"R&D expenditure and its macroeconomic effects: A comparative study of Israel and South Caucasus countries"

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NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
37	3	5

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R&D EXPENDITURE AND ITS MACROECONOMIC EFFECTS: A COMPARATIVE STUDY OF ISRAEL AND SOUTH CAUCASUS COUNTRIES

Abstract

The impact of research and development (R&D) expenditure is crucial for understanding contemporary economic development strategies. This study investigates the relationship between R&D spending as a percentage of GDP and economic growth, focusing on the South Caucasus countries (Azerbaijan, Georgia, and Armenia) and Israel, which is notable for its substantial R&D expenditure (5.71% of GDP in 2020). The objective is to evaluate the impact of R&D expenditure on economic development through the application of rigorous empirical methods. By employing a quantitative approach, this study aims to offer a detailed analysis of the impact of R&D investment on economic growth across various countries. Ordinary least squares (OLS) regression analyzes the association between R&D expenditure and GDP levels. Granger causality tests are utilized to investigate the causal relationships. The results demonstrate a significant positive relationship between R&D expenditure and GDP across all studied countries. Furthermore, the analysis reveals that GDP growth stimulates increased R&D investments in Azerbaijan and Armenia, as evidenced by Granger causality tests. To sum up, this paper underscores the critical role of R&D spending in driving economic development and highlights the necessity for policy initiatives focused on strengthening R&D frameworks.

Keywords	R&D expenditures, economic growth, finance, econometrics, GDP, South Caucasus countries, Israel
JEL Classification	A12, I25, I28, O32

INTRODUCTION

R&D is indeed a cornerstone, directing global progress and exerting substantial influence on the international stage. In the current era, it serves not only as the primary catalyst for societal advancement but also plays an essential role in driving economic growth. This underscores the indispensable nature of scientific research in fostering meaningful development. The intrinsic and proportional relationship between the foundational concepts of R&D highlights their crucial role in shaping the trajectory of societal evolution.

In Israel, the core of R&D efforts is concentrated within prominent universities alongside numerous state and non-state research centers. The dynamic research landscape is further enriched by the significant contributions of innovative individuals, scientists, and entrepreneurs. Financial support for scientific endeavors is derived from diverse sources, including governmental allocations and contributions from private entities such as investors, institutions, and individual patrons. The importance of science and technology is underscored by their capacity to generate substantial benefits commensurate with the level of

emphasis placed on them. Similar to technology, R&D has the potential for significant transformation, where a relatively modest initial expenditure can yield substantial returns.

On a global scale, the primary challenge related to R&D is the disparity in expenditure and resource allocation among countries, which perpetuates economic inequalities and impedes collective progress. While advanced economies like Israel can utilize substantial R&D investments to spur innovation and economic growth, many developing countries face difficulties in allocating adequate resources for research initiatives. This global imbalance restricts the dissemination of scientific knowledge and technological advancements, thereby limiting opportunities for inclusive global development. Addressing this issue requires international cooperation, equitable funding mechanisms, and supportive policies to ensure that the transformative benefits of R&D are accessible to all nations, thereby fostering a more balanced and prosperous global society.

Global R&D expenditures have escalated to nearly USD 1.7 trillion, with about 10 countries accounting for 80% of this investment (UNESCO, 2023). In alignment with the Sustainable Development Goals (SDGs), countries have committed to significantly augmenting both public and private R&D investments and expanding the researcher workforce by 2030. This commitment is essential for fostering innovation, driving economic growth, and addressing global challenges such as climate change, public health, and sustainable development.

Investments in scientific research are distinguished by their cleanliness, transparency, and forward-looking nature. Capital directed toward scientific endeavors is renowned for its exponential growth, yielding surplus returns on a significant scale. Countries that allocate more than 2% of their GDP to scientific research typically demonstrate elevated technological potential and foster dynamic, innovative economies (Hasanov, 2021). The global landscape unequivocally illustrates that most countries wielding hegemonic economies in today's world allocate a higher percentage of their resources to scientific research.

Israel, alongside the Caucasus region, is a focal point of the study, owing to its status as the world's leading nation in R&D expenditure. In comparison, R&D expenditure in the Caucasus countries remains relatively low. There is a need to determine the importance of R&D and scientific investment as vital contributors to economic growth, particularly for developing countries. This analysis holds significance as it seeks to ascertain if increased R&D expenditure is associated with economic advancement in these regions. Such insights are crucial for guiding policy formulation and investment strategies to foster sustainable economic development through advancements in scientific knowledge.

