

***The relationship between R&D spending and economic growth
Proof based on empirical data from South Korea***

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Abstract:

The study aimed to explore the relationship between R&D expenditures and economic growth in South Korea during the period 1996-2021 by examining and measuring the impact of independent variables: R&D spending, gross fixed capital formation, and domestic credit to the private sector on the dependent variable, GDP growth, as an indicator of economic growth. The study relied on data from the World Bank and employed the non-linear autoregressive distributed lag model (NARDL) for econometric analysis. Key results indicate an asymmetric long-term relationship between R&D expenditures and economic growth. The study also reveals an asymmetric long-term relationship between growth and gross fixed capital formation (GFCF) and a symmetric relationship between growth and domestic credit to the private sector (DCP). However, the results indicate a symmetric relationship between R&D and growth in the short term.

Keywords: *R&D spending, economic growth, gross fixed capital formation, domestic credit to private sector, GDP*

Jel Classification Codes : *O32, O11, O4*

1. Introduction :

Expenditure on research and development (R&D) is critical to economic growth, particularly in economies that rely heavily on innovation. Research and development (R&D) endeavors are essential for advancing technology, boosting productivity, and boosting competitiveness. The literature has extensively shown the favorable link between research and development (R&D) investments and economic performance. This underscores the crucial function that R&D expenditures play in fostering sustainable economic expansion. (Sokolov-Mladenović et al., 2016).

Strategic (R&D) investments are necessary to sustain competitive advantage and guarantee long-term economic stability in advanced economies. For instance, data from the 28 EU member states (EU28) demonstrates that better rates of real economic growth, especially in times of economic volatility, are associated with increased (R&D) expenditure as a GDP percentage. (Sokolov-Mladenovic et al., 2016). A compelling illustration of how (R&D) expenditures affect economic growth is seen in Southern Korea. Significant (R&D) expenditures over the last few decades are credited with converting Southern Korea's economy from one centered on agricultural to one that is a major industrial and technology powerhouse. This economic revolution offers insightful information about how focused (R&D) strategies might support long-term economic growth and raises significant questions regarding the precise role that (R&D) spending has had in the development of economic Korea. in a world market that is evolving quickly.

Furthermore, in areas with substantial technological and economic obstacles, the significance of research and development in fostering sustainable economic development becomes even more crucial. Studies, for instance, in the Northwest Romania Development Zone have demonstrated a correlation between differences in employment levels and (R&D) expenditure and economic growth, underscoring the necessity of focused (R&D) strategies to support equitable regional development. (Badulescu et al., 2024). This emphasizes how crucial it is to boost (R&D) spending and make sure that it is effectively distributed and used in a variety of industries and locations.

Economic findings in emerging nations indicate that R&D investments and their effect on growth are complicated. (R&D) expenditures are necessary to close technology gaps and promote growth driven by innovation. But obstacles like poor human resources, insufficient infrastructure, and inefficient institutions might restrict how beneficial these expenditures are. (Maku, 2009). The examples of Slovenia and Croatia demonstrate that there may be a nonlinear relationship between government spending, particularly (R&D) spending, and economic development since the effects of these investments might differ based on the features of each country as well as the overall state of the economy. (Bošnjak, 2018).

The significance of research and development in promoting economic growth is also emphasized by emerging market economies, particularly through technical advancement and innovation. Research has demonstrated a positive correlation between (R&D) expenditures and economic growth in certain developing economies, such as Brazil, India, and Turkey. This suggests that allocating more resources to research activities is necessary to ensure sustainable long-term growth. Research on the BRICS-T nations—Brazil, Russia, India, China, South Africa, and Turkey— has also proven that (R&D) spending and economic growth are causally related, emphasizing the vital role that these investments play in advancing economic performance and technological advancement in both developed and developing nations. (Bayraktar et al., 2022).

Importance, goal and research problem

This study's significance arises from the need for a more thorough comprehension of the connection between economic growth and (R&D) expenditures, particularly in the context of Southern Korea, one of the world leaders in this area. Even though Southern Korea has had great success with (R&D) investments, it is still important to comprehend the opportunities and problems associated with promoting these investments and their effects on economic growth.

This study aims to explore the connection between R&D expenditure and economic growth in South Korea, with a particular emphasis on the contributions these investments make to productivity and technical advancement. We hope that our study will provide light on how better policies might be developed to support sustainable (R&D) initiatives and economic growth.

