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Human Capital as a Catalyst for Income Convergence: Evidence from ASEAN-8 Countries

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Abstract

Research Originality: This study takes a novel approach to analyzing the impact of human capital on income convergence in ASEAN-8 countries by comparing three indicators. This comparative analysis provides a more comprehensive understanding of human capital dynamics in ASEAN's economic convergence.

Research Objectives: This study investigates the impact of human capital on income convergence by applying the concept of β-convergence to the ASEAN-8 countries.

Research Methods: The analysis of β-convergence is based on the basic and augmented Solow growth models. The estimation is conducted using static and dynamic panel data regression from 1995 to 2019.

Empirical Result: The results reveal the existence of absolute and conditional β-convergence in ASEAN-8 countries, suggesting that poor countries grow faster than rich countries, with human capital playing a crucial role in this process. Human capital, measured by average years of schooling, gross tertiary enrollment ratio, and HCI, are important factors that significantly increase income convergence.

Implications: ASEAN-8 governments need to establish policies that enhance human capital, particularly in education, by increasing educational attainment and the rate of return to education.

Keywords:
income convergence; ASEAN-8; human capital, per capita GDP

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INTRODUCTION

Convergence is a significant issue in the analysis of economic growth, both conceptually and empirically. This discussion is crucial in Southeast Asia, considering the region's economy ranks third in Asia and fifth in the world in 2022. Convergence describes how fast the economies of developing countries, which generally have lower per capita incomes, tend to experience faster economic growth rates and catch up with developed nations (Romer, 2019). This phenomenon is known as β-convergence, which can be classified into absolute β-convergence and conditional β-convergence (Romer, 2019). Absolute β-convergence occurs when economies with lower initial per capita incomes consistently grow faster than their developed counterparts, regardless of other economic characteristics. Meanwhile, conditional β-convergence occurs when economies with lower initial per capita incomes achieve higher per capita incomes after accounting for factors that influence steady-state conditions.

On one hand, several studies provide evidence supporting income convergence across regions. Otsuka and Goto (2016) found total factor productivity convergence at the regional level in Japan. Johnson and Papageorgiou (2020) observed declining income inequality in developing countries due to improved governance and institutions. Meanwhile, Chambers and Dhongde (2016) reported reduced income disparity in developed and developing nations, with initially high levels of inequality reported. Enflo and Rosés (2015) also examined income convergence in Sweden from 1860 to 2000, attributing it to market expansion, migration, labor reallocation, and knowledge-intensive industries. In Southeast Asia, Eum and Maliphol (2023) found that a similar export structure between Southeast and Northeast Asia was positively associated with economic catch-up, leading to significant economic growth and reduced income inequality. Their findings contrast with earlier studies emphasizing trade liberalization, suggesting export diversification as a key driver of convergence.

On the other hand, previous studies present differing results that do not support income convergence. Kant (2019) found no convergence potential for sub-Saharan Africa, while South Asian countries exhibited some potential but would require 865 years at an annual rate of 0.3% to reach U.S. income levels. Haider et al. (2019) found no absolute income convergence among Asian nations, though conditional convergence was evident in East and South Asia, driven by investment-to-GDP ratio, openness, and inflation. Furuoka et al. (2018) found income convergence only between Malaysia and Indonesia, but 60% of country pairs demonstrated no convergence. They suggested that science, technology, and innovation infrastructure are more crucial for reducing income gaps than trade liberalization.

While earlier studies have investigated income convergence, many have overlooked the role of human capital in this process. There are limited studies on income convergence in ASEAN countries, particularly concerning the important role of human capital in education and its influence on income convergence. Previous research on convergence issues has focused more on developed countries such as the United States (Alexiadis et al., 2021; Ganong & Shoag, 2017), Japan (Fukuda & Okumura, 2020; Otsuka & Goto,

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2016), and Sweden (Eliasson et al., 2021). Within the framework of endogenous growth theory, human capital accumulation is a vital driver of economic growth. Human capital, alongside physical capital, can accelerate income convergence and promote technological innovation through investments in education, labor skills, and science (Carillo, 2024; Zhang & Wang, 2021; Marelli et al., 2019; Abdulla, 2021). Empirical evidence indicates that human capital significantly impacts income convergence. Otsuka et al. (2017) highlighted the influence of education and technological imitation. Lee (2020) identified a high working-age population and strong legal institutions as key factors supporting convergence through human capital strengthening.

