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Examining the Factors that Can Foster Technological Transition in Middle-Income Countries: Evidence from a Cointegration Approach

Sadik Aden Dirir

Faculty of Law, Economics, and Management, University of Djibouti, Campus de Balbala, Djibouti
https://orcid.org/0000-0002-8159-5442
e-mail: sadikaden1999@gmail.com

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Abstract: *Numerous nations and regions are utilizing significant technological progress to tackle economic, social, and environmental issues. In addition, emerging economies and companies devote a growing portion of their resources to research and development (R&D). On the basis of this, we understand that technological innovation is a key contributor to both economic growth and societal advancement. Hence, nations across the globe are competing for the latest technology by investing heavily in research and development. Regrettably, most of the papers focus on developed countries as a result overlooking the developing and emerging nations. As a result, this paper examines the factors that can promote technological transition in middle-income countries. To answer this question, the study employed regression models consisting of CCR, DOLS, and FMOLS to assess the long-run association that exists among the variables. What is more, a Granger causality test was carried on to analyze the causal direction among the variables. Within this context, the results showed that long-term technological change is influenced by factors such as internet usage, government spending, manufacturing value-added, and the credit offered to the private sector. However, because of its detrimental effects on research and development, the economic growth of middle-income countries is not favorably supporting a technological transition. Finally, the study offers a thorough framework that concentrates on a variety of macro factors, enabling researchers to further explore their effects and validate cutting-edge hypotheses about how they might affect a country's performance.*

JEL Classification:
O11; O32; O33

Keywords: *Research and Development; Technological Advancement; Economic Growth; Middle-Income Countries; Innovation; Cointegration Regression*

Introduction

The Second Industrial Revolution, which spanned from the years 1860 to 1900, is frequently referred to as such due to the vast array of technology introduced around that time. According to academics, the Second Industrial Revolution sparked a century of fast growth of new electrically powered manufacturing technology. This quickening of technological progress subsequently gave rise to a new economy that was defined by a rapid increase in industrial productivity as expressed in production per hour. Many people see that specific move to a modern economy as being emblematic of what occurs following any significant and persistent increase in the rate of technical progress (Atkeson & Kehoe, 2007).

Three key characteristics define the transition: a productivity paradox (an unexpectedly long lag between the rate of technological progress and the rate of recorded productivity gain); slow adoption of modern technology and ongoing spending on outdated ones (Del Vecchio et al., 2019). Between 1860 and 1900, a large number of innovations that significantly improved living conditions in the 20th century were developed. Power generation, the automobile's internal combustion engine, the manufacture of hydrocarbon as well as other fuels, telecommunications, transmitters, and central heating are some of these technologies (Jeekel, 2017).

Technology advancement is not possible without digitalization, and it has a substantial impact on productivity levels. The digitalization of the economy is essential to the economic development of a nation. The remarkable success of the G7 nations in generating rapid economic growth is attributable to increased levels of technological development and other aspects. The digitalization of economies brought about by recent advances in information and communication technology (ICTs) has changed upper-income nations' commercial features. These developments in technology have benefited upper-income nations in terms of higher performance, societal change, and rapid industrialization. Additionally, these nations are investing billions of dollars in Research and innovation, which has improved their success in terms of innovation and the economy (Peprah et al., 2019).

Globally, nations have undergone deregulation measures in recent years in an effort to improve economic output, which has boosted rivalry among firms. Hence, companies have expanded their R&D (research and development) investment (Turetken et al., 2019). Because domestic commodities are now more updated and appealing to home consumers, these innovations have significant ramifications for the growth of domestic economies (Adam et al., 2020). As a result, in nations with strong levels of innovation and Capital investments, the need for imports has reduced. Company investment in R&D is seen as a key component in the explanation of industrial specialization and competitiveness (Khan et al., 2021). These expenses are essential for developing new goods and subsequently enhancing the innovation process. Additionally, the economy's ability to compete on price is strongly impacted by these R&D expenditures. The upper-income nations have changed their economies from those copycat nations to a collection of innovative industries by concentrating on R&D investments and uniform policies (Najini et al., 2020).

Different terminology was employed to describe sustainability transitions, such as technological transitions (Geels, 2002) system innovations (Elzen et al., 2004) socio-technical transitions (Huttunen et al., 2013). These concepts' basic tenet would be that technological transitions entail long-term, comprehensive adjustments in favor of greater sustainable output and intake practices across a variety of dimensions. It is true that developments in individuals’ behavior, laws, economic networks, infrastructure, and cultural significance or society are also involved in addition to technological advancements (Slayton & Spinardi, 2016).

A wide spectrum of theoretical perspectives has examined the problem of how to foster and manage essential transitions. In accordance with Diebolt and Hippe (2022), technological transitions permit to enhance of the operational usage of the latest tech, identifying the technological and institutional adjustments changes in work technology's economic success, helping to achieve cost-savings, and transforming social structures in a way that is required for the spread of technology and make the economy of a nation more sustainable.

Previous papers and authors only gave importance to the technological advancement of G7, OECD countries, and upper-income countries. Rarely, addressing low and middle-income countries even if they addressed, they did not assess the long-term effect of the factors that foster technological advancement. in addition, their studies were only limited to some specific sectors such as the environment or education. As a result, our study fills in this gap and gives information on a number of variables outside of education and environment. The paper outlines and explains how macroeconomic conditions might hasten the pace of technological change. It also contributes to the body of existing knowledge by assessing the current development of middle-income countries. Finally, researching factors that encourage research and development will help us comprehend the novel approaches required to accelerate and profit from technological advancement. To ensure economic growth and sustain competitiveness through technology, this research will help managers, academics, and politicians determine the proper sorts of measures necessary in their specialties or nations of interest. Further, the paper also provides a comprehensive framework that focuses on a wide range of macro factors, allowing researchers to further investigate their effects and verify novel hypotheses about how they may influence a country's performance.