Finding out how much (R&D) spending has an impact on economic growth in Southern Korea and how that spending interacts with other economic elements to create sustainable development is the research challenge that this study aims to solve.

2.Theoretical Structure:

The theoretical framework of this study is based on several key economic theories. It begins with Keynesian perspective, where John Maynard Keynes highlights the importance of investment, especially (R&D) spending, as a critical factor in promoting economic growth. This investment increases productive capacity and stimulates innovation, leading to a multiplier effect that promotes economic expansion by increasing income and demand (Keynes, 1936).

Building on this foundation, Paul Samuelson and William Nordhaus integrate the neoclassical growth model, which focuses on the role of technological innovation. According to this view, (R&D) spending is vital to promoting technological progress that increases the potential output of the economy. In the context of Southern Korea, continued investments in (R&D) have been essential in sustaining long-term economic growth by driving technological advances (Samuelson and Nordhaus, 2010).

Robert Lucas Jr. expands on this paradigm by emphasizing the role that the role of human capital accumulation in driving economic progress. Lucas contends that the main factor promoting economic growth is human capital, which is bolstered by (R&D) efforts. Investments in education and skill development, which are closely related to research and development, produced a highly trained workforce in Southern Korea, propelling the nation's economic growth. (Lucas, 1988).

Paul Romer delve into the concept of internal technological change, noting that technological developments are driven by internal factors such as investments in (R&D) by for-profit agents, which in turn leads to sustainable economic growth. In Southern Korea, (R&D) spending was a key factor in driving internal technological change, maintaining the country's globally competitive advantage (Romer, 1990).

Finally, Sergio Cessarato's insights into the analysis of savings and economic growth within the neoclassical framework further enrich the theoretical framework, highlighting the importance of saving in supporting economic growth. While traditional models suggest that saving mainly affects income levels, the theory of internal growth argues that saving is necessary to drive investments in research and development, human capital, and technology. In Southern Korea, the high savings ratio enabled significant investments in research and development, contributing to Strong economic growth of the nation (Chisarato, 1999).

3. Literature Review:

In the economic literature, the connection between (R&D) expenditure and economic growth is becoming more and more significant. This literature analysis has been objectively separated to cover several factors connected to the influence of (R&D) investment on economic growth since (R&D) is a fundamental driver of technological innovation, which in turn boosts productivity and competitiveness in different economies. The influence of research investment is one of the various dimensions on which the literature is examined. Research and development's role in attaining sustainable development and green growth is finally discussed, along with development in various economic types, the distinction between public and private spending, the connection between R&D between (R&D), technological innovation, and sustainable growth, regional and sectoral differences. This method makes it possible to comprehend in great depth how (R&D) expenditure has affected economic development in various situations.

Economic growth and research and development spending in different economies

(R&D) spending has been identified as a critical factor in promoting economic growth across various economies. Several studies have confirmed the positive impact of (R&D) spending on economic growth, particularly in advanced and emerging economies. For example, (Inekwe, 2015) showed that (R&D) spending contributes significantly to economic growth in upper-middle-income economies, while its impact remains intangible in lower-income economies. Similarly, (Tung and Hoang, 2024) Stressed the advantages of R&D expenditure for economic growth in developing countries, emphasizing both the long-term advantages and its role in assisting these nations in avoiding the middle-income trap. These findings support those of (Kalm, 2023) They found a substantial positive relationship between economic progress and (R&D) expenditure. across a variety of emerging and recently developed nations, highlighting the importance of funding (R&D) initiatives. to accomplish long-term economic expansion.

However, (Bozkurt,2015) concentrated on Turkey and found a one-way causal link between economic growth and research and development, in which the latter positively affects GDP growth rates. This emphasizes how crucial (R&D) spending is over the long run to economic growth, particularly for nations hoping to join the global market.

governmental and private R&D expenditures

The distinction between governmental and private spending on (R&D) was studied, with mixed results on their impact on economic growth. (Szarowská, 2017) found that public spending on (R&D) in selected EU countries had a significant positive impact on economic growth, while commercial spending on (R&D) was insignificant. This highlights the importance of government intervention in (R&D), especially in areas where private investment in (R&D) may not be sufficient. Similarly, (Choi and Cho, 2023) in Southern Korea noted that public investment in (R&D) had a short-term impact on economic growth, while investment in (R&D) by companies and universities showed no immediate impact, despite its long-term impact.

