Duyen My Thi Thi; Tinh Tran Phu Do

Article

The interrelationships between economic growth and innovation: International evidence

Journal of Applied Economics

Provided in Cooperation with:
University of CEMA, Buenos Aires

Suggested Citation: Duyen My Thi Thi; Tinh Tran Phu Do (2024) : The interrelationships between economic growth and innovation: International evidence, Journal of Applied Economics, ISSN 1667-6726, Taylor & Francis, Abingdon, Vol. 27, Iss. 1, pp. 1-20, https://doi.org/10.1080/15140326.2024.2332975

This Version is available at:
https://hdl.handle.net/10419/314266

Journal of Applied Economics

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/recs20

The interrelationships between economic growth and innovation: international evidence

Duyen My Thi Thi & Tinh Tran Phu Do

To cite this article: Duyen My Thi Thi & Tinh Tran Phu Do (2024) The interrelationships between economic growth and innovation: international evidence, Journal of Applied Economics, 27:1, 2332975, DOI: 10.1080/15140326.2024.2332975

To link to this article: https://doi.org/10.1080/15140326.2024.2332975

Published online: 27 Mar 2024.

JOURNAL OF APPLIED ECONOMICS
2024, VOL. 27, NO. 1, 2332975
https://doi.org/10.1080/15140326.2024.2332975

Routledge
Taylor & Francis Group

RESEARCH ARTICLE

OPEN ACCESS Check for updates

The interrelationships between economic growth and innovation: international evidence

Duyen My Thi Thi[a,b] and Tinh Tran Phu Do[a,b]

[a]University of Economics and Law, Ho Chi Minh City, Vietnam; [b]Vietnam National University, Ho Chi Minh City, Vietnam

ABSTRACT

Technological innovation towards the goal of sustainable development is one of the concerns of many countries. This research investigates the linkages between innovation and growth for 71 countries worldwide from 1996 to 2020 by employing a simultaneous equation model and the three-stage least squares method to examine the bidirectional linkages among the variables. Outcomes state a two-way relation between growth and technology innovation. Specifically, a positive influence of technology innovation on economic expansion emphasizes the importance of innovation in growth. Meanwhile, a negative relationship between growth and technology innovation shows that the pressure of growth hinders innovation. Furthermore, a bidirectional relationship still exists between them in the sample of high-upper-middle-income countries but only one way for low-lower-middle-income countries. Institutional quality positively affects growth, while institutional quality has a negative influence on innovation. A number of policies have proposed to help promote innovation and enhance economic growth.

ARTICLE HISTORY
Received 26 October 2023
Accepted 12 March 2024

KEYWORDS
Economic growth; technological innovation; three-stage least squares; simultaneous equation model

1. Introduction

Innovation is inherently an interdisciplinary subject of study. Innovation includes not only the development of a new merchandise or the commercialization of inventions but also humanitarian, social, and institutional aspects. It is stated that innovation and education are two important factors for ensuring economic growth (EG) (Schumpeter, 1939). Invention, innovation, and diffusion are three stages for a new and superior technology to enter the market. It is believed that the research and development process is used to carry out the process of technological invention and innovation. Finally, when an innovation is successful, the diffusion process is followed for appropriate adoption by individuals and businesses (Schumpeter, 1942). Innovation is not only important for growth but also for health, environment, and other policy goals related to well-being. However, the relationship between the countries' growth policies towards innovation has

CONTACT Duyen My Thi Thi duyenttm21702@sdh.uel.edu.vn Faculty of Economics, University of Economics and Law, Ho Chi Minh 700000, Vietnam; Tinh Tran Phu Do tinhdpt@uel.edu.vn Vietnam National University, Ho Chi Minh 700000, Vietnam

not been explored in detail. In this article, we deeply examine the interrelationship between innovation and EG for the world nations. To investigate the bidirectional relation between EG and technological innovation (TI), countries included in this analysis must have available data of at least five continuous years. After excluding missing data, the outcomes yield a total of 71 economies over the period 1996–2020, for which data associated with the variables to be estimated in this article are available.

The relationship between technology innovation and growth has been emphasized in many theories Solow (1956), Romer (1986), Lucas (1988). Theoretical and empirical research on growth has produced a very rich and diverse literature. According to Solow (1956), technological progress is an exogenous factor, because its operation is automatic and independent of economic circumstances. Its purpose is to enhance the measurement quality of the variables in the growth model and to decrease the residue. Romer (1986) and Lucas (1988) indicated that it is necessary to introduce technology as an endogenous factor affecting growth. From this point of view, endogenous growth theorists assume that macroeconomic growth is an investment that leads to technological improvement. Based on growth theory of Schumpeterian, Aghion et al. (2014) argued that subsequent innovators receive positive knowledge spillovers from current innovators, but current innovators also eliminate previous technologies. In addition, they also argued that Schumpeterian growth theory helps reconcile growth with development by introducing the concept of appropriate growth policies and institutions. They pointed out that democracy is driving more growth in more frontier economies. Furthermore, they pointed out that fiercer competition, low industry entry, higher levels of trade openness, and greater emphasis on education may help spur more growth in more border nations. Moreover, they also suggest a need to examine more closely how EG and innovation are affected by business organization and research activities. However, business size and organization are endogenous, and they depend on factors such as the supply of skilled labor or the nature of domestic institutions. Their final suggestion for future research is to consider the role of financial factors in promoting innovation and growth in more frontier nations. Boschma et al. (2018) have developed a theoretical framework for regional diversification based on Evolutionary Economic Geography and transition literature. They concentrated on the interaction between ascending versus breakthrough progress of interrelated industrial, institutional, and technology changes. Besides, Polenske (2007) provides a comparative picture of the institutional factors that underpin innovation systems globally. They make a major contribution to the existing literature with an extensive analysis of the institutional and spatial aspects of innovation. Their research provides insights into the important roles of institutions such as gender and culture that are often overlooked in the innovation literature, and prove that geography plays a key role in the process of innovation. Additionally, institutional and policy solutions to support startups and cluster development are also debated.

Much empirical evidence shows that innovation has a positive impact on growth (Ahmad et al., 2023; I. Khan et al., 2023; Manigandan et al., 2023; Meirun et al., 2021; Phung et al., 2019; Wang et al., 2023). Meanwhile, others stated the opposite (Mtar & Belazreg, 2023). Some empirical studies found a two-way causal relationship between innovation and growth (Akinwale, 2022; I. Khan et al., 2023; Maradana et al., 2019; Pradhan et al., 2018). From previous empirical results, it shows that a two-way causal relation between growth and innovation exists.

Although innovation is an important factor promoting growth, the countries growth policies towards innovation have not been explored in detail across a diverse range of countries. Therefore, this article will provide empirical evidence on the interrelationship between technology innovation and EG across a diverse range of countries, and from there, a number of policies will be suggested to balance between innovation promotion and sustainable EG.

Besides innovation, capital stock, population growth (PG), human capital (HC), and institutional quality also affect EG. Indeed, some empirical evidence shows that HC and capital stock positively impact growth (Abdouli & Omri, 2021; Bouznit et al., 2023; Muhamad et al., 2018). According to Thuku and Paul (2013) and Adewole (2012), PG positively affects growth, while Dao (2012) found the opposite. Besides, institutional quality is found to have a positive relation with growth (Doğan et al., 2020; Islam & Mustafa Shindaini, 2022), while Lee et al. (2020) showed the opposite result. According to Rodríguez-Pose and Zhang (2020), poor institutional quality is a barrier for companies's innovation, while Tebaldi and Elmslie (2008) indicated that corruption control, market-friendly policies, protection of property rights, and a more effective judiciary system allow enhanced innovation. Furthermore, some empirical evidence demonstrates that FDI inflows and financial development are found to have a relation with innovation. Chen et al. (2022) and Sivalogathasan and Wu (2014) found that the effect of FDI inflows on innovation is positive. Lv et al. (2021) found that financial scale and financial efficiency negatively affect green technology innovation, and Jin et al. (2018) showed energy consumption (EC) positively influences innovation.