The major goal of this study is to look into what influences the technological transition in middle-income countries from the period 2000 to 2020. The primary justification for choosing middle-income nations is that they are looking for ways to integrate higher-income nations and improve their subpar economic performance. As a result, they spend a major part of their GDP on R&D and education. Consequently, the paper considered the expenditure on research and development as a proxy for technological advancement. While various variables, which are suspected to affect the expenditure in research and development were selected. In addition to that, the paper uses the ARDL bounds test to assess the long-run cointegration that exists between the variables and regression models composed of DOLS, FMOLS, and CCR to evaluate the long-run impact on research and development. Last but not least, a Granger causality test is performed to analyze the causality direction among the variables.

This article is set up in the following manner to achieve the aforementioned goal. The following subsection presents the contextual background, which includes earlier literature. The third section of the paper describes the study’s methodology and provides information on the data source and model specification. The findings are presented in the fourth section, which is preceded by the fifth section's analysis and discussion of the findings. Conclusions and research implications are presented in the last part.

Contextual Backgrounds

The tale of economic expansion is just one of many. All nations have experienced growth over the past 70 years, and numerous low-income nations have seen rapid development and the emancipation of millions of people from extreme poverty (Canh et al., 2019). According to conventional growth theory, poorer nations will typically experience robust growth and "close the gap" with rich nations. Nevertheless, only a small number of nations have attained high-income levels, as well as the rate of income has varied and fluctuated across many nations. Officials in middle-income nations with low growth have recently been concerned with the idea that they are caught in a middle-income trap (Alouini & Hubert, 2019). The existence of this alleged trap and the kinds of practices that might aid nations in escaping it have been hotly contested topics. Consequently, many authors contemplated if overcoming the middle-income trap may be achieved through technological advancement and more expenditure in research and development.

The search for potential drivers of technical advancement has long been a hot subject in academic circles and research. The development of the literature in this area can be divided into two roughly distinct categories: conceptual designs and empirical analyses. The papers can also be separated into two distinct study categories: variables at both the macro- and micro-levels affecting innovation.

Scholars Balasubramanian and Lee (2008) have outlined the elements that influence a nation's rate of development as the inventory of knowledge, decision-making, manufacturing industry, corporate strategy, data processing layout, Capital investments, facilities, nation landscape, and companies' access to financial resources. Discovering the national-level factors driving innovation has become one of the top priorities for scholars and policymakers on a macroeconomic level (Berg et al., 2019). According to the literature, factors such as earnings, trade, qualified workforce, quality of institutions, financial deepening, debt instruments, corruption, spillover effects, and R&D expenditure are crucial in determining the pace of technological advancement (Xin et al., 2019).

Barro and Lee (1996) contended that a nation's profit is essential for innovation. Income heavily influences aspects such as infrastructure, facilities, and expenditure in R&D. Therefore, a nation's ability to innovate technologically is improved by an increase in its income. As per (Su et al., 2021), variations in state policies, as reflected in the organizational quality, facilities, taxation, and the extent to which property rights are upheld, are to blame for the technological disparities between nations. Harley (2003) offers additional support, contending that the main driver of ongoing economic growth is the enduring nature of technological change.

Studies have been carried out in empirical studies to contrast the nations by breaking down the various elements of the digital economy. The Innovation Index (GII), Global Competitiveness Index, Internet connectivity, E-government Development Index, and High-Technology Exports are among the elements of the digital age (Richter et al., 2017).

Experts like (Afonasova et al., 2019) contrasted the economic sectors of Russia and the EU by dissecting the elements of each region's digital economies. The scholars also contrasted the economic systems of Russia and the EU nations based on how developed their digital economies were. The authors conclude that Russia maintains a prominent hold in the two aspects of the digital economy, Network Readiness, and ICT development, by examining the impact of various digital economic models on economic progress and social processes. Nevertheless, the nation underperforms behind EU nations in the manufacturing of high-tech exports, which demand significant R&D investments. Park (2019) looked at statistical issues specific to the digital economy, like quantitative measures. The financial evaluation for GDP is one of the significant measurement issues that the authors emphasized. The resilience of digitalization is impacted by a number of data limitations, such as the standard measure of online transfers.

Spending on R&D financed by banks is positively correlated with innovation. Theoretically, because business-financed R&D is seen as a key contributor to the explanation of manufacturing expertise and competitiveness, and because it is essential for the development of new products, thus, there is a positive relationship between BFR&DE and technological innovation. Additionally, these R&D Investments have a big impact on the economy's ability to compete on price (Curtis et al, 2020). Businesses that are able to fund their R&D expenditures with internal resources or external financing from funding sources benefit from rapid growth in technology. Therefore, bank financing of R&D is essential for innovation.

R&D activities are progressively beginning to be truly integrated on a worldwide scale. Over the last 20 years, channels of collaboration between companies, nations, and research centers based in various nations have grown (Dincer, 2019). Since the advancement of the information age in the second quarter of the 1990s (when publicly owned R&D expenditures significantly increased), this most recent change has become especially notable. On the one hand, multinational corporations (MNCs) are conducting an increasing amount of upstream R&D internationally; moreover, some emerging economies are beginning to receive sufficient attention as destinations for MNCs' offshore R&D activities, alongside advanced countries (Pradhan et al., 2019).

In accordance with Zhou et al., (2021), technological innovation is a key factor in boosting productivity and economic growth, particularly in developing nations. It can also be a defining factor for reducing inequality across regions once developing nations experience a long-term "technological catch-up" effect. Notwithstanding, not all advancement in technology reduces the demand for resources. For instance, in 2016, 41% of the world's population still did not cook with electricity and ecologically friendly sources of power, despite advancements in internet and power technologies (Tsuboi, 2019).