In contrast, (Blanco et al., 2018) pointed to the divergent roles of the governmental and private sectors in driving convergence in (R&D) within the EU. While business has been the main driver of (R&D) convergence in the 15 EU countries, government spending has played a more important role in the new 13 member states. This suggests that the source of (R&D) funding

(governmental or private) can have different impacts depending on the economic context and market maturity.

Innovation in Technology, (R&D), and Sustainable Economic Growth

Technology innovation and spending on (R&D) are tightly related, and technical innovation promotes sustainable economic growth. (Sokolov-Mladenović et al., 2016) discovered that the real GDP growth rate in the EU 28 nations might rise by 2.2% with a 1% increase in R&D investment as a proportion of GDP. This emphasizes how important technical innovation is for fostering economic growth since it encourages research and development.

Moreover, there is growing recognition of R&D's contribution to green economic growth. (R&D) expenditure considerably increases green growth, according to (Huang et al., 2022) investigation of the link between fiscal spending, including R&D, and green economic development in heavily polluted Asian nations. Similarly, (Lin and Zhu, 2019) explained that financial spending on (R&D) promotes green economic growth through technological advancement, suggesting that (R&D) is a pivotal factor in achieving economic growth and environmental sustainability.

Regional and sectoral differences in the impact of (R&D) spending

The impact of (R&D) spending on economic growth varies by region and sector. For example, (Bayraktar et al., 2022) investigated the BRICS-T countries and found a two-way causal relationship between (R&D) spending and economic growth, suggesting a strong interdependence between the two. In contrast, (Zhang et al., 2021) Highlighted the role of public R&D spending in supporting green economic growth in the Belt and Road Initiative (BRI) region, although the impacts have been highly variable between countries with different GDP levels.

In South Asia, (Fang et al., 2022) found that research and development, especially in renewable energy, has been instrumental in advancing green economic growth. by reducing carbon emissions and promoting industrial structural change. These regional studies emphasize the importance of context-specific strategies in exploiting (R&D) spending for economic growth.

The contribution of (R&D) expenditure to sustainable development and green growth

Additional studies confirm the relationship between (R&D) spending, green economic growth, and sustainable development. For example, (Sun et al., 2023) reviewed the role of technological innovation and human capital in promoting sustainable economic growth through the use of modern technologies and clean energy sources. (Wu and Yao, 2022) also discussed the role of carbon productivity in China's economic growth patterns, noting the importance of increasing carbon productivity for sustainable growth.

On the other hand, (Xie and Huang, 2022) examined the role of financial expansion and (R&D) in improving China's economic performance, emphasizing the significant impact of (R&D) spending in promoting financial expansion and economic growth. In a similar (Bošnjak, 2018) highlighted nonlinear influences on the link between government expenditure and GDP and focused on how government expenditure and economic growth relate to each other in Slovenia and Croatia.

(Babatunde, 2018) investigated how government expenditure on infrastructure affected Nigeria's economic growth, showing how investments in health and education may spur growth while spending on natural resources and agriculture had the reverse effect.

The importance of the current study in light of previous studies

Previous literature points to the critical role of (R&D) spending in promoting economic growth, as the importance of these expenditures in supporting technological innovation and

stimulating sustainable development across various economies has been emphasized. However, most of these studies have focused on regions or groups of countries such as the European Union or emerging economies in general, with less emphasis on the comprehensive analysis of advanced individual economies such as the Southern Korea.

Research gap

Although there are studies indicating the effect of R&D expenditures on economic growth in South Korea., there is a lack of comprehensive analysis covering the long- and short-term effects of such spending in the overall Korean context. Previous studies have not focused enough on how other economic factors, such as household spending, private sector credit, and total capital formation, Influence the effectiveness of R&D expenditures in driving economic growth in South Korea.

This research gap presents an opportunity for a detailed study that involves a thorough analysis of the relationship between R&D expenditures and other economic factors, along with their combined effect on economic growth.

Possible scientific addition to the current study

Our study aims to bridge this gap by providing a comprehensive analysis of how R&D expenditures affect economic growth in Southern Korea, with other factors such as household spending, private sector credit, and total capital formation included in the analytical model. We shall be able to comprehend these components' interconnections and how they affect economic growth better thanks to this method.

