“R&D expenditure and nominal GDP growth in Uzbekistan: Exploratory evidence from first difference and distributed lag models”

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R&D EXPENDITURE AND NOMINAL GDP GROWTH IN UZBEKISTAN: EXPLORATORY EVIDENCE FROM FIRST DIFFERENCE AND DISTRIBUTED LAG MODELS

Abstract

This study investigates the association between R&D expenditure and nominal GDP growth in Uzbekistan, where R&D intensity (0.12-0.17% of GDP) falls significantly below global benchmarks. Given the short annual series available (2010–2024, N = 15) and measurement constraints, the findings are presented as exploratory associations rather than established causal effects. The dependent variable is based on GDP at current prices, so the estimated dynamics reflect nominal rather than real output growth, and R&D is measured as a share of GDP, which shares a common component with the dependent variable and may mechanically contribute to a negative association. A robustness check using reconstructed absolute R&D expenditure shows that the negative association persists, mitigating though not eliminating this concern. We apply first-difference and distributed-lag models to address non-stationarity issues indicated by Augmented Dickey–Fuller tests. The results suggest a statistically significant negative association between R&D intensity and nominal GDP growth. The first difference model suggests that a 1% increase in R&D intensity is associated with a 0.19% decrease in nominal GDP growth ($p < 0.05$). The distributed lag model suggests contemporaneous (–0.25%, $p < 0.01$) and one-year lagged (–0.16%, $p < 0.05$) negative associations, with a cumulative two-year association of –0.42%. The best-fitting model explains 68% of the variation in nominal GDP growth. The study concludes that enhancing R&D efficiency, building absorptive capacity, and fostering private sector participation are essential prerequisites for achieving positive returns from R&D investment in transitional economies.

Keywords R&D expenditure, nominal GDP growth, Uzbekistan, first difference model, distributed lag model, transitional economy

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INTRODUCTION

Research and development (R&D) has become a central driver of sustainable economic growth in the contemporary global economy, serving as a primary catalyst for technological advancement, productivity gains, and international competitiveness. This recognition is reflected in the scale of global commitment: worldwide R&D expenditure has reached nearly USD 1.7 trillion, and, in alignment with the Sustainable Development Goals, countries have pledged to expand both public and private research investment and enlarge the researcher workforce by 2030 (UNESCO, 2023). R&D is thus widely regarded as indispensable not only for national prosperity but also for addressing shared challenges such as climate change, public health, and sustainable development.

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Yet the global landscape of R&D investment is profoundly uneven. Approximately ten countries account for around 80% of all R&D spending, with innovation leaders such as Israel allocating more than 5% of GDP to research, over twice the global average, while many developing economies invest below 0.5% of GDP. This concentration restricts the diffusion of scientific knowledge and technological capability, narrowing the opportunities for inclusive development in lower-income and transitional economies and raising a fundamental question about whether modest research investment can generate the returns observed in advanced economies.

Uzbekistan epitomizes this tension. Over the past decade, the country has undergone rapid economic transformation, with nominal GDP rising from 88.1 trillion soums in 2010 to over 1,535 trillion soums in 2024, accompanied by market-oriented reforms and deeper integration into the global economy. Over the same period, however, R&D expenditure has remained persistently low, averaging only 0.12–0.17% of GDP, well below the levels of innovation-driven economies and even below those of comparable transitional economies. This combination of dynamic growth and minimal research intensity makes Uzbekistan a revealing case for examining how, and whether, R&D shapes economic performance in a transitional setting.

The broader scientific question motivating this study concerns the effectiveness of R&D investment in promoting growth in economies operating far below global research benchmarks. Although the theoretical case for positive R&D effects is well established, the strength and even the direction of this relationship may depend on the absolute level of investment, the public-private composition of research, absorptive capacity, institutional quality, and human capital. These mediating conditions are especially salient in post-Soviet Central Asian economies, which combine a legacy of centralized research systems with ongoing institutional transition and remain almost absent from the empirical literature. Clarifying the R&D and growth nexus in this context is therefore essential to designing science and technology policies that can translate research investment into sustainable economic development.

Two important caveats define the scope of this study from the outset. First, the analysis is explicitly exploratory: it rests on a short annual series of fifteen observations (2010–2024), which limits statistical power and the number of controls that can be included. Second, due to data availability, the dependent variable is constructed from GDP at current prices, so the study examines the association between R&D intensity and nominal GDP growth rather than real economic growth, while the R&D variable is expressed as a share of GDP and therefore shares a common component with the dependent variable. Accordingly, the results should be interpreted as exploratory associations that motivate further research with real output measures and longer time series, rather than as definitive causal estimates.

1. LITERATURE REVIEW

The relationship between research and development (R&D) expenditure and economic growth has been a subject of extensive academic inquiry, particularly following the emergence of endogenous growth theories in the 1980s and 1990s.

The theoretical basis for understanding the relationship between R&D and economic growth originates from neoclassical and endogenous growth theories. The seminal work of Solow (1956) established the neoclassical growth model, which attributed long-run economic growth primarily to exogenous technological progress. While this model provided valuable insights into capital accumulation and convergence, it treated technological change as an unexplained residual.

The limitations of the neoclassical approach motivated the development of endogenous growth theory. Romer (1986) introduced a model where knowledge accumulation drives long-run growth, emphasizing the role of increasing returns to scale from knowledge spillovers. Subsequently, Romer (1990) developed a more explicit model of endogenous technological change, where R&D activities by profit-maximizing firms generate new ideas that drive sustained economic growth. In this framework, R&D investment directly contributes to the stock of knowledge, which in turn enhances productivity and output.

