



# Exploring the Nexus between Research and Development Expenditure and Economic Growth: Empirical Insights from Asian Countries

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## Abstract

*This study examines the impact of R&D expenditure on economic growth in 35 Asian countries, analyzing 870 data points from World Bank reports and economic surveys. Guided by a positivist philosophy, it uses a quantitative, deductive, exploratory, and descriptive approach. Econometric tools, including panel unit root testing, Pedroni co-integration test, GMM, and Arellano-Bond test, reveal a long-term relationship between economic growth and past R&D spending. Economic growth increases by 1.5104 units for each unit rise in previous R&D expenditure, while past economic growth also positively influences current growth. However, a negative correlation exists between current R&D spending and growth, with a 2.844-unit decline per unit increase in spending, indicating inefficiencies or misallocation of R&D resources. The study highlights the need for policymakers to optimize R&D investments to enhance their effectiveness and ensure sustainable long-term economic development in Asian countries.*

## Introduction

Governments around the world place a high premium on economic growth since it affects living standards, employment rates, and the general prosperity of a country. R&D projects are often the driving force behind innovation, which is essential to this growth (Ozcan & Ari, 2014). Politicians and economists have made a big deal out of how important R&D is to fostering economic growth during the past few decades. R&D investments are essential for boosting productivity, advancing technology, and maintaining competitive advantages in the global market (Fosu, 2015).

R&D expenditure refers to the financial resources allocated by businesses, governments, and other organizations towards the R&D of new products, processes, or services and the enhancement of existing ones (Han et al. 2014). This expenditure encompasses costs associated with basic research, applied research, and experimental development activities to drive innovation and technological advancement. R&D spending fosters scientific discoveries and technological breakthroughs, increasing productivity, competitive advantage, and long-term economic growth. The measurement of R&D expenditure often includes salaries of researchers and developers, costs of materials and equipment, and overhead expenses related to R&D activities (Sheikh & Hassan, 2023).



R&D expenditure is a critical driver of economic growth as it fosters innovation, enhances productivity, and stimulates technological advancements. By investing in R&D, economies can develop new products, improve existing technologies, and create more efficient processes, enhancing industries' competitiveness (Siyanbola et al., 2016). Empirical studies have shown a positive correlation between R&D spending and gross domestic product (GDP) growth rates. For instance, a study by the Organization for Economic Co-operation and Development (OECD) in 2023 highlighted that countries with higher R&D investment tend to experience faster economic growth due to the spillover effects of innovation on various sectors of the economy. Additionally, R&D activities attract foreign direct investment, as multinational companies often seek to invest in regions with a robust innovation ecosystem, further boosting economic development.

Moreover, R&D expenditure contributes to human capital development by fostering a skilled workforce capable of driving and sustaining technological progress. This investment in human capital raises labor productivity and enables economies to adapt to and leverage new technologies. Furthermore, R&D initiatives often lead to the creation of high-tech industries and startups, generating employment opportunities and promoting a culture of entrepreneurship. Thus, sustained investment in R&D is essential for long-term economic resilience and growth (Olaoye et al., 2020).

Various theoretical and empirical studies have substantiated the relationship between R&D expenditure and economic growth. R&D activities lead to developing new products and processes, which drive productivity improvements and economic expansion. Schumpeter's theory of creative destruction highlights how innovation spurred by R&D can lead to economic growth by continuously rejuvenating the industrial base with new technologies (Schumpeter, 1942). Furthermore, endogenous growth theory posits that technological change, driven by R&D, is a significant factor in long-term economic growth (Romer, 1990).

Investments in R&D lead to new technological advancements, enhancing productivity and efficiency across various sectors (Griliches, 1992). R&D activities often require highly skilled labor, which fosters human capital development and improves the workforce's overall capabilities (Nelson & Phelps, 1966). The benefits of R&D extend beyond the investing firm or country, as innovations can spill over to other sectors and regions, amplifying the impact on economic growth (Jaffe, 1986).

The community hypothesizes that R&D expenditures contribute to economic progress. Research promotes innovation, and innovation expands the demand and decreases the production cost. However, research can only contribute to society and the economy when the research activities touch the community and production process. The library research could not impact economic growth. In most developing countries, research is performed for a specific purpose but not for the community. Likewise, some research is conducted to prove specific pre-determined targets against research norms and values. More achievement cannot be expected when the research does not cover the local people, society, ground reality, market, and economy.

This study examines the impact of R&D expenditure on economic growth in selected Asian countries.