By integrating these variables into the analysis, our study will provide new insights into how to improve the effectiveness of (R&D) expenditures for sustainable economic growth. It will also help identify economic policies that can support these expenditures more effectively in the context of Southern Korea.

As such, the study will contribute to enhancing academic understanding of the effects of (R&D) expenditures on economic growth in a country that is a pioneer of technological innovation, providing a model that can be followed in other countries seeking similar results, taking into account the impact of multiple economic factors.

4-Materials and Methods

Data Analysis

We employ the non-linear autoregressive distributed lags model (NARDL) to analyze the results, all data of this study are composed of World Development Indicators (WB-2024), including an annual time series from 1996 to 2021 From the World Bank website, which was the latest data available at the time of the research. The GDP growth rate serves as the dependent variable, while the independent variables include R&D expenditure (RDE), gross fixed capital formation (GFCF), and domestic credit to the private sector (DCP). The methodology applied in this analysis is explained in the following section.

The relationship between GDP_growth and R&D expenditure in south korea is described as a
linear functional form:

$$GDP_growth_t = f(R\&D_t; GFCF_t; DCP_t) \quad (1)$$

$$GDP_growth_t = C_0 + R\&D_t + GFCF_t + DCP_t + \varepsilon_t \quad (2)$$

But we need to test this relationship in a nonlinear framework, so it's a nonlinear equation format;

$$GDP_growth_t = f(R\&D_POS_t; R\&D_NEG_t; GFCF_POS_t; GFCF_NEG_t; DCP_POS_t; DCP_NEG_t) \quad (3)$$

$$GDP_growth_t = C_0 + R\&D^+_t + R\&D^-_t + GFCF^+_t + GFCF^-_t + DCP^+_t + DCP^-_t + \varepsilon_t \quad (4)$$

Where; the independent variables $(R\&D; GFCF; DCP)$ are decomposed into its positive and negative partial sum:

Increases reaction: appears in equations (5,6,7)

$$POS = R\&D^+_t = \sum_{j=1}^t \Delta R\&D_j^+ = \sum_{j=1}^t \max(\Delta R\&D_t; 0) \quad (5)$$

$$POS = GFCF^+_t = \sum_{j=1}^t \Delta GFCF_j^+ = \sum_{j=1}^t \max(\Delta GFCF_t; 0) \quad (6)$$

$$POS = DCP^+_t = \sum_{j=1}^t \Delta DCP_j^+ = \sum_{j=1}^t \max(\Delta DCP_t; 0) \quad (7)$$

Decreases reaction:

$$NEG = R\&D^-_t = \sum_{j=1}^t \Delta R\&D_j^- = \sum_{j=1}^t \min(\Delta R\&D_t; 0) \quad (8)$$

$$NEG = GFCF^-_t = \sum_{j=1}^t \Delta GFCF_j^- = \sum_{j=1}^t \min(\Delta GFCF_t; 0) \quad (9)$$

$$NEG = DCP^-_t = \sum_{j=1}^t \Delta DCP_j^- = \sum_{j=1}^t \min(\Delta DCP_t; 0) \quad (10)$$

(Shin, Byungchul , & Matthew , 2014) Demonstrate that by relating (4) with the ARDL (p, q) model we get the NARDL (p, q) model as: appears in equation (11)

$$\begin{aligned} \Delta GDP_growth_t = & \rho GDP_growth_{t-1} + \theta^+ R\&D^+_{t-1} + \theta^- R\&D^-_{t-1} + \gamma^+ GFCF^+_{t-1} + \gamma^- GFCF^-_{t-1} + \sigma^+ DCP^+_{t-1} + \sigma^- DCP^-_{t-1} \\ & + \sum_{j=1}^{p-1} \varphi_j \Delta GDP_growth_{t-j} + \sum_{j=0}^q (\delta_j^+ \Delta R\&D^+_{t-j}) + \sum_{j=0}^n (\delta_j^- \Delta R\&D^-_{t-j}) + \sum_{j=0}^m (\delta_j^+ \Delta GFCF^+_{t-j}) \\ & + \sum_{j=0}^k (\delta_j^- \Delta GFCF^-_{t-j}) + \sum_{j=0}^s (\delta_j^+ \Delta DCP^+_{t-j}) + \sum_{j=0}^s (\delta_j^- \Delta DCP^-_{t-j}) + \varepsilon_t \end{aligned} \quad (11)$$

4-Results and the Diagnostic Tests

Unit Root Test

The table 1. presents the results of the unit root test for all variables in this study, using both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. These tests are used to

determine whether a time series is stationary or contains a unit root (non-stationary). (See **Appendix No 1**).