Lucas (1988) extended the endogenous growth framework by incorporating human capital as a key driver of economic growth. His model emphasized the complementarity between human capital accumulation and technological progress, suggesting that countries with higher levels of education and skills are better positioned to benefit from R&D investments.

Aghion and Howitt (1992) proposed a Schumpeterian growth model based on creative destruction, where innovations by entrepreneurs render previous technologies obsolete. This model highlights the dynamic nature of technological progress and the role of R&D in generating productivity-enhancing innovations. Similarly, Grossman and Helpman (1991) developed models linking R&D, innovation, and international trade, demonstrating how R&D investments in one country can generate spillovers that benefit other economies.

Building on these theoretical foundations, Mankiw et al. (1992) augmented the Solow model by incorporating human capital, improving its explanatory power for cross-country growth differences. Nonneman and Vanhoudt (1996) further extended this framework by adding R&D as a separate factor of production, providing a more comprehensive model for analyzing the determinants of economic growth in OECD countries.

The empirical literature on R&D and economic growth in developed economies generally supports a positive relationship. Griliches (1979) pioneered the econometric analysis of R&D productivity, establishing methodological foundations that continue to influence research in this field. His subsequent work (Griliches, 1992) examined the relationship between R&D and patent statistics, demonstrating that R&D investments translate into measurable innovation outputs.

Coe and Helpman (1995) investigated international R&D spillovers among 22 developed countries, finding significant positive effects of both domestic and foreign R&D capital stocks on total factor productivity. Their results highlighted trade as a channel for technology diffusion and the substantial spillover benefits of R&D investments in major economies.

Guellec and van Pottelsberghe de la Potterie (2004) analyzed the impact of R&D on productivity growth in 16 OECD countries from 1980 to 1998. They found that business R&D, public R&D, and foreign R&D all contribute positively to productivity growth, with estimated elasticities varying across countries and time periods. Their findings suggest that the returns to R&D investment are substantial but heterogeneous.

Griffith et al. (2004) examined the role of R&D in both innovation and technology absorption, using data from 12 OECD countries. They found evidence of a "two faces of R&D" hypothesis, whereby R&D stimulates innovation in technologically advanced countries while facilitating catch-up in countries further from the technological frontier.

Jones (1995) critically examined R&D-based growth models, noting that despite substantial increases in R&D inputs over time, growth rates in developed economies have remained relatively stable. This finding, sometimes called the "Jones critique," suggests that the relationship between R&D and growth may be more complex than simple endogenous growth models predict.

In the United States context, Goel et al. (2008) analyzed the impact of R&D expenditures on economic growth from 1953 to 2000, distinguishing between federal and local R&D spending. Their findings indicated that federal R&D spending was more effective than local R&D spending in promoting economic growth, suggesting the importance of scale and coordination in R&D activities.

Blanco et al. (2016) examined R&D expenditure and economic growth across US states from 1963 to 2007, finding that private sector R&D significantly enhanced state output and total factor productivity. Their estimated R&D elasticities ranged from 0.056 to 0.143, resulting in returns to state GDP from R&D spending of 82% to 211%, with substantial positive spillovers to other states.

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Research on European countries has yielded mixed findings regarding R&D and growth relationships. Freimane and Bāliņa (2016) investigated the impact of R&D expenditure on economic growth in EU member states, finding significant positive effects in Western European countries but weaker or insignificant effects in newer member states from Central and Eastern Europe.

Szarowská (2018) analyzed R&D expenditures and economic growth in eight Eastern European countries from 1995 to 2016. The study found that R&D expenditures, particularly government spending, positively influenced economic growth, alongside contributions from business R&D, higher education in science and engineering, and economic freedom levels.

Silaghi et al. (2014) examined the relationship between R&D and economic growth in Central and Eastern European countries, finding that the impact of R&D varies significantly depending on the level of economic development and institutional quality. They emphasized that the effectiveness of R&D spending depends on complementary factors such as human capital and governance.

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 the EU's regional policy positively influences economic growth in these regions, suggesting that targeted R&D investments can help reduce regional disparities.

Yüksel (2017) analyzed the relationship between R&D expenditures, exports, and economic growth in 28 EU countries from 1996 to 2014. Notably, the study found no significant direct relationship between R&D spending and economic growth but identified a causal link between R&D investment and exports, highlighting the indirect channels through which R&D may affect economic performance.

The literature on R&D and economic growth in developing economies presents a more nuanced picture, with findings varying considerably across countries and time periods. Inekwe (2015) examined the impact of R&D expenditures on economic growth in 66 developing countries from 2000 to 2009, distinguishing between high- and low-income levels. Using 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.

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 convergence with more advanced nations.

Kaur and Singh (2016) studied the impact of R&D expenditure on economic growth across 23 developing countries from 1991 to 2010. Their panel analysis, using fixed- and random-effects models, found that R&D investments positively affect GDP per capita, primarily by driving innovation, which in turn boosts productivity and economic growth.

More recent evidence further suggests that R&D investment does not automatically translate into stronger economic growth in developing economies. Fayyaz and Bartha (2025), examining 32 lower-middle-income countries, found that although R&D contributes positively to innovation, neither R&D nor innovation exerts a statistically significant direct effect on economic growth. Their findings indicate that the economic returns to research investment may remain constrained when the broader institutional and innovation ecosystem is insufficient to translate innovative activity into sustained economic performance.

