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THE POTENTIAL OF MACROECONOMIC FACTORS IN SHAPING THE LANDSCAPE OF TECHNOLOGICAL DEVELOPMENT: A TESTIMONIAL FROM UPPER-MIDDLE-INCOME COUNTRIES

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Abstract. *Purpose* – the main goal of the paper is to examine the role of macroeconomic factors in promoting the technological development of upper-middle-income countries.

Research methodology – to carry on with the investigation the paper selected the expenditure in research and development as a proxy for technological advancement while GDP per capita, Final consumption expenditure, Domestic credit to the private sector, national income, and government transparency are selected as proxies for the macroeconomic indicators. Moreover, a VECM approach is performed in order to capture the long-run and short-run relationship among the variables. Additionally, a Granger causality test was used to observe the causality direction among the variables.

Findings – the obtained results revealed that in the short run, all the selected variables have no prominent impact on R&D expenditure. However, the long run result, presented that the transparency situation of upper-middle-income countries, simultaneously the governments' final consumption, the amount of credit provided to the private sector, and national income are unfavorably affecting technological development while the GDP is positively affecting the expenditure in R&D.

Research limitations – the exclusive focus on macroeconomic factors and upper-middle-income countries as well as the fact of excluding the role of micro factors and low-income countries are the major limitation of the study.

Practical implications – policymakers and nations looking to accomplish technological transformation in the age of digitization can benefit from the study's findings.

Originality/Value – since prior studies highlighted the link of macroeconomic factors with specific sectors such as healthcare, education, and agriculture. Thus, giving little attention to or neglecting the information technology sector that compromises a more specific branch such as research and development. For that reason, this paper will bring light to this phenomenon.

Keywords: macroeconomic factors, R&D, technological development, upper-middle-income countries.

JEL Classification: O11, O32, O38.

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Introduction

Technology is derived from the word technique, which denotes information, experience, tools, and instrument. Previous decades have seen the generation of knowledge and expertise across many facets of society (Bismala et al., 2020). The total amount of information on the methods and strategies employed in the creation of materials is known as science. The word "technology" has now been expanded to include both the methods and processes themselves as well as the body of information about them. This knowledge today encompasses not just manufacturing but also other facets of social life (Lee, 2018).

Cui (2016) in one of his studies states that as nations transition from agrarian to industrialized societies, and then to post-industrial digital civilizations, many aspects of their features change, notably the importance placed on training and the work opportunities of labor. Contrasting the traits of modern society with the characteristics of manufacturing and agrarian civilizations has allowed everyone to track this progression. Although on a personal point, there may be prolonged life expectancies, extra leisure time, and a decline in hours spent on transportation, demographic change, and an increase in urbanization, the advancement of emerging technologies and scientific research has led to the higher significance of investigation and training, the complexity of institutions, bigger value of communication, higher levels of the employees in information, major roles for the mass communication, and a broader range of interdependence (Alam et al., 2019a).

Research and development are the standard strategies for fostering technological advancement, therefore appeals for additional R&D expenditure have become commonplace in both the governmental and general public spheres (Bengoa et al., 2017). It is easy to identify several breakthroughs as the main cause of the rise in living standards during the previous two centuries. Greater R&D, according to supporters, will provide new technical innovations that will promote wealth and economic development (i.e., an expansion in production per person) (Barkhordari et al., 2019).

Some supporters even go to the extent of claiming that nations compete with one another for technical supremacy (Muscio & Ciffolilli, 2018). The nations who triumph in this competition produce the most advanced technical goods, reaping the benefits of their achievement. These nations are thought to have better production and efficiency levels. It is anticipated that their employees would earn the greatest real earnings and thus have the best quality of life. The nations that succeed in achieving technological advancement could even be in a position to outperform others who are unable to reach the technological horizon (Chen et al., 2021). However, a significant portion of people who do not have such a pessimistic viewpoint nonetheless agrees that higher investment in R&D will boost future salaries and performance (Godil et al., 2021). In light of this, governments shouldn't be reluctant to proactively promote and finance R&D efforts, particularly if private industry R&D is insufficient.

One of the key factors in boosting a nation's prosperity and competitiveness is its expenditure on research and development (Bor et al., 2010). Generally speaking, economic expansion is a long-term result of technical progress. Therefore, innovation increases overall factor productivity, which indicates an increase in overall output (Surani et al., 2017). Since Schumpeter, the importance of economic innovation practices in development has been extensively examined. Schumpeter is considered one of the pioneering economists who studied the macroeconomic link between technological innovation and economic development in this setting (Hasan & Tucci, 2010). Through the beginning of the twentieth century, the Neoclassical growth paradigm had narrowed its attention to the contributions that capital formation, technical advancement, population expansion, and output made to long-term economic development. Although the concept stresses how technology fosters progress, it has been acknowledged that technological advancements are an exogenous component. R&D was regarded as an endogenous element in economic development frameworks in the late 1980s because of the groundbreaking work of Peng (2010).

The major factor underlying technical advancements is R&D activity. R&D efforts yield ideas that are projected into products, which are then released onto the market through marketing. Nations can achieve greater technological levels and create new goods in this way to outperform others in terms of growth potential (Adomako et al., 2021). Therefore, governments should broaden the scope of R&D operations and devote additional GDP to R&D. Economic expansion concepts frequently challenge the idea that R&D expenditures are crucial to the cycle of economic growth (Beladi et al., 2021).

Typically, the following issues occupy a central place in the discussion of innovation strategy: First, the use of the finest methods in public policy to encourage private-sector innovation with the broadest potential societal consequences. Second, the spread of technology (across nations and businesses). Third, the recognition of revolutionary breakthroughs and strategies for promoting them. Four, the significance of non-R&D innovation. Lastly, the relative contributions of public and private R&D (Prokop et al., 2021). The most urgent technology obstacles for upper-middle-income countries have been recognized, and they include expanding experience and understanding industrial activities, enhancing the availability of capital for high-growth, new sophisticated activities, enhancing the contribution of universities of higher learning to community business incubators, and enhancing the democratic institutions of innovations and research systems (Vrontis & Christofi, 2021).