Further studies reinforce this argument by demonstrating the positive correlation between human capital and convergence. Alataş (2023) found that human capital, measured by secondary school enrollment rates multiplied by the percentage share of the school-age population, significantly improves income convergence across 72 countries. Similarly, Zhang and Wang (2021) showed that human capital, measured through average years of schooling, the percentage of the workforce with upper secondary education or higher, and a lifetime income approach based on the Jorgensen and Muller framework, accelerates economic convergence and the level of human capital determines the speed of convergence.

Marelli et al. (2019) emphasized that R&D investment and human capital positively contribute to income convergence, although variations exist across different economic regions. Additionally, human capital, measured by the student-teacher ratio and school enrollment rate, accelerates income convergence (Ibrahim, 2018). In contrast, India struggles to catch up to the Asian Tigers (South Korea, Taiwan, Singapore, and Hong Kong) due to the disparity in human capital, measured by average years of schooling, among its states (Arora & Ratnasiri, 2015). These findings suggest that while other economic factors remain important, education and skill development investments are critical for reducing income disparities and promoting long-term convergence.

The average years of schooling have been used as a proxy for human capital by Zhang and Wang (2021), Zhang et al. (2023), and Teixeira and Queirós (2016). Other studies employ the gross enrollment ratio for secondary school (Ibrahim, 2018; Marelli et al., 2019; Alataş, 2023) and the percentage of the workforce with upper secondary education or higher (Zhang & Wang, 2021) as a proxy for human capital. Meanwhile, some only use the human capital index (Ghatak, 2021) or human capital stock (Arora & Ratnasiri, 2015), which comprises average years of schooling and the Mincerian marginal rate of return to education. Many studies examining the impact of human capital on income convergence rely on a single indicator. However, this approach may limit the ability to identify human capital's consistent influence on promoting convergence, particularly in education.

This study, therefore, contributes to the issue of income convergence from several perspectives. First, unlike previous studies that typically examine these indicators separately, this study compares three indicators of human capital: (1) average years of schooling, (2) gross enrollment ratio, and (3) the Human Capital Index (HCI), a composite index

comprising average years of schooling and the rate of return to education. This comparison will provide a more comprehensive analysis and deeper understanding of human capital dynamics in ASEAN economic convergence. Second, this study breaks down the gross enrollment ratio into three levels: primary, secondary, and tertiary education. While gross enrollment ratios for secondary school alone have been used as proxies for human capital (Ibrahim, 2018; Marelli et al., 2019; Alataş, 2023), this measure fails to capture skilled labor, which is typically associated with the completion of upper secondary and tertiary education (Lee & Lee, 2016). Skilled labor can accelerate income convergence and drive technological innovation by leveraging investments in education (Carillo, 2024).

This study aims to fill the gap in the existing literature by providing empirical evidence related to the role of human capital in income convergence. Specifically, it has two objectives: first, to investigate how human capital affects income convergence among the eight ASEAN countries (hereafter referred to as ASEAN-8); second, to explore three educational indicators as proxies of human capital: average years of schooling, gross enrollment ratio, and the Human Capital Index (HCI). Additionally, it employs several estimation methods, including Ordinary Least Squares (OLS), fixed effects (FE), random effects (RE), Difference GMM (Diff-GMM), and System GMM (Sys-GMM), to test hypotheses related to both absolute and conditional β-convergence. The findings may provide important insights to policymakers and practitioners on potential strategies to promote more equitable human capital development. This study focuses on ASEAN-8 countries with an observation period of 1995-2019 using a panel data model.