1. LITERATURE REVIEW

The relationship between R&D expenditures and economic growth has been extensively analyzed, revealing its differential effects across various income levels and regions. Research typically shows that while R&D investments generally promote economic growth, this effect is more pronounced in high-income countries, with differing outcomes observed in developing nations over time. Inekwe (2015) explored the impact of R&D expenditures on economic growth in 66 developing countries, distinguishing between high and low average income levels during the period from 2000 to 2009.

Utilizing the generalized method of moments, the study demonstrated that R&D spending positively affects economic growth in high-middle-income countries but does not show the same effect in low-middle-income countries. Additionally, the influence of R&D expenditures varies between short-term and long-term horizons.

In a similar vein, Tung and Hoang (2024) investigated the effects of R&D spending on economic growth in 29 developing countries from 1996 to 2019, employing cointegration tests. Their results established a long-term relationship between economic growth and R&D investment,

while also noting that capital accumulation and education contribute positively to growth, whereas corruption has a detrimental effect. The findings suggest that enhancing R&D spending is essential for developing countries to achieve economic parity with more advanced nations. Kaur and Singh (2016) conducted a study on the impact of R&D expenditure on economic growth across 23 developing countries from 1991 to 2010. Their panel analysis, using both fixed and random effects models, revealed that R&D investments have a positive effect on GDP per capita, primarily by driving innovation, which in turn boosts productivity and economic growth.

Celli et al. (2021) evaluated R&D expenditures within the context of the European Union's Regional Policy, focusing on less developed regions. Their study found that this policy positively influences economic growth in these regions. In contrast, Yüksel (2017) analyzed the relationship between R&D expenditures, exports, and economic growth in 28 EU countries from 1996 to 2014. The study found no significant relationship between R&D spending and economic growth but identified a causal link between R&D investment and exports, highlighting the nuanced and multifaceted effects of R&D on economic outcomes. Table 1 provides a summary of various research studies that examine the relationship between R&D and economic development.

A thorough analysis of multiple studies on the macroeconomic effects of R&D expenditures reveals that R&D significantly improves overall productivity by advancing technology, fostering innovation, and increasing knowledge and skills. However, the impact of R&D investments varies between countries due to differences in development and investment levels, making it important to conduct a comparative examination of economies with diverse conditions, such as the South Caucasus countries and Israel.

The central objective of this paper is to highlight the critical role of scientific research in the economic development of the chosen countries. Several research hypotheses have been proposed to examine the relationship between R&D expenditure and economic outcomes:

H1: *How does R&D spending in Israel influence key macroeconomic indicators such as economic growth and the unemployment rate?*

H2: *To what extent does R&D expenditure in the South Caucasus contribute to economic growth?*

Table 1. Brief overview of studies on R&D and economic development

Author (s)	Countries	Main result
Recep and Alabaş (2017)	Turkey	ARDL model examined the relationship between R&D expenditures and economic growth from 1990 to 2014, finding that increased spending on R&D positively influences both short-term and long-term economic growth
Chawla (2020)	18 OECD countries	The study employed feasible generalized least squares modeling to investigate the evolution of R&D expenditures as a share of GDP from 1981 to 2012, revealing that as economic growth progresses, R&D intensity also increases
Blanco et al. (2016)	US	The study finds that R&D expenditures in the private sector from 1963 to 2007 significantly enhanced state output and total factor productivity, with estimated R&D elasticities ranging from 0.056 to 0.143, resulting in returns to state GDP from R&D spending of 82% to 211%, and substantial positive spillovers where 70% to 80% of these returns benefit other states, highlighting varying impacts based on human capital levels and economic development tiers
Tae (2023)	South Korea	The study examines the causal links between public, corporate, and university R&D investments and economic growth in Korea from 1976 to 2020, revealing long-term equilibrium relationships and short-term effects primarily driven by public R&D investment
Szarowská (2018)	8 Eastern European countries	The study found that R&D expenditures, particularly government spending, positively influenced economic growth from 1995 to 2016, alongside contributions from business R&D, higher education in science and education, and economic freedom levels
Wang et al. (2013)	23 OECD countries and Taiwan	The article revealed the impact of R&D spending on economic growth within the high-tech sector from 1991 to 2006. Their findings indicate that R&D expenditures positively affect GDP per capita within the high-tech sector
Goel et al. (2008)	The US	The study analyzed the impact of R&D expenditures on economic growth from 1953 to 2000, finding that federal R&D spending was more effective than local R&D spending