As matter of fact, prior studies highlighted the link of macroeconomic factors with specific sectors such as healthcare (Darvas, 2018), education (Olilingo & Putra, 2020), and agriculture (Czyżewski & Majchrzak, 2018). Thus, giving little attention to or neglecting the information technology sector that compromises a more specific branch such as research and development. As a consequence, this research aims to better investigate how macroeconomic factors, including a transparent government, contribute to technological development while taking into account the practical and dramatic elements of filling in the gaps of earlier literature. Based on this the paper answer question such as; Do macroeconomic factors contribute to the process of technological development in upper-middle-income countries? And how do these influences differ through the long-run and short-run aspects? To address these research questions, this study proposes a VECM model to assess the cointegration among the variables in both the long-run and short-run periods. Additionally, the study employs a Granger causality test to examine the causality direction among the variables.

The theoretical foundations of earlier studies reviews are explained in the upcoming section. The methodology section will include details on the data source, such as measurement details for each variable, and the research process adopted Moreover, the econometric model will be highlighted. Continuously, the discussion of empirical findings, data suitability, and results comes next. After validation of the findings, the implications, restrictions, and recommendations for further research are discussed.

1. Survey of the literature

Expenditure in research and development (R&D) is regarded as one of the most crucial factors in fostering economic progress. Coccia (2018) noted that by enhancing efficiency and expanding their base of knowledge, nations with adequate R&D expenditure may accomplish their desired economic development. The Goals for Sustainable Development (SDG9) now include creativity as one of its goals, and nations are urged to create a sustainable building, support an accessible and stable economy, and support innovation. Based on this R&D is the fuel to promote innovation. For instance, SDG9.5 urges nations to significantly expand public and corporate R&D expenditure. In different regions, East Asia and the OECD have the maximum R&D concentration; nationally, China and India have been the world's largest innovation hubs for the past 10 years (Knoll et al., 2021).

This approach had a substantial influence on R&D efforts in Russia, which changed to a market economy in 1991 after the Soviet Union fell apart. Industry groups, businesses, and local authorities have more influence now that state-owned firms are less dominant (Gokhberg, 1999). Nevertheless, Russia's R&D operations were adversely impacted by the country's shift to a market economy. because the public's straightforward contribution to R&D spending as a share of GDP has declined by around 75%. Due to this, the employment of half the researchers and scientists was endangered (Schweiger et al., 2022).

China's technology infrastructure was not as strong in comparison to that of developed nations during the beginning of the 1980s. After the Chinese economy underwent structural reform in 1978, the fields of technology and science grew quickly (Chen et al., 2015). In this regard, the administration's adoption of science and technology legislation in 1985 had a favorable impact on China's advancement of its technical infrastructure. Furthermore, in 1996, the Act Encouraging Corporatization of Scientific and Technical Research and Inventions was adopted. These strategies have placed a strong emphasis on commercializing academic results and building industry sectors' capability for R&D and innovation (Yao et al., 2021).

Wang and Wu (2015) examined the impact of firm and government R&D spending on China's economic development in different research. Based on the report, all R&D investments have a favorable impact on economic development, however, although there is a substantial association between enterprise R&D investments and growth, there is less link between government R&D investments and growth.

Institutional variables may also contribute to the explanation of R&D expenditure (Wu et al., 2016). By enhancing the businesses' potential for collaboration, a better institutional framework may encourage R&D activities. Simultaneously, Audretsch and Belitski (2020) claimed that the administrative contexts in which enterprises function in addition to the characteristics of the company do matter for innovation. This idea was reinforced by (Wang et al., 2015), who also noted that the R&D expenditures approach, framework, and process needed to be in line with institutional requirements. Institutional contexts are regarded as the most significant stimuli for a creative activity for a number of reasons. First, organizational issues have an impact on R&D investments since they are hazardous and long-term investments. Nevertheless, better institutions aid in reducing the organization issue among decision-makers thus assisting in boosting R&D spending. Second, the effectiveness of institutions spurs R&D spending by giving businesses exposure to a range of resources and innovations. Third, strong institutional qualities may draw international investments, enabling businesses to obtain external financing, reducing the amount of murky information, and offering incentives to businesses, which in turn encourages internal R&D investment. Last but not least, sound governance, such as robust intellectual property rights, offers investors safeguards and encourages investment in R&D.

Fiscal policy is one of the macroeconomic elements that influence research and development. This shows that increasing the quality and efficiency of public expenditure is a key strategy for preserving financial restraint (Muscio & Ciffolilli, 2020). The development of the required monitoring systems applied to specific expenditure areas, such as public actions in R&D, public schooling, health care, and infrastructure on a global scale, has advanced despite the systematic challenges raised by measuring the quality of public spending on R&D (Castellani et al., 2019).

In a prior study, Cincera et al. (2008) used both techniques to estimate an average performance of the link between inputs and outputs (such as governmental R&D incentives to the business sector, R&D expenditures by educational institutions, and R&D carried out in public research organizations). Macroeconomic statistics from a panel of OECD nations provide the foundation of the experimental study. The study's key findings may be summed up as follows. An indicator of the effectiveness of government expenditure on R&D is the link between inputs and outputs. Contrarily, stability-focused economic regulations, a legal framework that protects rights (such as patents), an industrial framework focused towards high-tech industrial sectors, a more beneficial taxation system for global trade, and increased liberalization in the workforce and commodity marketplaces are discovered to favorably influence technological development. Additionally, high inflation rates and the proportion of government spending to overall consumption have a detrimental impact on technological development.

As per Guceri and Liu (2019), a nation like the United Kingdom launched its first R&D tax motivational program in 2000 in an attempt to resolve its "economic output dilemma", which refers to the UK private sector's subpar overall factor productivity achievement in contrast to certain other advanced nations like the United States (US), France, and Germany. Firms find it simpler to adopt volume-based plans over cumulative plans, which concentrate benefits on the growth in R&D expenditure from a previous time span. Volume-based plans focus benefits on the total quantity of acceptable R&D completed in the time frame. Companies have been shown to employ stop-and-go tactics in evolutionary plans, potentially leading to inefficiencies (Ientile & Mairesse, 2009).