Coccia (2009) analyzed the relationship between R&D investment and economic performance across countries at different development levels. The study found that the impact of R&D on growth is contingent upon a country's absorptive capacity, including factors such as human capital, institutional quality, and technological infrastructure.

Pessoa (2010) provided a comprehensive review of the R&D and economic growth literature, emphasizing that while the theoretical case for positive R&D effects is strong, empirical evidence is mixed, particularly for developing economies. The review highlighted measurement issues, reverse causality concerns, and the importance of complementary factors in mediating the relationship between R&D and growth.

Research on Asian economies has documented varied experiences with R&D and economic growth. Choi and Cho (2023) examined the causal links between public, corporate, and university R&D investments and economic growth in South Korea from 1976 to 2020. The study revealed long-term equilibrium relationships and short-term effects primarily driven by public R&D investment, highlighting the important role of government in coordinating national R&D efforts.

Wang et al. (2013) analyzed the heterogeneous effects of high-tech industrial R&D spending on economic growth in 23 OECD countries and Taiwan from 1991 to 2006. Their findings indicated that R&D expenditures positively affect GDP per capita within the high-tech sector, suggesting that the sectoral composition of R&D matters for economic outcomes.

Kumar et al. (2019) examined the effect of information and communications technology (ICT) and tourism on economic growth in Israel using an augmented Solow framework. Their findings emphasized 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.

In the Middle East context, Peled (2001) analyzed the impact of defense-related R&D on Israel's industrial sector and found a substantial reciprocal relationship. The study highlighted how defense R&D played a pivotal role in shaping the higher education system, particularly in science and engineering, and influenced the composition of the workforce in Israel.

Shachmurove (2019) examined the determinants of economic growth in Israel, emphasizing that factors such as immigration, significant capital injections, technological advancements, and the transformative shift from conventional practices to cutting-edge technologies all contributed to Israel's remarkable economic development. The study highlighted R&D as a key factor in Israel's transition to an innovation-driven economy.

The literature on R&D and economic growth in post-socialist and transition economies is particularly relevant for understanding the Uzbekistan context. Pop Silaghi et al. (2014), using dynamic panel estimation for Central and Eastern European countries, found that the growth effects of R&D expenditure vary considerably according to the source of research funding. Their results showed that business-sector R&D expenditure contributes positively to economic growth, whereas public-sector R&D expenditure does not exhibit a statistically significant growth effect. These findings suggest that the economic returns to R&D in transition economies depend not only on the overall level of research expenditure but also on its composition and the capacity of the economy to transform research investment into productive outcomes.

The findings of Pop Silaghi et al. (2014) are particularly instructive for understanding the challenges facing transition economies. Their analysis of Central and Eastern European countries demonstrates that the growth effects of R&D depend substantially on the sector in which research activities are undertaken. While business-sector R&D expenditure was found to have a positive effect on economic growth, public-sector R&D did not generate a statistically significant growth effect. This distinction highlights the importance of the structure and effectiveness of R&D investment, suggesting that increasing research expenditure alone may be insufficient unless such investment is effectively translated into commercially and economically productive activities.

Tarı and Alabaş (2017) employed an ARDL model to examine the relationship between R&D expenditures and economic growth in Turkey from 1990 to 2014, finding that increased spending on R&D positively influences both short-term and long-term economic growth. This finding suggests that the positive R&D-growth relationship can be observed in upper-middle-income transitional economies with sufficient investment levels.

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Chawla (2020) employed feasible generalized least squares modeling to investigate the evolution of R&D expenditures as a share of GDP in 18 OECD countries from 1981 to 2012, revealing a bidirectional relationship where economic growth progress also increases R&D intensity. This finding highlights the potential for reverse causality in the R&D and growth relationship.

Several studies have examined whether the relationship between R&D and economic growth exhibits threshold effects or non-linearities. Hasanov (2023) noted that countries allocating more than 2% of their GDP to scientific research typically demonstrate elevated technological potential and foster dynamic, innovative economies. This suggests a potential threshold below which R&D investments may not generate significant growth effects.

The global landscape illustrates that most countries with hegemonic economies allocate a higher percentage of their resources to scientific research. Israel, the world leader in R&D intensity, allocates over 5% of its GDP to R&D, followed by South Korea at 4.8% (UNESCO Institute of Statistics, n.d.). In contrast, most developing countries invest less than 1% of GDP in R&D, potentially below the threshold required for positive growth effects.

Keller (2004) examined international technology diffusion and its role in economic growth, finding that the benefits of R&D depend significantly on a country's ability to absorb and utilize foreign technologies. Countries with weak absorptive capacity may not benefit from R&D investments to the same extent as technologically advanced economies.

The composition of R&D spending (whether public or private, basic or applied) may significantly influence its economic effects. Gumus and Celikay (2015) examined the relationship between R&D expenditure and economic growth, finding that the effectiveness of R&D varies depending on its composition and the economic context.

Shefer and Frenkel (2005) investigated the determinants of R&D investment at the firm level, finding that factors such as firm age, innovation history, high-tech sector affiliation, and export activity significantly influence R&D spending decisions. Their findings suggest that firm-level characteristics mediate the relationship between R&D and economic outcomes.

Cohen et al. (1996) explored the long-term effects of defense spending on the Israeli macroeconomy, finding complex relationships between defense R&D, civilian innovation, and economic growth. Their research highlights the importance of considering sectoral spillovers when evaluating R&D impacts.

