



## Section 9. World economy

DOI:10.29013/EJEMS-26-2-82-89



### DOES TECHNOLOGICAL INNOVATION DRIVE ECONOMIC GROWTH? PANEL EVIDENCE FROM EAST ASIAN ECONOMIES (1996–2024)

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**Cite:** Mammadli A. (2026). *Does Technological Innovation Drive Economic Growth? Panel Evidence from East Asian Economies (1996–2024)*. *European Journal of Economics and Management Sciences* 2026, No 2. <https://doi.org/10.29013/EJEMS-26-2-82-89>

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#### Abstract

In contemporary economic thought, technological innovation is considered a key driver of sustainable growth and global competitive advantage. However, published studies have yielded different empirical results depending on the country samples selected and their level of development. The aim of this study is to investigate the impact of technological innovation on economic growth within an empirical framework. Panel data analysis and random effects were used to estimate the model. To obtain accurate estimates, taking into account heterogeneity, autocorrelation, and cross-dependencies, the analyses were augmented using Driscoll-Cree standard errors. The results show that the impact of innovation on economic growth can be either positive or negative, depending on the country's level of technological maturity and its institutional infrastructure.

**Keywords:** *Technological Innovation; Economic Growth; East Asia; Panel Data Analysis*

**JEL Classification:** O30; O47; C33; F43

#### 1. Introduction

Technological innovation is widely recognized as a key driver of sustainable development and economic growth. While traditional production factors such as labor and capital face diminishing returns, innovation enhances productivity and supports structural economic transformation. However, empirical studies report mixed results, as the

impact of innovation varies depending on country groups, methodological approaches, and institutional conditions. In developing economies, factors such as limited technological capacity, high R&D costs, and short-term labor market adjustments may weaken or offset the positive effects of innovation.

East Asian economies are particularly important in this context, as countries such as

China, Japan, South Korea, Singapore, and Hong Kong have become major innovation hubs through the combination of foreign investment and domestic technological capabilities. However, differences in human capital, infrastructure, and institutional quality lead to heterogeneous outcomes across countries (Karaosmanoglu, E. A. I., & Mammadli, A., 2025).

This study examines the impact of technological innovation on GDP in selected East Asian countries over the period 1996–2024 using panel data analysis. Unlike previous studies, technological innovation is measured through a multidimensional Technological Innovation Index (TII), which incorporates technological creativity, infrastructure, and human capital based on Desai et al. (2002) and Archibugi and Coco (2002). The empirical analysis employs a Driscoll–Kraay regression approach to ensure robust results in the presence of het-

eroskedasticity, autocorrelation, and cross-sectional dependence.

The study concludes with policy implications aimed at strengthening innovation capacity and sustainable economic growth.

## 2. Literature Review

The relationship between technological innovation and economic growth has long been a central topic in the literature. Early studies emphasize the importance of R&D expenditures and patent activities in enhancing productivity and economic performance (Lichtenberg, 1992; Freire-Serene, 1999), while the impact of private R&D investment varies across countries and sectors (Wang & Wu, 2015; Sylwester, 2001; Falk, 2015). More recent research expands this perspective by highlighting the role of digital technologies, clean energy, and artificial intelligence as key drivers of economic growth.

**Table 1.** *Heterogeneous Findings and Literature Review on the Effects of Technological Innovation on Economic Growth*

Author(s)	Country Group	Period	Methodology	Key Findings
Lichtenberg (1992)	74 Countries	1964–1989	Panel Regression Analysis	Private-sector-funded R&D significantly promotes economic growth, whereas publicly funded R&D shows no significant impact; innovation driven by private investment plays a crucial role in enhancing productivity and long-term economic performance.
Freire-Serén (1999)	21 OECD Countries	1965–1990	Patent Data Analysis	R&D expenditures exhibit a strong positive relationship with economic growth, with a 1% increase in R&D leading to a 0.08% rise in real domestic income across OECD countries during the period 1965–1990.
Sylwester (2001)	20 OECD and G7 countries	1989–1996	Panel Regression Analysis	R&D expenditures do not show a significant relationship with economic growth in a broad sample of OECD countries, but they have a positive and significant impact on growth in G7 economies, indicating that the effectiveness of innovation investments depends on the level of economic development.
Kraemer and Dedrick (2001)	Asia-Pacific Countries	1984–1990	Granger Casuality test	Information technology investments have a strong relationship with economic growth, with evidence of bidirectional causality between the two variables in Asia-Pacific countries.

