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The Impact of Innovation and Economic Growth in Developed Countries

Sayef Bakari
LIEI, Faculty of Economic Sciences and Management of Tunis, University of Tunis El Manar, Tunis, Tunisia
Faculty of Legal, Economic and Management Sciences of Jendouba, University of Jendouba, Jendouba, Tunisia
E-mail: bakari.sayef@yahoo.fr

Abstract
This research examines the influence of innovation on the economic growth of 24 developed countries over the period from 1990 to 2021. Employing the static gravity model alongside the generalized method of moments, the empirical findings demonstrate a notable and positive impact of innovation on economic growth. Furthermore, employing cointegration analysis and the Panel Vector Error Correction model, the research confirms that innovation exerts a favorable and substantial influence on both short-term and long-term economic growth. Based on these findings, it is recommended to actively promote and support innovation in developed countries. This could involve implementing policies that foster research and development, ease access to financial resources for innovative firms, and establish a regulatory framework conducive to fostering innovation.

Keywords: Innovation, Economic growth, Static Gravity Model, GMM, Panel VECM, Developed countries

JEL classification: O31, O32, O47, O50

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1. Introduction

In the global economy, innovation plays a pivotal role by offering avenues for progress, bolstering competitiveness, and fostering growth. This topic is of paramount importance both in theory and practice, delving into the intricate mechanisms through which innovations influence economic development. Positioned at the crossroads of creativity, technology, and entrepreneurship, innovation emerges as a fundamental force driving economic transformation. It not only stimulates productivity but also gives rise to novel sectors of activity, elevating overall quality of life.

Theoretical discussions on the impact of innovation on growth often center around economic models that emphasize the dynamic interplay among technological progress, investments in research and development, and the overall productivity of production factors. Whether characterized as incremental or disruptive, technological advancements have the potential to set off cascading effects, reshaping conventional economic structures and creating innovative opportunities. From an economic standpoint, the importance of comprehending how innovation propels growth is unmistakable. Public policies, private investments, and business strategies frequently prioritize the promotion of innovation as a critical driver for economic development.

Consequently, a comprehensive exploration of this dynamic enables more informed economic decision-making and the maximization of innovation's benefits for society.

Within the scope of this study, we focus our attention on developed countries, an approach justified by the specificities of their economic context. Developed nations, characterized by strong institutions, advanced infrastructures, and high technological capabilities, provide a conducive environment for studying the relationships between innovation and growth. Through an examination of these advanced economies, our objective is to elucidate the manner in which investments in research and development (R&D), innovation strategies, and sectoral dynamics collectively influence economic growth trajectories. Established economies, comprising key participants such as the United States, Japan, and various European nations, maintain a tradition of allocating a significant portion of their Gross Domestic Product (GDP) towards R&D endeavors. In the year 2019, the United States exemplified this commitment by allocating approximately 3.1% of its GDP to R&D, a proportion mirrored by Germany, while Japan surpassed them with an investment of around 3.3% (source: UNESCO). These significant financial commitments underscore the prioritization of innovation as a driver of economic progress in these nations. Furthermore, developed nations set themselves apart with their commendable educational systems, as evident from robust educational indicators. The Program for International Student Assessment (PISA) serves as a benchmark, regularly evaluating student performance in countries belonging to the Organization for Economic Co-operation and Development (OECD). Notably, in 2018, Nordic countries such as Finland, Estonia, and Denmark achieved exceptional results in science and reading, showcasing the effectiveness of their educational systems (source: PISA 2018). Intellectual property protection, including expenditures on patents, emerges as a crucial indicator reflecting the emphasis placed on safeguarding innovations. The year 2019 witnessed global spending on patents reaching an impressive figure of approximately $265 billion. At the forefront of this endeavor were formidable economic forces such as the United States, China, and Japan, underscoring their dedication to safeguarding and nurturing innovation, as indicated by the World Intellectual Property Organization. The Global Innovation Index (GII) plays a pivotal role in assessing the innovation capabilities of a diverse range of nations. In 2021, countries such as Switzerland, Sweden, the United States, the United Kingdom, and the Netherlands found themselves among the leaders, boasting high innovation scores. This acknowledgment underscores the sustained efforts and successes of these nations in fostering innovation (source: GII 2021). Finally, an essential metric for evaluating the innovation landscape is corporate research and development (R&D) expenditures. In 2019, global corporate R&D spending reached an astounding $2.2 trillion. Sectors like healthcare, information technology, and automotive stood out as primary contributors to this significant investment, highlighting the strategic focus of corporations on advancing technological frontiers (source: UNESCO). Collectively, these paragraphs illustrate the multi-faceted commitment of developed countries to innovation, encompassing substantial investments in R&D, robust educational systems, emphasis on intellectual property protection, and substantial corporate contributions to research and development. These efforts position these nations at the forefront of the global innovation landscape, fostering economic growth and technological advancements. By specifically choosing developed countries, we seek to shed light on the intricate mechanisms characterizing these mature economies. The challenges these nations face in terms of innovation and the synergies between the public and private sectors offer a rich field of investigation with valuable insights for decision-makers, researchers, and economic actors.

Finally, the uniqueness and timeliness of this subject lie in the evolving nature of the global economy and the need to anticipate future trends. As innovation continually reshapes the landscape of economic competitiveness, this research adds to the existing body of literature by shedding light on the distinct characteristics of developed nations and their capacity to harness innovation as a driver of enduring economic expansion.

The main objective of this work is to thoroughly assess how innovation profoundly influences economic growth, with a specific focus on 24 developed countries. To accomplish this mission, the structure of our document has been meticulously crafted. In the second section, we will conduct a comprehensive review of existing literature, delving into detailed examinations of previous studies that have scrutinized the intricate relationship between innovation and economic growth. This will allow us to position our study within the context of current knowledge and identify potential gaps in existing understanding. The third section will be dedicated to a meticulous explanation of the empirical methodology we have adopted. We will highlight the specific model chosen for our analysis while providing insights into the structure and nature of the database used. This methodological transparency is crucial to ensure the robustness of our results. In the fourth section, we will unveil and interpret the empirical findings derived from our research. This will facilitate the identification of patterns, correlations, and noteworthy implications stemming from our quantitative analysis. Subsequently, in the fifth section, we will concentrate on the conclusions drawn from our comprehensive examination while offering well-founded recommendations derived from the insights garnered in this study. These conclusions and recommendations will serve to illuminate future prospects and inform strategic decisions within the realm of innovation and economic advancement.

