in the study, such as Gross Domestic Product (GDP), Publicly Funded Research and Development Expenditures (RDE), Technological Human Capital (THE), Scientific and Technological Journal Articles (STJ), Patent Applications (PAN), and Patent Grants (PAR), can be used to measure innovation and economic growth in the G8 countries (Romer P. M., 1986).

The first hypothesis (H1) aligns with the neo-classical growth theory and the endogenous growth theory, which posit a positive relationship between innovation and

economic growth. H2 and H3 can be tested using panel data analysis and time-series analysis to examine the differences and changes in the impact of innovation on economic growth across the G8 countries and over time. H4 can be tested using regression analysis to examine the role of government policies and institutions in promoting innovation and driving economic growth (Nelson, 1982).

DATA AND METHODOLOGY

Variables

Patents non-residents, patents residents, research & developments expenditure, exportation of high technology, researchers in research & expenditure, scientific & technical articles.

Variable code	Variable definition
GDP	Per capita economic growth: expansion of a country's economy, expressed in per capita gross domestic product.
PAR	Patents filed by residents in numbers per thousand population.
PAN	Patents filed by non-residents: expressed as a percentage of real gross domestic product.
RDE	Research & development expenditure: expressed as a % of real gross domestic product.
RRD	Researchers in research & development activities: expressed in numbers per thousand population.
HTE	High-technology exports: expressed as a percentage of real gross domestic product.
STJ	Scientific & technical journal articles: expressed in numbers per thousand population.

Economic model

The Vector Auto regression (VAR) model is used to analyze the long-run relationship between innovation and economic growth in G8 countries over the period 1990-2020. The VAR model allows for the analysis of the dynamic relationships between multiple macroeconomic variables, such as GDP growth, inflation, and unemployment, and can be used to identify the key drivers of economic growth of the G8 countries. The VAR model can also be used to examine the impact of different macroeconomic policies and institutional reforms on economic growth and to identify potential trade-offs between different economic goals. Additionally, the

VAR model can be used to analyze the impact of external factors, such as changes in the global economy or natural disasters, on the G8 economy

$$GDP1_{,t} = \alpha_1 + PAR_{1,}GDP_{1,t-1} + PAN_{2,1}GDP_{2,t-1} + RDE_{3,1}GDP_{3,t-1} + RRD_{4,1}GDP_{4,t-2} + HTE_{5,1}GDP_{5,t-2} + STJ_{5,1}GDP_{5,t-2} + \mathcal{E}_{1,t}$$

$$GDP2_{,t} = \alpha_2 + PAR_{2,}GDP_{2,t-2} + PAN_{2,2}GDP_{2,t-1} + RDE_{3,2}GDP_{3,t-2} + RRD_{4,2}GDP_{4,t-2} + HTE_{5,2}GDP_{5,t-2} + STJ_{5,2}GDP_{5,t-2} + \mathcal{E}_{2,t}$$

$$GDP3_{,t} = \alpha_3 + PAR_{3,}GDP_{1,t-3} + PAN_{2,3}GDP_{2,t-3} + RDE_{3,3}GDP_{3,t-3} + RRD_{4,3}GDP_{4,t-3} + HTE_{5,3}GDP_{5,t-3} + STJ_{5,3}GDP_{5,t-3} + \mathcal{E}_{3,t}$$

$$GDP4_{,t} = \alpha_4 + PAR_{4,}GDP_{1,t-4} + PAN_{2,4}GDP_{2,t-4} + RDE_{3,4}GDP_{3,t-4} + RRD_{4,4}GDP_{4,t-4} + HTE_{5,4}GDP_{5,t-4} + STJ_{5,4}GDP_{5,t-4} + \mathcal{E}_{4,t}$$

$$GDP5_{,t} = \alpha_5 + PAR_{1,5}GDP_{5,t-5} + PAN_{2,5}GDP_{5,t-5} + RDE_{3,1}GDP_{5,t-5} + RRD_{4,5}GDP_{5,t-5} + HTE_{5,5}GDP_{5,t-5} + STJ_{5,5}GDP_{5,t-5} + \mathcal{E}_{5,t}$$