2. METHODOLOGY

This empirical analysis incorporates the human capital-augmented Solow model proposed by Mankiw et al. (1992). By integrating human capital dynamics into the traditional Solow growth framework, this model enables a nuanced exploration of the multifaceted interactions between human capital accumulation and economic growth, reflecting the pioneering insights of Mankiw et al. (1992) in understanding these intricate relationships. Nonneman and Vanhoudt (1996) expanded upon Mankiw et al.'s (1992) model by introducing the incorporation of the R&D to GDP ratio as an additional factor.

Gumus and Celikay (2015) investigated a significant relationship between R&D spending and economic growth and formulated the following functional equation:

$$\Delta GDP = f \begin{pmatrix} \Delta R \& D \; expenditure, \\ Other \; Factors \end{pmatrix}. \quad (1)$$

They analyzed the functional relationship by employing an econometric model estimated on panel data, considering both developing and developed countries and utilizing a logarithmic representation:

$$\ln\left(GDP_{it}\right) = \beta 0 + \beta 1 \cdot \ln\left(R \& D_{it}\right) + u_{it}. \quad (2)$$

Moreover, Shefer and Frenkel (2005) delved into the relationship where investment in R&D leads to the emergence of innovations, thereby stimulating economic growth. They utilized a multiple regression model to evaluate the extent of the correlation between a company's investment in R&D and the factors hypothesized to influence R&D expenditures. The general structure of the regression model utilized in this analysis is expressed as follows:

$$R \& D = f\left(A, \; I, \; C, \; HT, \; T, \; Ex\right), \quad (3)$$

where "R&D" measures research and development activities, "A" represents the firm's age, "I" indicates whether the firm has undertaken innovation in the past three years, "C" denotes the firm's affiliation with a large concern, "HT" specifies whether the firm belongs to the high-tech group rather than the traditional group, "T" refers to the total

annual turnover of the firm, and "Ex" pertains to the total export receipts of the firm. As discernible from the mentioned econometric analyses, it is evident that R&D holds substantial importance in the metrics of economic development, with a particular focus on factors like innovation and the contribution of the human labor force in these analytical frameworks.

Throughout the research endeavor, the goal is to formulate a new model by extrapolating from existing theories and practical instances. To undertake a multiple linear regression analysis in a specific context, the following general formula can be applied:

$$GDP = \beta 0 + \beta_1 R \& D + \beta_2 Unemp + \varepsilon. \quad (4)$$

The annual GDP serves as the dependent variable, reflecting economic changes. Meanwhile, R&D stands as an independent variable representing the expenditure rate on research and development as a proportion of GDP. Additionally, Unemp (Unemployment) is an independent variable signifying another factor influencing the dependent variable. The unemployment rate is a meaningful metric, playing a crucial role in assessing temporal variations and proving valuable for evaluating comparative performance in different scenarios. The annual unemployment rate stands as another distinct economic indicator that correlates with GDP and R&D. The intercept symbolized as $\beta 0$ denotes the constant term, whereas $\beta 1$ and $\beta 2$ signify the coefficients corresponding to each independent variable. The error term ε encompasses unobservable factors that impact the dependent variable. In econometric modeling, it is a standard practice to use the natural logarithm of variables to address non-linearity and facilitate the interpretation of percentage changes. The transformation of the multiple linear regression formula into a log-linear form is as follows:

$$\begin{aligned} Ln\left(GDP\right) &= \beta 0 + \beta_1 \ln\left(R \& D\right) \\ &+ \beta_2 Ln\left(Unemp\right) + \varepsilon. \end{aligned} \quad (5)$$

To underscore the significance of the research maximally, it is crucial to meticulously choose available data from reliable sources. Despite its small size, Israel emerges as a nation with diverse economic facets on the global stage. Specifically, the

advancement of science and research fields in the country stands as a primary factor contributing to Israel's active participation in the global database. The study procured Israel's and South Caucasus countries' annual economic indicators by leveraging data from global institutions and local government bodies, including reputable sources such as the World Bank (2023a), International Monetary Fund (IMF), Central Bureau of Statistics (CBS), ILOSTAT, and Bank of Israel (BOI). The diverse socio-economic indicators within these data platforms not only enhance the empirical robustness but also serve as invaluable reservoirs for conducting meticulous scientific research. Importantly, these platforms are recognized for their reliability in furnishing the necessary data essential for comprehensive economic analyses. It should be noted that the data on R&D expenditures for Azerbaijan, Armenia, and Israel span the period from 1996 to 2021, whereas for Georgia, the data cover the periods from 1996 to 2005 and from 2013 to 2021.