2. Literature survey

The interconnection between innovation and economic growth constitutes a foundational pillar for the advancement of contemporary societies. This correlation is extensively examined across diverse economic theories, bolstered by references and citations from esteemed economists. The theory of endogenous growth, pioneered by Paul Romer and Robert Lucas, posits that innovation serves as an intrinsic catalyst for sustained economic expansion. Romer (1990) underscores in his seminal work 'Endogenous Technological Change' that the accrual of knowledge, propelled by research and development endeavors, plays a pivotal role in fostering enduring economic progress. Consequently, innovation emerges not merely as an outcome of growth but rather as its fundamental driver. Moreover, Schumpeter (1942), in his seminal treatise 'Capitalism, Socialism, and Democracy,' introduced the concept of 'creative destruction.' Schumpeter (1942) elucidates that innovation transcends the mere introduction of novel products or processes; it also encompasses the obsolescence of established ones. This dynamic process engenders growth by instigating a perpetual cycle of rejuvenation and enhancement, thereby enriching the vitality of the economic landscape. The works of Robert Solow, Nobel laureate in economics, have highlighted the importance of investments in research and development (R&D) in economic growth. In his model of exogenous growth, Solow (1956) points out that the accumulation of physical capital is a source of growth, but it is innovation that leads to sustained productivity gains. Moreover, investments in human capital, such as education and training, are essential to foster innovation and maximize its impact on growth. David (1985) explored the concept of positive externalities related to innovation. He highlights in his article 'Clio and the Economics of QWERTY' how some innovations can generate benefits not only for the innovator but also for the entire economy. Patents, as legal instruments protecting intellectual property rights, encourage innovation by providing innovators with financial incentives while promoting the diffusion of knowledge. Mabrouki (2018) utilized VAR modeling techniques and Granger causality analysis to investigate the influence of innovation and human capital on economic growth within the context of the Tunisian economy spanning 1970 to 2015. The study aimed to elucidate the interconnected dynamics of these variables and their implications for the country's economic development. Through rigorous empirical analysis, the research revealed a significant correlation between human capital and economic growth, emphasizing the pivotal role of skilled human resources in driving economic progress in Tunisia during the specified timeframe. Phung et al. (2019) conducted a comprehensive analysis covering 69 developed and developing countries, examining the relationship between innovation and economic growth from 2006 to 2014. Employing a robust analytical framework, they employed the two-step system Generalized Method of Moments (GMM) in their research. The study yielded compelling evidence supporting the assertion that innovation positively influences economic growth across the diverse set of countries studied. Mtar and Belazreg (2021) investigated the relationship between innovation and economic growth within the context of 27 OECD countries over the period 2001-2016, employing the VAR (Vector Autoregression) approach for their analysis. The empirical findings of their study underscored the significance of innovation as a catalyst for economic growth across the examined countries. In Bakari's (2022) examination of Romania's economic landscape from 1990 to 2020, the study explored the impact of patents on economic growth. Employing cointegration analysis and the Autoregressive Distributed Lag (ARDL) model as methodological tools, the empirical findings revealed a positive association between patents and economic growth. The study provided evidence suggesting that the presence and utilization of patents in Romania during the specified timeframe were associated with a favorable effect on the overall economic growth of the country, highlighting the potential role of intellectual property and innovation in contributing to Romania's economic development. In the investigation led by Ben Yedder et al. (2023), which covered the MENA (Middle East and North Africa) region from 1998 to 2022, the focus was on examining the influence of patents on the interaction between domestic investment and economic growth. Through empirical analysis, the researchers concluded that patents did not exhibit any discernible impact on economic growth within the MENA countries during the specified period. Additionally, the study revealed that the relationship between domestic investment and economic growth did not appear to be affected by the presence or absence of patents.

Similarly, Othmani et al. (2023) explored the impact of patents on economic growth within the United States over the period from 1980 to 2020. Utilizing cointegration analysis and the Vector Error Correction Model (VECM), they found compelling evidence indicating the absence of a causal relationship between patents and economic growth, both in the short run and the long run. These findings suggest that, over the studied decades, the presence or absence of patents did not directly influence the overall economic growth of the United States. Yedder et al. (2023) conducted a comprehensive investigation into the impact of patents on the relationship between domestic investment and economic growth within the MENA region from 1998 to 2022. Their empirical analysis confirmed that patents did not exert any discernible influence on overall economic growth in MENA countries during the specified period. Furthermore, the study revealed that the relationship between domestic investment and economic growth in these countries was not significantly affected by the presence or absence of patents. These empirical observations underscore the intricate dynamics prevailing in the MENA region, suggesting that conventional expectations regarding the interplay between patents, domestic investment, and economic growth may not hold true within this specific geographical and temporal context. In a separate study, Bakari (2019) conducted an extensive analysis of the relationship between economic growth and innovation using a panel Autoregressive Distributed Lag (ARDL) model. The study encompassed data from 76 developed and developing countries across various geographic regions spanning from 1995 to 2016. The empirical findings provided compelling evidence supporting the positive impact of both innovation and the internet on driving economic growth. Additionally, the study highlighted a reciprocal relationship, indicating that economic growth positively influences innovation and the internet, suggesting a reinforcing feedback loop between these factors. In their inquiry spanning from 1996 to 2020, Nihal et al. (2023) delved into the intricate correlation between patents and economic growth, specifically within the realm of G8 countries. Employing an extensive methodological approach encompassing cointegration analysis, Panel Vector

Autoregression (VAR), and Granger causality tests, the researchers revealed a positive association between patents and economic growth in the G8 nations. These empirical findings suggest that, over the analyzed period, the presence of patents contributed positively to the overall economic growth dynamics within this cohort of influential economies. In a study spanning from 1981 to 2014 and focusing on eleven European Union countries, Blind et al. (2022) utilized panel cointegration techniques to explore the impact of formal standards and patents on economic growth. Contrary to expectations, the empirical results indicated that patents did not exhibit a significant effect on long-term economic growth in the studied panel of European Union countries. This suggests that, over the specified timeframe, the presence or absence of patents did not demonstrate a discernible influence on the sustained economic growth patterns of the countries examined. Bakari et al. (2022) conducted an extensive investigation into the relationship between innovation and economic growth within the context of the Tunisian economy, employing the ARDL bounds testing methodology over the period from 1985 to 2018. The empirical findings unveiled a nuanced dynamic, indicating a negative impact of innovation on economic growth in the long run. Interestingly, in the short run, the researchers found that innovation did not exert a significant influence on economic growth. Rahman et al. (2023) focused their examination from 1990 to 2020 on the impact of technological innovation on economic growth in Bangladesh. Utilizing the dynamic Autoregressive Distributed Lag (ARDL) simulation method, the researchers revealed compelling findings indicating a positive influence of technological innovation on economic growth, both in the long run and in the short run. This suggests that, over the specified period, the adoption and integration of technological advancements positively contributed to Bangladesh's economic development, showcasing the immediate and sustained positive effects of technological innovation on the country's overall economic growth dynamics.