METHODS

The sample used in this study comprises eight ASEAN countries: Indonesia, Malaysia, Singapore, Thailand, Vietnam, the Philippines, Cambodia, and Brunei Darussalam, covering a 25-year observational period from 1995 to 2019. The data was sourced from the World Development Indicators (WDI) and the Penn World Table (PWT), version 10.01. PWT 10.01 data refers to Feenstra et al. (2015). Data extracted from the WDI includes per capita GDP, FDI inflow, trade openness, inflation, and gross enrollment ratio. Meanwhile, data from PWT 10.01 consists of population data, average years of schooling, and the Human Capital Index (HCI).

Due to limitations in trade openness data throughout the observation period, Laos and Myanmar were excluded from the study. In addition, the data period used only extends up to 2019 as data on average years of schooling and the human capital index from PWT 10.01 (the latest update) are available only until that year. Furthermore, due to missing data issues for the gross enrollment ratio across ASEAN countries, this study employs multiple imputations to address this problem. Unlike conventional methods, multiple imputation provides consistent, asymptotically normal, and nearly efficient estimates. It can be applied to various data types and models and can be performed using standard statistical software (Zhu, 2014). We assume that the gross enrollment

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ratio for each level of education (primary, secondary, and tertiary) follows a logistic trend (Lee & Lee, 2016). The research variables in this study are presented in Table 1.

This study adopts an augmented Solow growth model that incorporates human capital accumulation. Based on the augmented Solow model, this research employs relevant variables referenced in previous research (Zhang et al., 2023; Zhang & Wang, 2021; Nayak & Sahoo, 2022; Nam & Ryu, 2024; Zia & Mahmood, 2019; Haider et al., 2019; Lim & McAleer, 2004) to investigate absolute β-convergence and conditional β-convergence in ASEAN-8 countries, adding human capital variables related to education, proxied by average years of schooling, gross enrollment ratio, and the Human Capital Index (HCI). The models utilize the average per capita GDP growth rate as the dependent variable and initial per capita GDP as an explanatory variable to assess income convergence. The data processing follows Alataş (2023) using a five-year interval of data samples from 1995-2019 for panel data β-convergence analysis, resulting in five data points for each country. This approach helps to eliminate the influence of business cycle fluctuations and reduce serial correlation due to the nature of the data..

Table 1. Research Variables

Variables	Measurements	Data sources	References
Dependent Variable			
Economic Growth	Average per capita GDP growth rate (Constant 2015 USD)	WDI	Zhang et al. (2023), Zhang & Wang (2021)
Independent/Explanatory Variables			
Initial per capita GDP	Initial per capita GDP at the beginning of each interval of each country	WDI	Zhang & Wang (2021)
Average years of schooling	The average educational attainment among the population aged 15 and above, is expressed as the mean number of years of education received.	PWT 10.01	Zhang & Wang (2021)
Gross enrollment ratio	The proportion of all enrolled students, irrespective of age, compared to the population of the age group that officially corresponds to the level of education shown (primary, secondary, and tertiary education)	WDI	Ibrahim (2018)
Human Capital Index (HCI)	A composite human capital index constructed using average years of schooling and the Mincerian rate of return to education	PWT 10.01	Zhang et al. (2023)
Control Variables			
Foreign Direct Investment (FDI) Inflow	Net FDI inflows as a percentage of GDP	WDI	Nayak & Sahoo (2022), Zia & Mahmood (2019)
Trade openness	Value of goods and services exported and imported as a percentage of GDP	WDI	Nam & Ryu, (2024), Zhang et al. (2023)
Inflation	GDP deflator (annual %)	WDI	Haque et al. (2022)
Population growth	Annual population growth rate (%)	PWT 10.01	Zhang & Wang (2021)

The absolute β-convergence and conditional β-convergence are tested using the following equation, based on the study by Gathak (2021) and Gugler Vanoli (2017):

$$\frac{1}{T} log \left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha_1 + \beta_1 log(y_{i,0}) + \nu_{i,T} \quad (1)$$

where T denotes the duration of the time interval, which is 5 years in this study; $y_{i,T}$ represents the per capita GDP in country i at time T (end of the interval); $y_{i,0}$ denotes the initial per capita GDP at the beginning of each interval; and $\nu_{i,T}$ is the error term. If the estimated coefficient β_1 is negative and significant, it indicates absolute β-convergence. However, if $\beta_1 \geq 0$, it indicates non-convergence or divergence.