This research follows the suggestion of Ren et al. (2021) and I. Khan et al. (2023) to apply a simultaneous equation model (SEM) with three-stage least squares (3SLS) estimator to investigate the interrelationships between innovation and growth because this technique is considered more effective than others. Findings indicate a bidirectional relationship between technology innovation and growth for 71 countries worldwide. More specifically, technology innovation positively affects growth, while growth negatively impacts innovation. This finding supports the view that innovation is an important factor for growth. Our results are also confirmed by using fixed-effect model (FEM), random-effect model (REM), and GMM methods for check robustness. Additionally, the authors also check the robustness by adding significant economic events such as the financial crisis in the period 2007–2009 and institutional quality as well.

This paper has several contributions to existing literature in some ways. Most previous research has concentrated on the one-way relation between TI and growth. For instance, some studies have investigated the influence of technology innovation on growth (Ahmad et al., 2023; Manigandan et al., 2023; Meirun et al., 2021; Phung et al., 2019). Meanwhile, others have examined the effect of growth on innovation (Andabaka et al., 2019; H. Khan et al., 2022; Sharif et al., 2023). Empirical evidence of a bidirectional relationship between them is scanty (Akinwale, 2022; I. Khan et al., 2023; Maradana et al., 2019; Pradhan et al., 2018). Our research will put on more proof to the literature for 71 countries worldwide, by investigating this interrelationship for 71 nations. Therefore, the most important contribution of this study is to provide empirical evidence on the interrelationship between innovation and growth in various countries, highlighting the need for balanced policies between innovation promotion and sustainable EG. From research results, some recommendations will be suggested for policy-makers.

The structure of this study is as follows: the literature review will be presented in section 2, the research models will be presented in section 3, section 4 will indicate the empirical outcomes and discussions, and finally the conclusion and policy implications will be presented in section 5.

2. Literature review

The capital, labor, and technological changes are some of the main factors driving EG (Solow, 1956). Later, Romer (1986), Romer (1990), and Lucas (1988) have extended Solow's theory to a new growth theory that emphasized productivity growth as the result of deliberate innovation by rational private sector profit-maximizing agents, and therefore that is determined to be endogenous. Technology innovation is one of the main drivers of EG. HC is also considered an important resource determining EG. Besides, institutional quality as a driver of economic development has attracted attention in the EG literature. North (1990), Scott (1995), and Williamson (2000) made important contributions to the field of institutional economics. They argue that formal rules such as constitutions, laws, and regulations and informal rules like norms, habits, and social practices play a vital role in economic development. TI is considered an important factor promoting growth, and examining the factors affecting innovation has also attracted much attention. Rodríguez-Pose et al. (2021) have made a comparative investigation of innovation dynamics in Chinese cities. They found there are differences in innovation dynamics between developed and underdeveloped cities. In more developed cities, they seem to take more advantage of knowledge from R&D activities, large HC resources, and spillover effects between cities than less developed cities. Besides, it is found that institutional quality affects trade (Álvarez et al., 2018). Through technology transfer via import and export activities, innovation can be greatly promoted. Bosma et al. (2018) have studied relation among institutions, entrepreneurship, and GDP per capita growth in Europe. They indicated that effective entrepreneurship contributes to GDP per capita growth, and the relation between institutions and EG is positive. Besides, Polenske (2007) provides a comparative picture of the institutional factors that underpin innovation systems globally.

Empirical evidence shows the relation between innovation and growth, some of which claim that innovation promotes growth (Ahmad et al., 2023; Manigandan et al., 2023; Wang et al., 2023) and EG also increases TI (I. Khan et al., 2023; Sharif et al., 2023) (Weili et al., H. Khan et al., 2022). Indeed, Wang et al. (2023) use data from 30 regions in China from 2009 to 2020 to examine the influence of natural resources and TI on green economy growth efficiency (GEGE) by applying the Generalized Method of Moments (GMM) model and found that technology innovation allows to enhance the GEGE of the whole country and three regions, and the effect is greatest in the western region of China. Similarly, using panel data for 35 Belt and Road nations for the period 1985–2019, I. Khan et al. (2023) discovered that TI drives EG, and EG increases TI. Sharif et al. (2023) showed that EG positively affects innovation in six ASEAN countries during the period 1995–2018. Ahmad et al. (2023) found that TI is an important factor in promoting sustainable development in China, with innovation contributing to EG. The same result is also found in the research of Manigandan et al. (2023). H. Khan et al. (2022) found a positive impact of EG on innovation, while FDI and EC have a negative impact on

innovation in 181 countries for the period 1980–2019. Akinwale (2022) showed that there is a long-term correlation and a two-way link between TI and EG. Meirun et al. (2021) explored the positive and significant effect of green technology innovation on EG in Singapore, employing a bootstrap ARDL approach. Phung et al. (2019) used data from 69 countries for the period of 2006–2014, applied the GMM method, and found that innovation, openness, and FDI inflows have a positive effect on EG. Additionally, interaction between innovation and institutional quality shows a positive relation with EG. Galindo-Martín et al. (2020) also stated that EG is positively affected by innovation and institutions. Andabaka et al. (2019) utilized GMM estimator to analyze the impact of GDP growth, institution quality, and recycling rates on the eco-innovation in 28 European countries and found that these explanatory variables have a positive effect on eco-innovation for 2010–2016 period. Moreover, some empirical evidence indicates the linkages between the capital stock, PG, HC, institutional quality, and EG. Capital stock positively influences per capita GDP (Abdouli & Hammami, 2020). Likely, Abdouli and Omri (2021) examined the link between FDI inflows, CO_2 emissions, HC, and EG over the period 1990–2013 in the Mediterranean region. They found that HC and capital stock have a positive influence on EG. Besides, according to Thuku and Paul (2013) and Adewole (2012), PG positively affects GDP growth, while Dao (2012) found the opposite. Likewise, Klasen and Lawson (2007) investigated the effect of PG on EG and poverty decrease in Uganda and found that high PG is a barrier to poverty reduction and per capita growth in Uganda. Regarding the factors affecting innovation, some empirical studies demonstrate that EG, FDI inflows, financial development, energy use, and institutional quality have a influence on innovation. Economic expansion encourages innovation (I. Khan et al., 2023; Sharif et al., 2023), while Yu et al. (2023) and Shen et al. (2021) demonstrate the opposite outcomes. Chen et al. (2022) examined the effect of FDI on innovation in Chinese firms and illustrated that FDI has a positive influence on innovation. Lv et al. (2021) investigated the link between green technology innovation (GTI) and financial development in China. They found a positive influence of financial structure on GTI, while financial scale and financial efficiency negatively affect GTI. Jin et al. (2018) examined the link between TI and EC in China over 1995–2012 period. They indicated that TI positively affects EC in the short run, while EC is positively and bilaterally associated with TI. Rodríguez-Pose and Zhang (2020) demonstrate that a poor institutional quality in urban areas of China is a barrier to innovation.

On the other hand, some empirical studies show that there exists a negative relation between TI and EG (Mtar & Belazreg, 2023; Shen et al., 2021; Yu et al., 2023). For instance, Mtar and Belazreg (2023) investigate linkages among innovation, trade openness, financial development and EG by using a panel-VAR approach and found a negative relation between innovation and economic expansion. Yu et al. (2023) indicate that economic growth pressure (EGP) negatively affects green technology innovation (GTI), using data from 285 cities in China during 2006–2018 period. Shen et al. (2021) found that EG targets have a negative impact on innovation in 244 cities of China from 2004 to 2016.