In their exploration spanning from 2002 to 2021, Bakari et al. (2023) scrutinized the impact of innovation and Research and Development (R&D) on economic growth within the context of the Middle East and North Africa (MENA) countries. Employing the gravity model statistic as their analytical tool, the researchers concluded that neither innovation nor R&D demonstrated any discernible impact on economic growth in the studied MENA countries during the specified timeframe. These empirical findings suggest that, according to the gravity model statistic employed, the conventional assumptions about the positive relationship between innovation, R&D, and economic growth may not hold true within the unique economic landscape of the MENA region during the period under investigation. In Mabrouki's (2023) study spanning from 1990 to 2019, the impact of human capital, education, and patents on economic growth in Scandinavian countries was systematically investigated. Employing the Westerlund Panel cointegration tests and the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model, complemented with pooled mean group (PMG) estimators, the researcher provided robust evidence supporting a positive relationship between human capital, education, patents, and economic growth in the Scandinavian context. These findings suggest that, during the specified timeframe, the accumulation of human capital, educational investments, and the presence of patents contributed positively to the overall economic growth in these countries. Ahmad et al. (2021) explored the interconnection between eco-innovation and economic growth within the G7 countries over the period from 1980 to 2016. Their empirical results revealed a positive and favorable relationship, indicating that eco-innovation had a beneficial impact on economic growth among the G7 nations during the specified timeframe. These findings suggest that the integration of environmentally friendly innovations and practices contributed positively to the overall economic development of the G7 countries.

In the examination of emerging economies conducted by Ahmad et al. (2020) spanning from 1984 to 2016, the researchers investigated the relationship between innovation and economic growth. By employing cointegration analysis and the Cross-Sectionally Augmented Autoregressive

Distributed Lag (CS-ARDL) model, the study revealed a positive and enduring relationship between innovation and economic growth in the long run. These findings imply that, over the studied period, the introduction and sustained adoption of innovative practices positively contributed to the overall economic development of emerging economies. Gyedu et al. (2021) investigated the influence of innovation on economic growth within both the G7 and BRICS countries over the period from 2000 to 2017. Employing the Vector Autoregression (VAR) model and the Generalized Method of Moments (GMM) model, their empirical findings indicated that Research and Development (R&D), patents, and trademarks collectively exerted a positive impact on economic growth in both groups of countries. This suggests that, during the specified timeframe, investments in R&D, the presence of patents, and the utilization of trademarks played a beneficial role in fostering economic development in the G7 and BRICS nations. Ahmad and Zheng (2023) examined the relationship between innovation, specifically Research and Development expenditures (R&DE), patents, and economic growth across thirty-six OECD economies. Their results revealed a nuanced and cyclical nexus between innovation and economic growth, with positive shocks to R&DE and patents positively associated with economic growth during economic boom periods. Notably, the study suggested a pro-cyclical relationship between R&DE, patents, and economic growth among OECD countries, showcasing the dynamic and context-dependent nature of this intricate relationship. In their evaluation spanning from 1960 to 2019, Nsor-Ambala and Amewu (2023) explored the impact of financial innovation on economic growth in Ghana. Employing a non-linear Autoregressive Distributed Lag (ARDL) time series econometric model, the researchers found no substantial evidence supporting the idea that Financial Innovation significantly influences economic growth in Ghana. Razzaq et al. (2023) focused on the impacts of green technology innovation on economic growth within the top 10 GDP countries from 1995 to 2018. Employing the method of moments quantile regression, their findings indicated a positive relationship between green technology innovation and economic growth, suggesting that the introduction and adoption of environmentally friendly technological advancements had a beneficial impact on the overall economic growth of the leading economies.

Across various regions and temporal frames, a breadth of empirical studies illuminates the intricate relationship between innovation and economic growth, enriching our understanding of this complex dynamic. From Mabrouki (2018)'s investigation uncovering the correlation between human capital and economic growth in Tunisia to Bakari (2022)'s research in Romania affirming the positive link between patents and economic development, these studies offer diverse perspectives. Ben Yedder et al. (2023)'s exploration in the MENA region challenges conventional assumptions, revealing nuanced dynamics. Furthermore, Othmani et al. (2023)'s findings regarding patents in the United States highlight the intricate nature of this relationship. Collectively, these studies contribute to a comprehensive comprehension of the multifaceted interplay between innovation and economic growth, showcasing the dynamic and context-specific nature of this relationship across diverse geographical and temporal contexts.

3. Data and methodology

In this work, we will examine the impact of innovation on economic growth in the case of 24 developed countries (Australia, Austria, Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italia, Japan, Luxembourg, New Zealand, Norway, Netherlands, Portugal, Spain, Sweden, Switzerland, UK and USA) during the period 1990 – 2021. According to World Intellectual Property Organization (2021), the group of 24 developed countries raises a special interest in the innovation-growth link due to their significant contributions to global economic development and their advanced technological capabilities. These countries are known for their robust innovation ecosystems, characterized by high levels of investment in research and development, strong intellectual property protection, well-developed infrastructure, and skilled labor forces. Their economies heavily rely on innovation as a key driver of productivity, competitiveness, and sustainable growth. Therefore, understanding the dynamics of innovation and its impact on economic growth in these countries is crucial for policymakers, businesses, and researchers seeking to formulate effective strategies for fostering innovation-led growth. Referring to the works of Teixeira and Queirós (2016), Dahmani et al (2023), Dahmani et al (2022), Chatterjee (2020), Asteriou et al (2021) and Cheng et al (2021), the basic model is written as follows:

$$Y_{it} = \beta_0 + \beta_1 DI_{it} + \beta_2 L_{it} + \beta_3 I_{it} + \beta_4 X_{it} + \beta_5 M_{it} + \gamma_i + \varepsilon_t \quad (1)$$

where 'Y' designs economic growth, 'DI' designs domestic investment, 'L' designs labor, 'I' designs innovation, 'X' designs exports, 'M' designs imports, 'γ' is a country-specific effect not observed, 'ε' is the term error, 'i' is the individual dimension of the panel (the country) and 't' is the temporal dimension. To linearize the equation (1), all variables are logarithmically changed in equation (2):

$$Ln(Y)_{it} = \beta_0 + \beta_1 Ln(DI)_{it} + \beta_2 Ln(L)_{it} + \beta_3 Ln(I)_{it} + \beta_4 Ln(X)_{it} + \beta_5 Ln(M)_{it} + \gamma_i + \varepsilon_t \quad (2)$$

Table 1 shows the chosen variables and their sources. All variables are taken from the World Bank Indicator.