Even though it often involves technology, innovation can also involve other fields (organizational innovation or structural innovation). Economic growth cannot be separated from systemic reform. China has depended on multi-dimensional manufacturing institutional reforms and optimization as practical approaches to achieving domestic economic transformation and growth as a developing and transitioning market (Geldes et al., 2017). For generations, economists have continued to struggle to comprehend how changes in structural transformation, technological advancement, and economic growth are related. Technology has become more complex and has acquired new traits in recent years, though, as a result of the novel environment dominated by Industry 4.0 (such as big data, the digital economy, the Internet of Things, etc.) (Asongu & Nwachukwu, 2018).

Methodology

Data sources

The study provides unconventional evidence of the effects of internet users, the value-added of the manufacturing sector, government final spending, domestic lending to the private industry, GDP, national income, and financial sector lending to the private sector on Research & development activities in middle-income countries. The sample countries for the time series data consist of middle-income countries with a GNI per capita between $1,036 and $4,045. The reason behind considering these countries is the fact that Middle-income countries are often in a phase of rapid economic growth and development. Technological advancements play a crucial role in driving and sustaining this growth. By analyzing their technological development, we can understand the factors that contribute to economic progress and identify opportunities for further growth. What is more, Middle-income countries are increasingly becoming major players in the global economy. Analyzing their technological development allows us to assess their competitiveness in various industries and sectors. Understanding their strengths and weaknesses helps in identifying areas where they can gain a competitive advantage, foster innovation, and participate effectively in the global market. Consequently, the study performs three cointegration models namely the dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS), and correlated component regression (CCR) suggested by (Shin & Pesaran, 1999). This analysis used time-varying data from the World Development Indicator (WDI) database spanning the years 2000 to 2020. What is more, the paper, used R&D spending as the dependent variable and a proxy for technological advancement, with internet use, manufacturing value-added, government final expenditure, domestic credit to the private sector, GDP, national income, and monetary sector credit to the private sector as independent variables. The study's limited data size (20 years) reinforces the use of the DOLS, FMOLS, and

CCR approaches. Besides, past studies that were published in reputable periodicals followed a similar process. As an illustration, see (Streimikiene & Kasperowicz, 2016); (Uddin et al., 2017); and (Uddin et al., 2018). Hafner and Mayer-Foulkesr (2013).

Table 1. Variables' description

Variable	Abbreviation	Description	Measurement
Dependent	RD	Technological development	Research and development expenditure (% of GDP)
Independent	IT	Access to the internet	Individuals using the Internet (% of population)
	MV	Manufacturing sector	Manufacturing, value added (current US$)
	GE	Government expenditure	General government final consumption expenditure (current US$)
	DC	Credit to the private sector	Domestic credit to private sector (% of GDP)
	GDP	Economic growth	GDP (current US$)
	NI	National income	Adjusted net national income (current US$)
	MC	Financial support	Monetary Sector credit to private sector (% GDP)

Source: Author's Computation.

Model specification

The study employed the following macroeconomic indicators to establish the connection between R&D, internet users, manufacturing value-added, government final expenditure, credit loans provided to the private sector, GDP, national income, and monetary sector credit to the private sector:

$$RD_t = \int (IT_t, MV_t, GE_t, DC_t, GDP_t, NI_t, MC_t) \quad (1)$$

Based on equation 1 we observe that (RD) denotes the research and development expenditure while (IT) is the internet users, (MV) the value-added of the manufacturing sector, (GE) government final spending, (DC) domestic lending to the private industry, GDP, (NI) national income, and (MC) financial sector lending to the private sector.

The following equation serves as a representation of the empirical model:

$$RD_t = \beta_0 + \beta_1 IT_t + \beta_2 MV_t + \beta_3 GE_t + \beta_4 DC_t + \beta_5 GDP_t + \beta_6 NI_t + \beta_7 MC_t + \varepsilon_t \quad (2)$$

As given in eq. (2) β_0 and ε_t denotes the intercept and error term, consecutively. Additionally, β_1, β_2, β_3, β_4, β_5, β_6, and β_7, denote the coefficients of the independent variables.

- **ARDL bound test**

Upon performing the F-distribution, the (ARDL) Bounds assessment is carried out, and the input parameters for this test are recommended by (Pesaran and Timmermann, 2005). The measurement technique starts with Equation (3) and applies OLS to allow the F-test and the assessment of the sum of the lag components. This approach aims to determine whether there is any possibility for a long-term relationship between the variables. The model is expressed by the following description:

$$\Delta RD_t = \beta_0 + \beta_0 RD_{t-1} + \beta_2 IT_{t-1} + \beta_3 MV_{t-1} + \beta_4 GE_{t-1} + \beta_5 DC_{t-1} + \beta_6 GDP_{t-1} + \beta_7 NI_{t-1} + \beta_8 MC_{t-1} + \sum_{i=0}^{q} \gamma_1 \Delta RD_{t-i} + \sum_{i=0}^{r} \gamma_2 \Delta IT_{t-i} + \sum_{i=0}^{s} \gamma_3 \Delta MV_{t-i} + \sum_{i=0}^{t} \gamma_4 \Delta GE_{t-i} + \sum_{i=0}^{u} \gamma_5 \Delta DC_{t-i} + \sum_{i=0}^{v} \gamma_6 \Delta GDP_{t-i} + \sum_{i=0}^{w} \gamma_7 \Delta NI_{t-i} + \sum_{i=0}^{x} \gamma_8 \Delta MC_{t-i} + \varepsilon_t \quad (3)$$

As per equation (3) we perceive Δ which implies the first difference derivatives and q denotes the appropriate number of lags. ε_t is the stochastic error term. Consequently, this method verifies the invalid theory that cointegration does not exist ($\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = \gamma_8 = 0$) as well as the cointegration alternate theory ($\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq \gamma_6 \neq \gamma_7 \neq \gamma_8 \neq 0$) based on the F-test.