This study is divided into six segments. The remainder of this study is as follows: Segment two comprises theoretical and empirical literature on this topic. Section three includes methodology. This section presents the research design, data collection, data analysis process, and variable and model verification. The data are presented and analyzed in segment four under the results heading. In section five, results are discussed, and in segment six, the research conclusion, policy implication, and study limitations are presented.

## **Literature Review**

Endogenous growth theory posits that economic growth is primarily driven by internal factors rather than external influences. A seminal work in this domain was done by Romer (1990), who argued that technological change resulting from R&D activities is a fundamental source of long-term economic growth. According to this theory, investments in R&D lead to innovations that enhance productivity and economic growth.

The Solow (1956) Growth Model, developed by Robert Solow, initially emphasized capital accumulation, labor, and exogenous technological progress as the main drivers of economic growth. However, it did not explicitly incorporate R&D. Subsequent extensions of the model, such as those by Romer (1986) and Lucas (1988), integrated

R&D and human capital as critical components, acknowledging that technological advancements driven by R&D are crucial for sustained economic growth.

Empirical studies consistently show a positive relationship between R&D expenditure and economic growth. A survey by Coe and Helpman (1995) found that R&D investment significantly contributes to productivity growth in developed and developing countries. Similarly, a meta-analysis by Ugur et al. (2016) demonstrated that R&D investments positively correlate with economic growth across different contexts and periods. R&D activities generate knowledge spillovers that benefit other firms and industries. These spillovers occur when innovations developed by one firm are adopted by others, leading to widespread productivity improvements. Grossman and Helpman (1991) highlighted the importance of knowledge diffusion in their endogenous growth model, showing that spillovers from R&D can lead to substantial economic growth.

R&D activities are essential for technological innovation, which leads to the development of new products and processes. These innovations increase productivity by enabling more efficient use of resources and creating new markets. As firms innovate, they gain a competitive edge, increasing market share and profitability and stimulating economic growth (Griliches, 1992). Investment in R&D often involves significant training and development of human capital. Skilled researchers and scientists drive innovation, and their expertise spills over into other sectors of the economy, enhancing overall productivity. Lucas (1988) emphasized the role of human capital in growth, suggesting that economies with higher levels of human capital accumulation experience faster growth rates.

While the positive impact of R&D on economic growth is well-documented, several challenges and considerations must be addressed. These include the appropriate allocation of R&D resources, the lag between R&D investment and observable economic outcomes, and the need for supportive policies and institutions to maximize R&D effectiveness (Hall et al. 2010).

Abdul et al. (2020) observed the effect of R&D on economic growth in OECD countries. They found that the gross domestic expenditure on R&D expenditure and government research hurt economic growth. Their finding does not support the hypothesis that R&D expenditure will positively impact economic development.

Kadir et al. (2015) observed the impact of R&D expenditure on economic growth in Turkey. They concluded that no long-run relationship exists between real R&D expenditure and economic growth series. There is no causality relationship between R&D expenditure and economic growth.

Bayarcelik and Tasel (2012) examined the nexus between research, development expenditure, and economic growth. They found a positive and significant relationship between R&D expenditure and the number of R&D employees, influencing economic growth. Mladenovic et al. (2016) found a positive and significant relationship between R&D expenditure and economic growth in EU countries. They found that one percent increase in R&D expenditure causes a 2.2 percent increase in real GDP.

Sadraoui and Zina (2009) examined the effect of R&D expenditure on economic growth using the Generalized Moment Method (GMM) of 23 countries between 1992 -2004. They found that R&D expenditures positively and significantly impacted economic growth in the sampled countries. Similarly, Griffith et al. (2004), Howitt (1998), Zachariadis (2003), Rabiei (2011), and Wakellin (2001) found strong evidence of positive co-integration between R&D expenditure on economic growth.

0.Samimi and Alerasoul (2009) examined the impact of R&D expenditure on economic growth in developing countries. They could not find a significant effect of R&D expenditure on economic growth. Ulku (2004) investigated the impact of R&D expenditure on 20 OECD and ten non-OECD countries for the period 1981-1997. She found the positive effects of R&D expenditure on per capita GDP only in OECD countries. Benlaria et al. (2023) found a negative and significant impact on research expenditure on per capita output.

Gumus and Celikey (2015) searched the impact of R&D expenditure on economic growth. They found the positive and significant effect of R&D expenditure on economic growth for all 52 countries in the long run but the fragile relationship in the short run. Freimane and Balina (2016) observed the impact of R&D expenditure on economic growth in EU countries in 2000-2013. The result shows a statistically significant effect of R&D expenditure on economic growth in EU countries.