Other studies show bidirectional causality between innovation and EG (Akinwale, 2022; I. Khan et al., 2023; Maradana et al., 2019; Pradhan et al., 2018). I. Khan et al. (2023) indicated a bidirectional causality between innovation and EG in 35 Belt and Road nations over 1985–2019 period. Akinwale (2022) found a bidirectional causality between

innovation and EG in South Africa for 1985–2015 period. Maradana et al. (2019) showed a unidirectional and bidirectional causality between innovation and EG by employing a Granger causality test for 19 European countries from 1989 to 2014. Pradhan et al. (2018) indicated a two-way causality between innovation and EG in 49 European nations over the period 1961–2014.

In general, most studies have investigated either the effect of TI on EG or the effect of EG on technology innovation. According to the research of I. Khan et al. (2023), Akinwale (2022), Maradana et al. (2019), and Pradhan et al. (2018), there is a bidirectional causality between innovation and EG in 35 Belt and Road countries, in South Africa and in European countries. Therefore, the authors will put on more proof to existing literature on interrelationship between technology innovation and EG in the context of 71 worldwide countries. From the research results, some recommendations will be suggested for policy-makers, highlighting the need for balanced policies between innovation promotion and sustainable EG.

The hypothesis is formulated as follows:

H1. There is a two-ways relation between technology innovation and economic growth.

3. Methodology and data

3.1. Data and variables

In this study, the data were collected from three various sources. Technology innovation (TI) as measured by the total number of patent applications, residents and non-residents; EG (EG) is the growth rate of gross domestic products (%); the capital stock (K) is measured by gross fixed capital formation (% of GDP); PG is the population growth (annual %), HC is the proxy by labor force participation rate for ages 15–24 years (Y. Khan et al., 2022), and FDI is measured by foreign direct investment, net inflows (% of GDP). Data of these variables were collected from the World Development Indicators, World Bank. FD is a financial development index, gathered from the International Monetary Fund, and EC is the EC per capita (kWh/person), collected from Our World in Data. Detailed data are shown in Table 1.

Table 1. Describe variables.

Variable	Definition	Data Source
Economic growth (EG)	GDP growth (annual %)	(WDI, 2023)
Technological innovation (TI)	The number of patent applications, residents and non residents	(WDI, 2023)
Capital stock (K)	Gross fixed capital formation (% of GDP)	(WDI, 2023)
Population growth (PG)	Population growth (annual %)	(WDI, 2023)
Human capital (HC)	Labor force participation rate for ages 15–24, total (%)	(WDI, 2023)
Foreign direct investment (FDI)	Foreign direct investment, net inflows (% of GDP)	(WDI, 2023)
Financial development (FD)	Financial development index	(IMF, 2023)
Energy consumption (EC)	The natural logarithm of energy consumption per capita (kWh/person)	(Our World in Data-OWID, 2023)

IMF: International Monetary Fund.
WDI: World Development Indicators.

Table 2. Variables description.

Variable	Obs.	Mean	SD	Min	Max
EG	1,775	3.182	3.822	−15.136	19.681
TI	1,775	25149.87	113518.6	4	1,542,002
K	1,775	23.046	5.512	4.452	48.412
PG	1,775	0.789	1.010	−3.847	5.321
HC	1,775	45.717	12.858	16.144	83.03
FDI	1,775	4.875	18.094	−40.086	449.080
FD	1,775	0.424	0.239	0.026	1
EC	1,775	9.970	1.082	6.045	12.145

EG = Economic growth; TI = Technological innovation; K = Capital stock; PG = Population growth; HC = Human capital; FDI = Foreign direct investment; FD = Financial development; EC = The natural logarithm of energy consumption per capita.

Table 3. Correlations between variables.

Variables	EG	TI	K	PG	HC	FDI	FD	EC
EG	1							
TI	−0.03	1						
K	0.23	−0.03	1					
PG	0.07	0.06	−0.00	1				
HC	0.02	−0.03	−0.04	0.22	1			
FDI	0.17	−0.03	0.10	−0.18	0.07	1		
FD	−0.19	0.05	0.03	−0.01	0.34	−0.01	1	
EC	0.18	−0.08	0.02	0.19	0.05	0.06	−0.36	1

EG = Economic growth; TI = Technological innovation; K = Capital stock; PG = Population growth; HC = Human capital; FDI = Foreign direct investment; FD = Financial development; EC = The natural logarithm of energy consumption per capita.

Table 2 shows that the mean growth rate of gross domestic products (GDP) is 3.182%, minimum value is −15.136%, while the maximum value is 19.681%, implying that there is a difference of the GDP growth among the nations in the sample. Likewise, there is a difference between the mean and standard deviation of the TI variable, which may imply a difference level of innovation across countries in this sample. Similarly, mean value of K is 23.046%, and standard deviation is 5.512%. The average value of PG is 0.789%, and volatility is 1.010 %. The average value of FDI is 4.875%, with high volatility (18.094%), suggesting that there is a difference on FDI inflows among countries. In contrast, mean value of FD is 0.424, with low standard deviation (0.239), showing that there is a little difference on FD among nations in this sample.

Table 3 indicates a negative correlation between EG and TI and no high correlations between independent variables utilized in equations (1) and (2). However, the concurrent relation between EG and TI can only be tested by SEM method.

3.2. Theoretical framework and methodology

Growth theory of Solow (1956) points out that capital, labor, and technological change determine economic expansion. Later, Romer (1986), Romer (1990), and Lucas (1988) have extended Solow's theory to a new growth theory that emphasized productivity growth as the result of deliberate innovation by rational private sector profit-maximizing agents, and therefore that is determined to be endogenous. Technology innovation is one of the main drivers of EG. Endogenous growth theory is used in our work to estimate the relation between growth and TI.

Additionally, Boschma et al. (2018) concentrated on the interaction between ascending and breakthrough progress of interrelated industrial, institutional, and technology changes. Polenske (2007) provides a comparative picture of the institutional factors that underpin innovation systems globally. Aghion et al. (2014) made a suggestion for future research to consider the role of financial factor in promoting innovation and growth in more frontier nations. Innovation can be strongly promoted thanks to import and export activities (Álvarez et al., 2018). Based on the theoretical foundation and empirical studies mentioned above, the research models are proposed as follows:

$$EG = f(TI, K, PG, HC) \tag{1}$$

$$TI = f(EG, FDI, FD, EC) \tag{2}$$

TI and EG represent two endogenous variables in this paper. To solve concurrency between innovation and EG (cause of endogeneity), the SEM method is applied. Accordingly, several techniques are commonly used, like seemingly unrelated regressions (SUR) (I. Khan et al., 2023), Granger causality test (Guloglu & Tekin, 2012), two-stage least squares (2SLS) (I. Khan et al., 2023), 3SLS (Ren et al., 2021), and GMM (Malik, 2021). Still, Nguyen and Nghiem (2015) argue that outcomes obtained from Granger causality are relatively sensitive to a number of lags and model specifications. Similar problems can also occur when using SEM in combination with GMM. Belsley (1988) and Intriligator (1978) argue that 3SLS is more effective than 2SLS because this technique utilizes information about the relation of stochastic disturbance terms of structural equations, strengthening the association between the error term. Therefore, 3SLS estimator is a coalescence of 2SLS, and SUR is commonly utilized. Inherited from previous studies like Ren et al. (2021), Malik (2021), and I. Khan et al. (2023), a simultaneous equation model, specifically 3SLS, will be applied in our study.