Table 1 - Presentation of the database

Variables	Descriptions	Measures	Sources
DI	Domestic Investment	Gross fixed capital formation (constant 2015 US$)	World Bank Indicators
X	Export	Exports of goods and services (constant 2015 US$)	World Bank Indicators
L	Labor	Labor force, total	World Bank Indicators
M	Imports	Imports of goods and services (constant 2015 US$)	World Bank Indicators
I	Innovation	Patent applications, residents	World Bank Indicators
Y	Economic growth	Gross Domestic Product (constant 2015 US$)	World Bank Indicators

Source: Constructed by the author.

Within the scope of our empirical methodology, we have chosen to employ three distinct empirical models: the static gravity model of panel data, the Generalized Method of Moments (GMM) model of data, and the Vector Error Correction Model (VECM) of panel data. The selection of these three models aims to conduct a thorough examination of the nature of the impact of innovation on economic growth in developed countries in a robust and credible manner. The first model, the static gravity model of panel data, is an approach that relies on data collected over a specific period and across multiple countries. It allows for the examination of relationships between different variables, specifically innovation and economic growth, while considering the specific characteristics of each country. The second model, the GMM model of data, is based on the Generalized Method of Moments. This method is often utilized to estimate parameters in econometric models by minimizing the disparities between theoretical and observed moments.

This contributes to enhancing the validity of the obtained results. Lastly, the third model, the VECM model of panel data, is a cointegration model that explores long-term relationships between variables. It proves particularly useful in understanding how variables, such as innovation, can influence economic growth over an extended period. The primary objective behind the application of these three models is to ensure a robust and credible analysis of the impact of innovation on economic growth. By employing diverse approaches, we aim to corroborate our results and identify trends that persist regardless of the specific model used. This approach reinforces the robustness of our study and provides a more comprehensive perspective on the relationship between innovation and economic growth in the context of developed countries.

4. Empirical results

In this study, the empirical discoveries can be organized into five distinct paragraphs, each addressing specific facets of the research. Firstly, the outcomes derived from descriptive statistics present a comprehensive overview of the essential characteristics inherent in the dataset. This initial paragraph aims to provide a detailed understanding of the data's basic features. Following this, correlation analyses are employed to illuminate the intricate relationships among the diverse variables under scrutiny. The second paragraph delves into these correlations, elucidating the connections and dependencies within the dataset. The third category centers around the results obtained from estimating the static gravity model. This paragraph goes beyond mere description, offering valuable insights into the underlying forces and interactions shaping the observed phenomena. It serves as a critical juncture where the study transitions from descriptive statistics to a more nuanced exploration of the factors influencing the variables.

Moving forward, the fourth component involves the outcomes derived from estimating the GMM model. This paragraph contributes to the study's depth by providing a sophisticated perspective on the dynamic interplay between the variables. The focus shifts from static relationships to a more intricate analysis of the evolving patterns and influences captured by the GMM model. Lastly, the fifth category encapsulates the results of estimating the Panel VECM model. This final paragraph introduces a temporal dimension to the analysis, shedding light on the long-term implications of the phenomena under investigation. The Panel VECM model adds a valuable layer to the study, allowing for a more nuanced understanding of how the observed relationships may evolve over time. Together, these five paragraphs comprehensively frame the empirical findings, offering a multifaceted view of the complex dynamics within the dataset.

4.1. Descriptive statistics

Before presenting the empirical results, the study conducts pretests on the data, a practice often deemed crucial for generating hypotheses or gaining insights into the correlation of the target variable. Table 2 reveals that the probability of rejection for all variables was less than 5%, indicating their consideration in the subsequent analyses. Additional statistical measures, such as skewness and kurtosis, offer insights into the distributional characteristics of the variable of interest. Skewness, measuring the asymmetry of the distribution, indicates that all given variables exhibit positive skewness, highlighting the presence of outliers and the extent of their deviation from a normal distribution.

Table 2 - Descriptive statistics

Variable	Ln (Y)	Ln (DI)	Ln (L)	Ln (I)	Ln (X)	Ln (M)
Mean	26.90846	25.35574	15.66644	7.685201	25.81252	25.76604
Median	26.78711	25.32234	15.40647	7.613325	25.96594	25.87362
Maximum	30.62302	29.07762	18.92964	12.86712	28.52194	28.76831
Minimum	22.93640	21.12894	11.94257	2.484907	21.92005	21.94390
Std. Dev.	1.617812	1.646800	1.616463	2.326961	1.368109	1.383496
Skewness	-0.201816	-0.227062	-0.275300	0.174982	-0.589212	-0.444011
Kurtosis	3.013355	2.903272	2.953948	3.068560	3.035665	2.926645
Jarque-Bera	6.325065	6.153177	8.713243	13.62974	39.67162	22.66103
Probability	0.047536	0.046116	0.012822	0.002855	0.000000	0.000012
Sum	18432.30	17368.68	10731.51	5264.363	17681.58	17649.74
Sum Sq. Dev.	1790.245	1854.975	1787.259	3703.686	1280.258	1309.218
Observations	685	685	685	685	685	685

Source: Authors' calculations using EViews 12 software.

Furthermore, kurtosis, another statistical metric, gauges the peak or sharpness of the distribution relative to a normal distribution. The kurtosis coefficient values for all variables demonstrate their maximum values, suggesting that the variables exhibit pronounced peaks in their distributions. Taken together, the overall skewness and kurtosis coefficients affirm that the chosen variables follow a normal distribution. In conclusion, the results of the descriptive statistics not only provide information about the distributional characteristics but also assert that the selected variables are suitable for estimation in the context of panel data. The pretests ensure that the data meets the necessary assumptions for subsequent empirical analyses, reinforcing the robustness of the findings to be presented.

4.2. Correlation analysis

The Pearson correlation test plays a crucial role in empirical analyses of panel data by assessing linear relationships between two continuous variables observed across multiple units over time. By providing key insights into the direction and strength of these relationships, the test becomes an essential preliminary step. By identifying linear relationships and measuring the correlation strength through the Pearson coefficient, the test facilitates the validation of hypotheses regarding expected relationships. The obtained results offer an initial understanding of the data structure, guide the selection of subsequent analytical models, and lay the groundwork for more advanced analyses. In our specific context, the condition for variables to be estimable in panel data relies on positive correlation coefficients exceeding 60%, underscoring the significance of correlation in preparing data for robust and meaningful analyses.

Table 3 - Pearson's correlation test

Variable	Ln (Y)	Ln (DI)	Ln (L)	Ln (I)	Ln (X)	Ln (M)
Ln (Y)	1					
Ln (DI)	0.9940	1				
Ln (L)	0.9639	0.9560	1			
Ln (I)	0.9234	0.9201	0.9010	1		
Ln (X)	0.9270	0.9217	0.8364	0.8060	1	
Ln (M)	0.9443	0.9420	0.8691	0.8208	0.9913	1

Source: Authors' calculations using EViews 12 software.