Sezgin (2020) analyzed the relationship between R&D expenditure and economic growth in developing

and developed countries. He found R&D expenditures to positively and significantly impact economic growth in developed and developing countries. Bayraktar et al. (2022) observed the relationship between R&D expenditure in Brazil, Russia, India, China, South Africa, and Turkey (BRICS-T) countries in 2000-2018. They found bidirectional causality between research, development expenditure, and economic growth in BRICS-T countries.

Tung and Hoang (2024) examined R&D expenditure's impact on economic growth in 29 emerging countries between 1996 and 2019. they found the long-run co-integration between economic growth and research and developing expenditure. R&D expenditure and economic growth have a positive and significant relationship.

The existing literature extensively documents the relationship between R&D expenditure and economic growth, highlighting positive and negative impacts across various regions and contexts. Seminal works and empirical studies, such as those by Romer (1990), Coe and Helpman (1995), and Griliches (1992), underscore the importance of R&D in driving technological advancements and productivity improvements. However, divergences emerge in the findings from different geographical contexts. For example, while Abdulkadir et al. (2020) and Kadir et al. (2015) reported no significant long-run relationship or negative impacts of R&D on economic growth in OECD countries and Turkey, studies like those by Bayarcelik and Tasel (2012) and Freimane and Balina (2016) found positive effects in various countries, including EU and BRICS-T nations. Despite this rich body of work, there is a noticeable research gap concerning the specific nexus between R&D expenditure and economic growth in Asian countries. These countries' nuanced dynamics and unique economic structures warrant focused investigation to determine how R&D investments influence their growth courses, addressing a crucial gap in the literature.

## Methodology

### Research Design

This study is based on descriptive and exploratory research design. The primary aim of explanatory research is to describe the characteristics of population data and the results being studied. Exploratory research aims to explore a problem and situation to gain insights and familiarity for later investigation or to develop hypotheses. The positivist research philosophy guides this study, and it is quantitative as well as deductive in nature.

### Data and Data Analysis

This study is based on the secondary data. It utilized 870 data points from 35 Asian countries. The unbalanced panel data that covers 33 to 11 data points of different Asian countries from 1990 to 2023 are used. The secondary data are collected from reports from the World Bank and various economic surveys of the respective countries. The total data points, countries, and covered years are presented in Table 1.

**Table 1:** *Includes countries and data points*

Countries	Crossed	Duration	Data points	Countries	Crossed	Duration	Data points
Armenia	1	1997-2023	27	Magnolia	18	1997-2022	27
Azerbaijan	2	1996-2023	28	Myanmar	19	1997-2022	27
Brunei	3	2001-2023	23	Nepal	20	2008-2022	15
China	4	1997-2023	27	Omen	21	2011-2022	12
Cyprus	5	1998-2022	25	Pakistan	22	1997-2022	27
Georgia	6	1995-2022	28	Philippians	23	2001-2022	21
India	7	1996-2023	28	Qatar	24	2012-2022	11
Indonesia	8	2000-2022	23	Russia	25	1991-2022	32
Iran	9	2001-2022	22	Saudi Arabia	26	2003-2022	20
Iraq	10	1997-2022	26	Singapore	27	1996-2023	28
Israel	11	1996-2022	28	South Korea	28	1990-2022	33
Japan	12	1996-2022	28	Sri-Lanka	29	1996-2022	27
Jorden	13	2002-2022	21	Tajikistan	30	2001-2022	22

Countries	Crossed	Duration	Data points	Countries	Crossed	Duration	Data points
Kazakhstan	14	1997-2022	27	Thailand	31	1996-2022	27
Kuwait	15	1997-2022	27	Turkey	32	1990-2022	33
Kyrgyzstan	16	1996-2022	28	UAE	33	2011-2022	12
Malaysia	17	1996-2022	28	Uzbekistan	34	1991-2023	33
				Yemen	35	1991-2023	33
Total observations							870

Source: World Bank's Report and economic surveys of respective countries.

In this study, data are analyzed using EViews12. Some statistical and econometric tools are used to explore the relation and impact of R&D expenditure on economic growth in Asian countries. Descriptive statistics, panel unit root testing, panel co-integration test, and generalized linear model are used.