- **The DOLS estimates**

The DOLS adopts a generic procedure in a scenario where the factors are still perfectly correlated but are included in a different sequence to determine a long-term relationship (Stock and Watson, 1993). This model involves leads and delays in order to accommodate for parallel distortion and small sample prejudice. Least squares estimates can be used to derive the DOLS estimators, which are asymptotically accurate and unbiased even when the endogenous problem is present. Additionally, the parameters take into account potential autocorrelation and residual non-normality (Herzer, 2006). The formula is expressed as follows:

$$y_t = a + bX_t + \sum_{i=-k}^{i=k} \emptyset \Delta X_{t+i} + \varepsilon_t \quad (4)$$

b stands for the long-run elasticity in equation (4). The descriptor $\emptyset$ is the "coefficient" and refers to the distinction between the leads and lags of I(1) regressors. The above coefficients are used to account for residuals that may be endogenous, autocorrelative, or non-normal. They are regarded as nuisance parameters.

- **Robustness models FMOLS and CCR estimates**

To further support the dependability of the DOLS results, a modified and upgraded model (FMOLS) and canonical model (CCR) are used. The FMOLS regression was developed by Hansen and Phillips in 1990 to preserve the highest cointegrating values. The model also technique aids in accounting for the impacts of the autocorrelation problem in addition to the unobserved heterogeneity brought on by cointegrating the predictor components. In addition, Park (1992) created the CCR approach, that only utilizes a lagged model's static element to transform data. The CCR guarantees effectiveness for the information extraction of the unobserved heterogeneity from explanatory variables in a cointegrating framework to appear at zero frequency. Consequently, the CCR technique generates arithmetically effective approximation and chi-square tests without any problematic features. Consequently, to ascertain long-term elastic modulus. Below both models are obtained as follows:

$$ð_{FME} = \left(\sum_{t=1}^{T} Z_t Y_t'\right)^{-1} \left(\sum_{t=1}^{T} Z_t Y_t^{+} - T[\Lambda_{12}^{+}]\right) \quad (5)$$

$$ð_{CCR} = \left(\sum_{t=1}^{T} Z_t^{*} Z_t^{*1}\right)^{-1} \sum_{t=1}^{T} Z_t^{*} Y_t^{*1} \quad (6)$$

We perceive that Y_t^+, Z_t^* and Λ_{12}^+ terms eliminate the autocorrelation problem and unobserved heterogeneity. Standard Wald tests can be performed using the FMOLS and CCR estimator because they are monotonically impartial and employ a stable mixture-normal asymptotic distribution.

- **Granger test**

The purpose was to show the factors' causal linkages. To ascertain if there is a meaningful relationship between the indicators, the Granger causality test proposed by Granger (1969) was carried out. The strategy is explained in further context below:

$$X_t = \sum_{l=1}^{p} \left(a_{11,1}X_{t-1} + a_{12,1}Y_{t-1}\right) + \mu_t \tag{7}$$

$$Y_t = \sum_{l=1}^{p} \left(a_{21,1}X_{t-1} + a_{22,1}Y_{t-1}\right) + \epsilon_t \tag{8}$$

As illustrated in equation 7 and 8 p implies the order of the model, $a_{ij,1}(i, j = 1,2)$ denotes the coefficients expressed in the model, while μ_t and ϵ_t denotes the residuals. A causation linkage between X and Y may be established using F tests, and the parameters can be computed using simple least squares.

Findings

Table 2 provides a general conclusion of the dataset that were collected for this analysis as well as the statistical outcomes of different parametric tests. For middle-income nations between 2000 and 2020, each variable comprises 21 samples of time series data. There are 21 samples of data collected over time for each variable, covering middle-income nations from 2000 through 2020. According to actual observations, the entire series is asymmetric because all the variables display kurtosis levels under 4. Additionally, the small rates of the normality test (Jarque-Bera) show that all the indicators are properly scattered. While, the skewness results indicate GE, RD, IT, and MC are nearly symmetrical. MV and NI reveals a negatively skewed data whereas, DC which is the domestic credit provided to the private sector shows a positively skewed data. Based on these details, our subsequent step will be to carry out a correlation test between the variables.

Table 2. Descriptive Statistics

Items	RD	IT	MV	GE	DC	GDP	NI	MC
Mean	1.107965	22.84579	10.21492	12.37008	75.24143	13.20738	13.16843	71.63048
Median	1.121794	21.56293	12.60444	12.45848	71.16283	13.29778	13.30217	68.03207
Maximum	1.864758	57.25656	12.80423	12.68696	120.2577	13.49943	13.42008	118.0956
Minimum	0.646359	1.535809	0.000000	11.90390	51.06801	12.76095	12.70881	47.18915
Std. Dev.	0.322315	16.92717	5.080070	0.288933	20.46325	0.271533	0.249690	21.51728
Skewness	0.446075	0.406050	-1.572393	-0.498729	0.611721	-0.551155	-0.830671	0.575090
Kurtosis	2.562328	2.022364	3.479230	1.677284	2.186758	1.750294	2.088701	2.107992
Jarque-Bera	0.864052	1.413369	5.854422	2.401439	1.888402	2.429745	3.141711	1.853767
Probability	0.649193	0.493277	0.011948	0.300978	0.388990	0.296748	0.207867	0.395785
Sum	23.26726	479.7616	214.5133	259.7718	1580.070	277.3549	276.5369	1504.240
Sum Sq. Dev.	2.077738	5730.584	516.1422	1.669647	8374.891	1.474603	1.246900	9259.866
Observations	21	21	21	21	21	21	21	21

Source: E-views Computation.

