

## The Influence of Human Capital on Innovation in Vietnam

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### ABSTRACT

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This study examines the role of human capital in fostering innovation to support sustainable economic development in Vietnam. By employing the Autoregressive Distributed Lag (ARDL) model, alongside the Bounds Test and the Error Correction Model (ECM), this research aims to elucidate the existence of both long-term and short-term relationships between the identified variables. In addition, Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) methods are employed as robustness checks. Human capital is represented by university enrollment rates, while patent applications serve as innovation metrics. The analysis is conducted on annual secondary data spanning the period from 1990 to 2021 in Vietnam. The results indicate both short- and long-term associations between human capital and innovation in Vietnam. The results offer policy-relevant insights for development planning and human capital investment strategies in the Vietnamese context.

## 1. INTRODUCTION

Innovation constitutes a profound impetus for economic growth and development. Nations distinguished by elevated levels of innovation increasingly assume the mantle of economic leadership. It is indisputable that contemporary disparities in product quality and productivity are contingent upon the integration of scientific and technological advancements, essentially reflecting the extent of knowledge application. Countries endowed with advanced scientific and technological capabilities emphasize the critical importance of innovation in shaping their economic trajectories, thereby rendering investments in human capital, particularly within the domain of higher education, of paramount significance [1].

The realization of innovation necessitates a multitude of conducive conditions, with human capital occupying a central role. Innovation extends beyond the confines of individual organizational efforts, being intrinsically associated with ancillary factors such as the availability of a skilled workforce, access to collaborative networks, and the effective dissemination and transfer of new knowledge [2]. Human capital is indispensable in enhancing technological capabilities, whether through the assimilation of superior foreign technologies or the generation of indigenous innovations [3]. Consequently, human capital constitutes a fundamental element integral to both innovation and economic development [4]. In essence, human capital is not merely a supplementary asset, but a prerequisite for fostering innovation. The presence of highly skilled human capital exerts a positive influence on innovation and invention within Russia [5]. In lower-middle-income countries, university-level human capital emerges as a pivotal labor force driving

innovation capacity [6]. The intersection of institutional quality and human capital serves as the principal driver of innovation across Asian nations [7].

Vietnam has undergone rapid development, demonstrating significant economic advancements over the past few decades. From 2000 to 2019, the nation experienced an impressive average annual economic growth rate surpassing 6.6%. The liberalization of markets designed to attract Foreign Direct Investment (FDI), coupled with a swift transition towards a manufacturing-oriented economy, has facilitated Vietnam's ascent from a low-income status to that of an upper-middle-income country. According to the World Intellectual Property Organization (WIPO), Vietnam has recently garnered recognition for its remarkable achievements in the realm of innovation. The Vietnamese government has strategically prioritized innovation within its national development agenda, acknowledging its critical role in promoting economic growth, enhancing labor productivity, and strengthening national competitiveness.

The capacity for innovation serves as an essential foundation for the effective assimilation of external resources, such as FDI and advanced technology imports. Additionally, it is integral to efforts aimed at improving export performance and maximizing the advantages of international economic integration. However, the sustainability of innovation in Vietnam remains inadequate, as indicated by the country's low performance metrics in patents and inventions which are the key indicators that guide and measure the efficacy of innovation initiatives. Specific scientific indices of concern include: (i) the international rankings of domestic universities; (ii) the volume of patents filed with relevant agencies; and (iii) the frequency of citations of international research conducted

in Vietnam, which continues to lag behind that of Malaysia, Thailand, and other Southeast Asian nations.

Despite the acknowledged significance of human capital in promoting innovation, empirical research assessing its impact within the Vietnamese context remains limited. Therefore, the present study is both timely and necessary. This article is structured into five sections: following the introduction, Section 2 provides a literature review, while the subsequent sections are dedicated to methodological analysis, empirical results, and policy implications. Notwithstanding certain limitations inherent in the study, it evaluates the influence of human capital on innovation in Vietnam during the period spanning 1990 to 2021, thereby highlighting the pivotal role that human capital plays in driving innovation within the country.