Recent literature has expanded to consider the relationship between R&D, environmental sustainability, and economic growth. Magazzino (2015) explored the relationship among economic growth, energy use, and CO_2 emissions in Israel from 1971 to 2006, finding that real GDP drives both energy use and CO_2 emissions. This evidence highlights the importance of green R&D in achieving sustainable growth.

Zenghelis (2012) argued that green investment and innovation are crucial for restoring economic confidence and promoting sustainable growth. The study emphasized that R&D directed toward clean technologies can generate both environmental and economic benefits.

Wan and Sheng (2022) examined the relationship among green investment, clean energy consumption, carbon emissions, and economic growth in China, finding complex interdependencies that highlight the role of targeted R&D in achieving sustainable development goals.

Hasanov (2023) investigated the environmental and economic benefits of revolutionary inert anode technology in aluminum production, demonstrating how technological innovation resulting from R&D can simultaneously improve environmental outcomes and economic efficiency.

Despite the extensive literature on R&D and economic growth, significant gaps remain in our understanding of this relationship in Central Asian economies, particularly Uzbekistan. Existing research has largely focused on developed economies, with limited attention to transitional economies in the post-Soviet space.

The literature reveals several important patterns: (1) the R&D-growth relationship is generally positive in developed economies with high R&D intensity; (2) the relationship is weaker or insignificant in many developing countries; (3) threshold effects and absorptive capacity constraints may explain the heterogeneous findings; and (4) the composition of R&D and institutional factors mediate its economic effects.

This study contributes to the literature by providing empirical evidence on the R&D-growth relationship in Uzbekistan, a transitional economy with distinct characteristics including low R&D intensity, a predominantly state-controlled research sector, and ongoing economic reforms. By employing first difference and distributed lag models, the study captures both short-run dynamics and potential delayed associations between R&D intensity and nominal GDP growth, addressing methodological limitations of previous research.

The findings can fill the empirical gap on Central Asian economies and also provide policy-relevant insights for countries at similar stages of development seeking to leverage R&D investments for economic growth.

This study aims to examine the short-run and delayed associations between R&D intensity and nominal GDP growth in Uzbekistan over the period 2010–2024 using first-difference and distributed lag models.

2. METHOD

The study uses annual time series data for Uzbekistan from 2010 to 2024, comprising 15 observations. This period was selected based on data availability and represents a significant era of economic transformation in Uzbekistan, including market-oriented reforms and increased integration into the global economy. The data were obtained from multiple authoritative sources to ensure reliability and consistency. Table 1 presents the data sources for each variable.

The study employs three main variables to examine the R&D-growth nexus. Table 2 provides detailed descriptions of the variables used in the analysis.

Two measurement features of the variables should be emphasized. First, because GDP is measured at current prices, the first difference of its logarithm, D(LN_NGDP), approximates the growth rate of nominal rather than real output; over the study period, nominal dynamics in Uzbekistan were substantially affected by inflation, exchange rate adjustments, and statistical revaluations. Second, R&D is measured as a share of GDP, so its log-difference captures changes in R&D intensity rather than in absolute research spending; since GDP appears in the denominator of this ratio and also underlies the dependent variable, a mechanical negative association between the two series can arise.

All variables were transformed into natural logarithms to achieve several objectives: (1) to lin-

Table 1. Data sources

Variable	Description	Source
NGDP	Nominal Gross Domestic Product at current prices (billion soums)	State Statistics Committee of Uzbekistan
R&D	Research and Development expenditure (% of GDP)	State Statistics Committee of Uzbekistan
UNEMP	Unemployment rate (%)	State Statistics Committee of Uzbekistan, ILOSTAT

Table 2. Variable definitions

Variable	Symbol	Definition	Unit
Gross Domestic Product	NGDP	Total economic output at current (nominal) prices	Billion soums
R&D Expenditure	RD	Research and development expenditure as percentage of GDP	% of GDP
Unemployment Rate	UNEMP	Share of labor force that is unemployed	%
Log of nominal GDP	LN_NGDP	Natural logarithm of nominal GDP	–
Log of R&D	LN_RD	Natural logarithm of R&D	–
Log of Unemployment	LN_UNEMP	Natural logarithm of UNEMP	–

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earize potentially non-linear relationships, (2) to reduce heteroskedasticity, (3) to interpret coefficients as elasticities, and (4) to stabilize variance in the time series.

To capture the potential delayed associations between R&D expenditure and nominal GDP growth, distributed lag models were estimated. Economic theory suggests that R&D investments require time to translate into productivity gains and economic growth. The distributed lag model allows for both contemporaneous and lagged effects of the explanatory variables.

The general form of the distributed lag model is:

$$\ddot{A}LN\_NGDP_t = \beta_0 + \sum_{i=0}^{k}\beta_{1i}\Delta LN\_RD_{t-i} + \beta_2\Delta LN\_UNEMP_t + \varepsilon_t, \quad (1)$$

where k represents the maximum lag length, and β_{1i} captures the effect of R&D changes i periods ago on current GDP growth.