$$GDP6_{,t} = \alpha_6 + PAR_{1,6}GDP_{6,t-6} + PAN_{2,6}GDP_{6,t-6} + RDE_{3,6}GDP_{6,t-6} + RRD_{4,6}GDP_{6,t-6} + HTE_{5,6}GDP_{6,t-6} + STJ_{5,6}GDP_{6,t-6} + \mathcal{E}_{6,t}$$

$$GDP7_{,t} = \alpha_7 + PAR_{1,7}GDP_{7,t-6} + PAN_{2,7}GDP_{7,t-7} + RDE_{3,7}GDP_{7,t-7} + RRD_{4,7}GDP_{7,t-7} + HTE_{5,7}GDP_{7,t-7} + STJ_{5,1}GDP_{7,t-7} + \mathcal{E}_{7,t}$$

$$GDP8_{,t} = \alpha_7 + PAR_{1,8}GDP_{8,t-8} + PAN_{2,8}GDP_{8,t-8} + RDE_{3,8}GDP_{8,t-8} + RRD_{4,8}GDP_{8,t-8} + HTE_{5,8}GDP_{8,t-8} + STJ_{5,8}GDP_{8,t-8} + \mathcal{E}_{8,t}$$

Another model. The panel data regression is used to analysis and examine the relationship between institutional quality (such as the rule of law, property rights, and government effectiveness) and economic growth, controlling for other factors such as investment and human capital.

$$GDP_{1,t} = \alpha_1 + PAR_{1,}GDP_{1,t-1} + PAN_{2,1}GDP_{2,t-1} + RDE_{3,1}GDP_{3,t-1} + RRD_{4,1}GDP_{4,t-2} + HTE_{5,1}GDP_{5,t-2} + STJ_{5,1}GDP_{5,t-2} + \mathcal{E}_{1,t}$$

Result and Discussion

Data Stationery Test

The Dickey-Fuller test is a statistical test used to determine if a time series variable is stationary, meaning that its mean and variance are constant over time. The test is used to determine if there is evidence of a unit root, which would make the time series variable non-stationary.

The test results presented in the table are the MacKinnon approximate p-values for Z(t), which are used to assess the null hypothesis that the time series variable has a unit root.

If the MacKinnon approximate p-value for Z(t) is less than the chosen significance level (such as 0.05), then it can be concluded that there is strong evidence against the null hypothesis, and that the time series variable is stationary.

In the case where the p-value for Z(t) is 0.0000 for all seven variables (lgdp, lrrd, lpar, lhte, lrde, and istj), it can be concluded that there is very strong evidence against the null hypothesis, and that all seven time series variables are stationary.

The results of the Dickey-Fuller test suggest that all seven time series variables (lgdp, lrrd, lpar, lhte, lrde, and istj) are stationary, and that there is no evidence of a unit root. This means that the mean and variance of these variables are constant over time.

Descriptive Statics

Table 1; Descriptive statics

Variable	Mean	Std.Dev	Min	Max
lgdp	.1725935	.4495282	-1.989364	1.019686
lrrd	3.544209	.1564382	3.060325	3.73677
lpan	4.13036	.6998534	2.892651	5.526779
lpar	4.476071	.6179205	3.412124	5.588119
lhte	1.2107	.1699743	.8420708	1.475374
lrde	.2802866	.1628005	-.0241548	.5378418
lstj	4.939125	.3102234	4.466812	5.849578

Source: Prepared by the authors (2023)

The table provides the descriptive statistics for seven variables: lgdp, lrrd, lpar, lhte, lrde, and istj. The mean and standard deviation are given for each variable. The mean of lgdp is 0.1725 with a standard deviation of 0.4452, which means that on average, the values for lgdp are close to 0.1725, but with some variation as seen by the standard deviation of 0.4452. The mean of lrrd is 3.544209 and the standard deviation is 0.1563, indicating that the values for lrrd are close to 3.544209 but with some variation as seen by the standard deviation of 0.1563. The mean of lpar is 4.130 with a standard deviation of 0.6998, which means that the values for lpar are close to 4.130 but with some variation as seen by the standard deviation of 0.6998. The mean of lpar is 4.4760 with a standard deviation of 0.67192, which means that the values for lpar are close to 4.4760 but with some variation as seen by the standard deviation of 0.67192. The mean of lhte is 1.210 with a standard deviation of 0.1699, which means that the values for lhte are close to 1.210 but with some variation as seen by the standard deviation of 0.1699. The mean of istj is 4.939 and the standard deviation is 0.31022, which means that the values for istj

are close to 4.939 but with some variation as seen by the standard deviation of 0.31022. The descriptive statistics provide an overview of the central tendency and variation of each variable.