## 2. LITERATURE REVIEW

The concept of human capital has been defined in various ways. From an individual perspective, human capital is perceived as an asset, contrasting with the classical concept of the labor force [8]. Human capital signifies the human element within an organization, encompassing expertise, skills, and intelligence, which collectively contribute to the differentiation of the organization [9]. Another perspective emphasizes the knowledge and skills acquired by individuals through training activities and the accumulation process [10]. A related viewpoint, the production-oriented perspective of human capital, defines human capital as a fundamental resource for generating economic productivity [11].

In the 1990s, researchers introduced the concept of innovation in relation to new technologies. In recent years, this concept has further expanded. Innovation can result in the development of new products, processes, supplies, market exploitation, and/or organizational forms [12]. Innovation is recognized as a distinct activity through which inventions are functionally applied in the market for commercial purposes [13]. Regardless of the approach, companies and enterprises remain central to the innovation system, as innovation is intrinsically linked to the production of both material and intellectual products that cater to the needs of society.

In fact, the most significant contributions of human capital have emerged since the mid-20th century. Particularly, Becker is widely acknowledged as the founder of human capital theory, positing that human capital enhances labor productivity [14]. Moreover, Arrow [15] highlighted the influence of experience on technological change. Workers endowed with greater human capital are better equipped to adapt to economic structural changes and address new technological challenges [16]. On the one hand, human capital is perceived as an independent production factor that augments productivity at a specific technological level [17]. On the other hand, human capital is considered an input in the innovation process, thereby complementing technology. Educated individuals, as bearers of human capital, facilitate innovation, technological development, and adaptation to foreign technology [3]. Talented individuals can contribute to technological advancement if they have access to educational facilities, and such individuals can exert the most significant impact [18].

Empirical studies employing data from various countries worldwide substantiate the critical impacts of human capital as a catalyst for innovation. These impacts have been

corroborated by theoretical research findings [19] and empirical research outcomes [4, 20-22]. Human capital not only influences the rate of technological innovation in domestic production but also affects the pace of technology imitation and convergence with technologically advanced countries [23]. The relatively low level of innovative activity in certain regions of the European Union (EU) is attributed to insufficient investment in human capital [22]. Recent assessments have demonstrated the positive impact of human capital on innovation in specific countries, such as the substantial positive effects on innovation in regions of Israel [20]. Education and individual talent not only enable individuals to generate new ideas but also facilitate the absorption of knowledge from external sources. The capacity to innovate is contingent upon both the availability of human resources and the exchange of information through regional and inter-regional networks in Russia [24]. A strong correlation between human capital and the intensity of "basic" inventions has been established [25]. Unskilled human capital (individuals who complete primary and secondary education at the basic education level) does not enhance innovation in lower middle-income countries [26]. However, empirical research also indicates that the accumulation of human capital does not necessarily lead to innovation; China's human capital continues to accumulate, yet innovation remains uncertain [27].

Human capital endowed with a high level of education has a profoundly positive influence on innovation. The proportion of the population possessing advanced educational qualifications is pivotal for the economic development of nations and regions, as new technologies cannot be implemented without skilled labor, nor can they be developed or modified without the participation of highly qualified researchers [16, 18]. Human capital with superior education significantly contributes to innovation through: (i) highly educated employees' ability to invent and enhance new technologies, and (ii) their capacity to exploit technological advancements [28]. This demonstrates that human capital not only impacts a country's technological innovation but also its adoption of external technologies. Human capital is a fundamental element in generating new knowledge and fostering innovation [29]. Knowledge serves as an intrinsic driver for the continuous evolution of initiatives, with the expertise of skilled employees playing a crucial role in elucidating the persistence of innovation [30]. Valentina [31] identified a significant positive correlation between highly qualified human resources and the labor productivity of innovative Russian companies. For lower-middle-income countries, university-educated human capital is an essential workforce that drives innovation capacity [6]. The proportion of employees with higher educational attainment has a markedly positive impact on patent activity in Germany [21].