3. RESULTS

The South Caucasus countries have lower R&D expenditures compared to Israel, a discrepancy evident in both the share of R&D expenses relative to GDP and per capita R&D expenditures in current US dollars, with Israel significantly exceeding the South Caucasus nations in both measures (see Figure 1 and Figure 2). The below-average per capita R&D expenditures in the South Caucasus countries have resulted in the limited economic impact of scientific research in these regions. The

substantial gap in R&D spending is also apparent in the development level of their startup ecosystems. For the past four years, Israel has ranked 3rd in the Global Startup Ecosystem Index (GSEI) by Startup Blink, following the United States and the United Kingdom, with a GSEI score of 46,573 in 2023. In contrast, Armenia ranked 57th with 2,521 points, Azerbaijan ranked 84th with 626 points, and Georgia ranked 71st with 1,034 points. The lower per capita R&D expenditures in the South Caucasus countries have led to weaker effects of scientific research on their economies.

In 2022, Israel's economy grew by 6.5% to USD 521.69 billion, with a per capita income of USD 53,195.88, and the high technology sector, accounting for 18.1% of Israel's GDP and 48.3% of total exports in 2022, played a pivotal role as the linchpin of the nation's economic strength (Bajpai, 2023). In The Economist's 2022 assessment, Israel is prominently positioned as the fourth-ranking economy among OECD nations in terms of performance (The Economist, 2022; Wrobel, 2022). Despite the persistent threat of conflicts, Israel's contemporary market economy remains fundamentally robust and dynamic. With an economic freedom score of 68.9, Israel secures the 34th position among the freest economies in the 2023 Index, reflecting a substantial increase of 0.9 points. Notably, Israel is ranked 2nd out of 14 countries in the Middle East/North Africa region, surpassing both global and regional averages in its overall score (Heritage, 2023). In the preceding decade, the global economy expanded by 35%, with Israel contributing 0.3% to this growth when measured
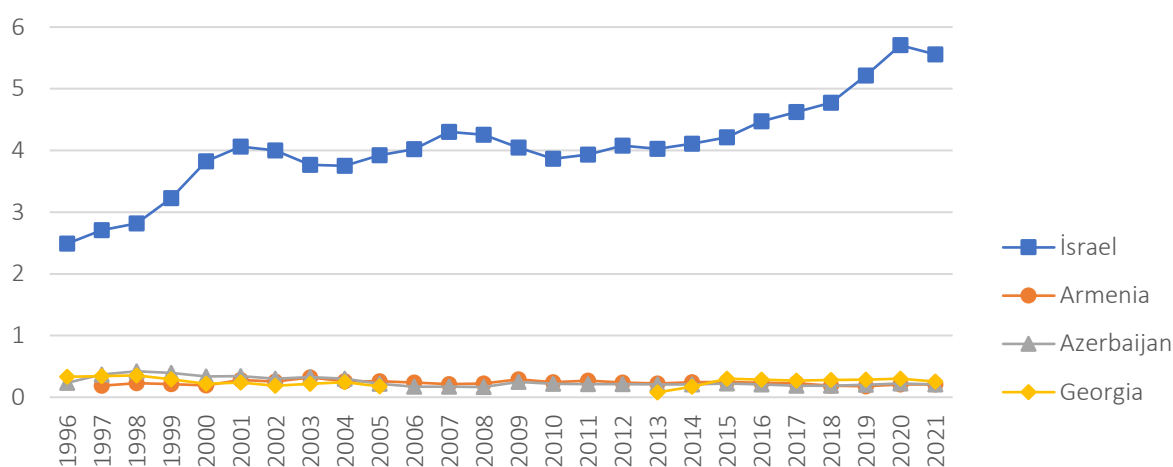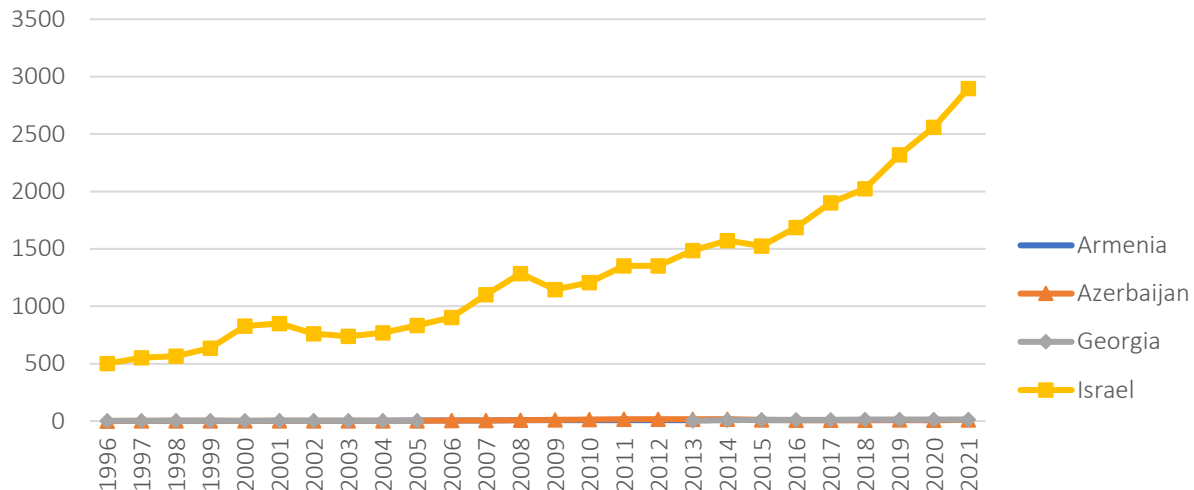