### Variable and Model Specification

This study includes GDP growth, R&D expenditure (R&D) expenditure, and previous years' R&D expenditure as the study variables. The economic growth is taken as dependent, and the rest are taken as independent variables. The present economic growth depends upon present and previous years' R&D expenditure. In this sense,

$$\text{Economic growth} = f(\text{R\&D expenditure, Previous years' R\&D expenditure}) \quad (1)$$

$$\text{In Symbol, GDPAC} = f(\text{RDEXP, LAGRDEXP}) \quad (2)$$

Where, GDPAC = gross domestic product in Asian Countries

The simple panel data model is specified as follows:

$$Y_{it} = X'_{it}\beta + \mu_{it} \quad (3)$$

Where  $Y_{it}$  is the dependent variable for individual entity 'i' at time 't.'  $X_{it}$  is a vector of the explanatory variable,  $\beta$  is a vector parameter to be estimated, and  $\mu_{it}$  is the error term. In panel data, the error term  $\mu_{it}$  can be decomposed into individual-specific effects ( $\alpha_i$ ) and individual error ( $\epsilon_{it}$ ). It can be calculated as specified as given below:

$$\mu_{it} = \alpha_i + \epsilon_{it} \quad (4)$$

In this study, the Panel GMM is used as the estimating model of the investigation. The GMM is a statistical method used for estimating parameters in models where the traditional assumptions (like homoscedasticity) may not hold (Xiao et al. 2007). GMM is particularly useful in panel data analysis because it handles heteroskedasticity and serial correlation (Ullah et al., 2018). GMM in panel data is a statistical technique used to estimate the parameters of a model by exploiting the idea that certain combinations of the data (called moment conditions) should be zero on average.

The GMM model assumes that the error term  $\mu_{it}$  is reasonable to the instrument. Let us consider the  $Z_{it}$  instruments, which include lags of the dependent variable and independent variables. The moment condition is written as given below:

$$E[Z_{it}(\mu_{it})] = 0 \quad (5)$$

After introducing study variables, the equation (5) is formed as:

$$E[Z_{it}(\text{GDPAC}_{it} - \alpha - \beta_1 \text{RDEXP}_{it} - \beta_2 \text{LAGRDEXP}_{it})] = 0 \quad (6)$$

To eliminate the individual-specific effect  $\alpha_i$ , the first differencing method is applied as given below:

$$\Delta Y_{it} = \Delta X'_{it}\beta + \Delta \epsilon_{it} \quad (7)$$

Where,  $\Delta Y_{it} = Y_{it} - Y_{it-1}$ ,  $\Delta X_{it} = X_{it} - X_{it-1}$  and  $\Delta \epsilon_{it} = \epsilon_{it} - \epsilon_{it-1}$

Since  $Y_{it}$  is still likely to be correlated with  $X_{it}$ , we use lagged  $X_{it}$  as instruments, i.e.,  $X_{it-2}$ . The GMM estimator is obtained by solving the following minimization problem (Arellano & Bond, 1991).

$$\bar{\beta} = \text{Min} \beta \left( \frac{1}{NT} \sum_{i=1}^N \sum_{t=2}^T Z'_{it} (\Delta Y_{it} - \Delta X_{it} \beta) \right) W \left( \frac{1}{NT} \sum_{i=1}^N \sum_{t=2}^T Z'_{it} (\Delta Y_{it} - \Delta X_{it} \beta) \right) \quad (8)$$

$Z_{it}$  is the instrument vector, and  $W$  is a weighting matrix often chosen as the inverse of the covariance matrix of the moment condition.

The instrument variables correlated with the endogenous variables are chosen but uncorrelated with the error term. Common choice includes lagged values of the dependent variable and independent variable.

$$Z_{it} = \{ \text{GDPAC}_{i,t-1}, \text{RDEXP}_{i,t-1}, \text{LAGRDEXP}_{i,t-1}, \text{GDPAC}_{i,t-2}, \text{RDEXP}_{i,t-2} \}$$

The simple panel data model for economic growth is specified as given below:

$$Y_{it} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 X_{it} + \alpha_i + \mu_{it} \quad (9)$$

$$\text{Or, } \text{GDPAC}_{it} = \alpha + \beta_1 \text{RDEXP}_{it} + \beta_2 \text{LAGRDEXP}_{it} + \mu_{it} \quad (10)$$

The first difference to remove  $\alpha_i$ , the equation (7), is converted as given below:

$$\beta_1 Y_{i,t-1} + \beta_2 X_{it} + \mu_{it} \quad (11)$$

$$\text{Or, } \Delta \text{GDPAC}_{it} = \beta_1 \Delta \text{RDEXP}_{it} + \beta_2 \Delta \text{LAGRDEXP}_{it}$$

They used  $Y_{i,t-2}$  and  $X_{i,t-2}$  as instruments for  $Y_{i,t-1}$  and  $X_{it}$ , respectively. The GMM estimator is obtained by minimizing the criteria function. The criteria function is specified as:

$$\hat{\beta} = \arg \min_{\beta} \left\{ \sum_{i=1}^N \sum_{t=1}^T Z'_{it} (\text{GDPAC}_{it} - \alpha - \beta_1 \text{RDEXP}_{it} - \beta_2 \text{LAGRDEXP}_{it}) \right\} \quad (12)$$

$$\text{Where, } Z_{it} = \{ \text{GDPAC}_{i,t-1}, \text{RDEXP}_{i,t-1}, \text{LAGRDEXP}_{i,t-1}, \text{GDPAC}_{i,t-2}, \text{RDEXP}_{i,t-2} \}$$

