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Research Paper

Innovation, Human Capital and Economic Growth in Ethiopia: a Systematic Review and an Empirical Study

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Abstract

In today's world, national innovation system (NIS) is one way of fostering economic growth, especially in developing countries. Human capital, research and development (R&D) and other innovation activities are the fundamental pillars of NIS. The aim of this study is to evaluate the contribution of human capital, innovation (patent as a proxy) and R&D on Gross Domestic Product (GDP) growth rate through systematic review and empirical analysis. An autoregressive distributed lag (ARDL) model was used to analyze the data extracted from the World Bank database and world innovation patent office data set from year 1990 to 2023. From the systematic review result, the roles of human capital and R&D expenditure have shown a positive influence on GDP growth rate of Ethiopia. The estimated model re-enforced the systematic review result as both human capital and R&D have shown statistically significant effect on GDP growth rate. In addition, gross capital formation and utility patent have also positive effect on real GDP growth. Recognizing the crucial role of human capital and R&D, this study suggests to the Ethiopian government to bolster these areas to drive effective economic growth. Fostering strong collaboration among NIS actors, and developing policies that strategically expand the pool of skilled and educated individuals in various sectors are recommended.

1. Introduction

The contribution of innovation to economic growth has been a central theme in economic literature for decades. Economic schools of thought have highlighted innovation's crucial role in sustained economic growth. Technological progress is considered the main engine of economic growth, according to both neoclassical and endogenous growth theories. Nevertheless, these growth theories have failed to provide a clear empirical explanation on how new knowledge specifically translates into enhanced economic outcomes for regions. Without solid theoretical foundations, empirical studies have explored factors such as labor mobility (Almeida & Kogut 1999), networks (Ter Wal & Boschma, 2009), and other potential facilitators of spillovers (Tsvetkova, 2015). Research shows that innovation efforts contribute to economic growth, both directly and indirectly through various macroeconomic variables (Furman et al., 2002). However, it is also plausible that innovation efforts are influenced by economic growth and other macroeconomic factors. This implies that, in practice, innovation activities and economic growth may mutually influence each other, suggesting a potential feedback loop between the two.

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Ethiopia's economy has improved greatly in the last few years, spurred by the Growth and Transformation Plans (GTP I and GTP II). According to National Plan Commission, Ethiopia aspires to join the middle-income countries by 2030 through industrial transformation (PDC, 2020; Afework, 2019; FDRE, 2020). National Innovation System (NIS) is increasingly recognized as pivotal drivers of economic growth and development, especially in developing nations where innovation and technological progress are essential for advancement (Weerasinghe et al., 2024; TECHIN, 2021). Freeman (1987), a prominent scholar, defined NIS as an interconnection of various actors that enhance new technologies and knowledge in the given nation. For a better innovation system, the key components of NIS, namely infrastructure, institution, research and development, technology transfer, and human capital, are used.

Central to a thriving NIS is research and development (R&D), which facilitates the creation of new technologies, processes, and products for spurring economic activity. New developments in technical know-how are fundamentally driven by R&D, which facilitates the exploration and application of new knowledge to existing production techniques. R&D is vital for advancing the ability to innovate and enhancing economic performance while it provides various innovations. Hence, nations should give high priority for both direct and indirect R&D investments to foster economic growth.

On the other hand, human capital refers to the skills, knowledge, and competence of the workforce. Education and training are instruments that enhance human capital and increase productivity and economic growth. Human capital is important as it enhances the ability to utilize and build upon innovations (Muhamad et al., 2018), thereby boosting Gross Domestic Product (GDP) and supporting the overall performance of the NIS. Human capital is an essential factor in R&D activities and in applying the new technologies resulting from successful R&D to production. Simply, high-level human resources can promote a company's technological R&D through integrating both internal and external knowledge. The integration mainly includes knowledge creation, dissemination and diffusion, and internal R&D activities transformation of companies (Sun et al., 2020). Therefore, high-level human capital can directly affect a company's R&D activities, thereby enhancing innovation level. On the other hand, new technologies open up new economic opportunities for investment in physical and human capital to take place. If these two can be integrated into a single framework, then it is possible to see the interaction between them in pushing economic growth and therefore bring the theory a step closer to the reality.

During the 18th century, the doctrine of economic growth has been the main focus of macroeconomic research; thus, previous studies focused on how it relates to variables like population and capital. The emergence of endogenous growth theories in the early 1990s marked a dramatic change by emphasizing the contribution of internal elements, especially technology, innovation, and human capital, to long-term economic growth. These ideas emphasize the significance of knowledge generation, human capital development, and R&D activities as major drivers of economic performance and technological innovation.

The interaction between human capital, R&D, and economic growth has been an area of research interest in economic literatures for decades. Knowledge, mostly produced through R&D, is a non-rivalries public good that supports long-term economic growth, according to the endogenous growth hypothesis, which was developed by (Romer, 1994). Knowledge spillovers amplify the impact of R&D by extending its benefits beyond the originating firm. A number researchers studied about the impact of human capital and R&D on economic growth within innovation ecosystem through empirical analysis.