The research by Guellec and van Pottelsberghe (2004) examined a group of 16 OECD nations and used, among other tools, an error-correction model (ECM) to calculate the effect of both government and private R&D on total factor productivity (TFP). The model they used presupposed similar coefficients for each of the 16 nations in the investigation. Guellec and van Pottelsberghe determined that the production elasticity of company (private) R&D in OECD nations from 1980 to 1998 was equal to 13% and grew with time. They discovered that the long-term elasticity of research conducted by governments and universities was significantly higher for public research: roughly 17%. Additionally, their analysis emphasized the significance of "foreign" R&D operations for many nations, especially the smaller OECD nations included in their group. Countries with smaller populations seemed to be significantly more affected by "cross-border" ripples than bigger ones, which is in line with their greater proportions of global co-publication and co-patenting. But in order to reap such advantages, a lesser nation would eventually need to grow more R&D-intensive and specialized.

Bottazzi and Peri (2007) similarly employed a VECM strategy, their attention was largely directed at how R&D may describe the dynamics of patents as a sign of innovative thinking as opposed to productivity (TFP). Additionally, they avoided directly addressing how governmental R&D spending affects the economy. Instead of R&D spending data, they used R&D employment data.

No error-correction strategy was used in Khan and Luintel's (2006) article. They elected to use a general output function approach instead, where country-specific intercepts and curves are permitted. They created association terms between a variety of factors, such as foreign direct investment and the percentage of high-tech businesses in trade, and the nation-specific norms of the expertise stock indicators to account for variance in the slopes of the R&D variables per nation. The diversity of associated factors was then linked to the heterogeneity of the country-specific regression coefficients that were the outcome of this experiment. However, using such a strategy makes it impossible to examine prospective responses from production on the left side of the equation regarding information stocks and the many dynamic relationships between output, productivity, and knowledge stocks on the right side.

Public and private research investment complement one another in that it attracts globally mobile R&D, or what can be considered a domestic R&D "crowding-in" impact. Such studies include a variety of factors, including the possibility of excellent collaborators, employment prospects, and the existence of a regional expertise cluster, frequently supported by an infrastructure for knowledge and technology transfer (Cassiman & Veugelers, 2002).

Panel data for 15 OECD nations are used by Bassanini et al. (2001), who additionally contain independent variables for the intensity of public and private R&D. They discover that private R&D has an advantageous projected effect (0.26) while public R&D has an adverse estimated effect (–0.37). The authors suggest that one explanation for the detrimental consequences of governmental R&D is the crowding out of private R&D activities. Additionally, they point out that publicly funded research may be more focused on developing fundamental information than on immediately enhancing productivity.

2. Methodology

2.1. Data

The study investigates the role of macroeconomic forces in shaping the landscape of technological development in Upper middle-income countries. The selected countries are well known for their great social diversity, significant degrees of education, advanced national insurance, free healthcare systems, accessibility to technology, and advanced legal frameworks. These mentioned characteristics reflect the transparency and partial administration of these countries. The technological development in upper-middle-income countries would likely depend on several factors, including the nature and scope of technological innovation, the level of investment in research and development, the extent of technology diffusion and adoption, and the impact of technological progress on economic growth and development. Additionally, technological development in upper-middle-income countries can be a sign of progress and advancement, as it can lead to increased productivity, improved competitiveness, and enhanced economic growth. It can also contribute to social and environmental development by improving living standards, promoting sustainable development, and addressing societal challenges such as poverty and inequality.

Consequently, macroeconomic policies and conditions can have a significant impact on the level of investment in research and development, the availability of funding for innovation, the extent of technology diffusion and adoption, and the overall environment for technological development in a country. For example, macroeconomic policies such as fiscal and monetary policies can impact the availability of funding for research and development (Tang et al., 2022). Inflation and interest rates can affect the cost of borrowing and the willingness of businesses to invest in new technologies (Chu et al., 2015). Government policies such as tax incentives, subsidies, and intellectual property protections can also influence the development and adoption of new technologies (Rao, 2016). Additionally, macroeconomic conditions such as economic growth, income levels, and the structure of the economy can affect the demand for technology and the ability of firms to innovate and compete (Das & Mukherjee, 2020). For instance, a growing middle class may create a larger market for new technologies, while a shifting economic structure may present new opportunities for innovation in specific sectors.

With that in mind, the percentage of GDP spent on research and development is considered a proxy for technological development. By investing in R&D, firms and governments can generate new knowledge and technologies that can drive innovation and economic growth. R&D activities can lead to the creation of new products and services, improved production processes, and the development of new materials, technologies, and systems that can be used across a range of industries. Because R&D is such a critical component of technological development, it is often used as a proxy for measuring the level of technological progress in a country or industry. Metrics such as R&D expenditure, patents granted, and scientific publications are commonly used to track changes in the level of technological development over time.

What is more, indicators such as GDP per capita, Final consumption expenditure, Domestic credit to the private sector, national income, and the CPIA transparency, accountability, and corruption in the public sector rating are selected as proxies for the macroeconomic indicators. Finally, to carry on with the study a vector error correction model is used to assess the cointegration between the variables. The model is used to analyze the long-run dynamics between two or more time series variables it is also important because it allows researchers and analysts to analyze the long-run relationships between multiple variables, while also accounting for the potential presence of short-term deviations from equilibrium. Similarly, the Granger causality test was applied to determine the nature of causality (unidirectional or bidirectional). The data are extracted from the World Bank Database, from the period 2000 to 2021. Table 1 presents the overall variables used in the study.

Table 1. Summary of the variables (source: author's computation)

Notation	Description	Source
Years	20 years	From 2000 until 2020
Countries	Upper middle income	
RD	Research and development expenditure (% of GDP)	World Bank Database especially from World governance indicators and Development Indicators.
TC	CPIA transparency, accountability, and corruption in the public sector rating (1 = low to 6 = high)	
GDP	The logarithm of the GDP per capita (current US$)	
FC	The logarithm of the Final consumption expenditure (current US$)	
DC	Domestic credit to the private sector (% of GDP)	
IC	The logarithm of the adjusted net national income (current US$)	

2.2. Research process

Figure 1 gives a general overview of the study's structure. The flowchart thoroughly looks into the analytic methodologies employed for the study. Additionally, it provides a comprehensive breakdown of the methodology utilized to draw logical conclusions throughout the study's results phase.