Author(s)	Country Group	Period	Methodology	Key Findings
Yanyun and Mingqian (2004)	Japan, China, Singapore, Philippines, South Korea, Malaysia, Thailand, and Indonesia.	1994–2003	Panel Regression Analysis	R&D expenditures and economic growth exhibit a bidirectional positive relationship, indicating mutual reinforcement between innovation investment and growth across East Asian economies.
Eid (2012)	17 OECD Countries	1981–2006	Panel Regression Analysis	R&D expenditures in higher education have a positive and statistically significant effect on economic growth in high-income OECD countries.
Wang and Wu (2015)	China	1997–2013	Panel Regression Analysis	R&D expenditures are strongly correlated with economic growth in China, while public R&D spending has an almost negligible effect on economic growth.
Maha Mohamed Alesbai Mohamed et al (2022)	Developing Countries	1990–2018	Error Correction Model (ECM), and Granger causality tests	Technological innovation is a key driver of economic growth, positively affecting both short- and long-run performance, with evidence of long-run bidirectional causality and short-run causality from innovation to growth.
Siti Nurazira Mohd Daud and Abd Halim Ahmad (2023)	84 Countries	2011–2017	Generalized Method of Moments (GMM)	Financial inclusion and digital technology are found to have a positive and statistically significant impact on economic growth, with digital technology also reinforcing the growth effects of financial inclusion.
Xu He et al. (2023)	38 Asian Countries	1990–2021	Augmented Mean Group Regression model	Clean energy consumption, technological innovation, and financial development positively and significantly affect economic growth in Asian countries, while population size and CO <sub>2</sub> emissions have negative effects, emphasizing the role of clean energy and innovation in sustainable growth.
Muhammad Asif et al. (2024)	BRICS Countries	2004–2023	Panel Data Analysis	Renewable energy consumption, technological innovation, and financial development are found to have a positive and significant impact on ecological sustainability, while economic growth has a negative effect, with trade openness playing a significant mediating role.
Ayesha Khan (2025)	Pakistan	1990–2023	Panel ARDL	Green innovation, technological development, FDI, and medium–high-tech exports positively and significantly affect economic growth in both the short and long run, while renewable energy has a negative long-run effect, emphasizing the importance

Author(s)	Country Group	Period	Methodology	Key Findings
Zahoor Ahmed (2026)	10 largest economies	1996–2021	Feasible Generalized Least Squares	of innovation and export competitiveness for sustainable development. AI has a direct negative impact on environmental sustainability across all quantiles, while its indirect effect through economic growth is positive, with renewable energy improving environmental outcomes and political globalization and corruption worsening them.

### 3. Data and Methodology

#### 3.1. Data and Sample Selection

This study uses a balanced panel dataset covering 1996–2024 for five East Asian countries. A multidimensional Technological Innovation Index (TII) is constructed, incorporating technological innovation, infrastructure, and human capital based on Desai et al. (2002) and Archibugi and Coco (2002).

For transparency and replicability, the dataset, coding procedures, and index construction steps (including normalization and geometric mean method) are provided in the online supplementary materials, enabling full replication without relying on the original dissertation (Mammadli, 2025).

**Table 2.** Description of Variables in the Model

Variable	Description	Data Source	Unit	Transformation
<b>GDP</b>	LnGDP	World Bank	USD	Log transformation
<b>Technological Innovation Index</b>	TII	Author-Calculated	0–1 scale	Used in original scale; log transformation not applied due to zero values in some components
<b>Labor Force</b>	LnLF	World Bank	persons	Log transformation

All variables used in this study cover the period from 1996 to 2024. The main explanatory variable is the Technological Innovation Index (TII), constructed by the authors, while labor force is included as a control variable and GDP serves as the dependent variable.