The panel GMM model is particularly effective at addressing endogeneity by utilizing instrumental factors, making it appropriate for complicated datasets where other methods fail (Hansen, 1982). It accounts for unobserved heterogeneity by adjusting for time-invariant individual effects, improving the estimates' reliability. Furthermore, it is robust to heteroskedasticity and serial correlation within panels, resulting in more efficient and unbiased parameter values than previous estimating techniques (Blundell & Bond, 1998).

## Results

### Descriptive statistics

Descriptive statistics must be used to produce insightful summaries and visualizations. Together, these measures of variability, such as range, variance, and standard deviation (SD), and measures of central tendency, such as mean, median, and mode, aid in understanding the distribution and spread of the data (Fisher & Marshall, 2009). The following Table 2 displays the key information about the data.

**Table (2):** Key information about the dependent and independent variables.

Calculation base	GDP Growth	R&D Expenditure
Mean	4.458641	0.742946
Median	4.786480	0.327256
Maximum	53.38179	5.705550
Minimum	-36.65815	0.015920
Std. Dev.	5.334467	0.955835
Skewness	0.252618	2.272166
Kurtosis	19.26752	8.234933

Calculation base	GDP Growth	R&D Expenditure
Coefficient of variance	119.64%	128.65%
Sum	3879.018	646.3634
Sum Sq. Dev.	24728.74	793.9368
Observations	870	870

Note: GDP growth (GDPAC) changes in annual percent, and research and development Expenditure (RDEXP) is measured percent of GDP

GDP = gross domestic product, R&D = research and development

Source: Authors calculation using EViews12, 2024

Table (2) provides critical descriptive statistics for GDP Growth and R&D expenditure of selected 35 Asian countries. The mean values indicate that GDP growth is 4.46 percent on average, while R&D expenditure is 0.74 percent. The median values suggest that half of the observations for GDP growth are below 4.79 percent and for R&D expenditure below 0.33 percent, indicating a skewed distribution in R&D expenditure. The range of values, highlighted by the maximum and minimum, shows substantial variability, especially in GDP growth, which spans from -36.66 to 53.38 percent. The SD further confirms this variability, with GDP growth showing more excellent dispersion (5.33) compared to R&D expenditure (0.96). The SD of R&D expenditure is less than another variable, so its mean value is more representative. Skewness values reveal that GDP growth is moderately skewed to the right (0.25), whereas R&D expenditure is highly skewed to the right (2.27). The kurtosis values indicate that both distributions are leptokurtic, with GDP growth having extremely high kurtosis (19.27), suggesting frequent extreme values. The coefficient of variance, which is over 100 percent for both variables, indicates significant relative variability. The coefficient of variation of GDP growth is less than that of another variable, so GDP growth is more consistent than that of another variable.

### Panel Unit Root Testing

Panel unit root testing is a statistical method used to determine if a time series variable, observed across different cross-sectional units (such as countries or companies), is stationary or contains a unit root. These tests are crucial in panel data analysis because non-stationary data can lead to spurious regression results. Thus, confirming the presence or absence of a unit root is essential before proceeding with further study (Levin et al., 2002). Popular tests in this category include the Levin-Lin-Chu (LLC) test and the Im-Pesaran-Shin (IPS) test, both of which improve power by combining information across cross-sections (Im et al. 2003).

Table (3): Results of panel unit root test summary

Methods	GDPAC		RDEXP	
	Level	First difference	level	First difference
Levin, Lin, Chu t		-19.895 (0.000)	1.486 (0.929)	8.74 (0.000)
Im, Pesaran & Shin W- stat	-9.959 (0.00) -10.240 (0.00)	-20.863 (0.000)	1.167 (0.878)	-12.514 (0.000)
ADF-Fisher Chi-square	257.469 (0.00) 353.878 (0.00)	514.180 (0.000)	69.834 (0.288)	288.13 (0.000)
PP-Fisher Chi-square		1074.402 (0.000)	68.365 (0.331)	397.368 (0.000)
Decision	GDP growth (GDPAC) is stationary at the level		R&D Expenditure (RDEXP) is stationary after the first difference.	