Ashenafi et al. (2024) presented the effect of human capital on small and medium enterprise performance using Covariance-Based Structural Equation Modeling (CB-SEM) data analysis technique. Formal education and managerial skill were used as an independent variable whereas performance of small and medium enterprises (SMEs) and innovative practices were dependent variables. Even though, the result of the study implicates that human capital has positive significance on the performance of SMEs, extensive work is expected to see its long-term impact on Ethiopia's economy, such as formulating innovation strategies and updating educational curriculum that can fit with

entrepreneurship. The study focused only on the relation between human capital and economic growth, without considering R&D. In contrast, Keraga & Mesele (2023) conducted an empirical analysis to understand the correlation between R&D and economic growth. He used General Structural Equation Model (GSEM) to analyze the relation between them using World Bank's enterprise survey dataset. The empirical result indicated innovation to have strong impact on firm productivity. However, it requires further work to develop innovation capabilities of firms. Since human capital and R&D are highly correlated, it is recommended to further evaluate their impact on GDP. Similarly, Kidanemariam (2015) employed Autoregressive Distributed Lag Model (ARDLM) and depicted that human capital and economic growth have long run impact since 1% increase in secondary education has produced 0.5096% change in GDP. However, the role of R&D was not considered in the study at all. Additionally, Suhatman et al. (2024) concluded that human capital and economic growth have unidirectional relation since the human capital has positive influence on economic development but the reverse is not true at all. Such result indicates that investment in human capital is essential for fostering economic growth.

Overall, the interplay between R&D and human capital is synergistic. Although R&D and human capital are highly correlated in NIS ecosystem, there is a notable gap in existing studies that measures the combined impact on economic growth. Hence, the objectives of the present study are (1) to conduct systematic literature review focusing on effect of innovation, R&D and human capital on economic growth, and (2) to investigate the extent of the effect of R&D expenditure, human capital (knowledge) and patent and utility patent (property right for innovation) on economic growth of Ethiopia.

2. Materials and Methods

2.1 Literature search strategy and inclusion/ exclusion criteria

This study utilized 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 the 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 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 literatures. The databases searched include Google Scholar and COnnecting REpositories (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 ensured a robust examination of the relevant literature and provided insights into the interactions between R&D, human capital, and economic outcomes.

2.2 Empirical analysis

Econometric analysis was carried out for validating the effect of R&D, patent and utility patent (innovation) and human capital on economic growth within NIS ecosystem through empirical test. From the systematic review, various R&D and Human capital metrics which have an impact on GDP were obtained. Hence, their statistical significance was evaluated by implementing econometric analysis. Since, the study's aim was to analyze the causal relation among R&D, Human capital and GDP, ARDLM was selected for econometric analysis. The main focus of the model was to predict the GDP growth rate using labour, physical capital, and human capital (accumulation of knowledge). ARDLM was expanded by adding human capital to obtain its impact on economic growth (Lucas, 1988). Hence, the model could show the effect of innovation, R&D and human capital on GDP growth.

2.2.1 Variables of study and sources of data

The study used GDP per capita growth rate as an index of economic growth and it also took into account variables such as expenditure on R&D, human capital– proxy by secondary school completion rate, employment size, number of patent file and number of

utility patent filed in domestic economy, and real capital formation as independent variables (Habib et al., 2019). Within this context, ARDLM was employed to capture the effect and variable magnitude on GDP growth rate. All the data were sourced from world innovation patent office and World Bank economic development indicators from 1990 to 2023 for Ethiopia case only. Table 1 and the subsequent paragraphs present the detail description of variables.

Expenditure on R&D: is the main factor for enhancement of technological productivity and innovation. Investment on 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 (Shimelis et al., 2021; Cirera et al., 2023; Getnet, 2014). A proper investment on R&D activities can enhance a country's technological productivity, establish products through innovation, and boost economic competitiveness. Thus, it was chosen to examine the role of R&D in fostering GDP growth and to measure the short and long run effect on economic development.

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 to enhance economic output. Thus, the reason to use this variable in the model was to evaluate how GDP growth rate was affected by the variation of employed population size. The variable has also correlation with human capital that impact economic dynamics during short and long term.

Human capital index: human capital is the other important variable of economic growth which is determined by workforce skill level and educational success. In a technological world, the skilled and educated persons play huge role in enhancing labour productivity and innovation. In ARDLM, 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.

Real gross capital formation: it was selected to represent various investments in physical assets, like production machinery, and infrastructure facilities (Atrsaw & Adane, 2024). The production capacity and economic expansion are highly depended on it. The variable was used in the model to assess the effect of infrastructure and asset development on the growth of economy.

Patent and utility patent: patents are used to measure on innovation and technological change. Utility patent is a form of intellectual property that protects what an invention is, how an invention works and/or how an invention is made and/or used. Thus, both can be used as a proxy to capture level of innovation regardless of the degree of innovation they represent.

Table 1: Description of variables

Variable	Description
Dependent variable	
Real GDP growth rate	Per capita economic growth: expansion of a country's economy, expressed in per capita gross domestic product
Independent variable	
R&D expenditure	GDP percentage share of R&D expenditure
Employment rate	Proportion of a country's population that is employed
Human capita (HC)	Percentage of secondary school completion rate
Gross capital formation (GCF)	Gross fixed capital formation (% of GDP)
Patent (PAT)	Number of patents filed by residents expressed in number
Utility patent (UPAT)	Number of petit Patents filed by residents expressed in number

2.2.2 Autoregressive Distributed Lag Model specification

The study employed ARDLM, specifically the "Bounds Testing Approach" for co-integration. The ARDLM is a widely accepted and suitable method for assessing long-run relationships, and it is frequently applied in empirical research. Several advantages justified the use of ARDLM for co-integration analysis. First, it can accommodate regressors that are integrated of order zero [I(0)], integrated of order one [I(1)], or a combination of them. Second, the ARDLM offers a statistically robust method for identifying co-integration in small samples, unlike Vector Autoregressive models which typically require larger datasets. Third, the ARDL procedure allows variables to have different optimal lag lengths, unlike some other techniques. Moreover, endogeneity concerns are mitigated as each variable in the model is treated as a single equation. Finally, the ARDL approach can differentiate between dependent and independent variables when a single long-run relationship exists, as only one reduced form of the equation is assumed.