Prior to the analysis, the labor force variable was transformed into its natural logarithmic form to reduce skewness and improve

interpretability. In contrast, the Technological Innovation Index (TII) was retained in its original form without log transformation in order to preserve zero values and maintain ease of interpretation.

Descriptive statistics for all variables are reported in Table 2. For transparency and reproducibility, the log-transformed independent variables are explicitly indicated in the (table 3).

**Table 3.** Summary Statistics of Variables

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
<b>LNGDP</b>	145	27.8099	1.172809	25.58376	30.56188
<b>TII</b>	145	0.347139	0.2541791	0	0.9025086
<b>LNLF</b>	145	18.74144	1.319809	16.61025	20.47633

Table 3 presents descriptive statistics based on 145 observations, indicating a balanced dataset. TII shows moderate variability, while LNGDP and LNFL exhibit relatively stable distributions with limited dispersion across the sample.

### 3.2. Econometric Model

An econometric model is specified to examine the impact of technological innovation and labor force on economic growth. The model is expressed as follows:

$\ln GDP_{it} = \beta_0 + \beta_1 \ln TII_{it} + \beta_2 \ln LF_{it} + \varepsilon_{it}$   
 where GDP represents gross domestic product, TII denotes the Technological Innovation Index, and LF refers to the labor force. The indices  $i$  and  $t$  indicate cross-sectional units and time periods, respectively. All ex-

planatory variables are included in logarithmic form to improve interpretability, while  $\varepsilon_{it}$  represents the error term.

### 3.3. Estimation Strategy and Diagnostic Tests

Before proceeding with panel data estimation, one must determine the most suitable model structure: pooled Ordinary Least Squares (OLS), fixed-effects (FE), or a model accounting for time-specific effects.

Panel data often include unit-specific effects reflecting unobserved heterogeneity across cross-sectional units (Tatoğlu, 2020). To test their significance, the F-test, Breusch–Pagan LM test, and Likelihood Ratio (LR) test are employed, guiding the selection of the appropriate panel model.

**Table 4.** Results of Model Selection Tests Among Estimation Methods

Tests	Unit and/or Time Effects	Unit Effects	Time Effects
<b>LR (Likelihood Ratio)</b>	54.44(0.000)	28.37(0.000)	0.39(0.2662)
<b>F</b>	3.04(0.000)	14.33(0.000)	0.3004 (0.000)
<b>LM (Breusch-Pagan)</b>	—	114.93(0.000)	0.000 (1.000)

**Not:** The values in parentheses represent the  $p$ -values

The results in Table 4 indicate significant unit-specific effects ( $p < 0.01$ ) based on the LR, F, and LM tests, while time effects are found to be insignificant. This suggests that the Pooled OLS model is inappropriate, and a panel model should be used. Accordingly, the Hausman test is applied to determine whether a fixed or random effects model is more suitable.

**Table 5.** Robust Hausman Test Results

Test	Robust Hausman Test
P-values	0.34 (0.8419)

The choice between fixed-effects and random-effects estimators was determined

using the Robust Hausman Test, the results of which are displayed in Table 5. The test yielded a  $p$ -value of 0.8419, which is significantly higher than the standard significance thresholds of 0.01, 0.05, and 0.10.

The results fail to reject the null hypothesis, indicating that the random-effects model is more appropriate and efficient. Diagnostic tests for heteroskedasticity, autocorrelation, cross-sectional dependence, and multicollinearity (VIF) were also conducted to ensure model validity. Given the small cross-sectional dimension ( $N = 5$ ), robust estimation techniques are employed to improve the reliability of the results.