Recent research findings have increasingly affirmed the influence of human capital on innovation within selected evaluated countries. The results of econometric analyses, utilizing the fixed effect model and the pooled model, have demonstrated that the increase in innovative activities within the economies of Russian regions is driven by the augmentation of various forms of human capital. This human capital is cultivated through education and vocational training programs, higher education, and doctoral programs [5]. Another study employed scatter plots and regression models to analyze the relationship between regional human capital, innovation, and economic development levels in European

regions. By utilizing a dataset encompassing regional human capital and other factors from the 19th and 20th centuries, the results revealed that historical regional human capital is a significant determinant of the current disparities in innovation and economic development [4]. A study employing panel data regression evaluated the impact of human capital components at the unskilled, skilled, and high-skilled levels on the innovation capabilities of 65 economies from 1985 to 2019. In this context, high-skilled human capital is represented by the number of R&D personnel, skilled human capital by higher education, and unskilled human capital by primary and secondary education. These components were used to estimate the innovation-enhancing effects of human capital. The findings indicate that high-skilled human capital enhances innovation capabilities in upper-middle-income and high-income countries, while skilled human capital serves as a critical labor force driving innovation capabilities in lower-middle-income countries. Conversely, unskilled human capital was found to play no role in innovation development [6]. More recently, the feasible generalized least squares (FGLS) method was employed to analyze factors influencing patent applications in 39 Asian economies from 2000 to 2021. The results underscored human capital as a principal driver of innovation [7]. Furthermore, a study utilizing a sample of high-tech firms listed on the stock market in China from 2009 to 2017 demonstrated that human capital mitigates the negative impact of financial constraints on persistent innovation investment. Managerial human capital contributes to an increase in future granted patents through continuous innovation investment [32].

Beyond the consideration of human capital, various studies at the macroeconomic level have delved into additional factors influencing innovation. Prior research has substantiated the relationship between innovation and Manufacturing Value Added [33]. FDI can provide significant advantages for innovation activities by facilitating the spillover of knowledge, technology, and management practices from home countries to host nations. Based on data from China between 1995 and 2000, research indicates that FDI has a positive impact on the number of domestic patent applications [34]. For high-income countries, foreign innovation spillovers via FDI play a critical role [6].

The impact of human capital on innovation has been validated through numerous studies, which consistently identify it as a fundamental determinant of innovative capacity. However, investigations into this effect within the context of Vietnam remain limited. Given the critical role of human capital as a driver of national innovation, this study endeavors to assess the influence of human capital on innovation in Vietnam. As a result, the study aims to propose policy implications aimed at enhancing human capital development, thereby facilitating the advancement of innovation.

### 3. RESEARCH MODEL AND DATA

This research adopts the endogenous growth framework [11, 17], which emphasizes that innovation is fundamentally fueled by knowledge accumulation and human capital, based on the model proposed by Diebolt and Hippe [4], Ngo [6] and Cheung and Lin [34]. This article presents the following research model:

$$PAT_t = \alpha_0 + \alpha_1 SET_t + \alpha_2 FDI_t + \alpha_3 IND_t + \varepsilon_t$$

In this equation, *PAT* represents innovation, *SET* stands for human capital, *FDI* represents FDI, *IND* denotes the industrial share of GDP, and  $\varepsilon$  denotes the residual term.

Measuring human capital involves various perspectives due to different approaches and limitations in data sources. Among these, the educational approach is the most used in macroeconomic research for several reasons: (i) formal education is recognized as the fundamental source of human capital accumulation; (ii) there is a strong correlation between the knowledge gained from this perspective and other perspectives; and (iii) there is a wealth of comparable international data available [35].

Various scholars have developed measures of human capital, specifically analyzing the proportions of males and females aged 25 and older with differing levels of educational attainment (no schooling, primary education, secondary education, and higher education) [36]. Human capital is divided into two categories: Basic Human Capital and Advanced Human Capital. Basic Human Capital consists of participation rates in basic education, encompassing primary, lower secondary, upper secondary, and vocational education. In contrast, Advanced Human Capital pertains to the participation rates in post-secondary education [37].