Table 3 showcases the results derived from correlation analyses conducted on the variables under consideration, demonstrating notably high positive correlation coefficients exceeding 60% across all variables. This significant finding underscores not only the presence of positive relationships among the examined variables but also their substantial strength. Essentially, these results imply that the variables included in the study exhibit considerable interdependence, lending credence to their predictability within the context of panel data analysis. In essence, the robust correlations observed suggest that these variables possess noteworthy and consistent predictive power over time, thus bolstering the reliability and validity of estimations made within the framework of longitudinal data analysis. Consequently, it can be inferred that the relationships identified among the variables hold a degree of stability and significance, thereby providing a solid foundation for further analysis and interpretation within this longitudinal data framework.

4.3. Static gravity model estimation

In this paragraph, the focus is on presenting the outcomes of the estimation conducted for the static gravity model. The model encompasses three different estimations: ordinary least square panel estimation (Pooled OLS), fixed effect static gravity model estimation, and random effect static gravity model estimation. The results of these estimations are compiled in Table 4. The key observation is that all three models Pooled OLS, Pooled OLS in Fixed Effect, and Pooled OLS in Random Effect consistently highlight a positive and statistically significant impact of the innovation variable, denoted as 'Ln (I)', on the variable representing economic growth, denoted as 'Ln (Y)'. This implies that the innovation factor is not only positively associated with economic growth but also carries statistical significance across the different model specifications, as evidenced by the consistency in results across the three estimation methods.

Table 4 - Results of the estimation of the static gravity model

Methods	Pooled OLS		Pooled OLS: Fixed Effect		Pooled OLS: Random Effect	
	Dependent Variable: Ln (Y)					
Variable	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
C	3.956842	0.0000	3.668917	0.0000	3.956842	0.0000
Ln (DI)	0.582542	0.0000	0.584713	0.0000	0.582542	0.0000
Ln (L)	0.233690	0.0000	0.221748	0.0000	0.233690	0.0000
Ln (I)	0.041386	0.0000	0.038207	0.0000	0.041386	0.0000
Ln (X)	0.302618	0.0000	0.275384	0.0000	0.302618	0.0000
Ln (M)	-0.140093	0.0001	-0.095563	0.0097	-0.140093	0.0001

Source: Authors' calculations using EViews 12 software.

The principal objective of conducting the Hausman test is to ascertain the most suitable model for our analysis, specifically delineating between the fixed effects model and the random effects model. The decision hinges upon the probability yielded by the Hausman test: if the probability equals or falls below 5%, preference is accorded to the fixed effects model; conversely, if the probability surpasses 5%, the inclination veers towards the random effects model. In our specific scenario, as delineated by the outcomes in Table 5, the probability stemming from the Hausman test not only falls below 5%, but precisely registers at 0.00%. This result underscores a high level of significance for the fixed effects model, thereby compelling us to retain it for our analysis.

Table 5 - Results of Hausman Test: Static Gravity Model

Correlated Random Effects - Hausman Test: Static Gravity Model			
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Period random	29.734664	5	0.0000

Source: Authors' calculations using EViews 12 software.

In light of this, we confirm that innovation exhibits a positive impact on economic growth in our specific scenario. More precisely, a 1% increase in innovation 'Ln (I)' is associated with a 0.038207% increase in economic growth 'Ln (Y)'. Furthermore, our analysis reveals that domestic investments 'Ln (DI)', labor 'Ln (L)', and exports 'Ln (X)' also contribute positively to economic growth 'Ln (Y)'. Conversely, imports 'Ln (M)' are identified as having a negative effect on economic growth 'Ln (Y)' in this context.

4.4. Generalized Method of Moments (GMM) model estimation

This paragraph primarily focuses on conveying the findings derived from estimating the Generalized Method of Moments (GMM) model. The GMM model, a statistical technique, involves three distinct estimations: ordinary least square panel estimation (Pooled OLS), fixed effect estimation within the GMM model, and random effect estimation within the GMM model. These separate estimations' results are systematically organized and presented in Table 6, serving the crucial function of enhancing clarity and acting as a reference point for readers aiming to comprehend and scrutinize the outcomes of the GMM model.

The central observation from the outcomes of these estimations is the consistent and robust nature of the positive and statistically significant impact associated with the innovation variable, denoted as 'Ln (I),' on the variable representing economic growth, denoted as 'Ln (Y).' This implies that, regardless of the specific estimation method employed whether it's Pooled OLS, GMM in Fixed Effect, or GMM in Random Effect the innovation factor demonstrates a consistent positive association with economic growth. Furthermore, the statistical significance of this relationship is consistently upheld across the various model specifications, as indicated by the uniformity in results across the three estimation methods.

Table 6 - Results of Generalized Method of Moments (GMM) model estimation

Methods	GMM		GMM: Fixed Effect		GMM: Random Effect	
Dependent Variable: Ln (Y)						
Independents Variables	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
C	3.773025	0.0000	3.511940	0.0000	3.773025	0.0000
Ln (DI)	0.604037	0.0000	0.604945	0.0000	0.604037	0.0000
Ln (L)	0.215637	0.0000	0.204511	0.0000	0.215637	0.0000
Ln (I)	0.039723	0.0000	0.036861	0.0000	0.039723	0.0000
Ln (X)	0.261093	0.0000	0.233903	0.0000	0.261093	0.0000
Ln (M)	-0.101084	0.0071	-0.057000	0.1475	-0.101084	0.0070

Source: Authors' calculations using EViews 12 software.

Table 7 presents the outcomes of the Hausman test associated with the Generalized Method of Moments (GMM) model. The noteworthy aspect is the clear indication that the probability linked to the Hausman test is below the conventional 5%, specifically at a remarkably low value of 0.02%. This unequivocally suggests that the fixed effect GMM model is the most suitable and, consequently, will be retained for further analysis.

Table 7 - Results of Hausman Test: GMM Model

Correlated Random Effects - Hausman Test: GMM Model			
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Period random	24.728425	5	0.0002

Source: Authors' calculations using EViews 12 software.

In light of this model selection, the results affirm that innovation 'Ln (I)' plays a crucial and positively significant role in influencing economic growth 'Ln (Y)'. Specifically, a 1% increase in innovation 'Ln (I)' is associated with a substantial 0.036861% increase in economic growth 'Ln (Y)'. Moreover, based on the estimation from the fixed effect GMM model, the confirmation extends to the positive impact of domestic investments 'Ln (DI)', labor 'Ln (I)', and exports 'Ln (X)' on economic growth 'Ln (Y)'. Conversely, imports 'Ln (M)' are identified as exerting a negative influence on economic growth 'Ln (Y)'.