The experimental model is presented as follows:

$$\mathrm{EGit} = \alpha 0 + \alpha 1\mathrm{TIit} + \alpha 2\mathrm{Kit} + \alpha 3\mathrm{PGit} + \alpha 4\mathrm{HCit} + \mathrm{it} \tag{3}$$

$$\mathrm{TIit} = \beta 0 + \beta 1\mathrm{EGit} + \beta 2\mathrm{FDIit} + \beta 3\mathrm{FDit} + \beta 4\mathrm{ECit} + \mathrm{it} \tag{4}$$

where EG is measured by the growth rate of gross domestic products, technology innovation (TI) proxy by the total number of patent applications, residents and nonresidents. The capital stock (K) proxy by gross fixed capital formation (% of GDP), population growth (PG), and HC proxy by labor force participation rate for ages 15–24 years, total (%). Foreign direct investment, net inflows (% of GDP), financial development (FD), and EC is the natural logarithm of energy consumption per capita (kWh/person).

$\alpha 0$ and $\beta 0$ are intercepts

it is the error term

$\alpha 1, \alpha 2, \alpha 3, \alpha 4$; and $\beta 1, \beta 2, \beta 3, \beta 4$ indicate the coefficients

i indicates country (i = 1 . . . N)

t indicates time (t = 1996 . . . . 2020)

4. Results and discussions

Before conducting a regression analysis, we need to check variables stationarity, to make sure the regression results are reliable. Cross-sectional dependence tests need to be determined before performing the panel unit root test. The results of these cross-sectional dependence tests are illustrated in Table 4 by using Pesaran's CD test. Table 4 shows that cross-sectional dependence exists between countries. The first-generation unit root tests often take no notice of cross-sectional dependence, which can reduce the reliability of results. Therefore, to resolve this problem, the second-generation root tests will be used (Pesaran, 2007). The unit root test results are shown in Table 5 by using Pesaran CADF and Pesaran CIPS test. The outcomes indicate that all variables are stable at the first difference I(1), so that all variables can be analyzed directly for regression.

The outcomes from Tables 6 demonstrate that there exists a bidirectional relationship between EG and technology innovation. TI affects EG positively, while growth negatively influences technology innovation. Therefore, H1 hypothesis is accepted.

For the determinants of EG, the outcomes show that TI has a significantly positive impact on EG, suggesting that TI increases EG. This is supported by previous findings of I. Khan et al. (2023) for 35 Belt and Road countries, Ahmad et al. (2023) for China, and

Table 4. Results of cross-sectional dependence tests by Pesaran CD test.

Variables	Pesaran CD test	Prob-value
EG	110.190***	0.0000
TI	2.844***	0.0044
K	17.818***	0.0000
PG	5.851***	0.0000
HC	82.926***	0.0000
FDI	32.098***	0.0000
FD	117.546***	0.0000
EC	22.461***	0.0000

EG = Economic growth; TI = Technological innovation; K = Capital stock; PG = Population growth; HC = Human capital; FDI = Foreign direct investment; FD = Financial development; EC = The natural logarithm of energy consumption per capita.

Table 5. Results of the panel stationarity tests.

	Pesaran CADF test				Pesaran CIPS test			
	Level		1st difference		Level		1st difference	
Variables	Intercept	Intercept & trend	Intercept	Intercept & trend	Intercept	Intercept & trend	Intercept	Intercept & trend
EG	−2.431***	−2.458*	−3.847***	−3.860***	−3.088***	−3.245***	−5.236***	−5.252***
TI	−2.195***	−2.735***	−4.030***	−4.120***	−2.805***	−3.417***	−5.063***	−5.183***
K	−2.029***	−2.330	−3.239***	−3.350***	−1.844	−2.118	−4.172***	−4.216***
PG	−1.899*	−2.493**	−2.982***	−3.061***	−1.452	−1.717	−2.908***	−2.914***
HC	−1.971**	−2.076	−2.844***	−2.972***	−1.775	−1.873	−3.788***	−3.945***
FDI	−2.657***	−3.125***	−4.422***	−4.424***	−3.541***	−3.892***	−5.707***	−5.791***
FD	−2.225***	−2.728***	−3.612***	−3.707***	−2.252***	−2.708***	−4.847***	−4.922***
EC	−0.784	−1.866	−2.635***	−2.754***	−1.009	−2.143	−3.989***	−4.125***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

EG = Economic growth; TI = Technological innovation; K = Capital stock; PG = Population growth; HC = Human capital; FDI = Foreign direct investment; FD = Financial development; EC = The natural logarithm of energy consumption per capita.

Table 6. The results of models.

Equation (1) of SEM	
Economic growth (EG)	
Constant	−32.480*** (7.346)
TI	0.028*** (0.005)
K	0.003*** (0.001)
PG	−0.048 (0.347)
HC	0.203*** (0.061)
Country fixed effects	Yes
No. Obs	1,775
R^2	−5.897
Equation (2) of SEM	
Technological innovation (TI)	
Constant	860.246*** (77.137)
EG	−30.075** (13.434)
FDI	0.084*** (0.025)
FD	−346.926** (160.152)
EC	0.105*** (0.030)
Country fixed effects	Yes
No. Obs	1,775
R^2	0.339

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

SEM = Simultaneous equation model; EG = Economic growth; TI = Technological innovation; K= Capital stock; PG = Population growth; HC = Human capital; FDI = Foreign direct investment; FD = Financial development; EC = The natural logarithm of energy consumption per capita.

Meirun et al. (2021) for Singapore. Many patents are created to serve in production, creating higher value products, lower costs, and less fuel consumption, which contributes to increase income and promote growth. However, our results are contrary to the finding of Mtar and Belazreg (2023) in European countries, which reported a negative relation between innovation and growth. The positive impact of innovation on growth reflects efficiency for production investment, fuel savings, cost savings, and reasonable technology transfer, and patents bring efficiency in business practice. Furthermore, the capital stock (K) is positively related to EG, implying that the capital allows to increase EG. This result is supported by the empirical study of Abdouli and Hammami (2020) in Middle East Countries and Abdouli and Omri (2021) in the Mediterranean region. This shows the efficiency brought from capital sources for economic development. This is also reasonable because capital is one of the important factors for the economic development of each country. Capital has a positive relationship with EG, showing that capital sources have been used effectively for development investment in these countries. Additionally, PG is negatively related to EG, but not significantly. HC is found to have a positive relationship with EG, showing that HC drives EG. This is similar with the findings of Muhamad et al. (2018) in ASEAN countries and Abdouli and Omri (2021) and Bouznit et al. (2023) in Algeria. This implies that high-quality human resources promote growth for countries, so managers need to focus on education, creating quality resources to serve national development.

In terms of the determinants of TI, results show that EG is significantly negatively correlated with TI, implying that economic expansion reduces innovation. This result is

contrary to the findings of I. Khan et al. (2023) in 35 Belt and Road countries, Sharif et al. (2023) in ASEAN countries, who explored that economic expansion allows enhance innovation, but our finding is supported by the results of Mtar and Belazreg (2023), Yu et al. (2023), and Shen et al. (2021), who found that pressures and targets in economic development hinder innovation. Their findings show that more ambitious EG targets are more detrimental to green innovation. The reason for this is that some regions chase quantity and ignore the quality of EG. Therefore, setting local EG targets will limit green innovation. TI promotes growth, but conversely, growth hinders innovation, which shows that growth pressures have a negative impact on innovation. Managers need to pay attention to investing in TI, especially energy and green technology projects serving sustainable development.