The specific ARDLM approach is outlined as equation (1), where *LnRGDPt*, *LnRDEt*, *LnEMRt*, *LnGCFt*, *LnHCAPt*, *LnPATt*, and *LnUPATt* are the natural logarithm of real GDP at time *t*, R&D expenditure at time *t*, employment rate at time *t*, gross capital formation at time *t*, human capital index at time *t*, number of patent filed at time *t*, and number of utility model (petit patent) at time *t*, respectively and εt, is an error term. $\alpha 1$, $\alpha 2$, $\alpha 3$, $\alpha 4$, $\alpha 5$, $\alpha 6$, and $\alpha 7$ are the coefficients measuring long-run relationships. The coefficients measuring short-run relationships are $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, $\beta 5$, $\beta 6$, and $\beta 7$. *N* is the lag length of the autoregressive process.

After confirming a long-run relationship among the variables, the stable long-run model given as equation (2) was used. Then, to estimate the vector error correction model (VECM), which reveals the dynamic short-run parameters, the standard ECM given as equation (3) was used, where Δ is the first difference operator; and *a*, *b*, *c*, *d*, *e*, *f* and *g* indicate the maximum lag length for each variable in the autoregressive process. ECT is the error correction term lagged by one period, and δ is the parameter of error correction, quantifying the speed of adjustment towards the long-run equilibrium.

ECT quantifies the interplay between the short-run and long-run relationships. Derived from the long-run model, it illustrates the speed at which variables return to their equilibrium state. A statistically significant coefficient for ECT is expected. A negative sign on this coefficient confirms the existence of a co-integrating relationship, whereas a positive sign suggests an explosive model with no convergence.

$$\begin{aligned} LnRGDP_t = {} & \alpha_0 + \alpha_1 LnRGDP_{t-i} + \alpha_2 LnRDE_{t-i} + \alpha_3 LnEMR_{t-i} + \alpha_4 LnHCAP_{t-i} + \\ & \alpha_5 LnGCF_{t-i} + \alpha_6 LnPAT_{t-i} + \alpha_7 LnUPAT_{t-i} + \\ & \beta_1 \sum_{i=0}^{n} \Delta LnRGDP_{t-i} + \beta_2 \sum_{i=1}^{n} \Delta LnRDE_{t-i} + \beta_3 \sum_{i=0}^{n} \Delta LnEMR_{t-i} + \beta_4 \sum_{i=0}^{n} \Delta LnHCAP_{t-i} + \\ & \beta_5 \sum_{i=0}^{n} \Delta LnGCF_{t-i} + \beta_6 \sum_{i=0}^{n} \Delta LnPAT_{t-i} + \beta_7 \sum_{i=0}^{n} \Delta LnUPAT_{t-i} + \varepsilon_t \end{aligned} \quad (1)$$

$$\begin{aligned} LnRGDP_t = {} & \beta_0 + \beta_1 \sum_{i=0}^{n} LnRGDP_{t-i} + \beta_2 \sum_{i=1}^{n} LnRDE_{t-i} + \beta_3 \sum_{i=0}^{n} LnEMR_{t-i} + \beta_4 \sum_{i=0}^{n} LnHCAP_{t-i} + \\ & \beta_5 \sum_{i=0}^{n} LnGCF_{t-i} + \beta_6 \sum_{i=0}^{n} LnPAT_{t-i} + \beta_7 \sum_{i=0}^{n} LnUPAT_{t-i} + \nu_t \end{aligned} \quad (2)$$

$$\begin{aligned} \Delta LnRGDP_t = {} & \beta_0 + \beta_1 \sum_{i=0}^{a} \Delta LnRGDP_{t-i} + \beta_2 \sum_{i=1}^{b} \Delta LnRDE_{t-i} + \beta_3 \sum_{i=0}^{c} \Delta LnEMR_{t-i} + \beta_4 \sum_{i=0}^{d} \Delta LnHCAP_{t-i} + \\ & \beta_5 \sum_{i=0}^{e} \Delta LnGCF_{t-i} + \beta_6 \sum_{i=0}^{f} \Delta LnPAT_{t-i} + \beta_7 \sum_{i=0}^{g} \Delta LnUPAT_{t-i} + \delta ECT_{t-1} + u_t \end{aligned} \quad (3)$$

If the ECT coefficient is equal to 1, it implies a complete adjustment within one period, indicating rapid adjustment. An ECT coefficient of 0.5 suggests that 50% of the adjustment occurs each period. An ECT coefficient of 0 indicates the absence of any adjustment.

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 k-nearest neighbors (KNN) imputation technique is used to handle the missing data (Murti 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 for providing 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 bias the result of the ARDLM.

3. Results and Discussion

3.1 Systematic review analysis

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. Fifty studies are included in the systematic review (Table 2). As it is shown in the figure, there are limited number of studies that implies the combined impact on economic growth, whereas, reports explaining the combined effects are large in number. The systematic review revealed that human capital and R&D improve national innovation system. The pivotal role of R&D in stimulating economic growth is well-established in the literature. 44.4% of the reviewed papers implies that improving R&D contributes positively on the economic growth. Whereas, 55.6% of the studies explain that enhancing human capital capabilities has large influence on GDP. Generally, this analysis implies the significant role of both pillars to the effectiveness of NIS for the development of country's economy.

Kassahun et al. (2025) evaluated the significance of R&D on Ethiopia firms, and he showed that the R&D fund in various firms has been allocated for capital expenditures instead of actual research. According to the study, 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 lack of funds, 42.86 % 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.