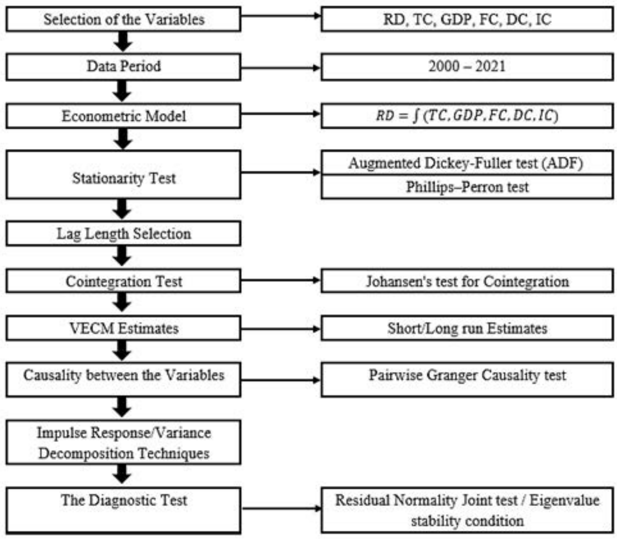

Figure 1. The analytical chart of the study

2.3. Model presentation

To ascertain the interaction between the variables, the current study utilized the following economic functions:

$$RD_t = \int \left(TC_t, GDP_t, FC_t, DC_t, IC_t \right). \quad (1)$$

2.4. Error correction term

In order to evaluate the cointegration between the chosen variables, the research utilizes a vector error correction model. Additionally, we will conduct a Granger causality test to establish the relationship and direction between the variables. The VECM model may be referred to as a constrained VAR because cointegration is present in the model. The fundamental presumption is that all indicators should be static within the appropriate direction or scale relative to the hypothesis that has to be met, notably in the first difference (Gujarati & Porter, 2010). It is possible to segregate the long-run and short-run elements of the data construction process using the VECM approach. Because it uses a VAR (Vector Autoregressive) method version. Consequently, the VECM model may be written as the following equation:

$$\Delta Y_t = \sigma + \sum_{i=1}^{k-1} \gamma_i \Delta Y_{t-1} + \sum_{j=1}^{k-1} \eta_j \Delta X_{t-j} + \sum_{m=1}^{k-1} \xi_m \Delta R_{t-m} + \lambda ECT_{t-1} + \ldots + u_t; \tag{2}$$

$$\Delta RD_t = \sigma + \sum_{i=1}^{k-1} \beta_i \Delta RD_{t-i} + \sum_{j=1}^{k-1} \phi_j \Delta TC_{t-1} + \sum_{l=1}^{k-1} \eta_l \Delta GDP_{t-l} + \sum_{m=1}^{k-1} \xi_m \Delta FC_{t-m} + \sum_{n=1}^{k-1} \vartheta_n \Delta DC_{t-n} + \sum_{o=1}^{k-1} \sigma_l \Delta IC_{t-l} + +\lambda ECT_{t-1} + u_t. \tag{3}$$

All of the variables that were utilized in the study are listed in the equation above. First, we examine the main variable, which consist of the research and development expenditure (RD), as well as the exogenous variables, which are the following: TC, GDP, FC, DC, and IC. The VECM equation has k–1 which suggest that the lag length is reduced by 1. Then we perceive $\beta_i, \phi_j, \eta_l, \xi_m, \vartheta_n, \omega_p$ that denotes for the short-run dynamic coefficients of the model's adjustment long-run equilibrium. Next, there is the ECT_{t-1} that signifies the error correction term. And finally, u_t which is the residuals (impulses).

2.5. Granger causality test

Additionally, it was intended to record how the different variables related to one another causally. The Granger causality test, recommended by (Granger, 1969), was performed to ascertain whether there is a causal link between the variables. Below a more comprehensive explanation of the model is provided:

$$X_t = \sum_{l=1}^{p} \left(a_{11,1} X_{t-1} + a_{12,1} Y_{t-1} \right) + \mu_t; \tag{4}$$

$$Y_t = \sum_{l=1}^{p} \left(a_{21,1} X_{t-1} + a_{22,1} Y_{t-1} \right) + \epsilon_t. \tag{5}$$

As illustrated in equations (4) and (5) is the model order, $a_{ij,1} (i, j = 1,2)$ are the coefficients of the model, and μ_t and ϵ_t denotes the residuals. Ordinary least squares can be used to estimate the coefficients, and F tests can identify the Causality relationship between X and Y.

2.6. Unit root test

To ensure the stability and reliability of the data the study performed stationarity tests that consist of the Augmented Dickey-Fuller test (ADF) and the Phillips-Perron test (PP). Starting with the augmented Dickey-Fuller test, it assumes that u is a white noise error term. However, if u is autocorrelated we would need a drift version of the test which allows for higher-order lags. Accordingly, the test is augmented using p lags of the original series (Dickey & Fuller, 1979). Furthermore, the Phillips-Perron test corrects for any serial correlation and heteroskedasticity in the errors by some direct modification to the test statistics (Phillips & Perron, 1988). Below the equations for both tests are presented.

$$\Delta y_t = \psi y_{t-1} + \mu + \alpha t + \sum_{i=1}^{p} \beta \Delta y_{t-1} + u_t; \quad (6)$$

$$\Delta y_t = \psi y_{t-1} + \mu^* + \delta t + u_t,\ u_t \backsim I(0), ARMA(p,q). \quad (7)$$

As per equation (6) p is used to augment the past autoregressive lags of the difference term. While μ and at denotes the time trend parameter and also the intercept. In equation (7) ψy consist of the initial term of the data while the term u_t implies the stationarity at level I(0). Additionally, μ^* expresses the intercept while δt denotes the time trend.