Figure 1. Share of R&D expenses in GDP

Figure 2. R&D expenses per capita

in Purchasing Power Parity terms and accounting for estimates of the informal economy (WER, 2023). The accomplishment of such outcomes in a small and resource-limited country would not have been achievable without the pivotal role of scientific research.

Israel stands as a noteworthy example, establishing a precedent by allocating over 5% of its GDP to scientific research, twice the average. Israel holds the position of the leading country in allocating the highest percentage of its GDP to R&D, reaching 5.71% in 2020. South Korea, the closest competitor to Israel, recorded a figure of 4.8% (UIS, n.d.). This substantial commitment to R&D plays a pivotal role in contributing to Israel's macroeconomic strength, highlighting the nation's impressive capabilities despite its relatively compact size. Even in the world's most powerful economic countries, including the United States, Germany, Japan, and China, expenditures on R&D remain below 4%. Nevertheless, the sheer scale of their economies leads to substantial investment amounts. Substantiated evidence establishes a positive correlation between investments in science and ensuing benefits, which include heightened income, increased influence, and overall prosperity. The greater the allocation of resources to scientific endeavors, the more significant the rewards, reinforcing the indispensable role of R&D in advancing global progress.

Over the past two decades, Azerbaijan's economy has experienced rapid development primarily driven by oil revenues. The country has also made sig-

nificant strides toward sustainable development in sectors such as agriculture (Gulaliyev et al., 2019a), human capital (Gulaliyev et al., 2019b), and renewable energy (Gulaliyev et al., 2020). Moreover, in the last decade, Azerbaijan has established the necessary infrastructure to foster the growth of its startup ecosystem. However, the low allocation of R&D expenditures across Azerbaijan and other South Caucasus countries has exacerbated the "brain drain," leading to a significant emigration of skilled professionals from these nations.

Georgia stands out as the country with the highest index for economic freedom and a favorable business environment in the South Caucasus region. Its GDP is predominantly driven by the non-oil sector. Despite also having limited natural resource rents, Armenia does not significantly differ in per capita income from the other two South Caucasus countries. Both Georgia and Armenia, although their startup ecosystems are not highly developed, are ranked among the top hundred countries in Startup Blink reports.

Table 2 presents the results indicating the stationarity of the time series for GDP (GDPit) and R&D expenditures (R&Dit) in both Israel and the South Caucasus countries. Table 2 shows that both the original series and their logarithms exhibit degrees of integration, specifically I(0) and I(1).