Both the ADF and PP tests show that GDP growth rate is $I(0)$, meaning it is stationary at its level form, regardless of whether a constant or a constant with a trend is included in the test. This suggests that the GDP growth rate does not exhibit a unit root and is stable over time. Similar to GDP growth rate, GFCF is $I(0)$ in both tests and under both conditions (with constant and with constant and trend). This means GFCF is also stationary at its level and does not require differencing.

In contrast, the tests indicate that RDE is $I(1)$, meaning it is non-stationary at the level but becomes stationary after first differencing. This suggests that RDE exhibits a unit root and its statistical properties like mean and variance change over time unless it is differenced. As well, Domestic Credit to Private Sector (DCP) is also $I(1)$ in both tests and under both conditions. This implies that DCP is non-stationary at the level and requires first differencing to achieve stationarity.

Co-integration in the NARDL Model

In the context of the NARDL model, co-integration refers to the existence of a long-term equilibrium relationship between the variables, despite the presence of short-term fluctuations. The NARDL model is particularly useful when you suspect that the relationship between variables might be nonlinear or asymmetric.

Bound Test for Co-integration:

The bound test is commonly used in the context of ARDL and NARDL models to determine whether there is co-integration between the variables. The test involves calculating an F-statistic and comparing it to critical values provided by (Pesaran, 2001). As a result, if the F-statistic is higher than the upper bound critical value, we can reject the null hypothesis of no co-integration, indicating that a long-term relationship exists. While, if the F-statistic is below the lower bound, we can accept the null hypothesis, indicating no co-integration. But, if the F-statistic falls between the lower and upper bounds, the result is inconclusive. (See **Appendix No 2**).

The results indicate that the F-Statistic exceeds the upper bound critical values at all significance levels, supporting the acceptance of the alternative hypothesis of co-integration. This confirms the existence of a long-run relationship between growth and the explanatory variables (RDE? GFCF DCP), suggesting a stable long-term relationship between the variables. However, this relationship may be either symmetric or asymmetric. Additionally, positive and negative shocks to the independent variables affect the dependent variable differently in both the short and long run. Consequently, GDP and RDE, GFCF, DCP, exhibit a long-term co-movement. The estimated asymmetric short-run and long-run coefficients from our NARDL model are presented in **Appendix No 3**.

Long-Run Relationship:

The NARDL model estimates separate long-run coefficients for positive and negative changes in the independent variables. This helps in understanding how increases and decreases in the independent variable impact the dependent variable differently over the long term. The Appendix No 3 presents the results of asymmetric long-run coefficients in a NARDL model, where the dependent variable is GDP.

Appendix No 3. provides insight into how positive and negative changes in the independent variables (R&D expenditure, gross fixed capital formation, and domestic credit to the private sector) affect GDP growth differently over the long run. (See Appendix No 3).

The results show that a positive change in R&D expenditure significantly boosts GDP growth, with a 1% increase in R&D spending leads to approximately a 0.63% increase in GDP in the long run. Conversely, a negative change in R&D expenditure has a significant and substantial negative effect on GDP growth. where, a 1% decrease in R&D spending leads to approximately a 3.04% decrease in GDP in the long run. The effect is much larger in magnitude compared to the positive changes, indicating strong asymmetric relationship.

Similarly, positive changes in gross fixed capital formation have a significant positive effect on GDP, with a 1% increase in GFCF is associated with a 0.6314% increase in GDP. However, negative changes in GFCF also reduce GDP, but this effect is not as strong as for positive changes. A 1% decrease in GFCF is associated with a 0.5291% decrease in GDP.