3. Findings

Table 2 provides a summary of the descriptive statistics, including the data used in this study and the statistical results of several parametric tests (Jarque-Bera, skewness, probability, and kurtosis). Each variable includes 21 samples of time series data for Upper Middle-Income countries between 2000 and 2021. According to real observations, the distribution is favorably skewed and the percentage of RD spans from 0.68 to 1.99 with a median of 1.22 and kurtosis of 2.05, and a standard deviation of 0.398%. GDP in upper-middle-income nations ranges from an average of 3.72% to a maximum of 4.03%. The maximum rate of economic growth cannot rise by more than 0.261% throughout the years since the standard deviation is less than 1. The results show that most of the variables, with the exception of transparency and domestic credit given to the private sector, have negatively skewed distributions. Additionally, the higher standard deviation value in DC illustrates the broad variation of domestic credit provided to the private sector and suggests that in nations with upper-middle incomes, the private sector needs more credit.

Table 2. Descriptive statistics (source: author's computation)

	RD	TC	GDP	FC	DC	IC
Mean	1.247327	3.376902	3.725607	12.91027	90.14900	12.98800
Median	1.223243	3.400350	3.838833	13.01254	82.21595	13.10075
Maximum	1.996084	3.681818	4.034850	13.18178	143.9245	13.25876
Minimum	0.684406	3.178571	3.292912	12.48955	58.64133	12.54162
Std. Dev.	0.398344	0.156642	0.261679	0.258046	27.50871	0.267380
Skewness	0.309693	0.053814	–0.601716	–0.565526	0.624437	–0.623666
Kurtosis	2.058733	1.809916	1.815042	1.744797	2.111440	1.812449
Jarque-Bera	1.163820	1.308894	2.614674	2.616912	2.153458	2.718938
Observations	22	22	22	22	22	22

A correlation matrix is a vital tool for establishing assumptions between variables before they are addressed. As a result, we can notice in Table 3 that every variable is closely related to the amount spent on research and development. This shows that RD tends to grow in value together with GDP, national income, final consumption of the government, transparency, and domestic lending to the private sector and vice versa.

Table 3. Matrix of correlation (source: author's computation)

Variables	RD	TC	GDP	FC	DC	IC
RD	1.000					
TC	0.949	1.000				
GDP	0.911	0.937	1.000			
FC	0.911	0.932	0.998	1.000		
DC	0.979	0.900	0.825	0.830	1.000	
IC	0.902	0.925	0.998	0.999	0.817	1.000

In Table 4 stationarity test is performed by using the Augmented Dickey-Fuller test and Phillips–Perron test. The statistical results are contrasted with the MacKinnon critical values. Hence, the data is deemed to be non-stationary if the results show that the t statistic count is more than the MacKinnon critical value. On the other hand, it is said to be stationary if the value is less than the estimated MacKinnon critical value. Both tests revealed that all the variables are only stationary at first difference. Consequently, we will proceed with the model estimation since the variables displayed the absence of unit roots.

Table 4. Unit root test (source: author's computation)

Variables	Panel A: Augmented Dickey-Fuller test (ADF) test				
	At level	Note	At first difference	Note	Decision
RD	0.946	Not stationary	–0.010**	Stationary	I (1)
TC	–0.039	Not stationary	–2.836*	Stationary	I (1)
GDP	–1.681	Not stationary	–2.714*	Stationary	I (1)
FC	–2.093	Not stationary	–3.486**	Stationary	I (1)
DC	1.388	Not stationary	–3.031**	Stationary	I (1)
IC	–2.315	Stationary	–2.523*	Stationary	I (1)
Variables	Panel B: Phillips–Perron test				
	At level	Note	At first difference	Note	Decision
RD	3.225	Not stationary	0.010***	Stationary	I (1)
TC	0.185	Not stationary	–2.836**	Stationary	I (1)
GDP	–1.397	Not stationary	–2.714*	Stationary	I (1)
FC	–1.628	Not stationary	–3.486*	Stationary	I (1)
DC	2.658	Not stationary	–3.031***	Stationary	I (1)
IC	–1.825	Not stationary	–2.523**	Stationary	I (1)

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

One of the metrics used to assess the VAR model is the optimal lag to impose. A VAR system's autocorrelation issues may be rectified by figuring out the ideal lag, which is helpful for demonstrating how long a variable takes to react to other variables. This test also verifies the accuracy of the information generated by the estimate of the Vector error correcting model. The metrics (LR), (AIC), (FPE), (SC), and (HQ) are evaluated to estimate lag candidates. Table 5's findings show that lag 1 is the ideal latency for the paper.

Table 5. Optimal lag selection (source: author's computation)

Lag	LogL	LR	Df	P	FPE	AIC	HQIC	SBIC
0	126.832	–	–	–	6.0e-14	–13.4258	–13.384	–13.129
1	239.797	225.93	36	0.000	**1.5e-17***	**–21.9775***	–21.691	–19.899*
2	630.604	781.61*	36	0.000	8.5e-34	–61.4005	–60.868*	–57.542
3	2987.24	4713.3	36	0.000	–	–319.916	–319.179	–314.573

Note: * indicates the lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level). FPE: final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan–Quinn information criterion.

The cointegration test aims to determine the cointegration of the non-stationary variables. If there is cointegration, the investigation of the VECM model can be continued. Table 6 demonstrates a cointegration with statistical values above the threshold value for the Trace statistic test. As a result, we establish the existence of a long-term link between the variables. Hereby, we will continue with the error correction model.

Table 6. Cointegration test (source: author's computation)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.991415	240.1102	95.75366	0.0000
At most 1 *	0.980917	144.9549	69.81889	0.0000
At most 2 *	0.851999	65.77519	47.85613	0.0005
At most 3	0.595735	27.56450	29.79707	0.0886
At most 4	0.305444	9.450798	15.49471	0.3253
At most 5	0.102425	2.161162	3.841465	0.1415

Note: * Denotes rejection of the hypothesis at the 0.05 level and Trace test indicates 2 cointegrating eqn(s) at the 0.05 level.