4.5. Panel VECM estimation

According to Baltagi (2008), the Panel VECM is an extension of the VECM tailored for panel data, which aggregates observations across multiple entities (individuals, firms, countries) over time. Holtz-Eakin et al (1988) affirmed that this model facilitates the analysis of both short-term and long-term cointegration relationships among variables in a panel context, taking into account interactions within each entity and between entities. Although the VECM was originally developed by Engle and Granger (1987), the Panel VECM extends their work by incorporating the panel dimension into the analysis of cointegrated time series, as highlighted by Pedroni (2004). Additionally, Bai and Ng (2004) also confirmed that the Panel VECM represents a powerful approach for studying dynamic relationships between variables within a panel data framework, providing a better understanding of short-term and long-term adjustment mechanisms across a diverse set of entities observed over an extended period.

The initial step in estimating the Panel VECM is pivotal to ensuring the validity of subsequent analyses. This step involves determining the order of integration for each variable using stationarity tests such as the Philips-Perron test and the Augmented Dickey-Fuller (ADF) test. These tests are widely employed in economic literature to assess the stationarity of panel data series. The PP and ADF tests are statistical tools commonly utilized to identify the presence of unit roots in panel data series. Unit roots indicate that panel data series are non-stationary, implying they exhibit systematic trends or behaviors that evolve over time. Conversely, a stationary panel series lacks systematic trends, and its statistical properties remain constant over time. The stationarity of variables is crucial within the context of the Panel VECM model as it ensures the validity of subsequent estimations and analyses. If variables are non-stationary, model estimations may be biased, leading to unreliable results. Conversely, if variables are stationary, it suggests that relationships between variables are stable and can be accurately estimated.

Table 8 - Units roots tests results

Phillips-Perron test							
At Level							
		Ln(Y)	Ln(DI)	Ln(L)	Ln(I)	Ln(X)	Ln(M)
With Constant	t-Statistic	0.0000	0.7107	0.5767	0.2266	0.6128	0.3950
	Prob.	0.5120	0.9675	0.6323	0.6652	0.2467	0.2697
With Constant & Trend	t-Statistic	0.9455	0.1747*	0.2496	0.4072	0.8485	0.4675
	Prob.	0.7972	0.0532	0.2716	0.8247	0.7716	0.5771
Without Constant & Trend	t-Statistic	1.0000	0.9999	1.0000	0.7266	1.0000	1.0000
	Prob.	1.0000	0.9987	1.0000	0.8055	1.0000	1.0000
At First Difference							
		d(Ln(Y))	d(Ln(DI))	d(Ln(L))	d(Ln(I))	d(Ln(X))	d(Ln(M))
With Constant	t-Statistic	0.0001***	0.0000***	0.0001***	0.0000***	0.0000***	0.0000***
	Prob.	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000
With Constant & Trend	t-Statistic	0.0000***	0.0000***	0.0004***	0.0002***	0.0001***	0.0000***
	Prob.	0.0000	0.0002	0.0000	0.0037	0.0000	0.0000
Without Constant & Trend	t-Statistic	0.0005***	0.0000***	0.0003***	0.0000***	0.0002***	0.0001***
	Prob.	0.0001	0.0001	0.0005	0.0000	0.0003	0.0002
Augmented Dickey–Fuller test							
At Level							
		Ln(Y)	Ln(DI)	Ln(L)	Ln(I)	Ln(X)	Ln(M)
With Constant	t-Statistic	0.2781	0.6952	0.5848	0.2191	0.6805	0.7581
	Prob.	0.4506	0.9579	0.7090	0.7031	0.6044	0.6726
With Constant & Trend	t-Statistic	0.8650	0.1747*	0.2496	0.4173	0.8485	0.4675
	Prob.	0.7308	0.0532	0.2716	0.8496	0.7075	0.5219
Without Constant & Trend	t-Statistic	1.0000	0.9978	0.9999	0.7152	0.9999	0.9999
	Prob.	1.0000	0.9973	1.0000	0.8108	1.0000	1.0000
At First Difference							
		d(Ln(Y))	d(Ln(DI))	d(Ln(L))	d(Ln(I))	d(Ln(X))	d(Ln(M))
With Constant	t-Statistic	0.0001***	0.0000***	0.0001***	0.0000***	0.0000***	0.0000***
	Prob.	0.0000	0.0008	0.0000	0.0006	0.0000	0.0000
With Constant & Trend	t-Statistic	0.0002***	0.0001***	0.0005***	0.0002***	0.0002***	0.0007***
	Prob.	0.0000	0.0047	0.0003	0.0037	0.0001	0.0001
Without Constant & Trend	t-Statistic	0.0005**	0.0000***	0.0003	0.0000***	0.0002***	0.0001***
	Prob.	0.0493	0.0001	0.3187	0.0000	0.0004	0.0003

Notes: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant

*MacKinnon (1996) one-sided p-values.

Source: Authors' calculations using EViews 12 software.

The results of the two stationarity tests are presented in Table n°8. It is evident to us that all variables are stationary in first differences; that is, all variables Ln (Y), Ln (DI), Ln (L), Ln (I), Ln (X), and Ln (M) are integrated of order (1). In this scenario, cointegration analysis and the Panel VECM model can be considered in the next step. Before investigating cointegration among the variables included in our model, it is crucial to determine the optimal number of lags to incorporate into our analysis. To achieve this, we employ various criteria such as the Akaike information criterion, the Schwarz information criterion, and the Hannan-Quinn information criterion. The results of this assessment are presented in Table n°9. It is evident to us that the optimal number of lags, according to the Schwarz information criterion, is equal to 1. This preliminary step allows us to judiciously select the number of lags to be included in our cointegrated analysis.

Table 9 - Lag order selection criteria

VAR Lag Order Selection Criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	5087.361	NA	9.76e-18	-22.14101	-22.08703	-22.11975
1	5281.683	382.7157	4.90e-18	-22.83086	-22.45304*	-22.68207
2	5347.622	128.1435	4.30e-18	-22.96132	-22.25965	-22.68499*
3	5393.650	88.24634	4.11e-18	-23.00501	-21.97950	-22.60115
4	5444.222	95.63429	3.86e-18	-23.06851	-21.71914	-22.53711
5	5492.864	90.71427	3.66e-18*	-23.12359*	-21.45038	-22.46466
6	5528.309	65.17504	3.67e-18	-23.12117	-21.12412	-22.33470
7	5559.013	55.65414	3.76e-18	-23.09809	-20.77719	-22.18409
8	5594.369	63.16432*	3.78e-18	-23.09529	-20.45054	-22.05375

* indicates lag order selected by the criterion
LR : sequential modified LR test statistic (each test at 5% level)
FPE : Final prediction error
AIC : Akaike information criterion
SC : Schwarz information criterion
HQ : Hannan-Quinn information criterion

Source: Authors' calculations using EViews 12 software.