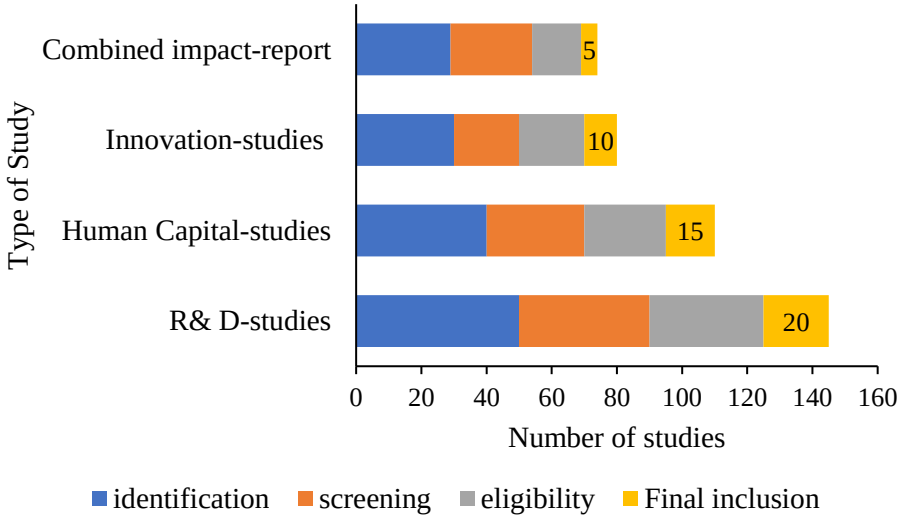

Figure 1: Review stages and studies distributions

Table 2: Summary of the systematic review by theme

Research theme	Research focus area	Reference
Innovation	National innovation system for development	Kassahun et al. (2025)
	Determinants of national innovative capacity	Furman et al. (2002)
	Science, Technology, and Innovation (STI) policy	Afework (2019)
	National innovation system	Lundvall (2007)
	Role of foreign direct investment	Bayissa et al.(2023)
	Improved beekeeping technology adoption	Fromsa & Edao (2024)
	National innovation system for developing economies	Kayal (2008)
	Adoption of new farm technology	Haile (2020)
	Technical innovation and national innovation system	Nelson (1993)
	Mapping national innovation system in OECD nations	Balzat & Pyka (2005)
	Agriculture –industry linkage and technology adoption	Tilahun (2018)
	National innovation system in the developing countries	Weerasingghe et al.(2024)
	Firm level adoption of technology in Ethiopia	Cirera et al.(2023)
Human capital	Forecasting GDP Growth	Azibaev (2024)
	Localization of knowledge and mobility of engineers in regional network	Almeida & Kogut (1999)
	Human capital barriers to technological absorption and innovation	Wondwossen (2015)
	Impact of human capital on economic growth	Curea & ciora (2013)
	Effect of human capital on performance of SME enterprises	Ashenafi et al.(2024)
	Impact of human capital development on economic growth	Kidanemariam (2015)
	Role of education on human capital	Becker (1964)
	Environmental quality, economic growth and human capital	Suhatman et al. (2024)
	The origins of endogenous growth	Romer (1994)
	Human capital and its impacts on economic growth	Hinsene et al.(2023)
Research and development (R&D)	Role of R&D on economic growth	Birhanu (2024)
	Impact of R&D on economic growth	Blanco et al.(2016)
	Technological policy and economic performance	Freeman (1987)
	Structural functional innovation system analysis	Mekonnen et al. (2022)
	Contribution of R&D expenditure on economic growth	Inekwe (2015)
	Role of university industry linkage	Tamrat & Garkebo (2020)
	Development policy review	Zemene et al. (2023)
	Industrial park development study	Abreham (2022)

Research theme	Research focus area	Reference
Innovation and human capital	Institutions, innovation and economic growth	Dejene (2020)
	Role of human capital and innovation capacity for economic growth	Muhamad et al.(2018)
	Technology transfer and innovation	Shimelis et al.(2021)
	Firm level human capital and innovation	Sun et al.(2020)
	National innovation system and Sustainable Development Goals	Li et al.(2023)
	Human capital and innovation in sub Saharan countries	Van Uden et al.(2017)
Innovation and R&D	R&D, innovations and firms productivity	Keraga & Mesele (2023)
	Impact of transportation infrastructure	Donaldson (2018)
	Impact of expansion of large scale agriculture	Getnet et al. (2022)
	Resilient infrastructure for firms growth	Braese et al.(2019)
	Adoption of improved agricultural technologies to enhance productivity	Saron & Tilahun (2020)
	Impact of quality infrastructure institutions on economic development	Madebo, 2020
	Electronic(digital) banking study	Yididya (2019)
	Adoption of soil organic carbon enhancing technologies among small scale farmers	Nguru et al.(2021)
	R &D, Innovation and economic growth	Ulku (2004)
Human capital and R&D	Role of national knowledge system for knowledge economy	Hou (2017)
Innovation, human capital and R&D	Human capital, intellectual property right and R&D for total factor productivity	Habib et al. (2019)
	Institutionalizing health technology assessment	Daniel et al.(2023)
	Productive capacity and economic growth	Admasu (2017)

Almost all of the funded researches are ideal rather than practical, that 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 & Mesele, 2023). Such problems hinder our research capabilities to achieve the country's productivity and economic growth. In order 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 exist in the country within various institutions and the amount of research expenditure (Mekonnen et al., 2022). Based on Belachew (2015), the key difficulties encountered by Ethiopian researchers when conducting various researches in their organization have been addressed from government policies and researchers. According to him, the main challenges of the researchers face include research administration and leadership problems, insufficient research resource and facilities, inadequate national policy and strategies, and limitation on outsourcing of research. The paper also emphasized that there is a relation between R&D expenditure and existence of researchers. Finally, the author recommended possible solution for fostering research in Ethiopia such as creating consistent research funding, enhancing different research councils, and boosting professional associations that can enhance country's economy through innovation.