**Table 6.** Results of Diagnostic Tests for Violations of Classical Assumptions

VIF	1.00
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#### Heteroskedasticity Test

**Levene, Brown and Forsythe Test**  
 $W0 = 5.3162745$   $df(4, 140)$   $Pr > F = 0.00051408$   
 $W50 = 4.0270232$   $df(4, 140)$   $Pr > F = 0.00401988$   
 $W10 = 5.3081158$   $df(4, 140)$   $Pr > F = 0.00052079$

#### Autocorrelation Tests

<b>VIF</b>		1.00	
<b>Bhargava et al. Durbin–Watson</b>	0.23166576	<b>Baltagi–Wu LBI</b>	0.38047281
<b>Correlation Tests</b>			
<b>Pesaran Test</b>	2.223(0.0262)	<b>Friedman Test</b>	36.817 (0.0000)
<b>Frees Test</b> (1.092)	0.0892 (%10)	0.1160 (%5)	0.1660 (%1)

The results in Table 6 indicate the presence of heteroskedasticity ( $p < 0.01$ ) and first-order autocorrelation, as confirmed by low Durbin–Watson and Baltagi–Wu statistics. Cross-sectional dependence is also detected, with Friedman and Frees tests providing strong evidence despite weaker Pesaran results due to small sample size ( $N = 5$ ). To address these issues, Driscoll–Kraay standard errors are employed for robust estimation. Additionally, the VIF value of 1.00 confirms the absence of multicollinearity.

#### 4. Empirical Results

This study uses a balanced panel dataset for five East Asian countries (1996–2024) and constructs a multidimensional Technological Innovation Index (TII) based on Desai et al. (2002) and Archibugi and Coco (2002). For transparency and replicability, the dataset and index construction details are provided in the online supplementary materials, allowing full replication of the analysis.

**Table 7.** Results of the Driscoll-Kraay Estimator

Variables	Coefficient	Driscoll-Kraay Standard Errors	T statistic	P-value
<b>TIE</b>	2.247917	0.2738184	8.21	0.000
<b>LNLF</b>	0.7220842	0.2265418	3.19	0.003
<b>Wald chi2(4) = 146.68</b>		<b>Prob &gt; chi2 = 0.0000</b>	<b>R2 = 0.7796</b>	

**Notes:** Dependent variable TII is in levels, explanatory variables are in logarithms coefficients interpreted as semi-elasticities

Table 7 reports the fixed-effects results with Driscoll–Kraay standard errors. The Wald statistic (146.68,  $p = 0.000$ ) confirms the overall significance of the model. The  $R^2$  value of 0.7796 indicates strong explanatory power. Both the Technological Innovation Index ( $\beta = 2.2479$ ,  $p = 0.000$ ) and labor force ( $\beta = 0.7221$ ,  $p = 0.003$ ) have positive and statistically significant effects, suggesting robust and reliable results.

- The TIE variable is positive and statistically significant at the 1% level ( $\beta = 2.2479$ ), indicating a strong positive impact on the dependent variable.
- The LNLF variable is statistically significant at the 1% level ( $\beta = 0.7221$ ,  $p = 0.003$ ), indicating a positive effect on the dependent variable. In logarithmic terms, a 1% increase in labor

force leads to an approximate 0.0072 unit increase in the dependent variable, ceteris paribus.

According to the obtained results, the final estimated model with statistically significant variables can be expressed as follows:

$$LNGDP_{it} = \beta_0 + 2.2479TI_{it} + 0.7221LNLFit + \epsilon_{it}$$

#### Result

This study examines the relationship between technological innovation and economic growth, providing theoretical and empirical evidence that innovation significantly promotes growth through higher productivity, efficiency, and structural transformation. The results show that R&D, human capital, and innovation capacity have a pos-

itive and statistically significant impact on economic performance.

The findings also suggest that the innovation–growth relationship varies across countries depending on development levels and institutional conditions. From a policy perspective, the study highlights the importance of increasing R&D investment, strengthening education systems, and supporting tech-

nological diffusion, along with improving financial systems and encouraging technology transfer.

Overall, the study contributes to the literature by confirming the strong innovation–growth nexus and suggests that future research could explore sectoral differences and the role of digital and green technologies.

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submitted 09.04.2026;

accepted for publication 23.04.2026;

published 30.04.2026

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