To test conditional β-convergence, we used the following equation to see the impact of human capital on income convergence:

$$\frac{1}{T} log \left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha_2 + \beta_2 log(y_{i,0}) + \pi' X_{i,T} + \vartheta_{i,T} \quad (2)$$

$$\frac{1}{T} log \left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha_3 + \beta_3 log(y_{i,0}) + \beta_4 h_{i,T} + \gamma' X_{i,T} + \varepsilon_{i,T} \quad (3)$$

where T denotes the duration of the time interval, which is 5 years in this study; $y_{i,T}$ represents the per capita GDP in country i at time T (end of the interval); $y_{i,0}$ denotes the initial per capita GDP at the beginning of each interval; $h_{i,T}$ denotes the human capital proxied by average years of schooling, gross enrollment ratio (primary, secondary, and tertiary education), and the Human Capital Index (HCI); $X_{i,T}$ is a set of control variables consist of foreign direct investment (FDI) inflows, trade openness, inflation, and population growth; $\vartheta_{i,T}$ and $\varepsilon_{i,T}$ is the error term. If the estimated coefficient β_2 and β_3 is negative and significant, it indicates conditional β-convergence. However, if β_2 and $\beta_3 \geq 0$, it indicates non-convergence or divergence. Equation (2) represents the baseline model without human capital, while equation (3) incorporates the human capital indicators.

We employ various estimation methods commonly used in studies on economic growth, human capital, and economic growth convergence, including OLS (Zhang & Wang, 2021; Arčabić et al., 2021), FE (Sharma & Sharma, 2022), RE (Haque et al., 2022), Difference GMM (Haque et al., 2022), and System GMM (Marelli et al., 2019; Zia & Mahmood, 2019; Arčabić et al., 2021; Magazzino et al., 2022). Our study focuses on the panel data regression method, combining cross-sectional and time-series data.

RESULTS AND DISCUSSION

As shown in Table 2, the average per capita GDP growth rate in the ASEAN-8 countries is 2.2%. The population of the ASEAN-8 countries has an average of 7.70 years of schooling, with the lowest and highest average years of schooling being 3.06 and 14.50 years, respectively. Among the ASEAN-8 countries, Cambodia has the lowest average years of schooling, while Singapore has the highest. Primary education exhibits the highest participation rates, while secondary education shows moderate participation with significant disparities across the ASEAN countries. Tertiary education has the lowest enrollment rates. The average HCI in the ASEAN-8 countries is 2.47, highlighting the need to improve overall education quality, including both attainment and participation,

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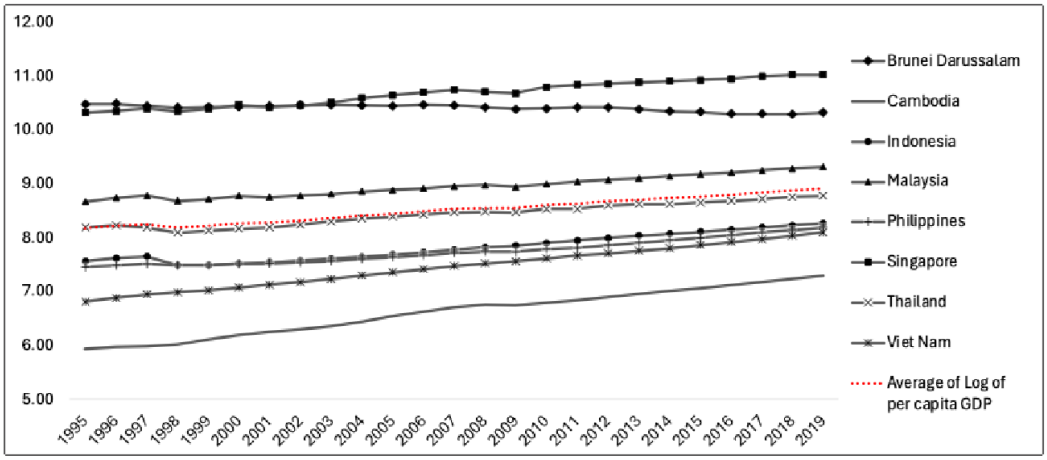
which are crucial for long-term economic growth. A statistical summary of the variables used in this research is presented in Table 2.