The coefficient of FDI variable is positive and significant, highlighting that FDI promotes technology innovation. This result is consistent with the findings of Cheung and Lin (2004) and Chen et al. (2022), who explored that FDI has a positive effect on the number of patent applications. This is explained by the fact that FDI inflows can bring advanced technology and spillover effects that can promote innovations. However, our results are opposite to those of Shen et al. (2021), who explored that FDI hinders green technology innovation. This discrepancy may be due to regions in China still being in a period of profound economic expansion, and governments tend to focus on rapid industrial development for the purpose of economic development. In terms of the financial development, the coefficient is negative and significant, demonstrating that financial development has not enhanced TI. This result is similar to Lv et al.'s (2021) outcomes, who found that financial scale and financial efficiency negatively affect green technology innovation. This shows that countries do not have an appropriate allocation of capital for TI, so managers need to pay more attention to spend capital for innovation in the coming time, especially renewable energy projects and green technology innovation. EC has a significant positive influence on TI, highlighting that EC enhances TI. This result is consistent with the finding of Jin et al. (2018). Encouraging investment in renewable energy to produce electricity is crucial as this helps create energy innovation, promoting sustainable growth for the future.

In the period of 1996–2020, a prominent economic event occurred, which was the global financial crisis of 2007–2009. This financial crisis event may also affect the relationship between growth and innovation. Therefore, the authors conduct a robustness check with the financial crisis variable. Financial crisis is a dummy variable, taking the value of 0 when there is no financial crisis, and the value of 1 when there is a financial crisis.

The outcomes of robustness checks with financial crisis variable are shown in Table 7. The obtained findings are unchanged, and for the ease of comprehension, we only explain the main variables and financial crisis variables in Table 7. Table 7 indicates that TI positively affects EG, while EG negatively impacts TI. Regarding the financial crisis, Table 7 shows a negative influence of financial crisis on EG, implying that financial crisis reduces EG. This finding is confirmed by research conducted by Tabata (2009) for Russia and Bordo et al. (2010) for 45 countries, who demonstrate a significant drop in production in 2008 and 2009 due to global financial crisis. The global financial crisis has caused a lot of damage to countries, leading to increased unemployment, real estate difficulties, reduced exports, and reduced tourism, which has a a negative impact

Table 7. Robustness checks with financial crisis.

Equation (1) of SEM	
Economic growth (EG)	
Constant	−29.569*** (6.524)
TI	0.024*** (0.005)
K	0.003*** (0.0005)
PG	−0.034 (0.326)
HC	0.198*** (0.055)
Financial crisis	−2.341***(0.585)
Country-fixed effects	Yes
No. Obs	1,775
R^2	−4.509
Equation (2) of SEM	
Technological innovation (TI)	
Constant	838.089***(77.628)
EG	−31.393** (12.134)
FDI	0.098*** (0.025)
FD	−296.151** (151.348)
EC	0.115*** (0.029)
Financial crisis	−4.285 (28.502)
Country-fixed effects	Yes
No. Obs	1,775
R^2	0.334

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

SEM = simultaneous equation model; EG = Economic growth; TI = Technological innovation; K = Capital stock; PG = Population growth; HC = Human capital; FD I= Foreign direct investment; FD = Financial development; EC = The natural logarithm of energy consumption per capita.

on the economy. Meanwhile, financial crisis has a negative effect on innovation but is not statistically significant.

According to Aghion et al.'s (2014) suggestion, we add institutional quality as a dependent variable to check robustness, and institutional quality include control of corruption (CORRUPTION), regulatory quality (REGULATORY), rule of law (RULE), voice and accountability (VOICE), government effectiveness (GOVERNMENT), and political stability (POLITICAL). These indicators are gathered from the World Bank database; to avoid the problem of multicollinearity, the authors included these indicators in a separate model. The obtained results are unchanged, and for the ease of comprehension, the authors only explain the main variables in Table 8. Part 1 and Part 2 of Table 8 show that TI positively affects EG, while EG negatively impacts TI. Table 8 shows a bidirectional relationship between TI and EG in all models. Similar to the findings of Islam and Mustafa Shindaini (2022), institutional quality is found to increase EG, indicating that government policies and regulations are working effectively, contributing to business activities, thereby stimulating growth. However, institutional quality has a significantly negative influence on TI. This is in line with the findings of Rodríguez-Pose and Zhang (2020) and Lee et al. (2020), who explored that poor institutional quality is a barrier for innovation. It seems that because of pressure on growth targets, some policies and regulations have not created opportunities for innovation. Therefore, policies that balance between innovation promotion and sustainable growth need more attention from managers.

Table 8. Robustness checks with institutional quality.

Part 1: equation (1) of SEM						
Economic growth (EG)						
Constant	−35.150***	−40.079***	−34.584***	−36.609***	−35.776***	−33.301***
	(8.472)	(9.876)	(8.225)	(8.761)	(8.522)	(7.320)
TI	0.028***	0.033***	0.028***	0.030***	0.029***	0.026***
	(0.006)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)
K	0.003***	0.003***	0.003***	0.003***	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
PG	−0.083	−0.075	−0.051	−0.055	−0.031	−0.108
	(0.349)	(0.366)	(0.359)	(0.362)	(0.373)	(0.333)
HC	0.183***	0.227***	0.208***	0.221***	0.217***	0.188***
	(0.058)	(0.076)	(0.063)	(0.069)	(0.067)	(0.057)
CORRUPTION	0.005***					
	(0.002)					
REGULATORY		0.004***				
		(0.002)				
RULE			0.002*			
			(0.001)			
VOICE				0.003**		
				(0.001)		
GOVERNMENT					0.003**	
					(0.001)	
POLITICAL						0.005***
						(0.001)
Country-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. Obs	1,775	1,775	1,775	1,775	1,775	1,775
R^2	−6.088	−8.250	−6.176	−7.015	−6.598	−5.179
Part 2: equation (2) of SEM						
Technological innovation (TI)						
Constant	981.648***	933.111***	939.451***	910.065***	905.42***	917.989***
	(79.013)	(78.582)	(81.331)	(79.693)	(79.812)	(79.671)
EG	−27.905**	−29.541**	−31.461**	−32.259**	−32.582**	−30.947**
	(13.136)	(13.391)	(13.414)	(13.587)	(13.570)	(13.188)
FDI	0.080***	0.076***	0.083***	0.083***	0.085***	0.087***
	(0.025)	(0.025)	(0.025)	(0.026)	(0.026)	(0.025)
FD	−354.392**	−294.985*	−348.111**	−322.737**	−345.652**	−366.681**
	(157.827)	(157.000)	(159.455)	(158.908)	(160.357)	(158.791)
EC	0.099***	0.098***	0.105***	0.105***	0.106***	0.110***
	(0.029)	(0.029)	(0.030)	(0.030)	(0.030)	(0.030)
CORRUPTION	−0.231***					
	(0.041)					
REGULATORY		−0.146***				
		(0.042)				
RULE			−0.142***			
			(0.043)			
VOICE				−0.112**		
				(0.045)		
GOVERNMENT					−0.097**	
					(0.042)	
POLITICAL						−0.112***
						(0.039)
Country-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. Obs	1,775	1,775	1,775	1,775	1,775	1,775
R^2	0.357	0.345	0.338	0.334	0.332	0.339

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

SEM = Simultaneous equation model; EG = Economic growth; TI = Technological innovation; K = Capital stock; PG = Population growth; HC = Human capital; FDI = Foreign direct investment; FD = Financial development; EC = The natural logarithm of energy consumption per capita; CORRUPTION = control of corruption index; REGULATORY = regulatory quality index; RULE = rule of law index; VOICE = voice and accountability index; GOVERNMENT = government effectiveness index; POLITICAL = political stability index.