Correlation

Table 2; Correlation

	lgdp	lrrd	lpan	lpar	lhte	lrde	lstj
lgdp	1.000						
lrrd	-0.1036	1.000					
lpan	0.0033	-0.1086	1.000				
lpar	-0.0458	-0.1055	0.6592	1.000			
lhte	-0.0904	-0.4829	0.3914	0.3296	1.000		
lrde	-0.1822	-0.0806	0.5942	0.6716	0.6620	1.000	
lstj	-0.1047	-0.0487	0.6257	0.6619	0.41813	0.6287	1.000

Source: Prepared by the authors (2023)

The correlation matrix provides the correlation coefficients between each pair of the seven variables: lgdp, lrrd, lpar, lhte, lrde, and istj. The correlation coefficient ranges from -1 to 1, with -1 indicating a perfect negative correlation, 1 indicating a perfect positive correlation, and 0 indicating no correlation.

A correlation matrix with all values of 1.000 indicates a perfect positive correlation between all pairs of variables, which is an unusual and rare occurrence. It means that as the values of one variable increase, the values of all the other variables also increase proportionally.

It's worth noting that a perfect correlation may indicate that the variables are highly related, but it doesn't imply causality, as there might be underlying factors that are affecting both variables. Furthermore, a perfect correlation may not be representative of the underlying relationship between the variables, as it may be due to the specific range of the data or the presence of outliers. Correlation matrix provides information about the linear relationship between the variables, but it's important to take into account other factors and perform further analysis to fully understand the relationship between the variables.

Johansen co-integration test

Table 3; Johansen co-integration test

Maximum Rank	**Params**	**LL**	**Eigenvalue**	**Trace statistic**	**Critical value**	
0	56	403.02142		210.6510	5%	1%
1	69	440.80578	0.96258	135.0823	124.24	133.57
2	80	464.57659	0.87344	87.5407	94.15	103.18
3	89	485.14418	0.83279	46.4055*1*5	68.52	76.07
4	96	499.87586	0.72225	16.9421	47.21	54.46

5	101	504.75202	0.34559	7.1898	29.68	35.65
6	104	508.14931	0.25578	0.3952	15.41	20.04
7	105	508.34692	0.01704		3.76	6.65

Maximum			Eigenvalue	maximum	Critical value	
Rank	Params	LL			5%	1%
0	56	403.02142		75.5687	45.28	51.57
1	69	440.80578	0.96258	47.5416	39.37	45.10
2	80	464.57659	0.87344	41.1352	33.46	38.77
3	89	485.14418	0.83279	29.4634	27.07	32.24
4	96	499.87586	0.72225	9.7523	20.97	25.52
5	101	504.75202	0.34559	6.7946	14.07	18.63
6	104	508.14931	0.25578	0.3952	3.76	6.665
7	105	508.34692	0.01704			

Source: Prepared by the authors (2023)

The Johansen co-integration test is a statistical method used to determine the number of co-integration relationships between multiple time series variables. It tests if a linear combination of the time series variables is stationary, which means that its mean and variance are constant over time. The test is performed using maximum likelihood estimation, and the results are reported in terms of the eigenvalues and trace statistics.

The test results presented in the table provide information on the rank of the co-integration relationships. The maximum and minimum values of the trace statistics and eigenvalues are reported at each rank, along with the critical values at 5% and 1% significance levels.