Figure 1 illustrates the trend in the logarithm of per capita GDP for the ASEAN-8 countries from 1995 to 2019. Most ASEAN-8 countries experienced an upward trend in per capita GDP during this period, eventually approaching the average of all ASEAN-8 countries except Singapore. The gap in per capita GDP among ASEAN-8 countries narrowed during this period. Hembram et al. (2019) found empirical evidence supporting the hypothesis that economies with similar initial per capita income and structural characteristics will converge in per capita income in the long run. Compared to other ASEAN nations, Cambodia and Thailand, which started with relatively low per capita GDP, tend to exhibit higher growth rates. This data indicates that the initial income level and subsequent per capita GDP growth rates determine a country's speed in catching up with more developed countries or those with higher per capita GDP.

Table 2. Statistic Summary

Variable	Obs.	Mean	Std. Dev.	Min	Max
Average per capita GDP growth rate	40	0.022	0.018	-0.01	0.05
Initial per capita GDP	40	8.452	1.405	5.94	10.93
Average years of schooling	40	7.696	2.184	3.06	14.50
Gross enrollment ratio					
- Primary education	40	105.545	9.110	91.01	136.53
- Secondary education	40	76.114	21.364	25.09	115.82
- Tertiary education	40	29.300	17.789	2.70	85.93
Human Capital Index (HCI)	40	2.472	0.465	1.51	3.99
FDI Inflow	40	5.792	5.895	-0.81	24.48
Trade openness	40	140.458	92.495	39.88	407.12
Inflation	40	5.039	4.976	-3.19	24.11
Population growth	40	1.564	0.682	0.34	3.53

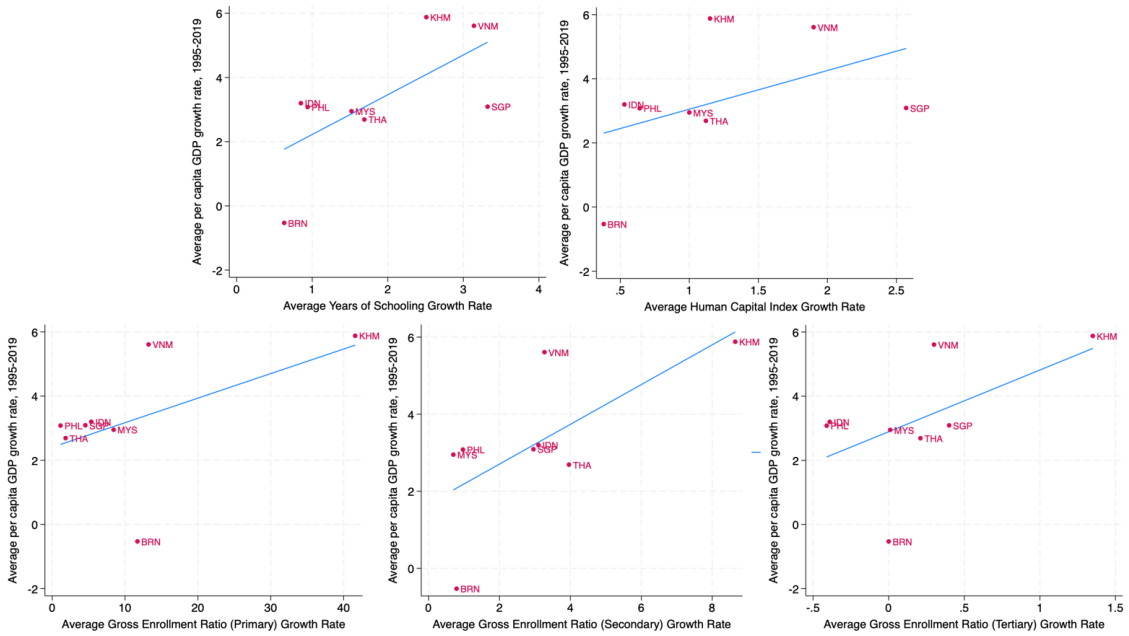
Figure 1. Trend of log of per capita GDP, 1995 – 2019