Table 7 presents the short-run results among the variables in proportion to the expenditure on R&D. The findings reveal no evidence of cointegration among the variables with R&D. This suggests during the short-run framework economic growth, government final consumption, domestic credit provided to the private sector, national income, and the government transparency do not contribute in the technological development of Upper-Middle-income countries. Nevertheless, we observe a negative cointegration between R&D with GDP, FC, and IC. For instance, a 1% increase in expenditure on research and development decrease the GDP, government final consumption, and national income by 0.51%, 0.56%, and 0.64% respectively.

Contrary to the short-run outcome which demonstrated no evidence of relationships among the variables. The long-run outcome displays the presence of cointegration among the variables. Within this scope, we observe that TC, FC, DC, and IC are negatively affecting the expenditure in R&D. This implies that the transparency situation of upper-middle-income countries, simultaneously the governments' final consumption, the amount of credit provided to the private sector, and national income are unfavorably affecting the technological development. Nevertheless, the economic growth of upper-middle-income countries is revealed to support technological development. This is supported by the 1% increase in GDP which results in a 7.3% increase in expenditure on research and development. The results are displayed in Table 8.

Table 7. Short-run estimates (source: author's computation)

VARIABLES	D_RD	D_TC	D_GDP	D_FC	D_DC	D_IC
ECT (–1)	–0.354 (0.542)	0.315 (0.334)	0.698*** (0.146)	0.548*** (0.146)	–64.99 (40.86)	0.638*** (0.136)
ΔRD (–1)	0.248 (0.768)	–0.169 (0.474)	–0.512** (0.206)	–0.564*** (0.207)	67.26 (57.94)	–0.647*** (0.193)
ΔTC (–1)	0.334 (0.520)	–0.127 (0.321)	0.107 (0.140)	–0.0217 (0.140)	–15.41 (39.19)	0.0225 (0.131)
ΔGDP (–1)	2.004 (5.945)	1.245 (3.670)	–5.765*** (1.596)	–5.828*** (1.602)	371.6 (448.2)	–6.712*** (1.496)
ΔFC (–1)	2.232 (5.839)	0.603 (3.605)	1.807 (1.568)	2.036 (1.574)	88.85 (440.3)	2.477* (1.470)
ΔDC (–1)	–0.00435 (0.00652)	0.00555 (0.00403)	0.005*** (0.001)	0.00514*** (0.00176)	–0.578 (0.492)	0.00506*** (0.00164)
ΔIC (–1)	–4.488 (4.841)	–1.198 (2.988)	4.636*** (1.300)	4.609*** (1.305)	–482.1 (365.0)	5.010*** (1.219)
Constant	0.0518 (0.0759)	0.0152 (0.0468)	0.06*** (0.0204)	0.049** (0.0205)	0.0014 (5.723)	0.061*** (0.0191)
Observations	20	20	20	20	20	20
R-squared	0.6043	0.5329	0.9137	0.8957	0.5991	0.9155
chi2	18.32339	13.6926	127.0069	103.0298	17.92952	129.9526
P > chi2	0.0189**	0.0901*	0.0000***	0.0000***	0.0218**	0.0000***

Note: Standard errors in parentheses, *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 8. Long-run estimates (source: author's computation)

Variables	Coefficient	Std.Dev	T–statistics	P–value
TC	–0.7061***	0.03826	–18.45	0.000
GDP	7.346***	0.67695	10.85	0.000
FC	–3.2439***	0.43344	–7.48	0.000
DC	–0.0037***	0.00036	–10.25	0.000
IC	–4.6522***	0.43611	–10.67	0.000
Constant	76.378			

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

The Impulse Response Function (IRF) displays how a variable responds to a shock (such as a stress of one standard deviation, a stimulus of one unit, etc.) over a specific period of time. A variable's impact on another factor cannot be determined using the Granger causality or the VD. To ascertain an impact's route, the IRF evaluation is crucial. The horizontal axis depicts time, while the vertical axis indicates the size of a variable's responses to a shock. The red dotted line substitutes for the confidence bands at 5% significance while the blue line represents the IRF. Table 9 shows the responses of RD, TC, GDP, FC, DC, and IC to one standard deviation shock of RD. Within this scope, we witness that the impulse responses estimate in Table 9 shows that the amount of expenditure in research and development in Upper Middle-income countries would probably decrease as a result of GDP and government consumption, domestic credit to the private sector, and national income. On the other hand, it would seem that the transparency and corruption regulations would expand overall technological development. Therefore, these areas require additional focus and funding to help boost technological progress during the coming ten years.

Table 9. Impulse response's function (source: author's computation)

Periods	RD	TC	GDP	FC	DC	IC
1	0.068002	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.114941	0.027005	–0.017025	–0.017004	–0.014690	–0.032655
3	0.223534	0.073350	–0.045293	–0.075262	–0.029346	–0.065743
4	0.515151	0.176368	–0.096951	–0.204501	–0.090158	–0.135450
5	1.284428	0.452286	–0.248377	–0.550764	–0.258181	–0.334988
6	3.335901	1.194493	–0.664293	–1.483842	–0.703091	–0.872437
7	8.825649	3.179417	–1.778213	–3.982346	–1.892621	–2.309054
8	23.52164	8.491946	–4.759761	–10.66969	–5.078169	–6.154294
9	62.86333	22.71404	–12.74278	–28.57249	–13.60642	–16.44923
10	168.1844	60.78820	–34.11490	–76.50046	–36.43713	–44.01006

Table 10 depicts the variance and the decomposition outcome of all the explanatory variables of the model in combination with the research and development variable for the entire time frame. It can be noticed from the table that the time period selected was fixed to 10 years and divided to 5 years in order to evaluate the shock of each of factors on R&D. The results imply that the government final consumption, which is anticipated to increase from 1.415% in 2022 to 13.844% in 2031, would have a greater variance shock of 13.844% on the technological development. Additionally, transparency is expected to impose a greater variance shock of 8.74% on the technological progress of Upper Middle-income countries in 2031. The remaining factors GDP, domestic credit to the private sector, and national income will only cause a moderate shock on the technological development with variances of 2.75%, 3.14%, and 4.58% respectively.