Specifically, four lag model specifications were estimated:

Lag Model 1

$$\Delta LN\ \underline{\ddot{A}}NG\underline{D}P_t = \beta_0 + \beta_1\quad LN\quad RD_{t-1} + \varepsilon_t. \quad (2)$$

Lag Model 2

$$\Delta LN\_NGDP_t = \beta_0 + \beta_1\Delta LN\_RD_{t-1} + \beta_2\Delta LN\_RD_{t-2} + \varepsilon_t. \quad (3)$$

Lag Model 3

$$\Delta LN\_NGDP_t = \beta_0 + \beta_1\Delta LN\_RD_t + \beta_2\Delta LN\_RD_{t-1} + \varepsilon_t. \quad (4)$$

Lag Model 4

$$\Delta LN\_NGDP_t = \beta_0 + \beta_1\Delta LN\_RD_t + \beta_2\Delta LN\_RD_{t-1} + \beta_3\Delta LN\_UNEMP_t + \varepsilon_t. \quad (5)$$

All statistical analyses were performed using *R* statistical software (version 4.5.0). The following *R* packages were utilized: *lmtest* for diagnostic tests including Durbin–Watson, Breusch–Pagan, and Breusch–Godfrey tests; *sandwich* for Newey–West heteroskedasticity and autocorrelation consistent (HAC) standard errors; and *tseries* for Phillips–Perron and KPSS unit root tests.

This study uses publicly available aggregate macroeconomic data from official statistical sources. No human subjects were involved, and no ethical approval was required. All data sources are properly acknowledged, and the analysis adheres to principles of scientific integrity and reproducibility.

3. RESULTS

Table 3 presents the descriptive statistics for the variables used in the analysis. The logarithmic transformation of GDP (LN_NGDP) shows a mean value of 12.8528 with a standard deviation of 0.9061, indicating substantial variation in economic output over the study period. The R&D expenditure as a percentage of GDP (LN_RD) demonstrates a mean of –1.9323 in logarithmic form, corresponding to approximately 0.14% of GDP. The unemployment rate (LN_UNEMP) exhibits considerable variability, with values ranging from 1.5892 to 2.3514 in logarithmic terms.

Table 3. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
LN_NGDP	12.8528	0.9061	11.3863	14.2443
LN_RD	–1.9323	0.1170	–2.1798	–1.7581
LN_UNEMP	1.8671	0.2902	1.5892	2.3514

Note: Variables are in natural logarithm form. Sample period: 2010–2024 (N = 15).

Table 4 displays the correlation matrix among the variables. A notable negative correlation exists between LN_NGDP and LN_RD (-0.5071), suggesting an inverse relationship between economic output and R&D intensity. The positive correlation between LN_NGDP and LN_UNEMP (0.6490) reflects the structural transformation of the Uzbek economy during the study period, where rapid economic growth coincided with increased labor market formalization and measurement improvements.

Table 4. Correlation matrix

Variable	LN_NGDP	LN_RD	LN_UNEMP
LN_NGDP	1.0000		
LN_RD	–0.5071	1.0000	
LN_UNEMP	0.6490	–0.6567	1.0000

Note: All correlations are Pearson correlation coefficients.

Table 5. Unit root test results (ADF, PP, and KPSS)

Variable	ADF Level (p)	ADF 1st Diff. (p)	PP Level (p)	PP 1st Diff. (p)	KPSS Level (stat / p)	KPSS 1st Diff. (stat / p)
LN_NGDP	0.8551	0.0256**	0.4946	0.5037	0.6113 / 0.022**	0.1325 / >0.10
LN_RD	0.1868	0.0248**	0.3912	0.0510*	0.2868 / >0.10	0.0823 / >0.10
LN_UNEMP	0.6193	0.0202**	0.8164	0.4899	0.3465 / >0.10	0.1880 / >0.10

Note: **, * denote significance at the 5% and 10% levels, respectively. For the ADF and PP tests, the null hypothesis is a unit root; for the KPSS test, the null hypothesis is stationarity, so rejection ($p < 0.05$) indicates non-stationarity, while p-values above 0.10 are reported as >0.10 due to the bounded p-value tables of the test. All tests were conducted with a constant; truncation lag parameter for PP and KPSS is 2.

Prior to model estimation, the stationarity properties of the variables were examined using the Augmented Dickey–Fuller (ADF) test, supplemented by the Phillips–Perron (PP) and KPSS tests as additional diagnostics given the small sample. Table 5 presents the results of all three tests at both level and first difference forms.

The three tests provide mixed but broadly compatible evidence. The ADF test indicates that all variables are non-stationary at levels and stationary after first differencing. The KPSS test, whose null hypothesis is stationarity, rejects level stationarity for LN_NGDP and does not reject stationarity for any of the first-differenced series, which is consistent with the ADF results. The PP test rejects the unit root in first differences only marginally for LN_RD ($p = 0.051$) and fails to reject it for the other differenced series; however, the PP test has particularly low power in very small samples. Given only fifteen observations, none of these tests is individually reliable, and the joint evidence should be treated with caution. Taken together, the ADF and KPSS results support treating the series as integrated of order one, I(1), and first differencing is therefore adopted as a prudent strategy to reduce the risk of spurious regression, while acknowledging that the small sample precludes a definitive determination of the order of integration.

Treating the variables as I(1) based on this evidence, the first difference model was estimated to examine the short-run dynamics between R&D expenditure changes and nominal GDP growth. Table 6 presents the estimation results for two model specifications.

The results suggest a statistically significant negative association between changes in R&D intensity and nominal GDP growth. In Model 1, the coefficient of D(LN_RD) is –0.1946 ($p < 0.05$), suggesting that a 1% increase in R&D intensity is associated with a 0.19% decrease in nominal GDP growth rate in the current period. The unemployment variable is not statistically significant. Model 2, which excludes the unemployment variable, yields similar results with a coefficient of –0.2054 ($p < 0.05$) for D(LN_RD).

To capture the potential delayed associations between R&D expenditure and nominal GDP growth, distributed lag models were estimated. Economic theory suggests that R&D investments typically require time to translate into productivity gains and economic growth. Table 7 presents the results of various lag specifications.