Figure 1 is illustrating the various macro indicators of middle-income countries. Starting with the domestic credit offered to the private, research and development expenditure, individuals using the internet, general government expenditure, and manufacturing value-added present a continuous increase over the last 20 years. In contrast, the national income and the economic growth of middle-income countries demonstrate a decrease over the years. Nevertheless, we observe that R&D and credit offered to the private sector are the main contributor to promoting technological advancement have increased steadily. This expresses the efforts of middle-income countries on investing and allocating resources in technology and research.

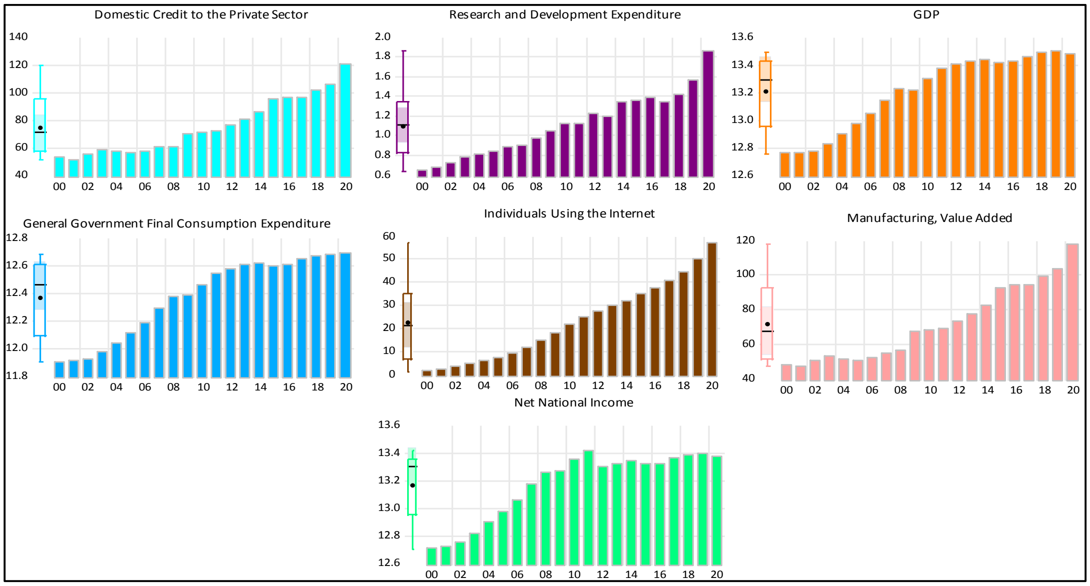

Fig. 1. Macro indicators of middle-income countries

Source: World development indicators.

To determine whether there are any linear connections between the variables, a correlation analysis is performed. According to the table 3 results, all of the variables are interlinked. There is a significant positive correlation between RD and IT, MV, GE, DC, GDP, NI, and MC. This suggests the value of research and development increases when all other components' ratios upsurge, and conversely. We performed unit root tests to ascertain the homogeneity of the chosen indicators as a result of the correlation analysis.

Table 3. Correlation Matrix

Variables	RD	IT	MV	GE	DC	GDP	NI	MC
RD	1.000							
IT	0.987	1.000						
MV	0.638	0.604	1.000					
GE	0.918	0.921	0.782	1.000				
DC	0.977	0.988	0.530	0.868	1.000			
GDP	0.908	0.911	0.799	0.999	0.855	1.000		
NI	0.838	0.830	0.852	0.970	0.758	0.975	1.000	
MC	0.977	0.989	0.529	0.873	0.999	0.860	0.765	1.000

Source: E-views Computation.

In this study, the unit root test was used to demonstrate the DOLS model's applicability and the premise that all the selected variables are not exceeding the first difference. Table 4 displays the outcomes of the DF-GLS and P-P unit root analyses. In accordance with the findings, all the indicators remained non-stationary at the level in both tests, with the exception of MV, but they all turned stationary at the first difference. Furthermore, the occurrence of diverse degrees of integration for components evaluated by the DF-GLS test as well as variables not surpassing the integration order of I (1) provides evidence in favor of using the ARDL test and regression frameworks to establish an association between the series.

Table 4. Stationarity tests

Different tests and variables		RD	IT	MV	GE	DC	GDP	NI	MC
DF-GLS	At level	-1.290	-1.401	-1.625*	-1.240	0.782	-1.234	-1.192	0.786
	First difference	-2.141**	-1.898**	-3.056***	-1.889*	-2.084**	-1.935*	-2.067**	-2.076**
P-P	At level	1.391	-1.877	-2.357	-1.510	4.836	-1.720	-2.198	3.765
	First difference	-2.850*	-3.784**	-4.356***	-4.794***	-3.250**	-6.423***	-2.997*	-2.986*

Note: ∗∗∗, ∗∗, and ∗ signifies a critical value of 1%, 5%, and 10% levels, respectively.

Source: E-views Computation.

After identifying the characteristics of the series' homogeneity, we carried out the bounds test for serial correlation. In this analysis, an ideal lag length was applied to calculate the F-statistic, which was based on the Akaike Information Criterion's lower critical spectrum (AIC). The conclusions of the ARDL constraints analysis, which was applied to examine the linkage between the variables, are documented in Table 5. The results demonstrate that if the forecasted average of the F-test exceeds the results of both constraints, then there is a long-term relationship between the variables (lower and upper bound). Accordingly, the statistics show that the expected F-statistic value (6.921334) exceeds the likelihood value of 10%, 5%, 2.5%, and 1% of the critical maximum bound in the ratios zero and one. This implies that the factors have a long-term linkage, permitting us to discard the null hypothesis.

