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Innovation, human capital, and economic growth in Ethiopia: A systematic review and empirical analysis

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Abstract

National innovation systems are recognized as key drivers of economic growth, particularly in developing economies. Human capital and research and development are fundamental pillars supporting the effectiveness of these systems. This study evaluates the contribution of human capital and research and development to gross domestic product through a systematic review of prior research and empirical validation. The systematic review indicates that labor force participation and research expenditure positively influence gross domestic product, while educational investment exhibits a long-term impact. To provide a comprehensive understanding, the study employs a Cobb-Douglas production function model using World Bank data from 2000 to 2023. Empirical results reveal that both research and development and human capital have statistically insignificant effects on gross domestic product growth. These findings highlight the need for greater policy attention on strengthening human capital development and research capabilities by increasing research funding, fostering collaboration among innovation system actors, and implementing strategies to enhance the availability of skilled and educated personnel across sectors for sustainable economic growth.

Keywords: Economic growth, human capital; innovation system; research and development; systematic review.

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1. INTRODUCTION

Ethiopia's economy has experienced significant growth in recent years, largely driven by the Growth and Transformation Plans (GTP I and GTP II). According to the National Plan Commission (NPC, 2020), Ethiopia is poised to transition into a middle-income country by 2030 through industrial transformation. In this context, the National Innovation System (NIS) is crucial to the successful implementation of the 10-year Homegrown Economic Reform (HGER) plan (Ethiopia, 2020). NIS has become increasingly recognized as a fundamental driver of economic growth and development, particularly in developing countries where technological advancement and innovation are key to progress (Huang et al., 2024; Weerasinghe et al., 2024).

Freeman (1987) defines the NIS as a network of interrelated actors that collectively foster the generation of new technologies and knowledge within a nation. The effectiveness of an innovation system depends on key components such as infrastructure, institutions, research and development (R&D), technology transfer, and human capital (Bera & Rahut, 2024). At the heart of a successful NIS lies R&D, which plays a pivotal role in the creation of new technologies, processes, and products that stimulate economic activity. R&D fosters the exploration and application of novel knowledge to existing production techniques, thus facilitating technical advancements. The ability to innovate and enhance economic performance is intrinsically tied to R&D, which also generates a variety of innovations. Consequently, nations must prioritize both direct and indirect investments in R&D to catalyze sustainable economic growth.

Human capital, encompassing the knowledge, skills, and competencies of the workforce, is another essential component of the NIS. Becker (1964) conceptualizes human capital as the intellectual and technical capacities embodied in individuals. Education and training are instrumental in enhancing human capital, thereby increasing productivity and promoting economic growth. Human capital plays a critical role in the utilization and expansion of innovations (Muhamad, 2018), directly contributing to GDP growth and supporting the broader performance of the NIS. Moreover, human capital is a key factor in R&D activities and in applying the technologies derived from successful R&D efforts to production. In essence, a highly skilled workforce can drive technological R&D by integrating both internal and external knowledge. This integration involves processes such as knowledge creation, dissemination, diffusion, and the transformation of companies' internal R&D activities (Sun et al., 2020). Therefore, the availability of high-level human capital has a direct impact on the success of R&D efforts, enhancing the level of innovation. On the other hand, the introduction of new technologies also opens up fresh economic opportunities for further investment in both physical and human capital. Integrating these two forces into a unified framework provides a comprehensive understanding of their mutual interaction in fostering economic growth, thus advancing theoretical concepts towards practical application.

Historically, economic growth theories have been central to macroeconomic research, particularly in the 18th century, when scholars focused on variables such as population and capital. The emergence of endogenous growth theories in the early 1990s represented a paradigm shift, emphasizing the importance of internal factors, particularly technology, innovation, and human capital, as critical drivers of long-term economic growth. These theories underscore the significance of knowledge generation, human capital development, and R&D activities as major determinants of technological innovation and economic performance.

The interaction between human capital, R&D, and economic growth has been a topic of considerable interest in economic literature. According to the endogenous growth theory proposed by Romer (1994), knowledge, largely produced through R&D, is a non-rivalrous public good that underpins long-term economic growth. Knowledge spillovers, which extend the benefits of R&D beyond the originating firm, enhance the broader impact of technological innovation on economic development.