Additionally, numerous studies—both prior and recent [38, 39], have employed years of schooling, represented by the average years of education, as a proxy for human capital. The Human Development Index (HDI), a composite measure reflecting human development across the dimensions of health, knowledge, and income, has also been used to assess the relationship between HDI and patent applications in various countries [40]. Human capital is measured by accumulated years of schooling and income from education, using data provided by the Penn World Table 10.01 [41]. This human capital index has also been employed in various previous studies [42-44].

In the context of Vietnam, the current availability of data on human capital is limited. Therefore, this article utilizes reliable proxies from available data sources to represent human capital, particularly regarding its impact on innovation. Consistent with prior research, this study employs the tertiary enrollment rate as a proxy for high-quality human capital. This metric reflects the capacity for technological absorption and the availability of specialized R&D personnel, both of which are fundamental prerequisites for fostering innovation.

Innovation encompasses progressively incremental changes; however, these incremental alterations are often difficult to discern and quantify. Furthermore, the evaluation of the success of innovation typically necessitates a substantial period of time, usually at least a decade [45]. Previous research has employed a variety of metrics to assess innovation, among which the total number of patent applications and patents granted are commonly recognized as indicators [6, 7, 33, 46-49]. The foundational criteria for the patentability of any invention rest upon its utility (i.e., industrial application) and novelty [50]. Nonetheless, it is important to note that not all inventions are subject to patenting, and there can be significant temporal lags between the conception of an invention and its subsequent realization as an innovation [51]. Despite these acknowledged limitations, researchers persist in utilizing this measure for several reasons: (i) inventions are generally commercialized; (ii) comprehensive statistical data on patent registrations have been systematically compiled over extensive periods; and (iii) the financial costs associated with securing a patent imply the anticipation of potential economic

returns [52]. Consequently, the number of patent applications is employed as a representative measure of innovation, selected due to its frequent application in previous studies and the advantages articulated by Hasan and Tucci [52]. Moreover, the utilization of patent data in the analysis of innovation offers substantial benefits, including its systematic documentation over long temporal series and its reflection of a segment of the output of innovation, which is intrinsically linked to the input associated with national-level research and development investments.

As the industrial sector is a primary driver of R&D, the variable IND is employed as a control [33] to represent the economic structure and account for innovation-related factors external to human capital. Additionally, in Vietnam, FDI is a crucial channel for the transfer of technology and R&D processes from multinational firms. As a proxy for 'imported' R&D and exogenous knowledge, the FDI variable is integrated into the model [5, 34], hypothesized to positively influence innovation via technology spillovers.

The research employs the Autoregressive Distributed Lag (ARDL) methodology, as developed by Pesaran et al. [53], due to several distinct advantages inherent in the ARDL model: (i) it provides flexibility in the order of cointegration tests [53]; (ii) it is efficaciously applicable to small sample sizes [54]; and (iii) the application of the ARDL model ensures that the long-term estimated coefficients remain unbiased [55]. In addition, Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) methods are employed as robustness checks. These techniques effectively address potential endogeneity and serial correlation issues, ensuring the derivation of unbiased and efficient long-run estimates.

The ARDL model is delineated as follows:

$$\ln PAT_t = \gamma_0 + \sum_{i=1}^p \beta_1 \Delta \ln PAT_{t-i} + \sum_{i=0}^q \beta_2 \Delta \ln SET_{t-i} + \sum_{i=0}^q \beta_3 \Delta \ln FDI_{t-i} + \sum_{i=0}^q \beta_4 \Delta \ln IND_{t-i} + \phi ECT_{t-i} + \varepsilon_t$$

In this model, the following variables are utilized: *PAT* (total number of patent applications by non-residents and residents), *SET* (higher education enrollment rate), *IND* (industrial added value as a percentage of GDP), *FDI*, net inflows of GDP), *p* and *q* (optimal lag),  $\Delta$  (difference),  $\varepsilon_t$  (white noise),  $\beta$  represents the short-term coefficients, and  $\phi$  represents the long-term coefficients of the basic ARDL model (Table A1).