Furthermore, positive shifts in domestic credit to the private sector significantly boost GDP growth, with a 1% rise in DCP resulting in about a 0.19% increase in GDP over the long term. In contrast, negative changes in DCP have a positive but statistically insignificant effect on GDP growth, indicating that reductions in domestic credit have a minimal and non-significant impact in the long term. This implies that the relationship between DCP and GDP growth is largely balanced, with positive credit changes driving GDP growth, while negative changes have a negligible effect.

The constant term (4.099358) represents the base level of GDP growth when all independent variables are at zero, indicating that even in the absence of changes in R&D expenditure, GFCF, and DCP, GDP growth would still be positive.

As a results, positive changes in R&D expenditure (RDE_POS) and gross fixed capital formation (GFCF_POS) both have a strong positive impact on GDP. Then, negative changes in R&D expenditure (RDE_NEG) have a very large negative impact on GDP. Where, positive changes in domestic credit to the private sector (DCP_POS) positively affect GDP, but the impact of negative changes in DCP (DCP_NEG) is not significant. The asymmetric effects observed suggest that GDP is more sensitive to negative changes in R&D expenditure and GFCF compared to their positive changes. This analysis highlights the importance of maintaining and increasing research expenditure and investment in capital formation to ensure stable and positive economic growth in Korea.

Error Correction Term (ECT):

The table (4) presents the results of the asymmetric short-run coefficients in a NARDL model, focusing on how short-term changes in the independent variables (gross fixed capital formation and R&D expenditure) affect GDP growth. The table also includes the error correction term (CointEq(-1)), indicates how quickly deviations from the long-term equilibrium are corrected in the short run. A significant and negative ECT confirms the presence of co-integration and shows that any short-term disequilibrium is adjusted over time to return to the long-term equilibrium. (See Appendix No 4). The results indicate that positive changes in gross fixed capital formation (GFCF) have a positive effect on GDP growth in the short run, with a 1% increase in GFCF is associated with an 8.11% increase in GDP. Additionally, increases in (R&D) expenditure have a significant and substantial positive impact on GDP growth in the short run. A 1% increase in (R&D) spending leads to a 10.42% increase in GDP. While, negative changes in (R&D) expenditure have a significant and large negative effect on GDP growth in the short run, with a 1% decrease in (R&D) spending leads

to a 20.94% decrease in GDP. This suggests that maintaining or increasing (R&D) expenditure is crucial for sustaining short-term economic growth.

The error correction term (ECT) is negative and significant, with a coefficient of -1.334750. This indicates that any short-term deviations from the long-run equilibrium are corrected by about 133% in the following period, which suggests a very rapid adjustment process. The highly significant p-value (0.0000) confirms the robustness of this result. The magnitude greater than 1 suggests over-adjustment, meaning that the system not only corrects the deviation but also overshoots before stabilizing. **(See Appendix No 5)**

Both R&D expenditure and gross fixed capital formation have asymmetric impacts on GDP in the long run. This suggests that the economy reacts differently to increases and decreases in these variables over time. While, the impact of changes in domestic credit to the private sector on GDP is symmetric in the long run, indicating that the effects of credit expansions and contractions are similar.

Moreover, in the short run, the relationship between (R&D) expenditure and GDP is symmetric, meaning that short-term increases and decreases in (R&D) have similar effects on growth.

These findings indicate the complexity of the economic relationships involved, particularly in how different variables influence growth over different time horizons. The results can have significant implications for economic policy, especially in managing (R&D) investments and capital formation.

Diagnostic tests:

Significant tests were used to obtain the following results:

From **(Appendix No 6)** all the diagnostic tests (JB, Reset, LM and Arch) associated with asymmetric model indicate that the model is well specified.

The heteroskedasticity test gives a probability that is equal to $0.2502 > 0,05$ (5%). Therefore, the variance is constant. As a consequence, there is homoscedasticity. This means that the coefficients of the model are efficient.

The LM test indicates there is no autocorrelation of errors because $probabilit(chi^2) 0.2198 > 0,05$;

Ramsey's specification test shows a probability $F=0.1363 > 0,05$. So the model is well specified. Jarque Bera's normality test shows that $JB=0.764088 > 5,991$. Therefore, GDP_ growth follows a normal law.

5-Discussion:

The study's results, which explore the impact of R&D spending on economic growth in South Korea, show important insights into the dynamics of innovation-driven investments and their long-term economic performance. The results highlight the asymmetric nature of the relationship between R&D spending and GDP growth, suggesting that positive and negative shocks to R&D spending have markedly different effects on economic outcomes.