Empirical studies have examined the relationship between human capital, R&D, and economic growth within the context of innovation ecosystems. For instance, Dinku et al. (2024) investigated the effect of human capital on small and medium enterprise (SME) performance using the CB-SEM data analysis technique. The study found that formal education and managerial skills positively influenced SME performance and innovative

practices. However, it acknowledged the need for further research on the long-term impact of human capital on the national economy, including the development of innovation strategies and educational curricula tailored to entrepreneurship. Notably, this study focused solely on the relationship between human capital and economic growth, without considering the role of R&D.

In contrast, Keraga and Araya (2023) conducted an empirical analysis to explore the relationship between R&D and economic growth, employing the General Structural Equation Model (GSEM) and using data from the World Bank's enterprise survey. Their findings highlighted the significant impact of innovation on firm productivity, although they emphasized the necessity of further work to strengthen firms' innovation capabilities. Given the strong correlation between human capital and R&D, the authors recommended an integrated approach to assess their combined impact on GDP.

Similarly, Gebrehiwot (2016) analyzed the impact of human capital development on economic growth using the ARDL method. The study found that human capital had a long-term effect on economic growth, with a 1% increase in secondary education contributing to a 0.5096% change in GDP. While the study examined the effects of human capital over both the short and long term, it did not account for the role of R&D. Additionally, Suhatman (2024) found that human capital and economic growth have a unidirectional relationship, with human capital positively influencing economic development, though the reverse was not true. This result suggests that investment in human capital is crucial for stimulating economic growth.

1.1. Purpose of study

The interplay between R&D and human capital is synergistic. R&D generates new knowledge, while human capital is essential for its creation, dissemination, and application. A skilled workforce is crucial for transforming R&D outputs into innovative products and processes. Conversely, R&D investments contribute to human capital development by creating new job opportunities and stimulating demand for education and training. This dynamic interaction between R&D and human capital is a key driver of economic growth and competitiveness.

Although R&D and human capital are highly correlated in the NIS ecosystem, there is a notable gap in existing studies that measure the combined impact on economic growth. Hence, the main objectives of the study are: (1) to conduct systematic review of literature focusing on effect of R and D and human capital on economic growth, (2) to investigate the extent of the effect of R and D (innovation) on economic growth of Ethiopia, and (3) to investigate the extent of the effect of human capital (knowledge) on economic growth of Ethiopia

To fully comprehend the relation between Ethiopian economic development, R&D, and Human capital, empirical data from many sources must be carefully analyzed using a variety of methodologies in addition to theoretical concepts. The following important questions are addressed in this study: (RQ1) What is the role of Research and Development in stimulating economic growth in the case of Ethiopia? and (RQ2) What is the role of human capital (knowledge) in the economic growth of Ethiopia?

2. METHOD AND MATERIALS

2.1. Data collection method

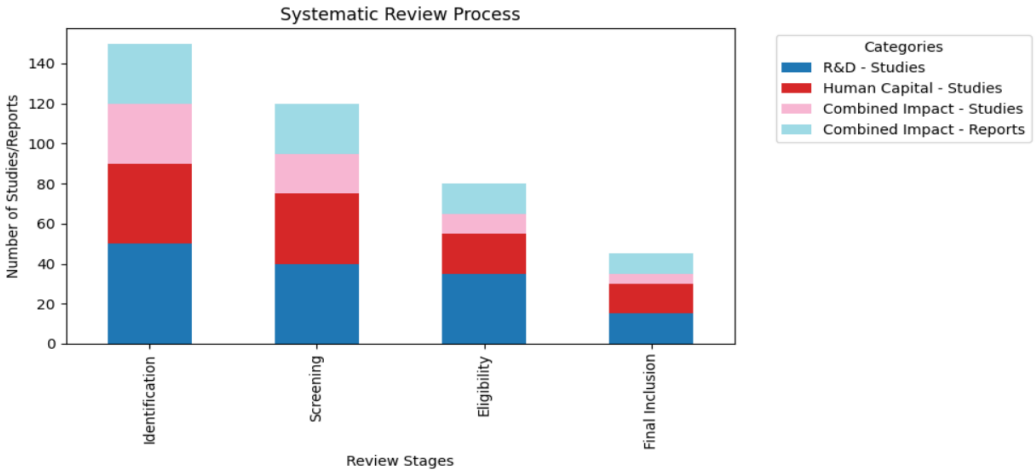
This study utilizes a systematic literature review to evaluate the combined effects of research and development (R&D) and human capital on Ethiopia's GDP, with a focus on Ethiopia's NIS. The review involved searching academic papers, government reports, and other authoritative sources published between 2010 and 2024. Studies were included if they examined the relationship between R&D, human capital, and economic growth within the context of Ethiopia's NIS. Exclusion criteria encompassed studies not directly relevant to Ethiopia's NIS, those not published in English (unless translated), and studies lacking methodological rigor. Data were extracted from selected studies, focusing on study characteristics, methodologies, and findings related to R&D and human capital.