Table 5. Bounds Test for long term assessment

F-Bounds Test	Value	Null hypothesis: No levels of relationship		
Test statistic		Significance	I (0)	I (1)
F-statistic	6.921334	10%	1.92	2.89
		5%	2.17	3.21
k	7	2.5%	2.43	3.51
		1%	2.73	3.9

Source: E-views Computation.

Upon acknowledging the association of the variables, the DOLS framework is used to examine how long-term trends in internet usage, the value-added from the manufacturing sector, government spending, domestic loan to the private sector, GDP, national income, and financial sector lending to the private sector on research and development in middle-income countries. Table 6 summarizes the DOLS outcome. When all other variables are maintained constant, the anticipated long-run coefficients of IT, GE, MV, and DC are positive and significant at 5% and 10% levels, indicating that a 1% increase in internet use, government spending, manufacturing value-added, and domestic credit to the private sector will result in 0.01%, 4.76, and 0.04% more research and development. This conclusion shows that long-term technological change is influenced by internet use, government spending, manufacturing value added, and domestic loans to the private sector. Additionally, the estimated long-run of GDP and MC coefficients are negative and significant at 5% and 10% levels, demonstrating that an increment in 1% of GDP and monetary sector credit to the private sector in middle-income countries is closely linked to a reduction in technological transition by 5.19% and 0.04%, respectively, over the long term. This reveals that the economic growth of middle-income nations is not favorably supporting a technological transition. Last but not least, the computed predictor of national income indicates that a rise in national income of 1% triggers an expansion in research and development of 0.28 percent, although this relationship is not statistically noteworthy. Furthermore, it is remarkable that the computed coefficients' values are accurate in both theory and practice. In the present study, a diagnostic test was used to assess the derived model's correctness of fit. We may conclude that the developed regression framework performs extremely well based on the R2 and enhanced R2 estimates of 0.9863 and 0.9789, correspondingly. As a result, 98% of the fluctuation in the shift of the outcome variable can be explained by independent factors.

Table 6. The DOLS estimates

DOLS. Dependent variable RD				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
IT	0.014186**	0.005861	2.420330	0.0309
MV	0.008389*	0.004337	1.934184	0.0752
GE	4.760721**	1.775912	2.680719	0.0189
DC	0.044128**	0.018829	2.343607	0.0356
GDP	-5.194696**	1.850994	-2.806436	0.0148
NI	0.286715	0.223510	1.282783	0.2220
MC	-0.041391*	0.019180	-2.158026	0.0502
C	6.285048*	3.141613	2.000580	0.0668
R-squared			0.986330	
Adjusted R-squared			0.978969	
S.E. of regression			0.046743	
Long-run variance			0.001467	

∗∗∗, ∗∗, and ∗ signifies a critical value of 1%, 5%, and 10% levels, respectively

Source: E-views Computation.

To evaluate the accuracy of the DOLS estimate, the FMOLS and CCR approaches were used in this research. Both models' estimations are shown in Table 7. The outcomes, therefore demonstrate how credible the DOLS inspection is. Since the observations showcase similar outcomes with the DOLS in terms of internet utilization, domestic lending to the private sector, the value-added from the manufacturing sector, and government final investment are all positive and noteworthy at critical degrees of 1% and 5%. The results further supported the negative relationship between GDP and lending from the financial sector to the private sector, which was significant at the 5% level for R&D. Ergo, it can be asserted that factors increasing the likelihood of technological transition in middle-income nations encompass the quantity of internet users, public spending, the total value generated from the manufacturing sector, and domestic lending to the private sector, whereas economic growth and monetary sector credit to the private sector cannot be regarded as such. The outcomes of the FMOLS and CCR models align with those of the DOLS. We perceive that the estimation's estimation R-square and altered R2 values show how closely the models fit the data, confirming that the regressors can reflect

98% of the variation in the movement of the dependent variable.

Table 7. The FMOLS and CCR estimates

FMOLS. Dependent variable RD				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
IT	0.016043***	0.004786	3.352164	0.0058
MV	0.008195**	0.003570	2.295365	0.0405
GE	5.324938***	1.450087	3.672151	0.0032
DC	0.050154***	0.015400	3.256820	0.0069
GDP	-5.828042***	1.513288	-3.851246	0.0023
NI	0.307934	0.184398	1.669944	0.1208
MC	-0.048520***	0.015698	-3.090760	0.0093
C	7.408722**	2.561595	2.892230	0.0135
R-squared			0.984849	
Adjusted R-squared			0.976010	
S.E. of regression			0.048383	
Long-run variance			0.000974	
CCR. Dependent variable RD				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
IT	0.017996**	0.006654	2.704309	0.0192
MV	0.011125*	0.005581	1.993363	0.0695
GE	9.606213**	3.325112	2.888989	0.0136
DC	0.091330**	0.033490	2.727098	0.0184
GDP	-10.59075**	3.617096	-2.927970	0.0127
NI	0.552639*	0.257476	2.146368	0.0530
MC	-0.089474**	0.032801	-2.727805	0.0183
C	13.89869**	5.587843	2.487309	0.0286
R-squared			0.970021	
Adjusted R-squared			0.952534	
S.E. of regression			0.068057	
Long-run variance			0.000974	

***, **, and * signifies a critical value of 1%, 5%, and 10% levels, respectively

Source: E-views Computation.