Table 10. Variance decomposition (source: author's computation)

Periods.	RD	TC	GDP	FC	DC	IC
1	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	87.31835	3.570180	1.418962	1.415562	1.056435	5.220512
3	76.46423	6.889924	2.640411	6.714036	1.214542	6.076858
4	71.98452	8.040337	2.536630	10.32167	1.988853	5.127994
5	69.30740	8.450564	2.566586	12.27213	2.651552	4.751768
6	67.88190	8.638975	2.664905	13.21743	2.952155	4.644643
7	67.28506	8.707765	2.718486	13.61327	3.070020	4.605407
8	67.05624	8.731383	2.740665	13.76513	3.116181	4.590397
9	66.96885	8.739889	2.749682	13.82256	3.133831	4.585192
10	66.93566	8.743067	2.753261	13.84422	3.140441	4.583350

Following an examination of the cointegration between the predictor variables (RD) and the regressors (TC, GDP, FC, DC, and IC), the granger causality test will be performed to ascertain the relationship between the variables (Granger, 1969). According to the estimation results, we perceive a unidirectional relationship between all the variables with the research and development at 1% and 10% significance levels except for transparency which revealed no prominent causality. For instance, GDP is the driving force behind the level of RD investment, rather than RD investment being the driving force behind GDP growth. This result may be due to a number of factors. For example, it could be that countries with higher GDP have more resources available to invest in research and development, and therefore see greater levels of RD investment. Alternatively, it could be that companies are more likely to invest in RD when they expect that economic conditions will be favorable for their products and services, which could lead to higher GDP growth. Next, as fiscal expenditure is one of the main ways that governments can support R&D investment in their countries. By providing funding, tax incentives, and other forms of support for R&D, governments can encourage businesses and other organizations to invest in research and development. In turn, this can lead to new technological innovations and improvements in productivity, which can contribute to economic growth. Third, the result behind unidirectional causation running from R&D to domestic credit provided to private sector may be due to the fact that R&D investment can lead to the development of new technologies and products, which can create new markets and opportunities for businesses. This can in turn lead to increased demand for credit to finance expansion and investment in these new markets. Additionally, R&D investment can lead to improvements in productivity and competitiveness, which can make businesses more creditworthy and therefore more likely to qualify for loans. Further, the outcome between national income and R&D is consistent with the idea that R&D investment is a luxury good, meaning that as incomes rise, individuals and businesses are more likely to allocate resources towards R&D investment. Additionally, higher national income may provide more resources for governments to invest in R&D through public funding, tax incentives, or other policy measures. Hence, we conclude that technological development has a long-run relationship with the GDP, government final consumption, domestic credit provided to the private sector, and national income. See Table 11.

Table 11. Granger causality test (source: author's computation)

Hypothesis	F-statistic	Prob.	Decision	Direction
RD granger cause TC	4.472	0.107	Dismiss	No causality
TC granger cause RD	1.350	0.509	Dismiss	
RD granger cause GDP	0.237	0.888	Dismiss	Unidirectional
GDP granger cause RD	21.49	0.000***	Maintain	
RD granger cause FC	0.521	0.770	Dismiss	Unidirectional
FC granger cause RD	13.292	0.000***	Maintain	
RD granger cause DC	5.683	0.058*	Maintain	Unidirectional
DC granger cause RD	3.135	0.205	Dismiss	
RD granger cause IC	1.814	0.404	Dismiss	Unidirectional
IC granger cause RD	19.85	0.000***	Maintain	

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

In accordance with Table 12, the various diagnostic tests that consist of Jarque-Berra for normality, and stability conditions are performed. Based on the findings we perceive that all the variables are normally distributed across the model. What is more the eigenvalue for stability condition indicates that the VECM imposes 5-unit moduli.

Table 12. The diagnostic test (source: author's computation)

Tests	Prob	Verdict
Residual Normality Joint test (Jarque-Berra)	0.311	All the variables are normally distributed.
Eigenvalue stability condition	The VECM specification imposes 5-unit moduli	

Discussion

Many emerging economies are currently on the forefront of development thanks to technological advancements and transmission that have benefited and still benefit sizable portions of their populations. A number of nations, including China, India, Korea, Taiwan, Singapore, and, to some extent, Brazil, have followed their own technological trajectories. Even so, given the potential that modern inventions like solar technology, mobile phones, and even the Internet could help them revitalize their transition to the 21st century's technological advancement, the applications of technology continue to stay a utopian fantasy for significant portions of Africa, Asia, as well as Latin America.

Since ancient times, technology has always remained at the center of progress, moving from one stage to another, from the industrial to the contemporary technological eras. The introduction of new goods, procedures, and services that improve the quality of lifestyle for both wealthy and less wealthy persons is the result of technology's ongoing innovation. Research, innovation, and technology are crucial components of progress since the majority of items utilized in contemporary life are the result of technology, and engineering, which are derived through the resources that are extracted and analyzed in industries.

It is necessary to examine the individuals and organizations that innovative culture in a certain field of technology, industry, or research level in order to comprehend how supporting the technology works. Actors often comprise people and groups functioning at various sizes, such as national and regional governments, city councils, colleges, for-profit and nonprofit businesses, startups, and technology users. The relationships and conduct of participants in an innovation system are governed by institutions, which are a collection of official and unofficial rules, conventions, decision-making processes, convictions, incentives, and expectations. Innovation frameworks are complex and adaptable because of the relationships between individuals and organizations throughout the numerous steps of the development process, which take place in various industries and at various scales.

Achieving a technology shift can be significantly impacted by institutional policies and macroeconomic conditions. To guarantee that technology contributes as much as possible to sustainable growth, there are four important domains where authorities need to set up legislative, administrative, financial, and policy frameworks. Also, adequate regulation of macroeconomics such the national income, wealth generation, adequate fiscal policies, economic growth, trade, and financial tools assist in promoting innovation and R&D. Accordingly, the goal of this paper was to examine how macroeconomic factors affect the process of technological development, particularly in upper-middle-income countries. Within this framework, a VECM approach and granger causality test are performed by using yearly data of economic indicators concerning the upper-middle-income countries for the period 2000 to 2021. Within the paper, the expenditure in research and development is considered as a proxy for technological development and five macroeconomic factors are selected as explanatory variables.