Forward and backward citation searches were conducted using Connected Papers and Litmaps to uncover additional relevant literature. The databases searched included Google Scholar and CORE. The extracted data were analyzed qualitatively to identify trends and assess the effectiveness and efficacy of Ethiopia's NIS in promoting economic growth. This comprehensive approach ensures a robust examination of the relevant literature and provides insights into the interactions between R&D, human capital, and economic outcomes.

Figure 1 depicts the overall review process by categorizing the research papers and various reports based on the impact of R&D and human capital on the country's GDP for the case of NIS. The Figure depicts four main review stages, namely, identification, screening, eligibility, and final inclusion. Around 45 studies are included in this systematic review. As it is shown in the figure, there is a limited number of studies that imply the combined impact on economic growth. On the other hand, reports that explain the combined effects are large in number.

Figure 1

Review of the stages and study distributions



In addition to the systematic review, this paper also used econometric analysis to validate the effect of R&D (innovation) and human capital on economic growth within the NIS ecosystem through an empirical test. From the systematic review, various R&D and Human capital metrics are obtained, which have an impact on GDP. Hence, their statistical significance is evaluated by implementing this econometric analysis. Since the study aims to analyze the causal relation among R&D, Human capital, and GDP, the Cobb-Douglas model is selected for econometric analysis. According to Lucas (1988), the Cobb-Douglas equation model was expanded by adding human capital to obtain its impact on economic growth. The main focus of the model is to measure the GDP using labour, physical capital, and human capital (accumulation of knowledge). Hence, the model can show us the effect of R&D and human capital on GDP.

The study used GDP growth rate as an index of economic growth, and it also takes into account variables such as expenditure on R&D, human capital index, employment size, and real capital formation as independent variables for human capital and R&D (Habib et al., 2019). Within this scope, to carry on with the examination regression model is performed to capture the causal relationship among the variables. As well as to determine the direction of these relationships. All the data were sourced from the World Bank economic development indicators from 2000 to 2023 for the Ethiopia case only. Table 1 presents a detailed description of the variables.

2.1.1. Expenditure on R&D

R&D expenditure is the main factor for the enhancement of technological productivity and innovation. Investment in research activities can include training and skill development costs, salaries of researchers, construction of R&D laboratories, infrastructural facilities for laboratories, joint venture costs, administrative

and facility maintenance expenses, and costs of intellectual properties. A proper investment in R&D activities can enhance the country's technological productivity, establish products through innovation, and boost economic competitiveness. Thus, this variable was chosen to examine the role of R&D in fostering GDP growth and to measure the short and long-run effects on economic development.

2.1.2. Human Capital Index

Human capital is the other factor of economic growth, which is determined by workforce skill level and educational success. In this technological world, the skilled and educated persons play a large role in enhancing labour productivity and innovation. In the selected model, the use of this variable enables the model to know the role of human capital in boosting economic output and its combined effects with other independent variables.

2.1.3. Employment Size

The economic potential to produce various services and goods is determined by the number of employees within the economy. A great capacity of productivity can be attained by a higher manpower, which results in enhanced economic output. Thus, the reason to use this variable in the model is to evaluate how the GDP growth rate was affected by the variation of the employed population size. Additionally, this variable also has a correlation with human capital that impacts economic dynamics during the short and long term.

2.1.4. Real Capital Formation

The gross fixed capital formation as a percentage of GDP was selected to represent various investments in physical assets like production machinery and infrastructure facilities. Hence, the production capacity and economic expansion are highly dependent on it. This variable is used in the model to assess the effect of infrastructure and asset development on the growth of the economy.