To determine the causation between the variables and whether it exists, one can use the F-statistic, which assesses Granger causality. Table 8 summarizes the Causality association between the indicators as well as the orientation of connection, such as one-way or two-way causality. Generally, the results of the test demonstrate a two-way causal association between all the factors and the research and development. Nonetheless to say, there was a one-way causation between RD and MC due to the credit given by the financial sector to the private sector. So, it is claimed that the drivers of research and development include the use of the internet by individuals, manufacturing value-added, final government spending, domestic credit to the private sector, GDP, and national income. Although lending from the financial sector to the private sector does not encourage innovation in middle-income nations.

Table 8. Granger's test for causality

Hypothesis	F-statistic	Prob.	Decision	Direction
IT granger cause RD	345.85***	0.000	Accept	Two-way causality
RD granger cause IT	7.012**	0.030	Accept	
MV granger cause RD	16.944***	0.000	Accept	Two-way causality
RD granger cause MV	17.714***	0.000	Accept	
GE granger cause RD	54.83***	0.000	Accept	Two-way causality
RD granger cause GE	11.683**	0.003	Accept	
DC granger cause RD	61.19***	0.000	Accept	Two-way causality
RD granger cause DC	6.243**	0.044	Accept	
GDP granger cause RD	55.523***	0.000	Accept	Two-way causality
RD granger cause GDP	11.037***	0.004	Accept	
NI granger cause RD	112.35***	0.000	Accept	Two-way causality
RD granger cause NI	7.2187**	0.027	Accept	
MC granger cause RD	77.237***	0.000	Accept	One-way causality
RD granger cause MC	1.403	0.496	Reject	

∗∗∗, ∗∗, and ∗ signifies a critical value of 1%, 5%, and 10% levels, respectively

Source: E-views Computation.

This study employed heteroscedasticity and the Jarque-Bera test for normality to confirm the accuracy of the cointegration value. The findings of the diagnostic techniques are presented in Table 9. There is no heteroscedasticity, and all models contain regularly dispersed residually dispersed residuals. Further, u sing the cumulative sum of recursive residuals (CUSUM) test, the model's toughness was evaluated. Figure 2's CUSUM graph displays a 5% level of significance. The remaining values are represented by blue lines, while red lines show confidence levels. The calculated results demonstrate that the investigated residuals' values remain within the range of significance at a 5% level of confidence, proving the model's validity

Table 9. Diagnostic results

	Models	Coefficient	Prob.	Decision
Jarque-Bera test	DOLS	1.284409	0.526131	Residuals are normally distributed across all the models.
	FMOLS	1.328596	0.514635	
	CCR	0.833122	0.659310	
	ARDL	1.396804	0.497380	
Heteroskedasticity Test: Breusch-Pagan-Godfrey				
F-Statistic	1.14494	Prob. F (8,11)	0.4066	
Observation × R-squared	9.08706	Prob. Chi-Square (8)	0.3350	

Source: E-views Computation.

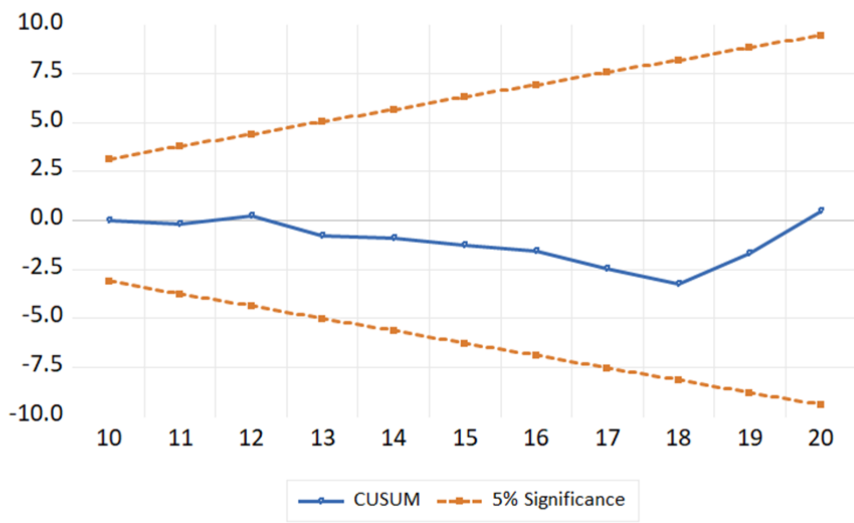

Fig. 2. Cusum

Source: E-views Computation

Discussion

Technology's growth and advancement have considerably improved our way of life. The influence of technology can be seen in almost every aspect of life. With the speed at which technology is developing, civilization is looking to evolve and produce simpler and longer-lasting methods of living. In light of the notable technological advancements of our time, we are being forced to give the connections in both technology and economic growth a lot of thought. The more we consider it, the more we come to the conclusion that advancements in technology are almost certainly the main force behind long-term economic progress. We also acknowledge that a complicated framework of social structures is required to assist innovation activities. Technology is not solely a market-driven concept, despite the fact that markets play a significant role in it. Nations need a new strategy if they want to support highly innovative economic structures because innovating economies need a joint initiative of industry and non-industry organizations to render the innovation process work effectively.

Technology and development are closely linked. Without the development of new technologies, humans might not have reached this point in their evolution. The significant transformations and economic progress we are currently witnessing are a result of modern technology. In the industrial sector, technology has increased productivity and quality. The risk associated with manufacturing businesses has decreased thanks to advancements in technology. While the average age of the population has increased globally due to significant advancements in health care, the fatality rate has also significantly decreased.

Every day, a new business introduces something more creative in an endeavor to outperform other companies in the competition for clients. This consumption quickens the pace of development every year. Nations' massive investments in research and development have accelerated technological change and reliance. Nations are building smart cities to improve the quality of their citizens and establish a sustainable economy among these nations we have Copenhagen, Seoul, Beijing, Amsterdam, and Singapore. Ironically, none of these nations are middle-income countries which force us to question how economic growth is tied to research and development, and what is the adequate ecosystem that may help foster a technological transition.