The findings demonstrated that in the short run there is no notable cointegration among the variables with R&D expenditure. In other words, during the short-run framework economic growth, government final consumption, domestic credit provided to the private sector, national income, and government transparency do not contribute to the technological development of Upper-Middle-income countries. Nevertheless, the study detected that R&D expenditure has negative cointegration with the GDP, government final consumption, and national income. This may be explained by the fact that R&D expenditure is a relatively fixed cost for firms, meaning that they are less likely to increase spending on R&D when the economy is experiencing a downturn. Another possibility is that during periods of economic growth, firms may be more likely to invest in physical capital (such as machinery and equipment) than in R&D. Next, the negative relationship between R&D expenditure and government final consumption may be explained by the fact that governments often allocate resources towards social programs and infrastructure during periods of economic growth, rather than towards R&D. Additionally, during periods of economic contraction, governments may reduce spending on R&D in an effort to cut costs. Third, the negative relationship between R&D expenditure and national income may be due to the fact that as national income rises, firms may shift their focus towards other types of investment, such as physical capital, rather than R&D. Additionally, higher national income may lead to greater competition for resources, which may make it more difficult for firms to allocate resources towards R&D.

Further, the long-term result displayed the presence of cointegration between the variables. According to the long-run outcome, we observed that the transparency situation of upper-middle-income countries, simultaneously the governments' final consumption, the amount of credit provided to the private sector, and national income are unfavorably affecting the technological development. However, it turns out that the development of technology is supported by the economic growth of upper-middle-income nations in the long run. Furthermore, the causality test among the variables presented a unidirectional association between all of the variables, with research and development at 1% and 10% significant levels, with the exception of transparency, which showed no clear causation. Therefore, we draw the conclusion that the GDP, government final consumption, domestic credit given to the private sector, and national income are all positively correlated with technological development over the long term.

The result obtained in the framework of economic growth and R&D is consistent with the study conducted by (Bozkurt, 2015). In his study, the author investigated the long-run and short-run relationship between R&D and economic growth in Turkey. The study uncovered that a 1% increase in GDP rises 1.6425% the fund allocated to R&D. Next, the negative result discovered in terms of government transparency and corruption agrees with the result obtained by (Alam et al., 2019b). In his research, the author used a GMM model on the institutional environment that influences R&D in emerging markets. He unveiled that the transparency and corruption levels of these countries decreased by 0.0021% the R&D. However, the present paper contradicts the findings obtained by (Rehman et al., 2020) in the scope of private credit provided to the domestic sector in proportion to R&D. The author examined the role of the public entities in supporting the R&D. The study showed that in OECD countries the public sector contributes by 0.3% increase in R&D. Finally, Kirca et al. (2021) examined the causality relationship between the national income per capita and R&D. According to the results of his bootstrap panel causality test, there is a unidirectional causal link between R&D spending and per capita income in Hong Kong and Korea. In contrast, in China and Turkey, there is a single direction of causation connecting per capita income to R&D spending.

Important policy implications that could be extracted from the study are that first, fiscal policy can play an important role in supporting R&D investment. Governments can use public funding, tax incentives, and other forms of support to encourage businesses and other organizations to invest in research and development. By doing so, they can help to create a more favorable environment for technological development, which can contribute to economic growth. Next, policymakers should focus on increasing investment in R&D, as this can have a significant impact on technological development. This can be achieved through a range of measures, such as tax incentives, grants, and loans. Third, policymakers should also focus on promoting innovation, as this can drive technological development. This can be achieved through measures such as patent protection, technology transfer agreements, and research partnerships. Fourth, the presence of strong and accountable institutions can facilitate technological development. Policymakers should focus on strengthening institutions such as regulatory bodies, intellectual property offices, and science and technology ministries. Fifth, access to credit can be a crucial factor in enabling businesses to invest in R&D and develop new technologies. Policymakers should focus on enhancing access to credit, especially for small and medium-sized enterprises (SMEs), as these businesses can play a critical role in driving technological development. Lastly, a skilled workforce is critical to technological development. Policymakers should focus on promoting education and skills development, especially in science, technology, engineering, and mathematics (STEM) fields.

Overall, policymakers and nations looking to accomplish technological transformation in the age of digitization can benefit from the study's findings. The research also provides a systematic approach to the macroeconomic aspects that should be used to create an environment that is conducive to and supportive of technological growth. As a limitation of the study, the exclusive focus on only macroeconomic factors excluded the possibility of investigating the role of micro factors that may have an influence on technological development. Therefore, it is recommended that enlarging the scope of new research that involves microeconomic factors and governance indicators that affect technological development as well as a particular focus on the R&D of Low-income countries needs to be addressed since the current paper only considers upper-middle-income countries.

Conclusions

Technological development in upper middle-income countries varies widely depending on the specific country and sector in question. Generally speaking, upper middle-income countries tend to have more advanced technology and infrastructure than lower-income countries, but may not be as advanced as high-income countries. Many upper middle-income countries have made significant progress in developing their technology sectors, particularly in areas such as information technology, biotechnology, and renewable energy. These countries often have well-educated and skilled workforces, strong institutions, and policies that promote innovation and entrepreneurship. However, there are also challenges associated with technological development in upper middle-income countries. These may include issues such as limited access to financing for R&D, weak intellectual property protections, and inadequate infrastructure. In addition, upper middle-income countries may face increasing competition from other countries, particularly emerging economies that are rapidly developing their own technology sectors. Within this framework, the current study investigated the potential of macroeconomic factors in shaping the landscape of technological development by mainly focusing on upper-middle-income countries. Accordingly, the results uncovered that the transparency situation of upper-middle-income countries, simultaneously the governments' final consumption, the amount of credit provided to the private sector, and national income are unfavourably affecting the technological development. Whereas, the economic growth of these countries is favourably supporting the research and development. Overall, while there is significant variation in the state of technological development across upper middle-income countries, many of these countries have made progress in developing their technology sectors and are well-positioned to continue to do so with the right policies and investments. Lastly, creating a favourable environment for technological development, governments can help to drive economic growth and improve the well-being of their citizens.

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