According to Habib et al. (2019), R&D expenditure and skilled labour have impact on innovation for improving economic growth. The paper links the impact of R&D and human capital on innovation to observe the change in firm productivity. It concluded that there is strong relation between firm productivity and innovation through employment size, labour force, and research expenditure.

Although the role of small and medium enterprise on the economic growth is very high for developing countries like Ethiopia, the skills and knowledges of both the owners and their employees are not enough and needs enhancement. According to Ashenafi 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, the formal education and managerial skills have positive significant on the performance of SMEs. Hence, the Ethiopian government should work on enhancing and updating strategies that include entrepreneurship-oriented curriculum in the formal education system. Moreover, SMEs should design and build innovative strategies to improve their performance. Hinsene 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. ARDLM was implemented to investigate the co-integration existence among the metrics and human capital. As the result, it was deduced that such metrics has long term impact on GDP whereas policy change has positive short-term effect on Ethiopia's economic growth.

The key productive resources of any country are its level of human capital and workforce. Admasu (2017) studied about the importance of human capital investment to enhance productive capacities of manufacturing sector and economic growth of Ethiopia. Primary, secondary, and tertiary educational levels were used as a metrics of the country's human capital. The number of both private and public educational institutes has increased; yet, their educational outcome is very low. This is due to inadequate government expenditure on quality of education (Van Uden et al., 2017). Various studies have stated that human capital has a strong economic impact on GDP; however, there is of human capital of Ethiopia's NIS, making the situation more complicated. 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 relation among economic growth and educational investment.

A well-educated and skilled man power have the capability to innovate and adopt new technologies that

can enhance a country's economy, especially in developing countries. Researchers applied many metrics of human capital and R&D in measuring GDP, such as number of researchers, education expenditure, research expenditure, levels of education, and labour force (Birhanu, 2024; Wondwossen, 2015). In most of the studies, these metrics have significant impact on GDP; however, further works need to be done. Some of them are formulating compatible innovation policy and strategy, proper research and education funding, building strong collaboration among different innovation actors, and creating suitable environment for skilled and educated man powers.

3.2 Descriptive analysis

The ARDLM is implemented after preparing the dataset for suitable econometric analysis using explanatory data analysis. Table 3 depicts the descriptive statistics results of both the dependent and independent variables to assess the statistical analysis of raw data.

Based on data shown in Table 3, the Ethiopian economy grew at 7.34 % rate annually on average, between 1990 and 2023. The variation of the growth rate of GDP, by 0.45% from its mean, implies that the independent variables may have their own impact on GDP variation. Figure 2 show the economic growth rate of Ethiopia over the past 33 years.

The economic growth rate was slow during the 1990s, but it began to increase at the start of the 2000s. Patent is awarded for strong and successful innovation that reaches to stages of commercialization and so that it requires strong capability. However, petty patent is a patent given for minor invention and the data shows that the number of utility model (petty patent) filed in Ethiopia economy on average is 185. Figure 3, illustrates the trends of patent, utility model against the GDP growth rate.

Table 3: Descriptive statistics of the study variables, for 33 number of observations

Variables	Mean	Std. Dev.	Min	Max
LNRGDP per capita	7.34	0.45	6.69	8.02
GCF share of GDP	28.34	6.80	20.21	39.42
Patent	11.63	13.73	1.00	61.00
utility model	185.08	131.01	18.00	392.00
Human capital	29.11	6.68	13.98	37.21
RDE share of GDP	0.29	0.16	0.10	0.69
Employment rate	78.79	0.99	76.62	80.03