According to research, the main factor contributing to poverty in poor nations is their lack of advanced technology. Fast growth requires a certain level of technological development as a prerequisite. As a result, it is challenging to bring about technological progress in underdeveloped nations because the pre-industrial social structures do not support large-scale technological advancements. It has been noted that slowing down economic expansion is the lack of appropriate technological innovation. Middle-income nations, like the rest of the world, have a real need for an innovation strategy. Due to the fact that many emerging economies are now at a stage of development where a new strategy for technology and growth is needed, middle-income countries may find the need to act more urgently than other countries if they need to overcome their economic ranking.

Within this framework, the study was conducted to identify the factors that promote technological transition in the long run, particularly in middle-income countries that are still seeking modern strategies and measures to transcend their economic ranking. A cointegration approach composed of DOLS, FMOLS, and CCR was used in order to assess the long-run cointegration among the variables selected. With that in mind, the findings exhibited that a 1% growth in individuals using the internet, government final expenditure, manufacturing value-added, and domestic credit to the private sector will result in a 0.01%, 4.76, and 0.04% increase in research and development. These results express that individual using the internet, government final expenditure, manufacturing value-added, and domestic credit to the private sector prompt a technological transition in the long run. On the other hand, the findings demonstrated that an increase in 1% of GDP and monetary sector credit to the private sector in middle-income countries is related to a 5.19%, and 0.04% reduction in technological transition in the long run. This reveals that the economic growth of middle-income nations is not favorably supporting a technological transition. Finally, national income presented an insignificant impact on research and development thus we rule that the national income of middle-income countries cannot contribute to promoting research and development. In addition to these results, the granger causality test revealed that all the factors exhibit a two-way causality with the research and development. Except, monetary sector credit to the private sector presented a one-way causality running from research and development to monetary sector credit to the private sector. Hence, this implies that individuals using the internet, manufacturing value-added, government final expenditure, domestic credit to the private sector, GDP, and national income cause the research and development. Whilst, monetary sector credit to the private sector does not cause research and development in middle-income countries.

Finally, innovative implications and recommendations can be generated from the actual study. Starting with the theoretical Policy Implications:

1. Creating favorable regulatory and policy environments: Government policies and regulations can shape the technological landscape, creating a supportive environment for innovation, research, and development.
2. Encouraging Research and Development: The government should provide support to universities, research institutions, and private companies to invest in research and development of new technologies. This can be done through funding and tax incentives.
3. Foster Collaboration: Collaboration between industry, academia, and government can promote technological innovation, share knowledge and expertise, and facilitate the commercialization of new technologies.
4. Supporting Market Formation: To facilitate technological transitions, it's important to create and sustain markets that are receptive to new technologies. Governments can support early adopters through grants and subsidies.
5. Ensuring Universal Access: As new technologies emerge, policymakers should ensure that they are accessible to all segments of society, regardless of their socioeconomic status.

Practical Policy Implications:

1. Establishing Innovation Funds: Governments can establish funds to support innovation in areas critical to economic growth, such as healthcare, energy, and transportation. These funds can be used to support research, development, and commercialization of new technologies.
2. Providing Tax Incentives: Governments can provide tax incentives to companies investing in research and development. This can encourage companies to invest in new technologies, which can drive technological transitions.
3. Creating Industry Partnerships: Governments can create partnerships between industry and academia to promote the development of new technologies. These partnerships can help to bridge the gap between research and commercialization.
4. Offering Training Programs: Governments can offer training programs to help workers develop the skills needed for new technologies. This can ensure that the workforce is equipped to transition to the new technological landscape.
5. Facilitating Access to Capital: Governments can provide access to capital for companies that are developing new technologies. This can be done through venture capital funds or other financing mechanisms.

Overall, policy implications for fostering technological transitions should aim to create a supportive environment for innovation, facilitate the commercialization of new technologies, and ensure that the benefits of technological change are widely shared.

Conclusion

The past few decades have witnessed a significantly accelerated pace in the development and utilization of new technologies. Despite, there are still some implementation gaps, notably in the least developed countries. This fast technological development is having an effect on almost every sector of the economy, society, and culture. In the upcoming years, it is highly probable that the rate of technological development and uptake will remain the same. Frontier technologies are frequently at the forefront of innovation and have many great potential combinations based on connectivity and digitization. Consequently, the paper examined the factors that foster technological transition in middle-income countries over the last 20 years. To carry on with the examination, the paper used the ARDL bounds test to assess the long-run cointegration that exists between the variables and regression models composed of DOLS, FMOLS, and CCR to evaluate the long-run impact on research and development. In addition, a granger causality test was performed to analyze the causality direction among the variables. Within this framework, the findings revealed that individuals using the internet, government final expenditure, manufacturing value-added, and domestic credit to the private sector prompt a technological transition in the long run. Whereas, the economic growth of middle-income nations is not favorably supporting a technological transition due to its negative impact on research and development. Last but not least, according to the results, the national income of middle-income countries does not appear to contribute to promoting research and development. Finally, the paper outlines and explains how macroeconomic conditions might hasten the pace of technological change. It also contributes to the body of existing knowledge by assessing the current development of middle-income countries. Additionally, researching factors that encourage research and development will help us comprehend the novel approaches required to accelerate and profit from technological advancement. This research will help policymakers, academics, and managers in this context by identifying the proper sorts of actions needed in their fields of specialization or nations of interest to ensure economic development and retain competitiveness through technology. Further, the paper also provides a comprehensive framework that focuses on a wide range of macro factors, allowing researchers to further investigate their effects and verify novel hypotheses about how they may influence a country's performance.

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