Note: (a) Benchmark: Individual intercept, (b) Figures in brackets indicate probability values

Source: Authors Calculation by using EViews12

The panel unit root test summary results indicate the stationarity properties of GDP growth (GDPAC) and R&D expenditure (RDEXP). For GDPAC, the Levin, Lin, and Chu t-test, Im, Pesaran, and Shin W-stat, ADF-Fisher Chi-square, and PP-Fisher Chi-square tests, all show significant p-values (0.00), indicating that GDPAC is stationary at the level. This means that GDP growth does not have a unit root, and its mean, variance, and autocorrelation structure do not change over time. On the other hand, the RDEXP results at the level show non-significant p-values for all tests (p-values of 0.929, 0.878, 0.288, and 0.331, respectively), indicating that RDEXP is non-stationary at the level. However, after taking the first difference, all tests show significant p-values (0.000), indicating that RDEXP becomes stationary. It suggests that RDEXP has a unit root at the level but becomes stable in its first differenced form, implying that its statistical properties become constant over time only after differencing. In short, GDP growth is inherently stationary, while R&D Expenditure requires differencing to achieve stationarity.

### Pedroni Residual Co-integration Test

A panel co-integration test is a statistical procedure used to determine whether a long-run equilibrium relationship exists among variables across different cross-sectional units in a panel data set. It helps to identify if non-stationary time series variables are co-integrated, implying that they move together over time despite being individually non-stationary (Pedroni, 1999; Kao, 1999). The Pedroni residual co-integration test determines a long-term equilibrium relationship between variables in panel data, consisting of multiple cross-sectional units observed over time. It extends traditional co-integration tests by allowing for heterogeneity in both the long-term relationships and the dynamics across the different units in the panel. The outcomes of Pedroni residual co-integration are presented in Table 4

**Table (4): Outcomes of Pedroni residual panel co-integration test**

Series: GDPAC, RDEXP, & LAGRDEXP

Total observation: 870, Null Hypothesis: No co-integration

Methods	Individual intercept		Individual intercept and trend		No intercept and trend	
	statistic	Weighted statistic	statistic	Weighted statistic	statistic	Weighted statistic
Panel v-statistic	-1.566 (0.941)	-2.139 (0.984)	-4.409 (1.000)	-5.005 (1.000)	0.283 (0.388)	-1.244 (0.893)
Panel rho-statistic	-7.178 (0.00)	-6.254 (0.000)	-4.624 (0.000)	-3.514 (0.0002)	-6.988 (0.000)	-4.455 (0.000)
Panel PP-statistic	-14.412 (0.00)	-13.005 (0.000)	-19.238 (0.000)	-14.674 (0.000)	-11.830 (0.000)	-7.485 (0.000)
Panel ADF-statistic	-7.921 (0.00)	-8.803 (0.000)	-10.327 (0.000)	-9.897 (0.000)	-7.251 (0.000)	-4.743 (0.000)
Group rho-statistic	-2.403 (0.00)	-	0.117 (0.546)	-	-3.422 (0.000)	-
Group PP-statistic	-14.072 (0.000)	-	-15.250 (0.000)	-	-11.609 (0.000)	-
Group-ADF-statistic	-8.874 (0.000)	-	-9.935 (0.000)	-	-8.090 (0.000)	-

Note: Figures in brackets indicate probability values.

Source: Authors calculation using EViews12, 2024

Table (4) shows the Pedroni residual co-integration test results for the series Gross Domestic Product (GDPAC), R&D expenditure (RDEXP), and lag value of GDP growth (LAGRDEXP) whether there is a long-term equilibrium relationship between these variables across the panel data set, which consists of 870 observations. The null hypothesis for all methods is that there is no co-integration. As brackets indicate, the test results show

various statistics and their corresponding p-values. In the majority methods of the test statistics (Panel v, rho, PP, and ADF statistics), the results under different model specifications (individual intercept, individual intercept, and trend, no intercept and trend) show significant negative values with p-values of 0.000 or close to it, except for the Panel v-statistic in some cases. This indicates strong evidence against the null hypothesis of no co-integration, implying a long-term co-integrating relationship between GDP growth, lag values, and R&D expenditure in Asian countries.

**Panel Generalized Methods of Moments**

Panel Generalized Methods of Moments (Panel GMM) is an econometric technique used for estimating parameters in panel data models, which contain observations across multiple periods for the same entities. It combines the GMM with panel data to handle issues like endogeneity, unobserved heterogeneity, and autocorrelation. By using multiple moment conditions derived from the data, Panel GMM provides efficient and consistent estimates. This method benefits dynamic panel data models using lagged dependent variables as instruments. The results of the GMM are displayed in Table 5.