The results indicate that the logarithm of GDP per capita time series for Israel is stationary at all levels above I(1). For Armenia and Georgia, the loga-

Table 2. Time series unit route test

Logarithmic Variables	None		Intercept		Intercept and trends	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Ln(GDP)Azerbaijan	–	+(**)	–	–	–	–
Ln(GDP)Armenia	–	+(**)	–	+(**)	–	–
Ln(GDP)Georgia	–	+(***)	–	+(**)	–	–
Ln(GDP)Israel	–	–	–	+(***)	+(***)	+(***)
Ln(R&D)Azerbaijan	–	+(***)	–	+(**)	–	–
Ln(R&D)Armenia	–	–	–	+(***)	–	+(***)
Ln(R&D)Georgia	–	+(***)	–	+(*)	–	–
Ln(R&D)Israel	–	+(***)	–	+(***)	–	+(***)

rithm of GDP per capita is stationary above I(1) under both the "no intercept and trend" and "with intercept" conditions. In Azerbaijan, stationarity at I(1) is observed only under the "no intercept and trend" condition. Regarding R&D expenditure, stationarity at I(1) is confirmed under the "with intercept" condition for each of these countries. Based on these findings, pairwise regression equations between ln(GDPPC) and ln(R&D) can be considered valid under the conditions of stationarity observed.

The statistical method is used to investigate the relationship between one dependent variable and one or more independent variables. The least squares regression analysis is utilized to explore the correlation between R&D and economic growth in Israel. The econometric analysis was conducted using annual data spanning from 1996 to 2021, primarily sourced from the World Bank (2023b).

According to Table 3, the acquired coefficient for R&D expenditure is 0.775, revealing a positive and statistically significant relationship (p-value < 0.0001). This suggests a direct correlation between the percentage of GDP allocated to research and development expenditures and the overall GDP. To put it differently, a 1% increase in the allocation of GDP to research and development is expected to result in a 0.775% growth in GDP. The obtained coefficient for the unemployment rate is −0.414,

indicating a statistically significant and negative relationship (p-value < 0.0001). This suggests an inverse correlation between R&D expenditure and unemployment. In simpler terms, a 1% increase in R&D expenditure as a percentage of GDP is associated with an anticipated decrease of 0.414% in the unemployment rate. This result aligns with the idea that allocating resources to R&D can spur innovation, thereby facilitating the creation of new employment opportunities.

Figure 3 unequivocally illustrates a consistent upward trajectory in R&D and signals a steadfast commitment to fostering innovation and knowledge-driven advancements within the economy. The simultaneous downward trend in the unemployment rate implies an inverse relationship with the ascending R&D expenditure, suggesting that increased investments in R&D may play a pivotal role in job creation and contribute to a more resilient labor market. This observed correlation not only underscores the positive impact of R&D on employment but also highlights the potential for generating new job opportunities, both directly within R&D-intensive sectors and indirectly through the expansion of industries driven by R&D. The compelling evidence underscores the critical importance of consistent expenditures and investments in R&D as pivotal drivers of both economic growth and employment. This highlights the enduring value of innovation as a key factor in fostering sustained prosperity within an economy.

Table 3. The results of the least squares method

Variable	Coefficient	Std. Error	t-Statistic	p-value
ln(R&D)	0.775	0.108	7.173	0.000
ln(Unempt)	−0.414	0.050	−8.195	0.000
C	25.981	0.230	112.925	0.000
Akaike info cri.	Schwarz cri.	Hannan-Quinn cri.	Durbin-Watson st.	Prob (F-statistic)
−2.073	−1.927	−2.031	1.164	0.000
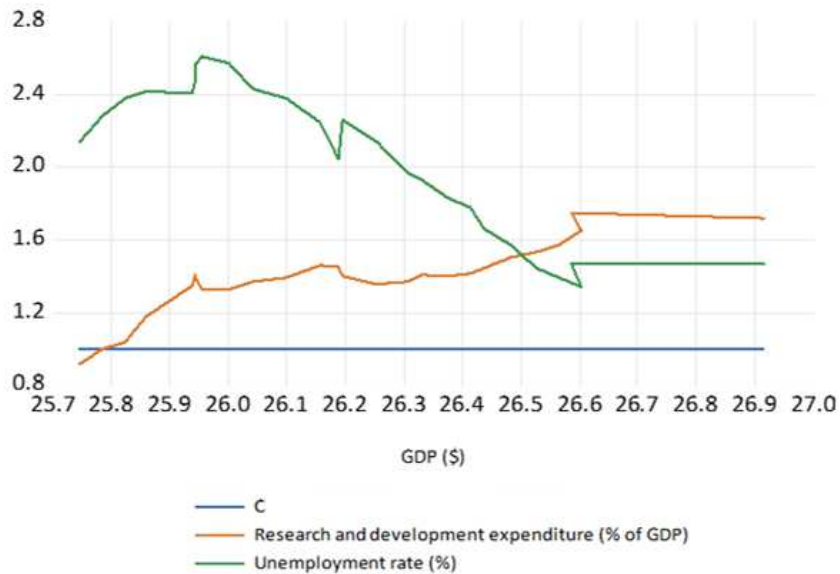
Figure 3. Distinct correlation trend between R&D expenditure and unemployment rate