Cointegration is a method that allows for the distinction between short-term links, often temporary and transient, and long-term links, which are more stable and durable. Its utility lies in the ability to capture long-term trends and understand the economic relationships between different variables. This approach is particularly important in economic and empirical models because it enables the consideration of short-term variations when analyzing long-term relationships, resulting in a more comprehensive and accurate view of economic dynamics. Furthermore, cointegration is employed in econometric modeling to assess the existence of causal relationships between variables. Using appropriate econometric methods, it becomes possible to determine whether one variable influence another or if both variables are influenced by a common third variable. This approach allows for a better understanding of underlying economic mechanisms, facilitating well-informed policy decisions.

Table 10 - Results of Kao Residual Cointegration Test

Kao Residual Cointegration Test		
	t-Statistic	Prob.
ADF	-11.52165	0.0000
Residual variance	0.000244	
HAC variance	0.000104	

Source: Authors' calculations using EViews 12 software.

In the specific context mentioned, the Kao (1999) cointegration test is used. According to econometric rules, the probability associated with this test must be less than 5% to confirm the existence of a cointegration relationship. The results of the cointegration analysis are presented in Table n°10, highlighting a significant probability of the Kao cointegration test, as it is less than 5% with a value of 0.0000. This finding confirms the existence of a cointegration relationship between the examined variables, leading to the adoption of the Panel VECM model for a more in-depth analysis. The estimation of the Panel VECM model provides us initially with the equation for the long-term equilibrium. This equation illustrates the impact of explanatory variables 'Ln (DI), Ln (L), Ln (I), Ln (X) and Ln (M)'on the dependent variable 'Ln (Y)' in the long run, and is presented as follows:

$$Ln\,(Y) = 0.134436 + 1.942124\,Ln\,(DI) + 4.722507\,Ln\,(L) + 1.541393\,Ln\,(I) + 1.305855\,Ln\,(X) - 6.067722\,Ln\,(M) \quad (3)$$

The long-term equilibrium equation of the Panel Vector Error Correction Model (VECM) indicates that the variable representing innovation 'Ln(I)' has a positive effect on the variable representing long-term economic growth 'Log(Y)'. It precisely explains that a 1% increase in innovation leads to a 1.541393% increase in long-term economic growth. As for other control variables, it is evident that domestic investments 'Ln (DI)', labor force 'Log (L)', and exports 'Log (X)' also have a positive impact on long-term economic growth. However, we observe that imports 'Log (M)' have a negative effect on long-term economic growth. To verify the credibility of the estimation results of the long-term equilibrium equation, it is important to test its significance.

Table 11 - Significance of the long-term equilibrium equation for the Panel VECM

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECT: C(1)	-0.025887***	0.005217	-4.962408	0.0000
C(2)	-0.250620	0.075633	-3.313654	0.0009
C(3)	-0.060306	0.021022	-2.868712	0.0041
C(4)	-0.334288	0.097850	-3.416333	0.0006
C(5)	-0.022838	0.006468	-3.531087	0.0004
C(6)	-0.165908	0.031055	-5.342333	0.0000
C(7)	0.190627	0.034073	5.594692	0.0000
C(8)	-0.000241	0.001260	-0.191510	0.8481

Form of Panel VECM Equation:

$$D(DLn(Y)) = C(1) * (DLn(Y(-1)) - 1.94212375498 * DLn(DI(-1)) - 4.72250736607 * DLn(L(-1)) - 1.5413928256 * DLn(I(-1)) - 1.30585499196 * DLn(X(-1)) + 6.06772205236 * DLn(M(-1)) - 0.134435701577) + C(2) * D(DLn(Y(-1))) + C(3) * D(DLn(DI(-1))) + C(4) * D(DLn(L(-1))) + C(5) * D(DLn(I(-1))) + C(6) * D(DLn(X(-1))) + C(7) * D(DLn(M(-1))) + C(8) \quad (4)$$

Source: Authors' calculations using EViews 12 software.

In this step, we will test the significance of the long-term equilibrium equation. It can be stated that this equation is significant, indicating a long-term relationship between variables when the Error Correction Term (ECT) has a negative coefficient and a significant probability (below 5%). Table n°11 presents the results of the significance test for the long-term equilibrium equation. It is evident that the coefficient of the Error Correction Term (ECT) is negative, specifically '-0.025887', with a highly significant probability below 5%, equivalent to 0.00%. In this case, we confirm the significance of the long-term equilibrium equation. Therefore, we affirm that innovation, domestic investments, labor, and exports have a positive and significant effect on long-term economic growth in the case of developed countries. Additionally, we confirm that imports have a negative and significant impact on long-term economic growth in the case of developed countries.

Table 12 - VEC Granger Causality/Block Exogeneity Wald Tests: Short run causality

VEC Granger Causality/Block Exogeneity Wald Tests			
Dependent variable : D(DLn(Y))			
Excluded	Chi-sq	df	Prob.
D(DLn(DI))	15.11827	1	0.0001
D(DLn(L))	3.816662	1	0.0507
D(DLn(I))	16.95413	1	0.0000
D(DLn(X))	34.02045	1	0.0000
D(DLn(M))	31.61358	1	0.0000

Source: Authors' calculations using EViews 12 software.

To assess immediate association within the Vector Error Correction Model, the WALD test is employed to identify short-term causality. The econometric guideline dictates that if the probability is below 5%, it signifies a short-term causal relationship between the two variables. Conversely, if the probability exceeds 5%, it implies the absence of a short-term causal link between the two variables. This test serves as a critical tool for determining the direction and significance of short-term causal relationships in the model, providing valuable insights into the dynamics between the variables under consideration. Table n°12 showcases the outcomes of the WALD test designed to identify short-term causal relationships. It is evident from the results that variables representing innovation 'Ln (I)', domestic investments 'Ln (DI)', labor 'Ln (L)', exports 'Ln (X)', and imports 'Ln (M)' all exhibit a causal impact on the variable signifying short-term economic growth 'Ln (Y)'.