The time series data, spanning the period from 1990 to 2021, serves as the foundation for this research. Within the article, all variables are transformed into their natural logarithmic forms prior to conducting the analysis (Table 1). The variables and their respective data collection sources are in Table 2.

**Table 1.** Descriptive statistics

	lnPAT	lnSET	lnFDI	lnIND
Mean	7.378216	2.484002	1.635611	3.525715
Median	7.627341	2.793251	1.571155	3.569043
Maximum	9.051813	3.736609	2.479851	3.694085
Minimum	4.127134	0.486400	1.022927	3.121232
Std. Dev.	1.342566	0.976345	0.356442	0.142205
Skewness	-1.063348	-0.750015	0.747791	-1.323902
Kurtosis	3.406223	2.273932	2.674612	4.113972

**Table 2.** Data sources

Variables	Variable Explanation	Data Sources
SET	School enrollment, tertiary (% gross)	World Bank Open Data   Data and General Statistics Office of Vietnam
PAT	Total number of patent applications. Patent applications are filed to obtain exclusivity over an invention (a product or process)	World Bank Open Data   Data
FDI	Net foreign direct investment (FDI) as a share of GDP Industry (including construction), value added (% of GDP)	
IND		

#### 4. ANALYSIS OF RESEARCH RESULTS

During the period from 1990 to 2021, Vietnam's Human Capital Index remained relatively robust. The higher education enrollment rate increased annually throughout this period, positively correlating with Vietnam's socio-economic development. However, this rate was only equivalent to the average for middle-income countries and significantly lower than that of higher middle-income countries, as well as lower compared to regional countries such as Singapore, Malaysia, and Thailand. Consequently, in 2024, Vietnam approved the Education Development Strategy to 2030, with a vision towards 2045. This strategy aims to develop an open education system, ensuring equity and equality in access to education, promoting lifelong learning, and targeting a university enrollment rate of at least 33% among the 18-22 age group by 2030. Furthermore, the government has also implemented programs to develop high-quality human resources for various economic sectors to improve Vietnam's Human Capital Index.

Vietnam has been recognized for achieving significant accomplishments in innovation during the decade from 2010 to 2019. The Vietnamese government has issued numerous guidelines and policies to promote the creation, protection, and development of intellectual property assets. The Science, Technology, and Innovation Development Strategy to 2030, issued by the Prime Minister, outlines one of its key orientations to increase the quantity, quality, and efficiency of intellectual property exploitation, focusing on developing the intellectual property of enterprises, alongside strengthening the protection and enforcement of intellectual property rights. The Intellectual Property Strategy to 2030 emphasizes the active participation of all societal actors in intellectual property activities, with research institutes, universities, and creative individuals, particularly enterprises, playing a leading role in creating and exploiting intellectual property assets. The Intellectual Property Development Program to 2030 aims to make intellectual property a vital tool in enhancing national competitiveness, creating an environment that encourages innovation and fosters economic, cultural, and social development. All these initiatives provide opportunities for Vietnam to learn, apply, innovate technology, and address the limitations of pioneering countries to develop capabilities and enhance socio-economic development efficiency. However, the number of patent applications and the patent application rate per capita remain very low, particularly in the number of patent applications submitted by Vietnamese entities.

**Table 3.** Unit root test results

Variable	ADF Test		PP Test	
	Level	First Difference	Level	First Difference
lnPAT	-2.074814	-4.160523***	-2.087603	-4.362460***
lnSET	-2.843862	-3.912614***	-1.839019	-3.913537***
lnIND	-2.602261	-4.301953***	-2.602261	-4.267203***
lnFDI	-3.280105	-4.117016***	-2.911309	-4.009362***

Note: \*\*\*, \*\*, \* correspond to statistical significance levels of 1%, 5%, and 10%, respectively.