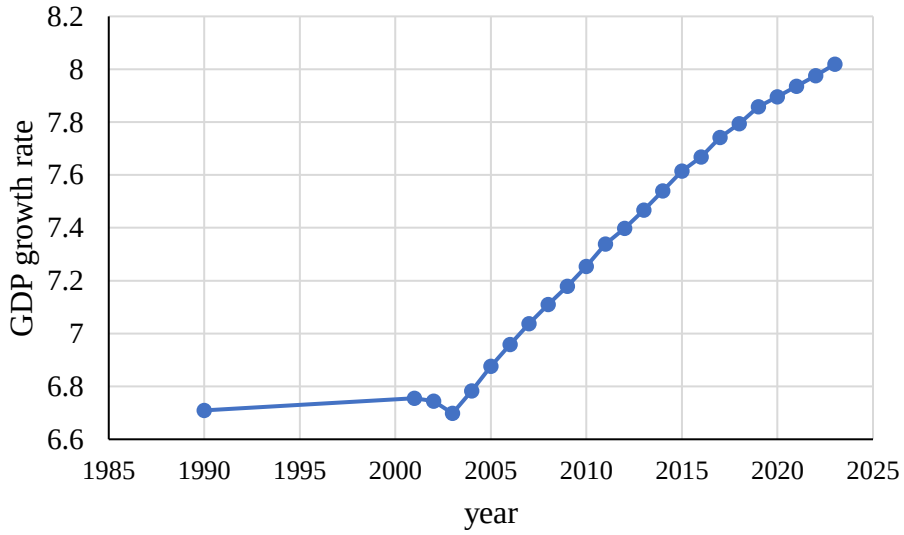

Figure 2: Real GDP growth rate trends of Ethiopia over the past 33 years

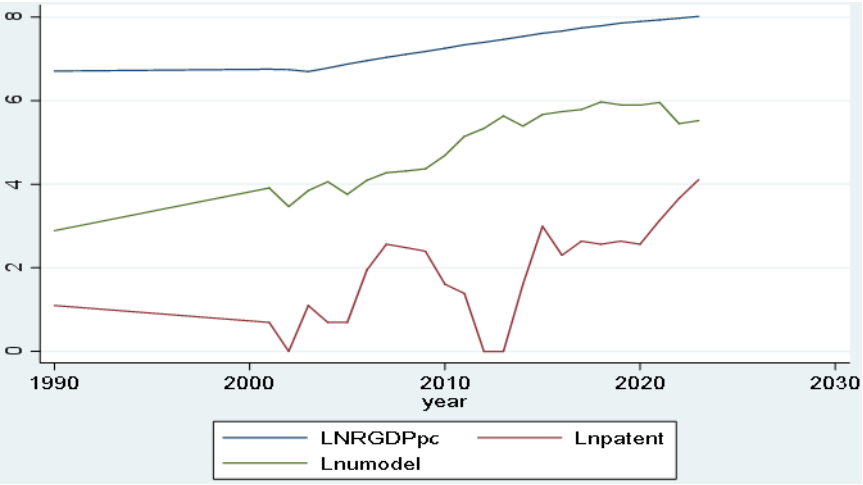

Figure 3: Logarithm of Real GDP per capita growth vs patent and utility model overtime

Regarding the research and development expenditure, the average R&D expenditure share of GDP of Ethiopia is 0.286 over the past 33 years. This reveal that the country has been spending less capital on research and development and related activities in the period. Figure 4 shows the trends of research and development expenditure share of GDP against the utility model and real GDP growth rate.

Regarding the human capital used, the lower secondary completion rate, total (% of relevant age group) and the result shows that the 10th grade completion rate on average was 29.1% over the 33 years. Secondary school completion rates are crucial for building human capital because they directly impact an individual's skills, knowledge, and employability, ultimately contributing to economic growth and social progress. Figure 5 show the trends of secondary school completion rate, trends of gross capital formation rate – share of GDP and GDP growth rate.

In addition to statistical analysis, the correlation analysis is also implemented before performing the model analysis. Table 4 depicts that GDP growth rate has positive correlation with human capital, R&D expenditure, gross capital formation, patent, petit patent, while it has negative correlation with employment rate. There is also a positive correlation between gross capital formations against all the other variables except with patent. Putting by order, utility model (0.897), patent (0.725) and human capital (0.560) are the top three variables having strong correlation with economic growth. This shows an interesting implication for Ethiopian economy as it depicts the work on innovation activities and human capital in order to transform its economy.

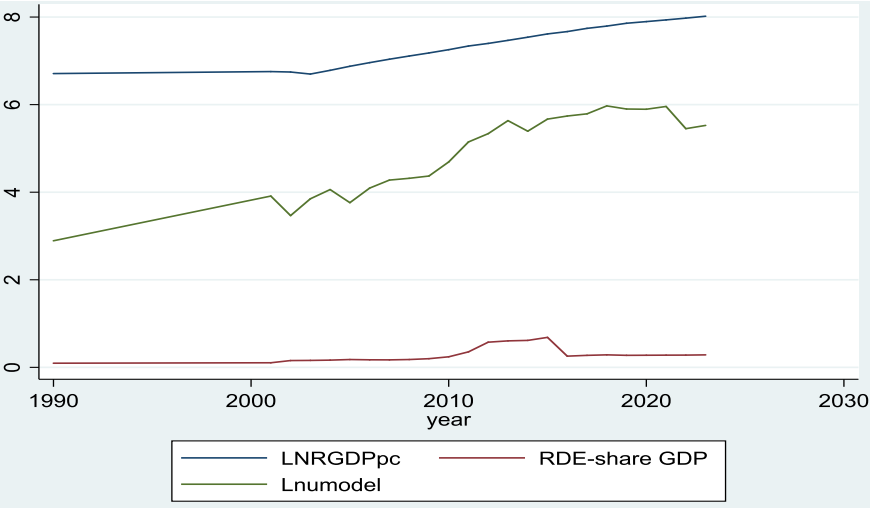

Figure 4: Real GDP growth rate vs Research and Development expenditure and utility model

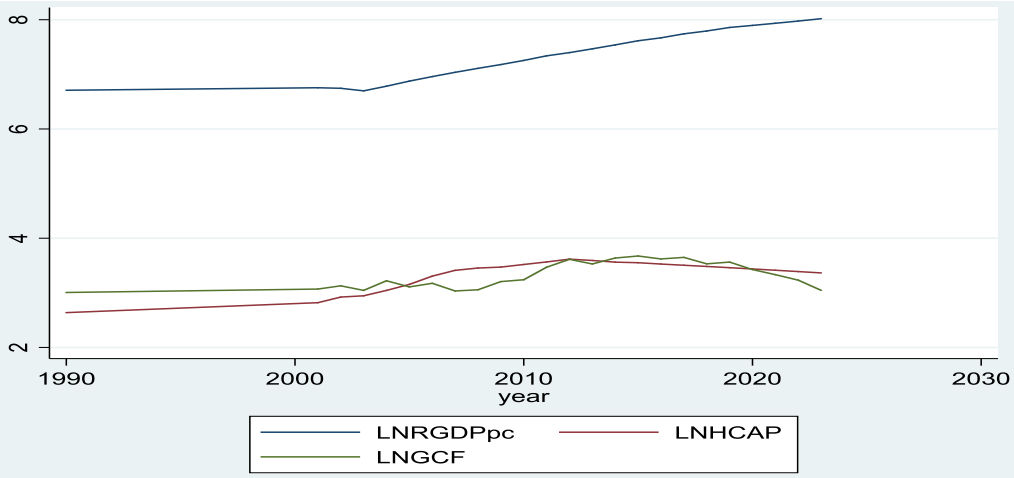

Figure 5: Real GDP growth rate vs human capita and gross capital formation trends