(R&D) spending

The results of the study show that increased (R&D) spending positively affects long-term GDP growth, as a 1% increase in (R&D) spending is associated with a 0.63% increase in GDP. This finding is consistent with the theory of internal growth, particularly the models proposed by Romer

(1990), which emphasize the role of knowledge and technological innovation as key factors in driving economic growth. In the Southern Korea, as the economy moved from agriculture to a technological industrial powerhouse, continuous investment in research and development was crucial in maintaining technological progress and maintaining competitive advantages in the global market.

However, the study also reveals that negative shocks to (R&D) spending have a disproportionately negative impact on GDP, with a 1% reduction in (R&D) spending leading to a 3.04% decline in GDP. This significant difference suggests that the economy is highly sensitive to (R&D) investment cuts, which can have cascading effects on technological innovation, productivity, and overall economic performance. The severe impact of R&D spending cuts can be explained through the lens of the Keynesian multiplier effect, where investment cuts lead to a larger-than-relative decline in economic production due to reduced productive and innovative capacity.

The findings of this study are in line with previous research on the connection between R&D spending and economic growth, particularly in advanced economies. For example, Sokolov-Mladenović et al. (2016) showed that increased R&D spending as a percentage of GDP is associated with higher economic growth rates in the European Union (EU28), especially during periods of economic volatility. The study emphasizes Southern Korea that investment in R&D is crucial to sustaining long-term economic growth, especially in technologically advanced economies where innovation drives productivity.

Moreover, the study's findings are also consistent with those of research conducted in other emerging economies, such as Turkey, where Bozkurt (2015) Recognized a positive causal connection between R&D spending and GDP growth. However, the magnitude of the impact observed in Southern Korea highlights the unique role of (R&D) in economies that have successfully leveraged innovation to transition to high-income status. The greater negative impact of (R&D) spending cuts observed in Southern Korea may be indicative of the country's heavy reliance on continuous innovation to maintain its economic model, making it more vulnerable to R&D investment fluctuations.

The asymmetric effects of R&D spending on GDP growth include important implications for the economic policy of Southern Korea. Findings suggest that maintaining or increasing R&D investment is essential to ensure stable economic growth. Therefore, policymakers should prioritize protecting and expanding R&D budgets, even during economic downturns, to avoid the disproportionate negative effects that R&D spending cuts may have on the economy.

In addition, the results of the study support the case in favor of targeted public sector interventions to complement private sector R&D efforts, as proposed by Szarowská (2017) in the context of the EU. In the southern Korea, where research and development in the private sector is significant, public investment can play a stabilizing role, especially during periods of economic uncertainty when private investment may decline. This dual approach can help mitigate the risks associated with the observed divergence and ensure that R&D continues to drive long-term economic growth.

Gross Fixed Capital Formation (GFCF)

The results of the study show that fixed gross capital formation (GFCF) Has a substantial effect on GDP growth in South Korea, both in the long and short term. Specifically, in the long run, a 1% rise in GFCF is associated with a nearly 0.63% increase in GDP, while a 1% decrease in GFCF leads to a 0.53% decrease in GDP. These findings indicate that capital formation, including

investments in physical assets like infrastructure, machinery, and buildings, is crucial for economic growth.

From the perspective of economic theory, this finding is in line with the neoclassical growth model, which emphasizes the role of capital accumulation in enhancing productive capacity. Investments in physical capital increase the economy's ability to produce goods and services, leading to growth. In the context of Southern Korea, which has experienced rapid industrialization, continued investments in capital formation have been key to maintaining its competitive advantage in the manufacturing and technology sectors.

However, the marked variation—where positive changes in GFCF have a slightly stronger impact on GDP than negative changes—suggests that the economy benefits greatly from increased capital investments, but may also be able to withstand declines in GFCF. This resilience may be attributed to other growth factors, such as technological advances or high levels of already existing infrastructure that continue to support economic activity even during periods of low investment.

The results of the current study regarding the positive impact of fixed gross capital formation (GFCF) on economic growth are consistent with many previous studies highlighted in the literature. For example, the study of Sokolov-Mladenović et al. (2016) in the economies of the European Union (EU28) showed that investments in physical capital contribute significantly to economic growth. This consensus suggests that the GFCF's role as a key driver of economic performance is consistent across various economic contexts, including Southern Korea.