The results of the unit root tests are presented in Table 3. These results indicate that after applying the first-order differencing, the data series exhibit stationarity across various significance levels. Consequently, the data series satisfies the necessary conditions to proceed with the subsequent stages of the ARDL model.

**4.1 Cointegration analysis**

The findings of the cointegration tests, as displayed in Table 4, reveal that the F-statistic values exceed the critical values of I(1) at all significance levels. Therefore, these results provide evidence of a long-term relationship, or cointegration, among the variables in the specified models.

**Table 4.** Results of the cointegration analysis

k	F-Statistic Value	Boundary Critical Values							
		90%		95%		97.5%		99%	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
3	6.735310	2.37	3.2	2.79	3.67	3.15	4.08	3.65	4.66

The lag structure of the ARDL model in this study was selected based on the Akaike Information Criterion (AIC), selected Model: ARDL (1, 2, 0, 1).

**4.2 Estimation of short-term and long-term coefficients of the model**

Tables 5 and 6 present the estimated long-term and short-term coefficients of the ARDL model.

The long-term analysis reveals that, at a 10% significance level, human capital, as denoted by the Standardized Education Training (SET), exerts a positive influence on innovation, measured by Patent Applications. In the short term, SET exhibit a positive effect on PAT at a 1% significance level. The Error Correction Term (ECM) coefficient is statistically significant at the 1% level and carries a negative sign, further corroborating the long-term relationship as evidenced by the ARDL bounds test. Consequently, the research findings indicate that among the variables representing human capital, SET positively impacts PAT. An increase of 1% in SET will lead to a 0.823% increase in PAT at a 10% significance level. This result aligns with the findings of Ngo [6]. Ngo [6], who concluded that for lower-middle-income countries, human capital at the university level constitutes a crucial labor force driving innovation capacity. Conversely, this finding contrasts with Ang et al. [56], who demonstrated that the innovation enhancement effect of labor attaining higher education levels is only observed in high-income countries and does not contribute to innovation enhancement and growth in lower-middle-income countries. This result also supports the findings of Vandenbussche et al. [1], wherein a highly educated workforce is identified as a

principal driver of growth and innovation. Furthermore, these significant findings reflect Vietnam's recent transition from the lower-middle-income status while maintaining its position as a technology follower. To effectively assimilate advanced foreign technologies, adapt them to domestic contexts, and foster the creation of new technologies through enhanced research and development efforts, the presence of a highly skilled and educated workforce is deemed indispensable.

Short-term results indicate that SET is positively correlated with innovation at a 1% level of significance. This confirms that highly skilled human capital is essential for innovation, notwithstanding the modest domestic patenting activity. While higher education enrollment immediately bolsters innovative capacity through the influx of skilled labor, its lagged effect is significantly negative. This suggests a potential misalignment where the expansion of educational output outweighs the development of specialized R&D infrastructure.

**Table 5.** Long-term estimation results

Variable	Coefficient	t-Statistic	Prob.
lnSET	0.823391	1.722513	0.0990
lnIND	-3.267544	-0.955524	0.3497
C	17.11572	1.272644	0.2164

**Table 6.** Short-term estimation results

Variable	Coefficient	t-Statistic	Prob.
Dln(SET)	0.743619	3.475498	0.0021
Dln(SET(-1))	-0.470034	-2.436121	0.0234
Dln(IND)	-1.952566	-2.599041	0.0164
CointEq(-1)*	-0.195774	-6.308689	0.0000

The study reveals that while the IND variable negatively impacts innovation in the short term, its effect diminishes and loses statistical significance over the long term. This is attributed to the prevailing labor-intensive nature of the Vietnamese economy. The focus on low-value-added manufacturing leads to a crowding-out effect, where resources are diverted away from research and development toward large-scale, low-tech production.