**Table (5): Outcomes of Panel GMM**

Dependent Variable: GDPAC, Transformation: First difference

Included period:32, Included cross sections: 32, Unbalanced panel observation: 800

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDPAC (-1)	0.221	0.002671	82.59090	0.0000
LAGRDEXP	1.5104	0.018883	79.99017	0.0000
RDEXP	-2.844	0.054315	-52.36558	0.0000
Effects Specification				
Cross-section fixed (first differences)				
Root MSE	6.931831	Mean dependent var		-0.074216
S.D. dependent var	5.466109	S.E. of regression		6.944865
Sum squared resid	38440.22	J-statistic		31.28551
Instrument rank	35	Prob(J-statistic)		0.502543

Source: Authors calculation by using EViews12, 2024

The Table presents the results of a Panel GMM estimation for the dependent variable GDPAC (GDP per capita) in first differences. The coefficient of lagged GDP (GDPAC(-1)) is 0.221, indicating that one unit increase in the previous period’s economic growth increases the current period’s GDP per capita by 0.221 units. The high t-statistic (82.59090) and p-value of 0.0000 suggest this effect is statistically significant. The coefficient lagged value of previous years’ R&D expenditure (LAGRDEXP) is 1.510448, implying that one unit increase at an earlier R&D expenditure results in a 1.5104 unit increase in economic growth. The LAGRDEXP is also highly statistically significant in determining Asian countries’ GDP growth. The coefficient of R&D expenditure (RDEXP) is -2.844230, suggesting that an increase in R&D expenditure is associated with a decrease in GDP growth by 2.844230 units. Current years’ R&D expenditure huts the current year’s GDP growth. The Panel GMM equation is found as given below:

$$GDPAC = 0,221*GDPAC(-1) + 1.5104*LAGRDEXP - 2.844*RDEXP \tag{13}$$

The Root Mean Squared Error (MSE) value is 6.931831, which indicates the model’s prediction accuracy. The Root Mean Squared Error (RMSE) of 6.931831 measures the average magnitude of the prediction errors made by the model in predicting the dependent variable. The root mean squared error (RMSE) of 6.931831 implies that the model’s predictions for GDP per capita are, on average, 6.93 units away from the actual values. A

lower Root MSE indicates a better fit of the model, meaning the predictions are closer to the exact values.

Mean dependent variance and S.D. dependent variance reflect the average and SD of the dependent variable. The mean dependent variable value represents the average value of GDP per capita in the dataset, indicating the central tendency of the dependent variable. The dependent variable's SD measures the dispersion or variability of GDP per capita around its mean, indicating how spread out the values are. Together, these statistics summarize the central tendency and variability of the dependent variable in the dataset. The S.E. of regression (6.944865) measures the average distance the observed values fall from the regression line, indicating the model's precision. The sum squared residual (38440.22) quantifies the total deviation of the observed values from the predicted values, assessing the model's overall fit. Both metrics help evaluate the accuracy and effectiveness of the regression model. J-statistic (31.28551) and its p-value (0.502543) suggest that the overidentifying restrictions are valid, indicating a good model fit. The J-statistic is a test statistic used in the GMM context to evaluate the validity of overidentifying restrictions. It measures how well the chosen instruments explain the variation in the model, testing the null hypothesis that the instruments are valid. A high p-value (e.g., 0.502543) associated with the J-statistic suggests that the instruments are valid and the model is correctly specified. The significant coefficients and satisfactory diagnostics indicate a well-fitted model where past GDP, agricultural expenditure, and R&D expenditure significantly impact GDP per capita.

The Generalized methods of moments are far from the problem of serial correlation. The Arellano-Bond serial correlation is used to identify the serial correlation problem. The Arellano-Bond serial correlation test is a diagnostic tool for dynamic panel data models estimated using GMM. It checks for serial correlation in the residuals, mainly focusing on second-order serial correlation, to validate the model's specification and the instruments used. The results of the Arellano-Bond serial correlation test are displayed in Table 6.

**Table (6): Outcomes of Arellano-Bond Serial Correlation Test**

Included observations: 800

Test order	m-Statistic	rho	SE(rho)	Prob.
AR(1)	-0.0982	-20101.781	204597.426	0.921
AR(2)	0.0334	2598.0477	77556.5871	0.973

The results of the Arellano-Bond serial correlation test for a dynamic panel data model with 800 observations are presented in Table (6). The AR(1) test has an m-statistic of -0.0982, a rho of -20101.781, an SE(rho) of 204597.426, and a probability value of 0.921. The p-value is more than 0.05 or 5 percent level of significance. So, we fail to reject the null hypothesis of no first-order serial correlation in the first-differenced residuals. The AR(2) test shows an m-statistic of 0.0334, a rho of 2598.0477, an SE(rho) of 77556.5871, and a p-value of 0.973. The very high p-value here also indicates that we failed to reject the null hypothesis of no second-order serial correlation. The failure to reject the null hypothesis for both AR(1) and AR(2) tests suggests no significant serial correlation in the residuals at either the first or second order. This outcome implies that the model specification is appropriate and the instruments used in the GMM estimation are valid. Therefore, the GMM estimators are likely consistent and reliable for inference.