Furthermore, the study by Bošnjak (2018), which examined the impact of government spending, including infrastructure investments, in Slovenia and Croatia supports the findings of the current study. Bošnjak found that investments in capital are essential to sustain economic growth, particularly in emerging economies. The positive but asymmetric impact of GFCF observed in Southern Korea is in line with these findings, underscoring the importance of capital formation in promoting long-term economic stability.

domestic credit to the private sector (DCP)

Analysis related to domestic credit to the private sector (DCP) reveals a positive correlation with long-term GDP growth. A 1% rise in DCP is associated with a 0.19% increase in GDP, this suggests that the availability of credit plays a supportive role in economic expansion. This relationship can be explained by the theory of financial evolution, which assumes that increasing credit to the private sector facilitates investment, consumption, and entrepreneurship, thereby boosting economic activity.

Interestingly, the study finds that negative changes in DCP Do not substantially influence GDP growth. This suggests that while the expansion of credit availability contributes positively to economic growth, a decline in credit does not immediately translate into a proportionate economic downturn. This may be due to factors such as strong financial institutions, government interventions, or the ability of firms to access alternative sources of financing during periods of credit contraction.

The symmetrical effect of positive and negative changes in DCP on GDP growth, as the study noted, suggests that the economy responds similarly to expansions and contractions in credit availability. This symmetry may reflect a well-developed financial system in the South Korea that can absorb shocks and maintain stability even when credit conditions tighten.

For domestic private sector credit (DCP), the results of the current study are also in line with previous research. For example, Choi and Cho (2023) examined the relationship between financial

development and economic growth in Southern Korea and found that the availability of credit positively affects growth. This is consistent with the current study's finding that increasing DCP leads to higher GDP growth in the long run.

In addition, Bayraktar et al. (2022), which explored the role of financial development in BRICS-T countries, supports the idea that expanding credit to the private sector is good for economic growth. However, the slight impact of negative changes in DCP observed in the current study is comparable to the results of studies such as Szarovska (2017), where government interventions helped mitigate the negative effects of credit contraction in the private sector during economic recessions. This divergence highlights the importance of a strong financial sector that can absorb shocks and maintain stability, which the Southern Korea seems to have achieved equilibrium.

The results of the study on GFCF and DCP highlight their critical roles in driving economic growth in Southern Korea. The positive impact of capital formation indicates the need for policies that encourage continued investment in infrastructure and other productive assets. Given the slightly stronger impact of positive changes in GFCF on GDP, it is essential to maintain a stable investment environment that supports continued capital accumulation.

Similarly, the positive correlation between DCP and GDP growth suggests that ensuring an adequate flow of credit to the private sector is vital to maintaining economic momentum. Policymakers should focus on maintaining a healthy financial sector that provides sufficient credit to businesses and consumers, while maintaining its resilience to deflations in credit availability.

6-Conclusion:

This study provided a comprehensive analysis of the impact of R&D spending on economic growth in Southern Korea, highlighting the critical role that innovation-driven investments play in shaping the trajectory of the national economy. The results showed the asymmetric effects of R&D spending, with increases in R&D spending significantly boosting GDP growth, while cuts in R&D spending lead to much greater economic downturns. Reinforces this investment sensitivity In research and development, there is a need for a continuous and even increased focus on innovation to ensure long-term stability and economic growth.

In addition, the study demonstrated the importance of fixed gross capital formation (GFCF) and domestic credit to the private sector (DCP) in supporting economic expansion. Investments in physical capital and the availability of credit show that they are essential components of a strong economic growth strategy. The resilience of the South Korean economy to changes in these factors highlights the strong foundation of the economy, supported by a well-developed financial system and strong infrastructure.

The findings of this study are consistent with and expanded on previous research, providing valuable insights into the dynamics of the South Korea economy. Policymakers are advised to prioritize R&D spending, maintain a stable investment environment, and ensure a healthy flow of credit to the private sector to support and promote economic growth. By addressing these areas, South Korea can continue to thrive as a leader in technological innovation and economic development.

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Appendices:

You can view all the appendices through the following link:

<https://drive.google.com/file/d/1k3MEQYqqTQfO4LeLEDo3gCJaEeVq88Z2/view?usp=sharing>