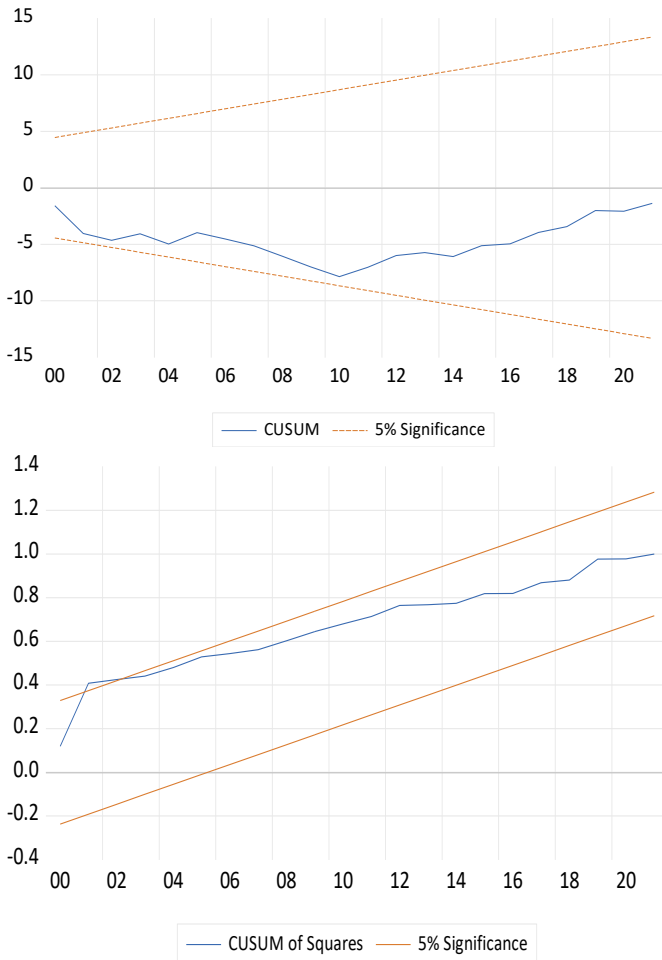
Ultimately, a series of diagnostic tests were executed to assess the model's adequacy (Table 7). These included the Ramsey RESET test to evaluate the correct functional form, the Lagrange Multiplier (LM) test to detect autocorrelation, the Breusch-Pagan-Godfrey test for heteroscedasticity, and a normality test for the residuals. The results of these assessments consistently suggested that the model did not exhibit any specification errors, as evidenced by p-values exceeding 0.05 (Figure 1).

A series of comprehensive residual tests were conducted to assess the model's performance. To ensure the reliability of the findings, CUSUM and CUSUMSQ tests were conducted. The results indicate that the coefficients are stable, as the cumulative sums stay within the critical 5% limits. Any momentary fluctuations outside the boundaries are minor,

suggesting that the model is free from structural breaks during the study timeframe.

**Table 7.** Diagnostic tests of the model

Type of Test	Statistic	P-Value
Ramsey	0.051180 (F (1,21))	0.8232
Correlation LM	1.448546 (Obs*R-squared)	0.4847
Breusch-Pagan-Godfrey	10.76332 (Obs*R-squared)	0.1493
Histogram-Normality	0.657711 (Jarque-Bera)	0.719747



**Figure 1.** Results of CUSUM tests

**Table 8.** Long-run estimates using Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) methods

Variable	DOLS		FMOLS	
	Coefficient	Prob.	Coefficient	Prob.
SET	0.388625	0.0848	0.699196	0.0002
FDI	0.646048	0.0038	0.795370	0.0000
IND	1.484872	0.0529	1.749566	0.0047
C	-1.052427	0.6808	-2.678167	0.1686
@TREND	0.075439	0.0003	0.054971	0.0007
Adjusted R-squared	0.964991		0.950779	
S.E. of regression	0.204410		0.275337	

While the ARDL estimates indicate that SET is only significant at the 10% level—with FDI and IND yielding no statistically significant impact—the FMOLS and DOLS

estimators provide more robust empirical evidence (Table 8). Specifically, all three variables achieve significance levels ranging from 1% to 10% under these models. This improvement confirms that once endogeneity and serial correlation are addressed, and exogenous technological progress is controlled via a time trend, the roles of human capital, FDI, and industrial structure in fostering innovation in Vietnam become significantly more pronounced and robust.