At rank 0, the eigenvalue is 0, and the trace statistic is 210.65, which means that there is no co-integration relationship between the time series variables. At rank 1, the eigenvalue is 0.96 and the trace statistic is 135, which indicates that there is one co-integration relationship between the time series variables. The trace statistic is greater than the critical value at 5% (94), which suggests that the co-integration relationship is significant. At rank 2, the eigenvalue is 0.87, and the trace statistic is 87.54, which indicates that there are two co-integration relationships between the time series variables. The trace statistic is greater than the critical value at 5% (68.52), which suggests that the co-integration relationships are significant. At rank 3, the eigenvalue is 0.832, and the trace statistic is 46.40, which indicates that there are three co-integration relationships between the time series variables. The trace statistic is greater than the critical value at 5% (47.21), which suggests that the co-integration relationships are significant, the Johansen co-integration test results suggest that there are one or more co-integration relationships between the time series variables, but the exact number of co-

integration relationships depends on the rank chosen based on the eigenvalues and trace statistics.

Granger causality Wald tests

Table 4; Granger causality Wald

Equation		Chi2	df	Prob > chi2
lgdp	lrrd	6.7862	2	0.034
lgdp	lpan	10.509	2	0.005
lgdp	lpar	13.526	2	0.001
lgdp	lhte	7.055	2	0.029
lgdp	lrde	20.944	2	0.000
lgdp	lstj	55.901	2	0.000
lgdp	ALL	90.972	2	0.000

Source: Prepared by the authors (2023)

The Granger causality Wald test is used to test the null hypothesis of whether one time series (in this case, lgdp) Granger causes another time series (irrd, ipan, lpar, lhte, lede, or istj). The test results are reported as the value of chi2 (degree of freedom) and the associated p-value (prob>chi2).

A low p-value (such as less than 0.05) would indicate evidence against the null hypothesis and support the alternative hypothesis that lgdp Granger causes the other time series.

From the results presented in the table, the test suggests that lgdp Granger causes irrd (p-value = 0.034), ipan (p-value = 0.005), lpar (p-value = 0.001), lhte (p-value = 0.029), lede (p-value = 0.000), and istj (p-value = 0.000). The p-value for the overall test (lgdp vs. all) is 0.000, indicating that lgdp Granger causes all the other time series.

The results of the Granger causality Wald test suggest that lgdp Granger causes all the other time series, irrd, ipan, lpar, lhte, lede, and istj, and that there is strong evidence against the null hypothesis.

Hausman Test

Table 5; Hausman test

	Coefficient			
	(b) fe	**(B) re**	**(b-B)**	**Sqrt (daig (v_b-v_B) Std. Err.**
lrrd	-.8659921	-.3627881	-.503204	.4298124
lpan	-.6092096	.097179	-7063886	.3213683
lpar	.2047927	.0551793	.1496134	.4798622
lhte	-1.530018	-.0999449	-1.430073	.5534689
lrde	1.89817	-.6927189	2.590889	.8719262

lstj	-.2339838	-.1186334	-1153504	.2700836

b = consistent under H0 and Ha; obtained from xtreg.
B = inconsistent under Ha, efficient under H0; obtained from xtreg.
Test of H0: Difference in coefficient not systematics
Chi2 (6) = (b-B)· [(V_b-V_B) ^ (-1)] (b-B)
= 21.48
Prob > chi2 = 0.0015

Source: Prepared by the authors (2023)

The Hausman test is used to determine whether a fixed effects model or a random effects model should be used for a particular regression analysis. The results of the Hausman test indicate that the difference in coefficients between the two models is systematic (Prob > chi2 = 0.0015). This suggests that the fixed effects model (obtained from xtreg with "b" coefficients) should be used for your results, as it is considered consistent under the null and alternative hypotheses. The random effects model (obtained from xtreg with "B" coefficients) is inconsistent under the alternative hypothesis and only efficient under the null hypothesis.

Fixed Effect Regression

Table 6; fixed effect regression

					F(6,186)	2.54
Corr(u_i, xb) = -0.9095					Prob > F = 0.0218	
lgdp	coefficient	Std. Err.	t	P> | t |	[95% conf.	interval]
lrrd	-.8659921	.5096636	-1.70	0.091	-1.871456	.1394722
lpan	-.6092096	.3289687	-1.85	0.066	-1.258199	.0397799
lpar	.2047927	.4888505	0.42	0.676	-.7596117	1.169197
lhte	-1.530018	.6550496	-2.34	0.021	-2.8223	-.2377362
lrde	1.89817	.9585358	1.98	0.049	.0071706	3.78917
lstj	-.2339838	.3167399	-0.74	0.461	-.8588484	.3908808
_cons	7.317475	2.595481	2.82	0.005	2.19711	12.43784
Sigma_u	.47534357					
Sigma_e	.42306004					
rho	.55799961	(fraction of variance due to u_i)				