Table 6. First difference model estimation results

Variable	Model 1	t-statistic	Model 2	t-statistic
	Coefficient		Coefficient	
Constant	0.2030***	21.62	0.2030***	21.30
D(LN_RD)	–0.1946**	–2.61	–0.2054**	–2.74
D(LN_UNEMP)	0.0655	1.17	–	–
R^2	0.4522		0.3840	
Adjusted R^2	0.3525		0.3327	
F-statistic	4.539**		7.481**	
Durbin–Watson	1.677		–	
Observations	14		14	

Note: ***, *, * denote significance at the 1%, 5%, and 10% levels, respectively. D() denotes first difference operator.

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Table 7. Distributed lag model estimation results

Variable	Lag Model 1	Lag Model 2	Lag Model 3	Lag Model 4
Constant	0.1978***	0.1973***	0.1955***	0.1956***
	(17.12)	(15.27)	(27.74)	(27.82)
D(LN_RD)_t	–	–	–0.2524***	–0.2359***
			(–4.44)	(–4.00)
D(LN_RD)_{t–1}	–0.0702	–0.0519	–0.1643**	–0.1391*
	(–0.77)	(–0.51)	(–2.77)	(–2.17)
D(LN_RD)_{t–2}	–	0.0801	–	–
		(0.68)		
D(LN_UNEMP)	–	–	–	0.0449
				(1.03)
R²	0.0512	0.0967	0.6807	0.7142
Adjusted R²	–0.0350	–0.1040	0.6169	0.6189
AIC	–42.13	–36.11	–54.29	–53.73
BIC	–40.43	–34.17	–52.03	–50.90
F-statistic	0.59	0.48	10.66***	7.50***
Observations	13	12	13	13

Note: ***, *, * denote significance at the 1%, 5%, and 10% levels, respectively. t-statistics are in parentheses.

The lag model results provide important insights into the temporal dynamics of R&D effects. Lag Model 3, which includes both contemporaneous and one-period lagged R&D changes, emerges as the best-fitting model among the estimated specifications based on the Akaike Information Criterion (AIC = –54.29) and adjusted R^2 (0.6169). This model explains approximately 68% of the variation in nominal GDP growth, a substantial improvement over the simple first difference model.

The coefficient estimates from Lag Model 3 suggest that both contemporaneous (–0.2524, $p < 0.01$) and lagged (–0.1643, $p < 0.05$) R&D changes show significant negative associations with nominal GDP growth. The cumulative two-year association, calculated as the sum of contemporaneous and lagged coefficients, equals –0.4167. This suggests that a 1% increase in R&D intensity is associated with a cumulative 0.42% decrease in nominal GDP growth over a two-year period.

Table 8 presents the diagnostic test results for the estimated models to assess the validity of the regression assumptions.

The diagnostic tests largely support the model assumptions. The Durbin–Watson statistics are close to 2 (1.677 and 2.089), indicating no severe autocorrelation problems. For the first difference model and Lag Model 4, the Breusch–Pagan test indicates homoskedasticity ($p > 0.05$) and the

Table 8. Diagnostic test results

Test	First Diff. Model 1	Lag Model 3	Lag Model 4
Durbin–Watson			
Statistic	1.677	2.089	2.089
p-value	0.262	–	0.525
Breusch–Pagan			
Statistic	0.595	–	5.078
p-value	0.743	–	0.166
Shapiro–Wilk			
Statistic	0.965	–	0.979
p-value	0.803	–	0.972
Breusch–Godfrey LM			
Statistic	0.583	–	7.664
p-value	0.747	–	0.022

Note: For Durbin–Watson, values close to 2 indicate no autocorrelation. For other tests, p-values > 0.05 indicate no violation of assumptions.

Table 9. Model comparison summary

Model	Specification	R²	Adj. R²	AIC	Best Model
First Diff. 1	D(NGDP) ~ D(RD) + D(UNEMP)	0.452	0.353	–	
First Diff. 2	D(NGDP) ~ D(RD)	0.384	0.333	–	
Lag Model 1	D(NGDP) ~ D(RD)_{t–1}	0.051	–0.035	–42.13	
Lag Model 2	D(NGDP) ~ D(RD){t–1} + D(RD){t–2}	0.097	–0.104	–36.11	
Lag Model 3	D(NGDP) ~ D(RD)t + D(RD){t–1}	0.681	0.617	–54.29	+
Lag Model 4	D(NGDP) ~ D(RD)t + D(RD){t–1} + D(UNEMP)	0.714	0.619	–53.73	

Note: The best model is selected based on the lowest AIC and highest adjusted R2.

Shapiro–Wilk test indicates normality of residuals ($p > 0.05$). However, the Breusch–Godfrey LM test for Lag Model 4 suggests some evidence of serial correlation ($p = 0.022$), which should be considered when interpreting the results.

Table 9 summarizes the comparison of all estimated models to identify the most appropriate specification for analyzing the R&D-GDP relationship in Uzbekistan.

Based on the model comparison criteria, Lag Model 3 is identified as the best-fitting specification among those estimated. This model achieves the lowest AIC value (–54.29) and a high adjusted R^2 (0.617), while maintaining parsimony with only two explanatory variables. The inclusion of both contemporaneous and one-period lagged R&D changes captures the dynamic nature of the R&D and growth relationship more effectively than alternative specifications.