In summary, this analysis, grounded in Vietnam's time-series data, reveals that human capital, and particularly high-level human capital, significantly contributes to the advancement of innovation. Both short-term and long-term assessments affirm that human capital exerts a positive influence on innovation, consistent with theoretical frameworks and supported by a substantial body of empirical research. High-level human capital is distinguished by its possession of advanced skills and competencies essential for effectively harnessing new technologies offered by foreign entities. Furthermore, this group plays a pivotal role in research and development, facilitating the creation of inventions, sophisticated tools, techniques, and cutting-edge technologies, which, in turn, bolster the national innovation capacity. While higher education currently falls short in generating high-level skills, it remains instrumental in fostering the exchange of ideas and competencies critical for innovation. Accordingly, investment in human capital is imperative for nurturing an innovative environment and expediting the overall development trajectory of the nation. Nonetheless, the estimation results indicate that the contribution of human capital to innovation, while positive, is relatively modest. This reflects the reality that, despite Vietnam's commendable literacy rates, access to higher education remains constrained. Enrollment and graduation rates in colleges and universities have seen significant improvements since 1989, although these rates are still comparatively low. Furthermore, participation from students hailing from low-income families and ethnic minorities in higher education remains disproportionately limited.

## 5. CONCLUSIONS

The influence of human capital on innovation has garnered significant attention from researchers seeking to identify reliable and prominent indicators to quantify the relationships between these variables in various economies. This study has employed the number of patent applications (total applications) as a measure of innovation. Human capital has been assessed through the higher education enrollment rate. The findings of this research indicate that human capital (represented by the higher education enrollment rate) exerts a positive impact in both the short and long term. These results align with those of preceding studies, underscoring the pivotal role of human capital in driving innovation. Hence, it is imperative for Vietnam to implement significant policy interventions, prioritizing the development of human capital, particularly advanced human capital, in conjunction with effective investment policies to foster and enhance innovation efficiency.

The enhancement of human capital necessitates time; nonetheless, the beneficial impacts of human capital persist over an extended period, thereby providing impetus for Vietnam to invest further in human capital. The empirical findings affirm the positive impact of the tertiary enrollment

rate on innovative capacity. Consequently, Vietnam should implement strategic policies aimed at expanding the scale of higher education while simultaneously enhancing its quality, with a primary focus on basic sciences and spearhead technologies.

Initially, efforts should be directed towards planning the network of educational and training institutions, fostering the development of high-quality human resources in the domains of fundamental sciences, traditional sectors, and emerging industries. Merely increasing resources for educational institutions to achieve improved educational outcomes for learners is insufficient to enhance learners' skills and competencies. Resources can only realize their full potential in bolstering capabilities if coupled with substantial structural reforms in the organization and management of universities. The government should establish breakthrough mechanisms and policies to attract and utilize foreign experts, scientists, and overseas Vietnamese to teach, research, and work in educational institutions in Vietnam. In addition, fostering synergistic linkages between the state, universities, and the private sector is essential for aligning higher education with national innovation goals and promoting long-term socio-economic sustainability.

Moreover, Vietnam should implement various training models, encourage lifelong learning, and formulate appropriate financial support policies to ensure that high school graduates have the opportunity to pursue higher education.

## STUDY LIMITATIONS

The study has certain limitations in using patents as a proxy for innovation and university enrollment rates for human capital. However, despite specific constraints in developing countries like Vietnam, these indicators ensure objectivity due to their official and reliable data sources. As standard proxies validated by numerous empirical studies, they maintain model consistency and align with contemporary research methodologies.

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**APPENDIX****Table A1.** Variance Inflation Factors (VIF)

	<b>Coefficient</b>	<b>Uncentered</b>	<b>Centered</b>
Variable	Variance	VIF	VIF
SET	0.012368	19.27322	2.358022
FDI	0.048586	29.67996	1.190928
IND	0.759677	2038.076	2.401665
C	8.920657	1908.858	NA