To verify that initial per capita GDP levels determine a country's speed of convergence towards catching up with developed countries, an Ordinary Least Squares

(OLS) regression was employed to test for absolute β-convergence. Employing a dummy variable (coded 1 for countries with below-average initial per capita GDP and 0 otherwise), the estimation results reveal a significant negative coefficient of -0.01 on the initial per capita GDP for countries below the average. This finding shows that countries with lower initial per capita GDP (such as Indonesia, Thailand, the Philippines, Cambodia, and Vietnam) exhibit higher rates of income convergence compared to those with above-average initial per capita GDP (such as Singapore, Brunei Darussalam, and Malaysia). It means, in terms of per capita income, ASEAN-8 countries with lower initial per capita GDP have successfully caught up with the developed countries.

Figure 2. Scatter plot between the human capital indicator and average per capita GDP growth rate



The scatter plots in Figure 2 illustrate the relationship between human capital indicators and average per capita GDP growth across the ASEAN-8 countries from 1995 to 2019. In general, the graphs suggest a positive association between human capital development and economic growth, although the strength of the relationship varies across indicators. Years of schooling and the human capital index correlate moderately positively with GDP per capita growth. This data suggests that countries with higher education attainment, as measured by average years of schooling, tend to experience greater economic growth (Breton, 2015). In examining gross enrollment ratios at different educational levels, primary education shows a weak relationship with economic growth, indicating that primary education is necessary but not sufficient for sustained growth. Meanwhile, secondary and tertiary enrollment ratios correlate positively with GDP per capita growth. This result implies that advancements in higher levels of education are more strongly associated with higher economic growth in the region (Carillo, 2024).

The empirical results of the absolute and conditional β-convergence analysis for the ASEAN-8 countries from 1995 to 2019 are presented in Tables 3 and 4. These tables

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display the empirical findings for five-year sub-periods, comparing the OLS, RE, FE, Diff-GMM, and Sys-GMM estimators. Based on the estimation results in Table 3, absolute β-convergence exists in the ASEAN-8 countries. All models exhibit consistent and significant coefficient signs except for the Diff-GMM model. The analysis reveals a negative relationship between initial per capita GDP and the average per capita GDP growth rate, indicating that ASEAN-8 countries experienced faster growth during 1995-2019.

These findings support the hypothesis of absolute β-convergence in the ASEAN-8 countries. The Breusch-Pagan LM and Hausman tests in the static panel model indicate that the best estimation method is fixed effect (FE). However, the FE approach cannot be applied because the data used in the analysis, specifically the initial per capita GDP, is constant over time and time-invariant. Therefore, the System GMM (Sys-GMM) method is more appropriate for interpreting the estimation results in Table 3. This method is chosen because it can address endogeneity issues arising from omitted variables and simultaneity (Bond et al., 2001). Moreover, Sys-GMM is preferred due to its greater consistency and efficiency than other models (Roodman, 2009).