Table 1

Dependent and independent variables

Variable	Symbols	Description	Measurement
Independent	RE	Expenditure on R&D	Research and development expenditure (% of GDP)
	LS	Employment size	Employment to population ratio
	HC	Human capital	Human capital index
	RCF	Real capital formation	Gross fixed capital formation (% of GDP)
Dependent	GDPgrate	Economic Growth	GDP growth (annual)

2.2. Data analysis

The study used thematic analysis to explain the results from the systematic review. Thematic analysis revealed that human capital and R&D improve the national innovation system. For the empirical study, the following analyses were used.

2.2.1. Mathematical expression of the model

In the Cobb-Douglas model, one of the most popular techniques used to model economic relationships like GDP growth while multiplicative variables are expected. Equation 1 depicts the general function of the Cobb-Douglas model (Lucas, 1988):

$$Y = \mathrm{A} \cdot K^{\alpha} \cdot L^{\beta} \cdot C^{\gamma} \quad (1)$$

where Y is output, A denotes total factor productivity, K represents physical capital, L is for labour, and C is human capital. $\alpha, \beta, and\ \gamma$ are elasticity for physical capital, labour, and human capital.

The relationship between the dependent and independent variables is modeled mathematically using the Cobb-Douglas method as shown below:

$$\mathrm{GDP}_{\mathrm{grate}} = \mathrm{A} \cdot RE^{\beta_1} \cdot HC^{\beta_2} \cdot LS^{\beta_3} \cdot RCF^{\beta_4} \quad (2)$$

where β1, β2, β3, and β4 are elasticities of each variable and A is total factor productivity.

To make the analysis simpler and more robust for interpretation, a log-linear transformation should be applied in Eq. 2. As a result, the linear equation is obtained as shown in Eq. 3, which helps to reduce outlier effects and data variation.

$$\ln GDP_{grate} = \ln A + \beta_1 \ln RE + \beta_2 \ln HC + \beta_3 \ln LS + \beta_4 \ln RCF + \varepsilon_t \quad (3)$$

Since this study used time series data, an Auto Regressive Distributed Lag model (ARDL) was implemented to analyze the short and long-run relations among dependent and multiple independent variables. The ARDL model equation is shown in Eq. 4.

$$\log GDP_{grate} = \alpha + \sum_{i=1}^{p} \beta_i \log GDP_{grate} + \sum_{j=0}^{q} \gamma_j \log RE + \sum_{j=0}^{q} \delta_j \log HC + \sum_{j=0}^{q} \theta_j \log LS + \sum_{j=0}^{q} \mu_j \log RCF \quad (4)$$

where βi, γj, δj, θj, and μj are coefficients that are used to indicate the relation between the independent variables and GDP growth rate.

Before implementing the regression method, knowing the relation, structure, and distribution throughout the dataset is required to properly prepare it for the analysis. Accordingly, the KNN Imputation technique is used to handle the missing data (Pujianto et al., 2019). The missing data is handled by identifying the nearest value and applying numerical analysis. In the imputed dataset, exploratory data analysis is implemented to provide suitable data to the econometric model. This includes statistical and correlational analysis. In the statistical analysis, the mean, standard deviation, range, skewness, and kurtosis are measured to explain the variability and data distribution. On the other hand, correlation analysis is carried out to determine the causal relation among variables and detect multicollinearity that potentially biases the result of the Cobb-Douglas model.

3. RESULTS

3.1. Thematic analysis results

The pivotal role of R&D in stimulating economic growth is well-established in the literature. The proportion of those papers is illustrated in Figure 2. Figure 2 illustrates the percentage of positive impact of R&D and Human Capital on GDP, which is obtained from the studies.

Figure 2

Percentage of studies showing positive impact on GDP by R&D and human capital

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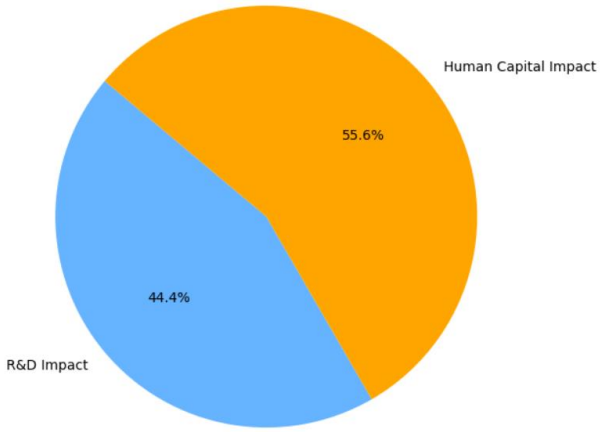


Specifically, 44.4% of the reviewed papers imply that improving R&D contributes positively to economic growth. Whereas, 55.6% of the studies explain that enhancing human capital capabilities has a large influence on GDP. Generally, this analysis implies the significant role of both pillars in the effectiveness of NIS for the development of a country's economy.