The study further investigated the effects of the logarithm of R&D expenditure on the logarithm of GDP per capita for the South Caucasus and Israel using a double regression equation. This method determines the impact of R&D spending on economic development in these countries. Table 4 indicates that the effects of R&D expenditure on GDP volume are positive in each of these countries.

The analysis of the relationship between these indicators using the Granger test (Table 5) suggests that an increase in GDP volume leads to an increase in R&D expenditures only in Azerbaijan and Armenia. This is primarily because allocations from the state budget mainly fund R&D expenditures in these countries. The absence of such a relationship in Israel indicates that R&D spending is predominantly financed by private investors. The high value added from other sources in Israel implies a lack of causality in the effects of R&D spending on GDP.

R&D expenditure in Israel significantly influences key macroeconomic indicators, such as economic growth and unemployment rates. The first research question posits that augmented investment in R&D can enhance economic activity and employment outcomes by driving innovation and boosting productivity. The negative causal relationship in Israel indicates that private financing of R&D and high value added from other sectors may dilute the direct impact of R&D spending on GDP.

Table 4. Effects of the logarithm of R&D expenditure on the logarithm of GDP per capita

Statistical measures	Israel	Azerbaijan	Armenia	Georgia
R^2	0.9338	0.959772	0.9712	0.701338
n-observations	26	27	26	27
β_0				
Coeff	−7.876197	5.643114	6.072135	6.416376
Std.eror	0.810940	0.098413	0.063689	0.191261
t-statistics	−9.712425	57.34143	95.33977	33.54772
p-value	0.0000	0.0000	0.0000	0.0000
$\beta 1$				
Coeff	1.453820	1.227035	0.998569	0.862597
Std.eror	0.078991	0.050242	0.035112	0.112581
t-statistics	18.40482	24.42253	28.43976	7.662021
p-value	0.0000	0.0000	0.0000	0.0000
D-W	0.2721	0.8891	1.0983	0.2372

Table 5. Granger causality relationship between LNRD and LNGDPPC

Hypotheses	Israel	Azerbaijan	Armenia	Georgia
LNRD does not Granger Cause LNGDPPC	–	–	–	–
LNGDPPC does not Granger Cause LNRD	–	+(***)	+(**)	–

Note: LNRD means the logarithmic transformation of the variable R&D expenditures. LNGDPPC refers to the logarithmic transformation of the variable GDP per capita.

R&D expenditure in the South Caucasus is hypothesized (the second research question) to positively influence economic growth, with increased expenditures potentially driving development through technological advancements and the creation of new economic opportunities. The causality test indicates that, in Azerbaijan and Armenia, an increase in GDP volume leads to a subsequent rise in R&D expenditures.

4. DISCUSSION

The outcomes suggest a positive association between R&D expenditure and economic growth. Nevertheless, it is imperative to interpret these findings cautiously and acknowledge the limitations inherent in the study. The identified relationship adheres to theoretical expectations, suggesting that augmenting R&D expenditure is associated with fostering economic growth through innovation and technological advancements. However, a judicious interpretation is essential, recognizing the constraints of this study and emphasizing the need for additional research to validate and refine these conclusions. This singular investigation contributes to a larger research framework aiming for a more holistic understanding of the intricate interplay between R&D expenditure and economic growth. Crucial considerations involve the study's limitations, such as the relatively limited country sample and the exclusion of certain factors influencing economic growth. Moreover, it is imperative to exercise caution when attributing causation to correlation; a positive relationship between R&D expenditure and GDP growth does not unambiguously establish a causal link. The presence of other unexplored variables impacting both R&D expenditure and GDP growth underscores the intricate nature of this relationship. In essence, while these findings offer valuable insights, the study underscores the need for a sophisticated and comprehensive research approach to untangle the complexities inherent in this dynamic.