Because the baseline R&D variable is expressed as a share of GDP, and GDP also underlies the dependent variable, a mechanical negative association between the two series cannot be ruled out a priori. As a robustness check, absolute R&D expenditure was reconstructed as the product of the R&D share and nominal GDP (RD_ABS = (RD/100) × NGDP, in billion soums), transformed into natural logarithms, and first-differenced. Unit root diagnostics indicate that LN_RD_ABS is non-stationary at level (PP $p = 0.224$; KPSS $p = 0.022$) and stationary after first differencing (PP $p = 0.014$; KPSS $p > 0.10$), supporting the use of the first-differenced series. As no reliable GDP deflator series was incorporated at this stage, the reconstructed variable is expressed in nominal terms; deflating both series remains a task for future research. The preferred specification (Lag Model 3) was then re-estimated with D(LN_RD_ABS) and its one-period lag in place of the intensity-based measure. Table 10 reports the results.

Table 10. Robustness check: Lag Model 3 with reconstructed absolute R&D expenditure

Variable	Coefficient	*t*-statistic	*p*-value
Constant	0.2988***	8.33	0.0000
D(LN_RD_ABS)_t	–0.2813**	–2.83	0.0180
D(LN_RD_ABS)_{t–1}	–0.2377**	–2.26	0.0472
R^2	0.4640		
Adjusted R^2	0.3568		
F-statistic	4.33**		
Durbin-Watson	1.757		
Observations	13		

Note: ***, ** denote significance at the 1% and 5% levels, respectively. The dependent variable is D(LN_NGDP). Diagnostic tests indicate no heteroskedasticity (Breusch–Pagan p = 0.845) and normally distributed residuals (Shapiro–Wilk p = 0.769).

The negative association persists when absolute R&D expenditure is used: both the contemporaneous (–0.2813, $p < 0.05$) and one-year lagged (–0.2377, $p < 0.05$) coefficients remain negative and statistically significant, with a cumulative two-year association of –0.52. This result is noteworthy because the reconstructed variable contains nominal GDP as a component, which would, if anything, bias the estimated coefficient in the positive direction; the persistence of a significant negative association therefore suggests that the baseline finding is not solely an artifact of the ratio-based measure. At the same time, the explanatory power of the robustness specification is lower (adjusted $R^2 = 0.36$ versus 0.62 in the baseline model), and in the simple first-difference specification without the lag the coefficient on D(LN_RD_ABS), while still negative (–0.1367), is not statistically significant ($p = 0.227$). These comparisons indicate that part of the strength of the baseline estimates does reflect the intensity-based construction of the R&D variable, reinforcing the exploratory character of the results and the caveat that all series remain measured in nominal terms.

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4. DISCUSSION

The central finding of this exploratory study is that R&D intensity shows a statistically significant negative association with nominal GDP growth in Uzbekistan, both contemporaneously and with a one-year lag. The contemporaneous coefficient of –0.25 and the lagged coefficient of –0.16 imply that a 1% increase in R&D expenditure is associated with a cumulative 0.42% reduction in nominal GDP growth over a two-year horizon. This pattern is consistent across the estimated specifications, although the small sample size warrants caution in interpretation, so the discussion that follows seeks to interpret why such a counterintuitive pattern emerges and how it relates to the findings of prior research.

This finding differs from the predominantly positive R&D–growth relationship documented in advanced economies, but is broadly consistent with evidence showing weaker or insignificant effects in developing and transition economies. This divergence suggests that the growth effects of R&D are likely to depend not only on the level of expenditure but also on absorptive capacity, institutional conditions, and the structure of the national innovation system.

One interpretation consistent with the negative coefficient is a threshold effect, although the present specification does not formally estimate a threshold model, so this reading remains a hypothesis rather than an established explanation. Our estimate is generated in an economy where R&D intensity averages only 0.12–0.17% of GDP, far below the level at which research investment is generally expected to become growth-enhancing. This reading is directly supported by Hasanov (2023), who finds that countries allocating more than 2% of GDP to research typically exhibit elevated technological potential. Moreover, the global benchmarks reported in UNESCO (2023) state that leading economies such as Israel and South Korea invest above 4.8–5% of GDP. Against these reference points, Uzbekistan's research effort appears to fall below the critical mass needed to generate positive spillovers, so incremental R&D spending may divert scarce resources rather than deliver measurable innovation gains.

A second mechanism is limited absorptive capacity. The negative result is consistent with the view that the growth payoff from R&D depends on an economy's ability to transform research activities into commercially and economically productive outcomes. In Uzbekistan, this process may be constrained by the limited integration of research activities with the productive sector and by the relatively weak role of business-sector R&D. This interpretation is consistent with Pop Silaghi et al. (2014), who show for Central and Eastern European transition economies that the growth effects of R&D depend importantly on the sector in which research is undertaken. While business-sector R&D expenditure contributes positively to economic growth, public-sector R&D does not exhibit a statistically significant growth effect. From this perspective, Uzbekistan's negative R&D–growth association may reflect not only the low level of research investment but also structural limitations in converting research expenditure into market-oriented innovation and productive economic activity.