## Results and Discussions

This study searches for the impact of R&D expenditure on economic growth in Asian countries. In thirty-five countries, 870 unbalanced panel data are utilized to search for the impact of R&D expenditure on economic growth. The GDP growth (GDPAC), R&D expenditure, and previous years' R&D expenditure (LAGRDEXP) have a long-run co-integration. This finding aligns with the findings of Romar (1986), Ugur et al. (2016), Bayraktar et al. (2022), and Tung and Hoang (2024). R&D expenditure and economic growth have long-run co-integration because investments in R&D drive technological advancements and productivity improvements, which are fundamental for sustained economic growth. Additionally, the positive feedback loop between economic growth and increased R&D funding reinforces their long-term relationship.

The previous years' R&D expenditure positively and statistically significantly impacted economic growth in Asian countries. One unit increase in R&D expenditure resulted in a 1.5104 unit increase in economic growth. This finding is also aligned with the finding of Mladenovic et al. (2016). The previous years' R&D expenditure has had a positive and statistically significant impact on economic growth because R&D investments enhance innovation and technological progress, which are crucial drivers of productivity and efficiency gains. These improvements, in turn, stimulate economic activities, increase output, and promote overall economic development. Additionally, the benefits of R&D investments often materialize over time, leading to sustained growth and a cumulative economic impact.

The present R&D expenditure hurts the present economic growth in Asian countries. This finding aligns with the findings of Samimi and Alerasoul (2009), Ulku (2004), and Benlaria et al. (2023). However, most of the studies are against this finding. They have observed the positive impact of R&D expenditure on economic growth. The findings of Sezgin (2020), Gumus and Celikey (2015), Femane and Balina (2016), Griffith et al. (2004), and Rabiei (2011) do not align with the findings of this study. The present year's R&D expenditure might hurt economic growth because it diverts resources from immediate productive uses to long-term projects that do not yield immediate returns. Additionally, the initial costs and uncertainties associated with R&D investments can strain current financial resources and budgets. Moreover, disrupting and reallocating labor and capital toward R&D activities might temporarily reduce overall economic output.

### **Conclusion, Policy Implications, and Limitations**

This study has searched the impact of R&D expenditure on economic growth in selected 35 Asian countries. The economic growth, research development expenditure, and previous years' R&D expenditure have long-run co-integration. The previous years' economic growth is also responsible for increasing present economic growth. One unit increase in previous economic growth results in a 0.221 unit increase in present economic growth. The previous years' R&D expenditures are statistically significant in explaining present economic growth. One unit increase in previous years' R&D expenditure results in a 1.5104 unit increase in economic growth. Surprisingly, however, R&D expenditure and economic growth are inversely related. One unit increase in R&D expenditure results from 2.844 unit decrease in economic growth in Asian countries.

R&D expenditure from previous years has substantially impacted economic growth in Asian countries, and policymakers should focus on creating a stable and supportive climate for long-term R&D investment. Tax breaks, grants, and subsidies can stimulate investment in R&D from the public and private sectors. Developing regulations that promote efficient resource allocation is also critical, ensuring that current R&D investments do not detract from immediate economic productivity. Establishing strong foundations for collaboration among academia, industry, and government can also improve the effectiveness and efficiency of R&D efforts. To counteract the short-term adverse effects of current R&D spending on economic growth, transitional support measures such as targeted training programs and financial aid can help smooth the reallocation of labor and capital. Policymakers can maximize the potential of R&D investments to create sustainable economic growth by creating an environment that supports immediate and long-term economic goals.

This study is based on the unbalanced panel data of 35 Asian countries collected from the World Bank reports and economic surveys of respective countries. Current R&D expenditure and previous years' R&D expenditure are used as expansionary variables, and economic growth is used as the response variable. Only 870 data points are analyzed. Some fundamental statistical and econometric tools like descriptive statistics, panel unit root testing, Pedroni residual co-integration test, Generalized method of Moments (GMM), and Arellano-Bond serial correlation test are used. Therefore, further research is necessary by using more countries, variables, data points, methods, and tools to derive comprehensive and more representative results than the present one.

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