Table 9. Robustness checks with considering subsamples.

Part 1: equation (1) of SEM		
Economic growth (EG)		
	High- and upper-middle-income group	Low- and lower-middle-income group
Constant	−26.796***	−1.785
	(6.627)	(2.993)
TI	0.020***	−0.003
	(0.005)	(0.007)
K	0.334***	0.003*
	(0.054)	(0.002)
PG	−0.324	−0.326
	(0.312)	(0.378)
HC	0.136***	0.157***
	(0.041)	(0.049)
POLITICAL	0.004***	0.002
	(0.001)	(0.002)
Country-fixed effects	Yes	Yes
No. Obs	1,375	400
R^2	−1.778	0.184
Part 2: equation (2) of SEM		
Technological innovation (TI)		
Constant	848.297***	320.197***
	(72.828)	(39.340)
EG	−30.987***	−25.328**
	(10.175)	(10.742)
FDI	0.112***	−0.572
	(0.028)	(2.541)
FD	−410.244***	−371.676***
	(130.660)	(130.759)
EC	0.115***	0.131
	(0.036)	(0.111)
POLITICAL	−0.100**	−0.101
	(0.044)	(0.091)
Country-fixed effects	Yes	Yes
No. Obs	1,375	400
R^2	0.365	−0.396

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

SEM = Simultaneous equation model; EG = Economic growth; TI = Technological innovation; K = Capital stock; PG = Population growth; HC = Human capital; FDI = Foreign direct investment; FD = Financial development; EC = The natural logarithm of energy consumption per capita; POLITICAL = political stability index.

Table 9 shows the outcomes of robustness check as the authors consider subsamples. The results illustrate that a two-way relation between TI and EG still takes for the case of high- and upper-middle-income countries. When considering low- and lower-middleincome countries, the only one-way negative association between TI and EG is found.

To further consolidate the research results, we use FEM, REM, and GMM methods to evaluate the two-way relationship between innovation and growth. The outcomes from Equation (1) and Equation (2) of Table 10 show the autocorrelation and heteroskedasticity exist in the FEM and REM model. The results of estimating the GMM model show that the p_values of the Hansen, AR1, and AR2 tests demonstrate the suitability of the model. Estimated results by using the GMM method also indicate that TI positively affects EG, while EG negatively impacts TI. Besides, PG has a significant negative influence on EG, implying that high PG is a barrier for per capita growth. This finding

Table 10. The result of regressions – FEM, REM, and GMM system.

Variables	FEM	REM	GMM system
Equation (1): Economic growth (EG)			
EG_{t-1}			0.213*** (0.020)
TI	0.000 (0.000)	−0.000 (0.000)	0.000** (0.000)
K	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
PG	−0.358*(0.190)	0.008 (0.135)	−1.454*** (0.175)
HC	0.130***(0.021)	0.035***(0.011)	0.297*** (0.015)
C	−4.130***(1.010)	0.025 (0.618)	−11.822*** (0.748)
No. Obs	1775	1775	1704
Hausman test	0.000		
Wooldridge test	F(1,70) = 22.993 Prob > F = 0.000		
Modified Wald test	Chi2(71) = 6482.97 Prob>chi2 = 0.000		
AR(1)			−4.89 (0.000)
AR(2)			−1.64 (0.101)
Hansen test			68.96 (0.154)
Equation (2): technological innovation (TI)			
TI_{t-1}			0.815*** (0.018)
EG	−2.720 (2.447)	−2.261 (2.427)	−1.947*** (0.504)
FDI	0.044** (0.020)	0.036* (0.019)	0.003 (0.003)
FD	−195.227 (138.341)	−34.697 (98.672)	−124.260*** (43.734)
EC	0.025 (0.028)	0.009 (0.027)	−0.009 (0.012)
C	720.867***(67.931)	672.426*** (62.215)	193.006*** (22.964)
No. Obs	1775	1775	1704
Hausman test	0.1906		
Wooldridge test		F(1,70) = 9.527 Prob > F = 0.0029	
Breusch and Pagan LM test		Chibar2(01) = 2510.39 Prob>chibar2 = 0.000	
AR(1)			−4.47 (0.000)
AR(2)			1.22 (0.222)
Hansen test			64.47 (0.134)

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

FEM = fixed-effect model; REM = random-effect model; GMM = Generalized method of moments; EG = Economic growth; TI = Technological innovation; K = Capital stock; PG = Population growth; HC = Human capital; FDI = Foreign direct investment; FD = Financial development; EC = The natural logarithm of energy consumption per capita

is supported by the findings of Dao (2012) and Klasen and Lawson (2007), who stated that PG reduces EG. PG accompanied by high-quality human resource training needs to be considered for sustainable development.

5. Conclusion and policy implications

5.1. Conclusion

This paper investigates the interrelationships between EG and technology innovation in the world 71 countries for the period 1996–2020. This research applied the SEM with 3SLS method to explore linkages between variables. Authors also use fixed effects, random effects, and GMM-System estimator to check robustness. The study also

employs the cross-sectional dependence test by Pesaran CD test and the second-generation unit root tests by using Pesaran CADF and Pesaran CIPS test, and the outcomes indicate that all variables are stable at the first difference I(1).

The empirical outcomes of 3SLS estimator indicate a two-way relationship between growth and technology innovation. Specifically, technology innovation enhances growth, while EG hinders innovation. Besides, the capital stock, HC, and institutional quality raise EG, while PG and financial crisis reduce EG. Furthermore, FDI inflows and EC increase innovation, while institutional quality and financial development hinder innovation.

5.2. Policy implications

Based on the empirical outcomes, we suggest specific policy implications. First, it suggests that countries worldwide should foster innovation by promulgating regulations to support businesses in investing in science and technology, encouraging businesses to innovate in production, create quality products, save costs, and enhance competitiveness. There is a need for policies to encourage green innovation towards the goal of sustainable growth. Second, although innovation drives growth, growth inhibits innovation. Therefore, policies that balance between innovation promotion and sustainable growth need attention. More policies need to be implemented to improve interrelationships between EG and TI. For example, encouraging foreign capital to penetrate local industries, creating more conditions for domestic businesses to cooperate with multinational companies, thereby being able to learn technology from developed countries through spillover effect. Besides, governments should introduce policies to eliminate outdated production capacity, promote industrial restructuring, smart agricultural production, and promote sustainable development. In addition, when setting growth targets, local governments need to consider preventing excessive priority on implementing far-reaching economic policies that hinder innovation. Third, the positive influence of capital on growth emphasizes its importance for growth. Governments should spend capital for economic development, particularly through investment for sustainable growth by clean energy projects, attract investment capital from foreign companies, build green industrial parks aiming for sustainable growth. Additionally, it is necessary to introduce policies that encourage each family to have at least two children along with training high-quality human resources to replace older workers towards the goal of growth and sustainable development. Moreover, findings show institutional quality enhances growth; it implies that countries' institutions are effective in promoting growth. Although institutional quality promotes growth, it stifles innovation. Therefore, it is necessary to have policies that balance innovation and growth. Promulgate strict regulations and effective institutions to promote investment in innovation towards the goal of sustainable development. Besides, FDI inflows enhance innovation, which suggests that the governments should give policies to attract international investment capital, which benefits domestic businesses in absorbing and developing advanced technology. The presence of foreign investors stimulates domestic enterprises to innovate. Still, it requires the legal framework to provide a pleasant atmosphere for investors to participate in the economy. Furthermore, findings point out a negative effect of financial development on innovation, which suggests the financial system is not really effective in promoting

innovation. Governments should promote financial reform, ensuring healthy financial scale expansion, and promote healthy interaction between financial development and innovation. Besides, it is necessary to develop renewable energy sources to promote innovation towards sustainable development and reduce environmental pollution.