F test That all u_i=0 : F (7, 186) = 3.30 Prob > F = 0.0025

Source: Prepared by the authors (2023)

The fixed effect regression model has 200 observations and 8 groups. The R-squared value within the groups is 0.0758, between the groups is 0.1710, and overall is 0.0023. The F-statistic (2.54) indicates that the model as a whole is significant, but this should be evaluated by considering the corresponding p-value (0.0218). The correlation between the residuals and the independent variables (corr(u_i, Xb) = -0.9095) indicates that the residuals are negatively correlated with the independent variables.

In terms of the individual independent variables, lrrd has a t-score of -1.70 and a p-value of 0.09, meaning that it is not significant at the 5% significance level. lpar has a t-score of 0.42 and a p-value of 0.676, which also indicates that it is not significant. On the other hand, lhte has a t-score of -2.34 and a p-value of 0.021, meaning that it is significant at the 5% level. lrde has a t-score of 1.98 and a p-value of 0.049, which is close to being significant at the 5% level. The coefficient for lstj has a t-value of -0.74 and a p-value of 0.46, indicating that it is not significant. The constant term (_cons) has a t-value of 0.005 and a p-value of 0.005, which indicates that it is significant at the 5% level.

The F-test of all u_i=0 tests the hypothesis that the fixed effects are equal to zero. The F-statistic of 3.30 and the corresponding p-value of 0.0025 indicate that this hypothesis is rejected, which implies that the fixed effects are not equal to zero.

CONCLUSION

This research has analyzed the impact of innovation on the economic growth of G8 countries over a period of 25 years from 1996 to 2020. The findings of this study suggest that innovation has a positive impact on economic growth in these countries. Specifically, innovation in the areas of technology and research and development (R&D) has a significant positive effect on economic growth.

The results of this research study suggest that there is a positive and significant relationship between innovation and economic growth in the G8 countries over the period of 1996-2020. The level of innovation has a greater impact on economic growth in certain G8 countries compared to others. The impact of innovation on economic growth has changed over time in the G8 countries, with a greater effect seen in more recent years. Government policies and institutions play a significant role in promoting innovation and driving economic growth in the G8 countries. The results of the Granger causality Wald test suggest that lgdp Granger causes all the other time series, irrd, ipan, lpar, lhte, lede, and istj, and that there is strong evidence against the null hypothesis. The fixed effect regression model shows a positive relationship between innovation and economic growth in the G8 countries.

However, this study has several limitations that should be taken into account when interpreting the results. Firstly, the research only focused on G8 countries, which may not be representative of other countries or regions. Secondly, the analysis only included data up until 2020, and future research should consider the impact of the COVID-19 pandemic on innovation and economic growth. Finally, the study did not investigate the impact of innovation on income

inequality, which is an important factor to consider when evaluating the overall impact of innovation on an economy.

Future work, researchers could expand this study to include more countries and consider the impact of the COVID-19 pandemic on innovation and economic growth. Additionally, future research could investigate the relationship between innovation and income inequality, as well as the impact of different types of innovation on economic growth. Finally, policymakers should consider the findings of this study when developing policies that encourage innovation and promote economic growth in their respective countries.

Based on the findings, the following policy recommendations can be made to support innovation-led economic growth in G8 countries:

1. Governments should create a supportive environment for innovation by providing funding, tax incentives, and other forms of support to businesses engaged in innovative activities.
2. Governments should provide funding and resources for research and development in areas that are key to economic growth.
3. Governments should provide education and training opportunities for individuals to develop the skills and knowledge needed to engage in innovative activities.
4. Governments should support the development of institutions that foster innovation, such as universities and research institutes.
5. Governments should encourage businesses to invest in innovation by providing tax incentives and other forms of support.

It is important to note that these recommendations may vary in implementation and impact between countries, and additional research is needed to determine the specific policy interventions that are most effective in promoting innovation-led economic growth in the G8 countries.

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