Belachew Alemayehu (2021) evaluated the significance of R&D on Ethiopian firms. The R&D fund in various firms has been allocated for capital expenditures instead of actual research. According to a recent survey, 45% of the total expenditure was used for the acquisition of machinery, 25.7% for buildings, and 15.2% for equipment, a mere 7.04% directly allocated to R&D activities. Due to a lack of funds, 42.86 percent of firms are unable to innovate. Such a mismatch suggests that the government's R&D strategy may focus more on infrastructure development than on developing the innovative capacity of firms and researchers.

Almost all of the funded research is ideal rather than practical, which hinders its immediate industry relevance. This problem is made worse by the gap that exists between research institutes and the corporate sector, which leads to little cooperation and a misalignment of research initiatives with business demands (Keraga & Araya, 2023). Such problems hinder our research capabilities to achieve the country's productivity and economic growth. For R&D investments to be more successful in the country's economic development, it is important to conduct research that can directly answer industry questions and design strategies that strengthen the relationship between academia and the corporate sector. Without these adjustments, R&D has little potential to contribute significantly to economic growth.

R&D is the engine of innovation that can be measured through the number of researchers existing in the country within various institutions and the amount of research expenditure (Hailu et al., 2022). Based on Tesfa (2015), the key difficulties encountered by Ethiopian researchers when conducting various research in their organization or institution have been addressed by government policies and researchers. The paper explained that the main challenges of researchers in Ethiopia include research administration and leadership problems, insufficient research resources and facilities, inadequate national policy and strategies, and limitations on outsourcing of research. The paper also emphasized that there is a relationship between R&D expenditure and the existence of researchers. Finally, the author recommended possible solutions for fostering research in Ethiopia, such as creating consistent research funding, enhancing different research councils, and boosting professional associations that can enhance the country's economy through innovation.

According to Habib et al. (2019), R&D expenditure and skilled labour have an impact on innovation for improving economic growth. The paper links the impact of R&D and human capital on innovation through empirical analysis. The Authors used those metrics as an input variable to observe the change in firm productivity. Using the empirical analysis, the paper described that there is a strong relation between firm productivity and innovation through employment size, labour force, and research expenditure.

Although the role of small and medium enterprises in the economic growth is very high for developing countries like Ethiopia, the skills and knowledge of both the owners and their employees are not enough and need enhancement. According to Dinku et al. (2024), the relation between SMEs, innovation, and human capital was measured using formal education, managerial skills, innovation practice, and performance of SMEs. As a result, formal education and managerial skills have a significant positive impact on the performance of SMEs. Hence, the Ethiopian government should work on enhancing and updating strategies that include an entrepreneurship-oriented curriculum in the formal education system. Also, SMEs should design and build innovative strategies to improve their performance.

Wegari et al. (2023) studied the relation of human capital and economic development for the case of Ethiopia by considering GDP as an index of economic growth. Several metrics were used to measure human capital, such as labor force, total government expenditure, education expenditure, and secondary school enrollment. The ARDL technique was implemented to investigate the co-integration among those metrics and human capital. Based on the paper results, such metrics have a long-term impact on GDP, whereas policy change has a positive short-term effect on Ethiopia's economic growth.

The role of technological upgrade or investment in a country is eminent in its productivity and development level (Todosiichuk, 2024). However, the key productive resources of any country are its level of human capital and workforce. Shiferaw (2017) discussed the importance of human capital investment to enhance the productive capacities of the manufacturing sector and economic growth of Ethiopia. The three educational levels of the country, namely, primary, secondary, and tertiary education used as a metric of the country's human capital. Nevertheless, the number of both private and public educational institutions has increased, but their educational outcome are very low. This is due to inadequate government expenditure on education and low quality of education (Van Uden et al., 2017). Various studies have widely stated that human capital has a strong economic impact on GDP, but one of the significant shortcomings of Ethiopia's NIS is the lack of human capital, making the situation more complicated (Curea & Ciora, 2013). According to Curea & Ciora (2013), the GDP would boost by 0.0063% for each 1% secondary education expenses. This mainly indicates an upbeat long-term relationship between economic growth and educational investment.