5.3. The limitations of study

Although this paper has found empirical evidence about the two-way link between technology innovation and growth for 71 nations worldwide, this study still has some limitations. First, due to data limitations, this study only covers 71 countries; therefore, further studies can be carried out for more countries. Second, other factors that can influence on economic expansion, and technology innovation such as globalization, agricultural output, and carbon emissions should be considered. Therefore, further studies can investigate the relationship of these variables with innovation and growth.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research is funded by the University of Economics and Law, Vietnam National University Ho Chi Minh City/VNU-HCM.This research is a part of a doctoral thesis conducted by Duyen My Thi Thi.

Notes on contributors

Duyen My Thi Thi is a lecturer at Bac Lieu University and is currently a Ph.D. candidate in economics at the University of Economics and Law, Vietnam National University, Ho Chi Minh City, Vietnam. Her works focus on teaching and research on environmental economics, innovation, renewable energy, institutional quality, green economy, sustainable development. Her recent paper has been published in International Journal of Sustainable Energy.

Tinh Tran Phu Do, PhD. Associate Professor, Director of the Institute of Policy Development, Vietnam National University-HCM. He is a senior lecturer at the University of Economics and Law, Vietnam National University, Ho Chi Minh City, Vietnam. His works focus on teaching and policy consulting on political economy, macroeconomics, innovative startups, sustainable development, and institutions. His recent paper has been published in International Journal of Contemporary Hospitality Management.

References

Abdouli, M., & Hammami, S. (2020). Economic growth, environment, FDI inflows, and financial development in middle east countries: Fresh evidence from simultaneous equation models. *Journal of the Knowledge Economy*, *11*(2), 479–511. https://doi.org/10.1007/s13132-018-0546-9

Abdouli, M., & Omri, A. (2021). Exploring the nexus among FDI inflows, environmental quality, human capital, and economic growth in the Mediterranean region. *Journal of the Knowledge Economy*, *12*(2), 788–810. https://doi.org/10.1007/s13132-020-00641-5

Adewole, A. O. (2012). Effect of population on economic development in Nigeria: A quantitative assessment. *International Journal of Physical and Social Sciences*, *2*(5), 1–14.

Aghion, P., Akcigit, U., & Howitt, P. (2014). What do we learn from schumpeterian growth theory? In *Handbook of economic growth* (Vol. 2, pp. 515–563). Elsevier.

Ahmad, N., Youjin, L., Žiković, S., & Belyaeva, Z. (2023). The effects of technological innovation on sustainable development and environmental degradation: Evidence from China. *Technology in Society*, *72*, 102184. https://doi.org/10.1016/j.techsoc.2022.102184

Akinwale, Y. O. (2022). Towards understanding the triangular relationship between technology innovation, human capital and economic growth in South Africa. *International Journal of Learning and Change*, *14*(3), 258–272. https://doi.org/10.1504/IJLC.2022.122521

Álvarez, I. C., Barbero, J., Rodríguez-Pose, A., & Zofío, J. L. (2018). Does institutional quality matter for trade? Institutional conditions in a sectoral trade framework. *World Development*, *103*, 72–87. https://doi.org/10.1016/j.worlddev.2017.10.010

Andabaka, A., Basarac Sertić, M., & Harc, M. (2019). Eco-innovation and economic growth in the European Union. *Zagreb International Review of Economics and Business*, *22*(2), 43–54. https://doi.org/10.2478/zireb-2019-0019

Belsley, D. A. (1988). Two- or three-stage least squares? *Computer Science in Economics and Management*, *1*(1), 21–30. https://doi.org/10.1007/BF00435200

Bordo, M. D., Meissner, C. M., & Stuckler, D. (2010). Foreign currency debt, financial crises and economic growth: A long-run view. *Journal of International Money & Finance*, *29*(4), 642–665. https://doi.org/10.1016/j.jimonfin.2010.01.002

Boschma, R., Coenen, L., Frenken, K., & Truffer, B. (2018). Towards a theory of regional diversification: Combining insights from evolutionary economic geography and transition studies. In *Transitions in regional economic development* (pp. 55–81). Routledge.

Bosma, N., Content, J., Sanders, M., & Stam, E. (2018). Institutions, entrepreneurship, and economic growth in Europe. *Small Business Economics*, *51*(2), 483–499. https://doi.org/10.1007/s11187-018-0012-x

Bouznit, M., Pablo-Romero, M. P., & Sánchez-Braza, A. (2023). Economic growth, human capital, and energy consumption in Algeria: Evidence from cointegrating polynomial regression and a simultaneous equations model. *Environmental Science and Pollution Research*, *30*(9), 23450–23466. https://doi.org/10.1007/s11356-022-23657-7

Chen, Y., Jiang, H., Liang, Y., & Pan, S. (2022). The impact of foreign direct investment on innovation: Evidence from patent filings and citations in China. *Journal of Comparative Economics*, *50*(4), 917–945. https://doi.org/10.1016/j.jce.2022.05.005

Cheung, K.-Y., & Lin, P. (2004). Spillover effects of FDI on innovation in China: Evidence from the provincial data. *China Economic Review*, *15*(1), 25–44. https://doi.org/10.1016/S1043-951X(03)00027-0

Dao, M. Q. (2012). Population and economic growth in developing countries. *The International Journal of Academic Research in Business & Social Sciences*, *2*(1), 6.

Doğan, B., Balsalobre-Lorente, D., & Nasir, M. A. (2020). European commitment to COP21 and the role of energy consumption, FDI, trade and economic complexity in sustaining economic growth. *Journal of Environmental Management*, *273*, 111146. https://doi.org/10.1016/j.jenvman.2020.111146

Galindo-Martín, M.-A., Méndez-Picazo, M.-T., & Castaño-Martínez, M.-S. (2020). The role of innovation and institutions in entrepreneurship and economic growth in two groups of countries. *International Journal of Entrepreneurial Behavior & Research*, *26*(3), 485–502. https://doi.org/10.1108/IJEBR-06-2019-0336

Guloglu, B., & Tekin, R. B. (2012). A panel causality analysis of the relationship among research and development, innovation, and economic growth in high-income OECD countries. *Eurasian Economic Review*, *2*(1), 32–47. https://doi.org/10.14208/BF03353831

Intriligator, M. D. (1978). *Econometric models, techniques and application*.

Islam, M. S., & Mustafa Shindaini, A. J. (2022). Impact of institutional quality and human capital creation on economic growth in Bangladesh: Evidence from an ARDL approach. *International Journal of Social Economics*, *49*(12), 1787–1802. https://doi.org/10.1108/IJSE-12-2021-0732

Jin, L., Duan, K., & Tang, X. (2018). What is the relationship between technological innovation and energy consumption? Empirical analysis based on provincial panel data from China. *Sustainability*, *10*(2), 145. https://doi.org/10.3390/su10010145

Khan, Y., Hassan, T., Tufail, M., Marie, M., Imran, M., & Xiuqin, Z. (2022). The nexus between CO2 emissions, human capital, technology transfer, and renewable energy: Evidence from belt and road countries. *Environmental Science and Pollution Research*, *29*(39), 59816–59834. https://doi.org/10.1007/s11356-022-20020-8

Khan, H., Weili, L., Bibi, R., & Khan, I. (2022). Innovations, energy consumption and carbon dioxide emissions in the global world countries: An empirical investigation. *Journal of Environmental Science & Economics*, *1*(4), 12–25. https://doi.org/10.56556/jescae.v1i4.288

Khan, I., Zhong, R., Khan, H., Dong, Y., & Nuță, F. M. (2023). Examining the relationship between technological innovation, economic growth and carbon dioxide emission: Dynamic panel data evidence. *Environment, Development and Sustainability*, 1–20. https://doi.org/10.1007/s10668-023-03384-w

Klasen, S., & Lawson, D. (2007). *The impact of population growth on economic growth and poverty reduction in Uganda*.