Situating the magnitude of our estimate within the wider empirical literature clarifies what is distinctive about the Uzbek case. The negative coefficient stands in sharp contrast to the strongly positive returns reported for advanced economies. Blanco et al. (2016), for example, estimate returns to state GDP from R&D of 82% to 211% across US states, and Wang et al. (2013) find positive effects of high-tech R&D on GDP per capita across OECD countries and Taiwan. The divergence is consistent with an income-conditional reading of the relationship: Inekwe (2015), examining 66 developing countries, finds a positive link between R&D and growth in high-middle-income economies but not in low-middle-income ones, and Uzbekistan's lower-middle-income status during the study period places it precisely in the group for which the positive nexus does not materialize. Even within Europe, the relationship is not uniform; Yüksel (2017) reports no significant direct effect of R&D on growth across 28 EU countries while identifying an indirect channel through exports, reinforcing the conclusion that the positive association observed in frontier economies cannot be assumed elsewhere.

Two further considerations qualify the interpretation of the negative effect. First, the possibility of a crowding-out effect cannot be excluded. In a resource-constrained economy, R&D financed by diverting funds from activities with higher immediate returns may depress short-run growth even if the long-run effect is benign. Second, the time horizon

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may be too short to capture delayed benefits. Choi and Cho (2023), studying Korea from 1976 to 2020, showed that the link between R&D and growth operates through long-term equilibrium relationships that unfold over decades. In contrast, the fifteen-year series available for Uzbekistan may capture only the front-loaded costs of research investment rather than its eventual returns. R&D activities typically require time before research outcomes are translated into innovation, productivity improvements, and measurable economic gains. Moreover, the relationship between R&D investment and economic performance may be endogenous, as stronger economic conditions can themselves expand the resources available for research and innovation. Consequently, the negative association identified in the present study should not be interpreted as evidence that R&D investment reduces economic growth in the long run; rather, it may partly reflect the short observation period and the complex temporal relationship between research investment and economic performance.

Taken together, these comparisons indicate that the negative relationship between R&D and growth in Uzbekistan is neither anomalous nor evidence that research investment is inherently unproductive. Rather, it reflects the conjunction of sub-threshold spending, weak absorptive capacity, and a research system with limited commercial orientation-conditions under which the costs of R&D are realized before its benefits. The practical implication is that the priority for transitional economies lies less in raising expenditure per se than in raising its efficiency: strengthening research-industry linkages and technology transfer, building the human capital and institutions needed to absorb new knowledge, expanding private-sector participation, and retaining skilled researchers so that domestic returns are not lost to emigration.

Several limitations should be borne in mind when interpreting these results. First, GDP is measured at current prices, so the dependent variable captures changes in nominal rather than real output. Because the study period coincided with substantial inflation, exchange rate adjustments, and statistical revaluations, part of the estimated dynamics reflects price movements rather than real economic growth, and the coefficients should therefore be read as associations rather than as estimates of the effect of R&D on real output. Second, the R&D variable is expressed as a share of GDP, so it shares a common component with the dependent variable. When output grows faster than research spending, the ratio falls mechanically, which can generate a negative association between the two series independently of any true relationship. The negative coefficient reported here may thus partly reflect this ratio structure rather than a behavioral effect of research investment. Third, the analysis rests on only fifteen annual observations, which limits statistical power, restricts the number of controls that can be included, and makes the estimates sensitive to individual data points. Fourth, the specification omits several determinants of growth, including capital formation, inflation, trade openness, the exchange rate, commodity prices, and structural breaks associated with the post-2017 reforms and the COVID-19 shock, so the possibility of omitted variable bias cannot be excluded. For these reasons, the findings are best regarded as exploratory. Future work should reconstruct the analysis using real GDP or real GDP per capita in constant prices, measure research effort in absolute real terms rather than as a ratio to output, incorporate a broader set of control variables and structural break tests, and extend the sample as longer post-reform data become available.

As a first step in addressing the ratio problem, the robustness check with reconstructed absolute R&D expenditure reported in the Results section shows that the negative association persists, although with reduced explanatory power, suggesting that the ratio structure amplifies but does not fully generate the estimated relationship; the measurement of output in nominal terms remains the principal constraint.

CONCLUSION

This exploratory study aimed to empirically examine the short-run and medium-term associations between R&D intensity and nominal GDP growth in Uzbekistan over the period 2010–2024, using first difference and distributed lag models on non-stationary annual time series data.

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The analysis suggests a statistically significant negative association between R&D intensity and nominal GDP growth. The first difference model suggests that a 1% increase in R&D intensity is associated with a 0.19% decline in nominal GDP growth. In contrast, the best-fitting distributed lag model among those estimated, which explains roughly 68% of the variation in growth and yields a Durbin–Watson statistic close to 2, indicating no severe autocorrelation, shows a contemporaneous association of –0.25% and a one-year lagged association of –0.16%, yielding a cumulative two-year association of –0.42%.

These exploratory results are consistent with the view that the relationship between R&D and growth is not universally positive but is contingent on country-specific conditions. In Uzbekistan, R&D intensity of 0.12–0.17% of GDP lies well below the levels typically associated with positive growth effects in the literature, a pattern consistent with, though not formally tested, a threshold interpretation, and this is compounded by limited absorptive capacity, a predominantly state-controlled research sector with weak commercial linkages, and the erosion of returns through brain drain. The central conclusion is therefore that raising R&D expenditure alone is unlikely to generate growth in transitional economies operating far below global research benchmarks; positive returns instead depend on improving the efficiency and commercial relevance of research, strengthening absorptive capacity and human capital, and expanding private-sector participation. Given the limited number of annual observations, the use of nominal output, and a ratio-based measure of research intensity, these results should be regarded as suggestive rather than definitive. Future research should extend the time horizon as longer post-reform data become available and incorporate measures of R&D composition and innovation outputs to better identify the conditions under which research investment becomes growth-enhancing.

AUTHOR CONTRIBUTIONS

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