Although there is a limited number of studies in this area, the available studies have tried to evaluate the relationship between R&D, human capital, and economic growth. A well-educated and skilled manpower can innovate and adopt new technologies that can enhance the country's economy, especially in developing countries. Various researchers mentioned many metrics of human capital and R&D, which are used in measuring GDP, such as the number of researchers, education expenditure, research expenditure, levels of education, and labour force (Agezew, 2024; Belete, 2015). In most of the studies, these metrics have significant impact on GDP but more works to be done include formulate compatible innovation policy and strategy, proper research and education funding, building strong collaboration among different innovation actors, and create suitable environment for skilled and educated manpower (Song et al., 2024; Ma et al., 2024). An empirical analysis should be implemented to check the validity of the systematic review results. Therefore, the empirical analysis is presented in the following section.

3.2. Results of the empirical study

As it is explained before, the Cobb-Douglas model is implemented after preparing the dataset for suitable econometric analysis using explanatory data analysis. Table 2 depicts the statistical results, such as mean, standard deviation, minimum, and maximum of both dependent and independent variables, to assess the statistical analysis of raw data.

Table 2

Descriptive Statistics of Variables for the original data log log-log-transformed data

Variable	GDPgrate	RE	HC	LS	RCF

Parameters					
Mean	8.609629	0.296528	0.384208	78.79592	33.1746
Std dev.	3.082784	0.088392	0.000659	0.991567	4.698199
Min.	1.514726	0.17089	0.382785	76.627	22.17146
Max.	13.5726	0.60474	0.385	80.031	40.67127

Source: Authors' calculation

Table 3 illustrates the statistical results of each variable after applying the linear logarithmic transformation. Based on the result, the economy of a country grew at a rate of 2.3% annually on average during the past 24 years. Also, the growth rate of GDP varies by 0.36% from its mean. This implies that the independent variables may have their impact on GDP variation. The country achieved its peak economic growth at a rate of 2.74%, while its weakest growth rate is 0.415%. Generally, the descriptive statistics data illustrated that GDP growth rate and R and D expenditure have some variation, while employment size and human capital are relatively stable with small standard deviation values of 0.012317 and 0.000276, respectively, for the chosen period.

Table 3

Descriptive statistics of variables for log-transformed data

Variable / **Parameters**	**log_GDPgrate**	**log_RE**	**log_HC**	**log_LS**	**log_RCF**
Mean	2.307609	0.830715	0.868867	4.391854	3.551001
Std dev.	0.366271	0.037436	0.000276	0.012317	0.142714
Min.	1.256961	0.775137	0.86827	4.364715	3.185173
Max.	2.745513	0.957333	0.869199	4.407097	3.753526

Source: Authors' calculation

In addition to statistical analysis, the correlation analysis is also implemented before performing the model analysis. Figure 3 depicts that the GDP growth rate has a positive correlation with human capital, while it has a negative correlation with R&D expenditure. There is also a negative correlation between human capital and R&D expenditure. Since the log_RCF and log_LS have a strong correlation, it is better to drop the log_RCF, which has less effect on economic growth in terms of R&D and human capital. Because the two variables may influence the GDP growth rate than capital formation.

Lag selection is required to implement the ADRL model on the transformed data. Since it measures the correct number of lagged terms that include each variable throughout the model. Thus, the model can appropriately give the dynamic interaction among variables. In the ARDL model, the selected lag orders for the three variables are obtained as:

log_GDPgrate: 1 lag

log_RE: 2 lags

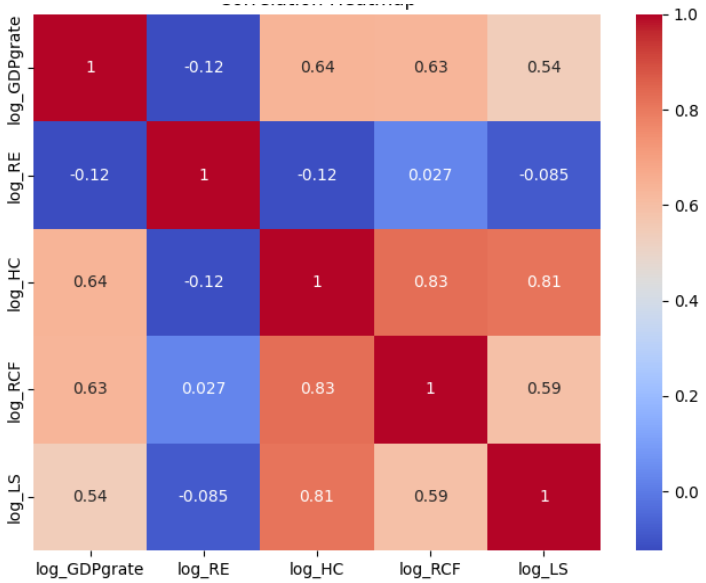
log_HC: 3 lags

log_LS: 4 lags

This implies that the value of GDP growth rate at current time is affected by its previous value. Also, the effect of independent variables on economic growth can be modeled by considering their pervious value.

Figure 3

The correlation result among log-transformed variables



The ARDL model result is shown in Table 4. The role of both R and D and Human capital on GDP growth rate was analyzed using this model. Since log_RE has a negative coefficient, it has a negative relation with GDP growth rate, and due to their large p-value, they are statistically insignificant. On the other hand, log_HC, log_LS, and GDP growth rate have a positive relation, although their effect is insignificant statistically with a high p value as compared to as shown in Table 4. The overall result indicated that the country's economic growth through innovation has been positively affected by human capital rather than R&D.

Table 4

ARDL model results

Variable	Coeff.	Std. err	t-statistic	p-value
const	-603.5945	331.132	-1.823	0.085
log_GDPgrate	0.2043	0.195	1.048	0.308
log_RE	-0.5057	1.723	-0.294	0.772
log_HC	688.9089	414.363	1.663	0.114
log_LS	1.6565	9.006	0.184	0.856

Source: Authors' calculation

As explained before, the ARDL model was adopted for implicating both short-run and long-run effects of independent variables on the dependent variable. Hence, the short-run and long-run effects of log_GDPgrate, log_RE, log_HC, and log_LS are presented in Table 5. The result implies that the immediate decrease of 0.505729 units in log GDP growth rate occurs as the R&D expenditure increases by 1 unit. In contrast, one unit increase in human capital causes a 688.90888-unit immediate maximization of log GDP growth rate. Similarly, the employment size has a positive impact on short-term GDP growth since a 1.656506 unit increase in GDP is obtained for a unit change in employment size. Hence, the human capital and employment size have a positive effect on economic growth for a short period.

Similarly, the human capital has a pronounced effect in a long period of time with 865.7 unit increase of log_GDPgrate. Also, the employment size has a positive impact on the sustainable economic growth of the country. However, the effect of R&D expenditure has a negative impact on the country's long-term economic enhancement which implicates a need to evaluate the efficiency and effectiveness of research activities.

Table 5

Short and long run effects

Variable	Short Run Effect.	Long Run Effect
log_GDPgrate	0.204266	0.256701
log_RE	-0.505729	-0.635550
log_HC	688.90888	865.752567
log_LS	1.656506	2.081733

4. DISCUSSIONS

This study aimed to investigate the relationship between research and development (R&D), human capital, and economic growth, with a specific focus on evaluating the significance of R&D and human capital as key determinants of economic growth within Ethiopia's National Innovation System (NIS). Both a systematic review and empirical analysis were employed to gather theoretical and empirical insights into the importance of these pillars in driving economic growth. The results from both methods demonstrate that R&D and human capital are critical components of the NIS, particularly in developing countries like Ethiopia.

The systematic review highlights the substantial impact these two pillars have on economic growth through their dynamic interaction. According to Tesfa (2015), the primary challenges limiting university-based R&D include issues related to human resource development, availability of research facilities, dissemination of research findings, government strategies for research, and research motivation. The econometric analysis reveals that R&D expenditure (RE) has a statistically insignificant effect on economic growth (p-value of 0.772). Additionally, short-term results show that R&D expenditure has a negative effect (-0.505729), suggesting that quick resource allocation, skills training, and funding may not immediately lead to economic development. Long-term analysis also indicates a negative impact (-0.635550) of R&D expenditure on economic growth, reflecting inefficiencies in how research expenditures are utilized, thus hindering their intended impact.