In summary of this section, our investigation focused on three specific models: the fixed-effects gravity model, the fixed-effects GMM model, and the long-term Panel VECM model. All these models converged to similar conclusions. Specifically, they converged on the point that innovations serve as a source of economic growth and have a positive impact on it. These findings align with those reported by Pece et al (2015) and Maradana et al (2017) but contradict the results obtained by Dauda et al (2019) and Feki and Mnif (2016), which suggested an unfavorable effect of innovation on economic growth. Furthermore, our results also confirm the positive influence of domestic investments on economic growth, consistent with the studies of Bakari and Tiba (2022) as well as Bakari (2021). However, this conclusion contradicts the results obtained by Aslan and Altinoz (2021) and Topcu et al (2020). Similarly, our findings support the notion that labor has a positive impact on economic growth, corroborating the results of Hanushek and Woessmann (2020) and Akram et al (2021). Additionally, our results confirm the positive effect of exports on economic growth, in line with the conclusions of Rahman et al (2021), Blavasciunaite et al (2020), and Raghutla (2020). Conversely, our observations indicate that imports have a negative impact on economic growth, aligning with the results obtained by Safi et al (2021), Rahman et al (2020), and Sunde et al (2023).

5. Conclusion

Exploring the ramifications of innovation on economic growth holds paramount significance, aimed at providing enlightenment to policymakers and private stakeholders in the formulation of well-informed policies and investments. Through meticulous examination of the influence of innovation on factors such as productivity, job creation, global competitiveness, and addressing societal challenges, a nuanced understanding of the underlying mechanisms of economic dynamics is attained. This precise comprehension offers the opportunity to devise targeted strategies to promote sustainable economic development. Within a scientific context, such an approach contributes to broadening our comprehension of the intricate interactions between innovation and growth, thereby laying the groundwork for an enlightened and holistic approach to contemporary economics.

In this study, our objective was to evaluate the impact of innovation on economic growth in 24 developed countries (Australia, Austria, Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, New Zealand, Norway, Netherlands, Portugal, Spain, Sweden, Switzerland, UK, and USA) over the period from 1990 to 2021. Our empirical methodology focused on three specific models: the fixed-effects gravity model, the fixed-effects GMM model, and the long-term Panel VECM model. All these models converged towards similar conclusions, affirming that innovation constitutes a source of economic growth and exerts a positive impact on it. Furthermore, the results of the short-term estimation of the Panel VECM model revealed that innovations indeed drive economic growth.

The findings indicating that innovation spurs economic growth both in the short term and long term in developed countries during the period 1990-2021 are in line with various economic theories and empirical observations. Innovation can stimulate short-term economic growth by fostering new business opportunities, enhancing production processes' efficiency, and encouraging investments in cutting-edge technologies. For instance, the introduction of novel technologies in the manufacturing sector can bolster productivity and lead to immediate economic expansion. Investments in research and development (R&D) and the assimilation of new technologies can also spur demand for skilled and specialized labor, thereby positively influencing employment and short-term economic growth.

In the long term, innovation plays a pivotal role in the structural metamorphosis of the economy by enhancing productivity, nurturing global competitiveness, and fostering economic diversification. Economies adept at innovating and embracing new technologies can maintain a sustainable competitive edge in global markets. Additionally, innovation stimulates the inception of novel industries and the obsolescence of outdated ones, fostering the economy's long-term adaptation and growth. For instance, transitioning to renewable energy industries can not only bolster economic growth but also contribute to long-term environmental sustainability. Moreover, innovation can lead to beneficial externalities, such as advancements in health, education, and other spheres, which, in turn, can bolster long-term economic growth by fortifying human and social capital.

Developed countries typically boast robust institutions, well-established infrastructure, access to financial and human resources, and an environment conducive to innovation and entrepreneurship. These attributes create a conducive ecosystem for translating innovative concepts into marketable products and services, reinforcing the nexus between innovation and economic growth in these nations. Additionally, developed economies often exhibit more open markets and closer economic integration with other countries, facilitating the swift diffusion and adoption of innovations, thereby amplifying their impact on economic growth.

The paper makes several significant contributions to the understanding of the relationship between innovation and economic growth in developed countries. Firstly, it provides empirical evidence supporting the positive impact of innovation on economic growth, as demonstrated through rigorous econometric analysis across 24 developed nations. Secondly, by employing various econometric models such as the fixed-effects gravity model, the fixed-effects GMM model, and the long-term Panel VECM model, the study offers a comprehensive analysis of the innovation-growth nexus from both short-term and long-term perspectives. Thirdly, the paper identifies key factors driving economic growth, including domestic investments, labor, exports, and innovation, while highlighting the negative impact of imports. Lastly, by focusing on developed countries known for their significant contributions to global innovation and economic development, the paper provides valuable insights for policymakers, businesses, and researchers aiming to leverage innovation for sustainable development, job creation, and enhanced global competitiveness.

To optimize innovation's impact on the economic growth of developed nations, several key recommendations and strategies are proposed. Firstly, augmenting investments in R&D from both governmental and private sectors to stimulate the creation of new technologies is advocated. Concurrently, fostering collaborations between the public and private sectors is encouraged, with fiscal incentives or subsidies to facilitate these partnerships. Another pivotal focus entails investing in education and training to cultivate a highly skilled workforce, particularly in fields such as science, technology, engineering, mathematics, as well as in entrepreneurship and creativity. Additionally, governments are urged to bolster entrepreneurship and social innovation through funding policies, incubators, accelerators, and mentoring networks. It is also underscored that establishing a flexible and supportive regulatory environment, coupled with endorsing the adoption of emerging technologies and reinforcing intellectual property protection, are pivotal elements to foster innovation while ensuring consumer and environmental protection.

While the analysis offers valuable insights into the relationship between innovation and economic growth in developed countries, there are several limitations worth noting. Firstly, the study's focus on developed nations may limit the generalizability of its findings to other contexts, such as emerging economies or regions with different levels of economic development. Additionally, the reliance on econometric models and statistical analysis, while robust, may oversimplify the complex dynamics underlying the innovation-growth nexus, overlooking qualitative aspects and contextual factors that could influence the relationship. Moreover, the study's time frame (1990-2021) may not capture longer-term trends or structural shifts in innovation and economic growth patterns. Lastly, while the paper identifies key variables driving economic growth, it may overlook other important factors such as institutional quality, political stability, and social dynamics, which could also play significant roles in shaping the innovation ecosystem and its impact on economic development.

Further research in this area could explore several avenues to deepen our understanding of the innovation-growth relationship in developed countries. Firstly, investigating the role of specific innovation policies and interventions, such as intellectual property rights protection, public investment in research and development, and technology transfer mechanisms, could shed light on their effectiveness in fostering economic growth. Additionally, comparative studies across different types of economies, including emerging markets and developing countries, could provide insights into how contextual factors influence the innovation-growth nexus. Furthermore, longitudinal studies spanning longer time periods could capture the evolution of innovation ecosystems and their impact on economic development over time. Lastly, interdisciplinary research drawing on insights from economics, sociology, political science, and other fields could offer a more holistic understanding of the multifaceted nature of innovation and its implications for sustainable growth and societal well-being.

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