Numerous determinants contribute to the overarching economic development, and it is imperative to consider a myriad of factors that play a role in shaping the economic landscape of Israel. This approach aims to explore additional elements that have the potential to impact and influence the current economic scenario in Israel. Shachmurove's (2019) scholarly inquiry emphasizes that determinants such as immigration, significant capital injections, technological advancements, and the transformative shift from conventional practices of cultivating citrus and polishing diamonds to the integration of cutting-edge technologies all play a substantial role in driving economic development in Israel. Examining the interplay of information and communications technology (ICT) and tourism on per-worker output, Kumar et al. (2019) utilize an augmented Solow framework. Their findings emphasize a noteworthy and favorable long-term association between mobile cellular subscriptions, representative of ICT, and output per worker, highlighting the pivotal contribution of technological progress to sustaining economic growth. Peled (2001) highlights the substantial impacts of defense-related R&D on Israel's industrial sector, emphasizing a reciprocal relationship. Moreover, it played a pivotal role in shaping the higher education system, particularly in science and engineering, leaving a lasting impact on the research community and influencing the composition of the workforce in Israel.

Observations from Israel suggest that heightened investment rates and reductions in defense spending could positively affect economic growth. Nevertheless, Cohen et al. (1996) conducted an exploration into the enduring effects of defense spending, delving into its influence on the broader macroeconomy in Israel. In addition to these considerations, contemporary studies also examine the enduring advantages of sustainability and green criteria for the economy. In a study covering the period 1971–2006, Magazzino (2015) explored the relationship among economic growth, energy

use, and CO_2 emissions in Israel, with unit root tests revealing all variables are integrated of order one, and causality results indicating that real GDP drives both energy use and CO_2 emissions. From a worldwide standpoint, Zenghelis (2012), Wan and Sheng (2022), and Hasanov (2023) have indicated that the incorporation of green principles results in enhanced economic efficiency. These intriguing factors bring attention to the presence of diverse determinants associated with economic growth.

The comparative analysis of the impact of R&D expenditure on GDP per capita in Azerbaijan, Armenia, Georgia, and Israel reveals distinct trends. Israel exhibits the most pronounced positive correlation between R&D spending and GDP per capita, with a robust R-squared value of 0.9338, indicating a strong model fit. Azerbaijan and Armenia also demonstrate significant positive coefficients for R&D expenditure, indicating substantial contributions to economic growth. In contrast, Georgia displays lower R-squared and Durbin-Watson values, suggesting that factors beyond R&D investment may exert greater influence on its GDP dynamics. In general, R&D expenditure exerts a positive influence on GDP per capita in Azerbaijan, Armenia, Georgia, and Israel, although the extent of impact varies due to local economic conditions and funding approaches. These results offer significant insights into the intricate correlation between R&D investment and economic growth across diverse geopolitical settings, emphasizing the critical role of deliberate investments in R&D for fostering sustainable economic development.

CONCLUSION

The objective of this paper was to analyze the effects of R&D expenditure on economic development in Israel and the South Caucasus countries through robust empirical methods. The analysis provides compelling evidence of a significant positive relationship between R&D expenditure (as a percentage of GDP) and current GDP, underscoring R&D investment as a crucial driver of economic prosperity. Additionally, the study highlights the necessity of addressing unemployment challenges in Israel to fully harness the benefits of R&D. Conversely, the findings reveal that R&D expenditures have minimal or negligible effects on GDP volume in the South Caucasus countries. This limited impact is attributed to the relatively small scale of R&D investments and the modest output of high-value innovative products in these countries. As a result, the influence of R&D on GDP through these channels remains minimal.

The analysis confirms the hypothesis that R&D expenditure positively affects both GDP and unemployment. Nevertheless, the study notes the need for further research to confirm these results and addresses the limitation that the analytical approach used does not establish causality. Specifically, the econometric results demonstrate that R&D investment positively impacts economic growth in Azerbaijan and Armenia, highlighting the role of R&D in fostering economic development within the South Caucasus region.

AUTHOR CONTRIBUTIONS

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