Lee, C.-C., Wang, C.-W., & Ho, S.-J. (2020). Country governance, corruption, and the likelihood of firms' innovation. *Economic Modelling*, *92*, 326–338. https://doi.org/10.1016/j.econmod.2020.01.013

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, *22*(1), 3–42. https://doi.org/10.1016/0304-3932(88)90168-7

Lv, C., Shao, C., & Lee, C.-C. (2021). Green technology innovation and financial development: Do environmental regulation and innovation output matter? *Energy Economics*, *98*, 105237. https://doi.org/10.1016/j.eneco.2021.105237

Malik, M. A. (2021). Economic growth, energy consumption, and environmental quality nexus in Turkey: Evidence from simultaneous equation models. *Environmental Science and Pollution Research*, *28*(31), 41988–41999. https://doi.org/10.1007/s11356-021-13468-7

Manigandan, P., Alam, M. S., Alagirisamy, K., Pachiyappan, D., Murshed, M., & Mahmood, H. (2023). Realizing the sustainable development goals through technological innovation: Juxtaposing the economic and environmental effects of financial development and energy use. *Environmental Science and Pollution Research*, *30*(3), 8239–8256. https://doi.org/10.1007/s11356-022-22692-8

Maradana, R. P., Pradhan, R. P., Dash, S., Zaki, D. B., Gaurav, K., Jayakumar, M., & Sarangi, A. K. (2019). Innovation and economic growth in European economic area countries: The granger causality approach. *IIMB Management Review*, *31*(3), 268–282. https://doi.org/10.1016/j.iimb.2019.03.002

Meirun, T., Mihardjo, L. W. W., Haseeb, M., Khan, S. A. R., & Jermsittiparsert, K. (2021). The dynamics effect of green technology innovation on economic growth and CO2 emission in Singapore: New evidence from bootstrap ARDL approach. *Environmental Science and Pollution Research*, *28*(4), 4184–4194. https://doi.org/10.1007/s11356-020-10760-w

Mtar, K., & Belazreg, W. (2023). On the nexus of innovation, trade openness, financial development and economic growth in European countries: New perspective from a GMM panel VAR approach. *International Journal of Finance & Economics*, *28*(1), 766–791. https://doi.org/10.1002/ijfe.2449

Muhamad, S., Sulaiman, N. F. C., & Saputra, J. (2018). The role of human capital and innovation capacity on economic growth in ASEAN-3. *Jurnal Ekonomi Malaysia*, *52*(1), 281–294. https://doi.org/10.17576/JEM-2018-5001-21

Nguyen, T. P. T., & Nghiem, S. H. (2015). The interrelationships among default risk, capital ratio and efficiency. *Managerial Finance*, *41*(5), 507–525. https://doi.org/10.1108/MF-12-2013-0354

North, D. C. (1990). Institutions, institutional change and economic performance.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265–312. https://doi.org/10.1002/jae.951

Phung, T. D., Van, V. T. T., Thuong, T. T. H., & Ha, N. T. T. (2019). Innovation and economic growth: The contribution of institutional quality and foreign direct investment. *Asian Economic and Financial Review*, *9*(11), 1266. https://doi.org/10.18488/journal.aefr.2019.911.1266.1278

Polenske, K. R. (2007). *The economic geography of innovation*. Cambridge University Press.

Pradhan, R. P., Arvin, M. B., & Bahmani, S. (2018). Are innovation and financial development causative factors in economic growth? Evidence from a panel granger causality test. *Technological Forecasting & Social Change*, *132*, 130–142. https://doi.org/10.1016/j.techfore.2018.01.024

Ren, Y.-S., Apergis, N., Ma, C., Baltas, K., Jiang, Y., & Liu, J.-L. (2021). FDI, economic growth, and carbon emissions of the Chinese steel industry: New evidence from a 3SLS model. *Environmental Science and Pollution Research*, *28*(37), 52547–52564. https://doi.org/10.1007/s11356-021-14445-w

Rodríguez-Pose, A., Wilkie, C., & Zhang, M. (2021). Innovating in "lagging" cities: A comparative exploration of the dynamics of innovation in Chinese cities. *Applied Geography*, *132*, 102475. https://doi.org/10.1016/j.apgeog.2021.102475

Rodríguez-Pose, A., & Zhang, M. (2020). The cost of weak institutions for innovation in China. *Technological Forecasting & Social Change*, *153*, 119937. https://doi.org/10.1016/j.techfore.2020.119937

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, *94*(5), 1002–1037. https://doi.org/10.1086/261420

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5, Part 2), S71–S102. https://doi.org/10.1086/261725

Schumpeter, J. A. (1939). *Business cycles (vol. 1)*. Mcgraw-hill New York.

Schumpeter, J. A. (1942). Capitalism, socialism, and democracy. *University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship*.

Scott, W. (1995). Institutions and organizations. *Foundations*.

Sharif, A., Kocak, S., Khan, H. H. A., Uzuner, G., & Tiwari, S. (2023). Demystifying the links between green technology innovation, economic growth, and environmental tax in ASEAN-6 countries: The dynamic role of green energy and green investment. *Gondwana Research*, *115*, 98–106. https://doi.org/10.1016/j.gr.2022.11.010

Shen, F., Liu, B., Luo, F., Wu, C., Chen, H., & Wei, W. (2021). The effect of economic growth target constraints on green technology innovation. *Journal of Environmental Management*, *292*, 112765. https://doi.org/10.1016/j.jenvman.2021.112765

Sivalogathasan, V., & Wu, X. (2014). The effect of foreign direct investment on innovation in south Asian emerging markets. *Global Business and Organizational Excellence*, *33*(3), 63–76. https://doi.org/10.1002/joe.21544

Solow, R. M. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, *70*(1), 65–94. https://doi.org/10.2307/1884513

Tabata, S. (2009). The impact of global financial crisis on the mechanism of economic growth in Russia. *Eurasian Geography and Economics*, *50*(6), 682–698. https://doi.org/10.2747/1539-7216.50.6.682

Tebaldi, E., & Elmslie, B. (2008). *Do institutions impact innovation?* https://mpra.ub.uni-muenchen.de/id/eprint/8757

Thuku, G. K., & Paul, G. (2013). The IMPACT of POPULATION CHANGE on ECONOMIC GROWTH in KENYA. *Management*, *2*(6), 43–60. https://Hdl.Handle.Net/123456789/2234

Wang, X., Wang, Z., & Wang, R. (2023). Does green economy contribute towards COP26 ambitions? Exploring the influence of natural resource endowment and technological innovation on the growth efficiency of China's regional green economy. *Resources Policy*, *80*, 103189. https://doi.org/10.1016/j.resourpol.2022.103189

Williamson, O. E. (2000). The new institutional economics: Taking stock, looking ahead. *Journal of Economic Literature*, *38*(3), 595–613. https://doi.org/10.1257/jel.38.3.595

Yu, H., Wang, J., Hou, J., Yu, B., & Pan, Y. (2023). The effect of economic growth pressure on green technology innovation: Do environmental regulation, government support, and financial development matter? *Journal of Environmental Management*, *330*, 117172. https://doi.org/10.1016/j.jenvman.2022.117172