Although both pillars of the NIS are recognized for their significant influence on GDP across various sectors, the empirical analysis confirms that only human capital demonstrates a positive relationship with GDP growth, though it remains statistically insignificant. The study further identifies a high correlation between research capability (RCF) and labor size (LS) with human capital (HC), leading to the exclusion of Log_RCF to reduce multicollinearity, as its variation did not significantly impact R&D and human capital. The remaining variables, R&D expenditure, human capital, and labor size, were not statistically significant about GDP growth, as indicated by large p-values. Nevertheless, the empirical findings support the critical role of human capital in fostering economic growth, particularly in terms of skilled labor capable of adopting technological advancements and driving innovation that ultimately enhances national productivity.

Extensive literature underscores the importance of human capital and innovation capability in Ethiopia's economic productivity. The knowledge generated through R&D can enhance productivity and facilitate technology adoption across various sectors, including agriculture and manufacturing. These NIS pillars improve competitiveness by enabling firms to produce innovative products and reduce reliance on traditional methods. Despite their significant potential contributions to Ethiopia's economic growth, these pillars have not been adequately addressed by the government and relevant bodies. The empirical findings highlight that strengthening human capital and labor size are key strategies for achieving rapid and sustainable economic development.

Many studies indicate that the Ethiopian government has yet to design an effective innovation strategy, allocate sufficient funding for R&D, or address the shortage of skilled human resources in various sectors. Additionally, small and medium enterprises often rely on outdated methods, and there is a lack of adequate research infrastructure, professional development opportunities, and collaboration between research and business institutions. To foster economic growth through innovation, the government must establish a robust innovation framework that defines and clarifies the roles and responsibilities of each NIS actor. Furthermore, industries and research institutions must collaborate to drive the development of Ethiopia's economy.

5. CONCLUSION

The appropriate development of national innovation systems plays a crucial role in fostering economic growth, particularly in developing countries such as Ethiopia. However, the enhancement of such systems depends significantly on the effective interaction among their actors and the implementation of various pillars. This study explores the impact of human capital and research and development on economic growth. A systematic review is employed to examine existing literature on Ethiopia, aiming to understand both the theoretical and empirical relationships among R&D, human capital, and GDP growth. Although the body of research in this area is limited, the findings suggest that both R&D and human capital influence GDP growth. For instance, some studies indicate that labor force participation and research expenditure positively impact GDP, while others highlight the positive long-term effects of formal education, such as primary, secondary, and tertiary education, and government expenditure on GDP. Given that many of these studies focus on specific sectors, such as small and medium enterprises, empirical analysis is necessary to validate the results from the systematic review in a comprehensive manner.

For the empirical analysis, a Cobb-Douglas production function was chosen, as it allows for the examination of the effects of innovation and human capital on economic growth. This model assesses the impact of independent variables on the dependent variable, helping to identify which factors significantly affect economic growth. The selected independent variables, based on the systematic review, include R&D expenditure, human capital index, labor size, and capital formation. Data were obtained from the World Bank economic development indicators, spanning the years 2000 to 2023 for Ethiopia.

Statistical and multiple correlation analyses were performed to prepare the data for the selected model. The findings revealed a high correlation between real capital formation and employment size. Consequently, real capital formation was excluded from the model, as its impact was found to be less significant compared to employment size. Thus, the independent variables were reduced to three: R&D expenditure, human capital index, and employment size, with GDP growth rate as the dependent variable.

The ARDL analysis results indicate a positive but statistically insignificant relationship between the human capital index and GDP growth rate. Similarly, the other variables showed no statistically significant impact on economic development. Therefore, it is recommended that the government, educational institutions, and enterprises collaborate to improve the skilled and educated workforce, which is essential for economic growth in developing countries.

Additionally, the empirical analysis highlights issues such as improper allocation of research resources and insufficient funding for research and education. To enhance the impact of the national innovation system on Ethiopia's economy, the government should formulate effective innovation strategies and policies that prioritize education and research funding. Policymakers should also focus on educational systems and workforce enhancement programs to maximize the positive impacts of human capital. Furthermore, a strategy should be developed to manage R&D expenditures, ensuring that research outputs align with the country's economic goals.

Although this study provides both theoretical and empirical analyses of the impact of R&D and human capital on GDP, it is limited to data from Ethiopia. Future research should expand to include other developing countries to gain a more comprehensive understanding of the role of national innovation systems in economic growth. Additionally, the empirical methods used in this study are based on classical approaches, and it is

recommended that more advanced models, such as machine learning techniques, be employed for future predictions.

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