Table 4: Correlation among the variables

Variables	GDP	GCF_GDP	Patent	Utility model	Human capital	RDE_GDP	Employment rate
GDP	1.000						
GCF_GDP	0.4906	1.000					
Patent	0.7248	-0.0876	1.000				
Utility model	0.8969	0.7389	0.3998	1.000			
Human capital	0.5598	0.7119	0.1856	0.6363	1.000		
RDE_GDP	0.3778	0.7620	0.0504	0.5090	0.6975	1.000	
Employment rate	-0.5821	0.0003	-0.4658	-0.4729	0.2473	0.1168	1.000

3.3 Econometrics analysis

Lag selection is required to implement the ADRLM on the transformed data, as it measures the correct number of lagged terms that include each variable throughout the model. Thus, the model can approperiately gives the dynamic interaction among variables. In the ARDLM, the selected lag orders for all the six variables are 3 lags each. 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 lagged values.

The ARDLM result is shown in Table 5. Both R&D and human capital have strong positive impact on GDP growth. Specifically the effects of lag 2 of R&D expenditure and lag 1 and current values of human capital on GDP growth rate are significant. This shows that there could be strategic implication to accelerate Ethiopian economic growth. Regarding the patent–proxy for innovation variable, it has ambiguous results. On one hand, the current value of patent and its lag 2 has significant and positive effect on economic growth, whereas, its 1st and 3rd value lag has negative impact on growth rate.

The ARDLM result shows the existence of long run relationship between the patent, utility model, human capital, RDE expenditure and economic growth in Ethiopian economy. To confirm this, the error correction model was estimated and Bounds test was conducted.

Table 5: Autoregressive Distributed Lag Model results

	Model 1: With patent				Model 2: With utility model			
Variables	Coef.	Std. Err.	t	P>|t|	Coef.	Std. Err.	t	P>|t|
RGDP growth rate								
L*1	.552	.104	5.30	0.119	1.512	.223	6.76	0.002
L2.	-.347	.157	-2.21	0.270				
L3.	.726	.1036	7.02	0.090				
Gross capital formation								
--.	-1.078	1.496	-0.72	0.602	-23.560	8.916	-2.64	0.057
L1.	4.198	3.116	1.35	0.407	-29.571	10.125	-2.92	0.043
L2.	8.801	1.091	8.07	0.079	3.803	4.542	0.84	0.450
L3.	1.750	2.757	0.63	0.640	21.729	8.471	2.57	0.062
Patent								
--.	3.810	1.463	2.60	0.233				
L1.	-2.503	1.382	-1.81	0.321				
L2.	3.646	1.922	1.90	0.309				
L3.	-3.990	1.547	-2.58	0.236				
Human capital								
--.	27.464	4.071	6.75	0.094	50.85	19.704	2.58	0.061
L1.	28.534	5.948	4.80	0.001	-111.6	47.230	-2.36	0.077
L2.	11.190	11.113	1.01	0.498	20.513	24.853	0.83	0.456
L3.	6.989	4.636	1.51	0.373	33.873	10.429	3.25	0.031
RDE –share of GDP								
--.	-120.66	99.968	-1.21	0.440	-57.34	110.504	-0.52	0.631
L1.	12.662	94.165	0.13	0.915	820.05	368.345	2.23	0.090
L2.	235.158	49.028	4.80	0.001	166.71	110.124	1.51	0.205
L3.	-90.805	35.470	-2.56	0.237				
Utility model								
--.					2.177	.950	2.29	0.084
L1.					.893	.419	2.13	0.100
L2.					-1.589	.743	-2.14	0.099
L3.					-4.112	1.584	-2.60	0.060
_cons	-485.04	56.692	-8.56	0.074	360.70	228.89	1.58	0.190
Goodness of the model								
Log likelihood		-31.534				-75.660		
Root MSE		4.9778				20.3499		
Prob > F		0.0053				0.0000		
Adj R-squred		0.9992				0.9998		

* L-denotes the lag and number shows lag length

The short run and long run effect of R&D, patent, utility patent and human capital on RGDP growth rate are presented in Tables 6 and 7. The result implicates that the lag 1 impact of GDP on its current growth rate is negative which implies conditional convergence of growth rate. The result of the ARDLM bound test confirm that using the F-statistics, the null hypothesis, which is 'no level relationship', rejected. This indirectly imply that there is long run relationship between all the four variable with real GDP growth rate.

Table 6: Short and Long Run Effects-using the patent model

Variables	Short run effect	Long run effect
RGDP growth rate	LD. -0.209	L1. -0.085***
GCF	LD. -8.021**	L1. 151.072***
Patent	D1. -4.27***	L1. 9.389
Human capital	D1. 14.98***	L1. 41.17***
RDE share of GDP	LD. -286.92**	L1. 5710.61***

*L-stands for lag (e.g. L1-lag 1, L2-lag 2), D-stands for differencing (D1-differencing 1)

Table 7: Short and Long Run Effects-using the utility patent model

Variables	Short run effect	Long run effect
RGDP growth rate	L2D. 0.963***	L1. 0 .414***
GCF	L2D. -14.54 **	L1. 33.076***
Utility Patent	L2D. 2.84***	L1. 7.05***
Human capital	L2D. -35.13***	L1. 171.78***
RDE share of GDP	*D1. -164.69***	*L1. 1576.82****

3.4 Discussions

The error correction result shows that human capital and gross capital formation have positive and significant effect on GDP growth rate in the long run whereas the same variables have negative impact in the short run. On the other hand, the R&D expenditure has positive impact on GDP growth in the short run that is via creating temporary employment and injection to the economy; however, the result shows negative impact on GDP growth in the long run. This result is consistent across both models as can be seen from Table 6 and 7.

The error correction model shows that utility patent has positive and significant impact on economic growth in both the short run and long run. By the same fashion, patent has similar effect on economic growth of Ethiopia except in the long run where it is not significant but still positive. This implies that Ethiopian economy is responsive for innovation and value creation so that demands foster innovation activities in the country. In order to foster innovation activities, all the innovation ecosystem stakeholders should enhance their capability in terms of policies, human capital, investment and others aspects.

The results of both the systematic review and empirical analysis reveal that R&D, patent and utility model and human capital are the key determinants of economic growth, which implies a key pillars of NIS, especially in developing countries like Ethiopia. This finding is in line with the result of study by Inekwe (2015), which reveals that the effect of R&D spending on growth is positive for upper middle-income economies while insignificant in lower income economies. In addition, their study has shown that the R&D spending has different short and long run effects on growth. Another study conducted in the US shows that the effect of R&D on economic growth is more in states with better human capital compared to other states (Blanco et al., 2016). There are also controversial findings with regard to the role of R&D and innovation on economic growth. For instance, study by Ulku (2004) shows that there is no evidence for constant returns to innovation in terms of R&D, implying that innovation does not lead to permanent increases in economic growth. However, these results do not necessarily suggest a rejection of R&D based growth models given that neither patent nor R&D data capture the full range of innovation and R&D activities.

As it is observed on the econometric analysis, the expenditure of R&D has statistically significant positive effect on GDP growth rate in the long run in the model considering utility patent model. However, R&D expenditure has a significant negative effect during short run, implying that quick resource allocation, skill and knowledge trainings, and fund allocation may not convert into economic development. In the same way, the R&D expenditure exhibits a negative long-run impact on countries economic growth in the patent model. Such result indicates that the research outcomes do not have an impact on economic growth since there are inefficiencies of how research expenditures are utilized for the intended purpose.

The systematic analysis of literatures has shown that NIS pillars have great impact on GDP. Similarly, the empirical analysis showed that partly R&D expenditure in the utility model in the long run and human capital in both models have statistically significant positive effect on GDP growth rate. The study also found that gross capital formation (GCF) has positive effect in the long run and negative effect in the short run on GDP growth

rate in both models. The employment rate is omitted due to multi-collinearity problem. Moreover, an extensive studies confirmed that the economic productivity of Ethiopia is highly depend on the knowledge, skill, and innovation capability of manpower. The knowledge produced from research and development can enhance the production level and adoption of technology in several sectors of the country, including agricultural and manufacturing sectors. Such NIS pillars improve the ability of competitiveness by supporting firms to yield more innovative products and minimizing the reliance on traditional methods. The empirical findings illustrate that enhancing human capital and R&D expenditure are key strategy to in boosting quick and sustainable economic development.

To enhance Ethiopia's economy through innovation, the government should formulate a robust innovation framework that define and control the responsibility of each NIS actors. Moreover, various industries and research institutions must collaborate and work together for the development of Ethiopia's economy.

4. Conclusions

The development of a national innovation system significantly influences economic growth, particularly in developing countries like Ethiopia. However, its enhancement highly depends on proper interaction of its actors and various pillars implementations. Among them, this study tried to explore the impact of human capital, patents and utility patent and R&D in fostering the economic growth. A systematic review is applied to examine existing literatures of Ethiopia that helps to understand both theoretical and empirical relation among R&D, patent, human capital, and GDP growth rate. Although the studies conducted in this regard are limited, they revealed that R&D and human capital have an impact on GDP growth rate. Since many of the studies were conducted in specific sectors like small medium enterprises, an empirical analysis is required for validating the systematic analysis result in a comprehensive manner.

For the empirical analysis, ARDLM was used to estimate the effect of innovation (patent, utility patent), R&D expenditure, gross capital formation and human capital on economic growth. The analysis revealed that human capital has positive effect on GDP per capita growth in the long run, whereas, R&D expenditure have positive effect on GDP growth rate in the long run and negative effect in the short run. Furthermore, the effect of patent is significant and positive in the long run and negative in the short run. However, the utility model has significant positive effect on GDP growth in both short run and long run cases. Regarding the gross capital formation, it has negative effect in the short run and positive effect in the long run. Thus, the government, educational institutions, and enterprises should work together for developing the country's economy by obtaining a skilled and educated manpower.

The study suggests the following policy implications. First, the government and its allies have to allocate enough budget for the R&D expenditure of the country, which will be used to align the research activities output with economic goals of the country. There may also be a need to build a proper strategy and monitoring mechanism regarding the optimal utilization of R&D budget. Secondly, the government and its stakeholders should formulate innovation strategies and foster collaboration for enhancing the quality of education by allocating enough education and research funding for boosting the NIS impact on the country's economy. Thirdly, policy makers should take into account educational systems and workforce enhancement programs. Lastly, the government needs to utilize skilled and educated individuals in various sectors, which could help building strong institutions and impacts economic growth. Given that this study employed classical empirical methods, it is recommended that future research utilize more advanced predictive models, particularly machine learning, for enhanced analysis.

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