Table 3. Absolute β-Convergence in ASEAN-8: A Comparison of Estimation Models with 5-Year Sub-Periods

Dependent Variable: Average per capita GDP growth rate

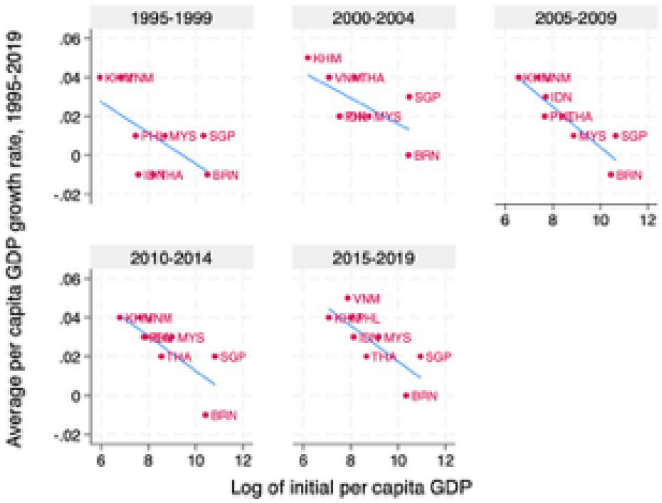
Variables	Static Panel			Dynamic Panel	
	OLS	FE	RE	Diff-GMM	Sys-GMM
	(1)	(2)	(3)	(4)	(5)
Average per capita GDP growth rate (lag)				-0.1557 (0.2062)	0.1155 (0.4350)
Initial per capita GDP	-0.0078*** (0.0015)	-0.0118* (0.0074)	-0.0059** (0.0030)	0.0082 (0.0135)	-0.0079** (0.0032)
Observations	40	40	40	24	32
R-squared	0.3830	0.0896	0.3830		
Breusch-Pagan LM test		*p-value* = 0.0186			
Hausman test		*p-value* = 0.0098			
AR(1)				0.885	0.603
AR(2)				0.387	0.637
Hansen test				0.289	0.546

Robust standard errors in parentheses
Statistically significant at ***1%, **5%, *10%

The estimation results in Column 5 of Table 3, using the Sys-GMM estimator, indicate the presence of absolute β-convergence among ASEAN-8 countries. The negative coefficient of the initial per capita GDP variable denotes that a 1% increase in initial per capita GDP leads to a decrease in the average per capita GDP growth rate by 0.0079%. This estimation further corroborates this Figure 3, which shows evidence of absolute β-convergence in ASEAN-8 countries across five-year sub-periods. The negative slope indicates that the higher a country's initial per capita GDP, the lower its average per capita GDP growth rate. Cambodia and Vietnam, with lower initial per capita GDP, have higher average per capita GDP growth rates compared to Singapore and Brunei Darussalam. These findings are supported by Sharma and Sharma (2022) and Nayak and Sahoo (2022). Sharma and

Sharma (2022) also found absolute β-convergence among developing countries converging towards the same steady state. Furthermore, Nayak and Sahoo (2022) showed that regions in India with lower initial per capita income grow faster than regions with higher initial per capita income, providing evidence of absolute β-convergence.

Figure 3 Absolute β-Convergence of ASEAN-8 for 5-year periods, 1995-2019



After controlling for FDI inflows, population growth, trade openness, and inflation, the estimation results using OLS, RE, and Sys-GMM provide strong evidence of conditional β-convergence (Table 4). While most models show consistent results, some variables are statistically insignificant. Inflation exhibits a statistically significant relationship and consistently correct sign across nearly all estimated models. In the static panel models, the coefficients of most variables using OLS and RE estimations show consistent and significant signs. According to the Breusch-Pagan LM and Hausman tests, the best estimation method is OLS.

According to OLS estimates, there is an increase in income convergence of 0.003 percentage points after incorporating the human capital factor, both with the indicator of average years of schooling and HCI. This finding is supported by evidence showing that an increase in average years of schooling by 1 year will increase the average per capita GDP growth rate by 0.003%. Meanwhile, a 1-point increase in the HCI is associated with a 0.01% increase in the average per capita GDP growth rate, indicating a greater impact than average years of schooling. In contrast, although including gross enrollment ratios at the primary, secondary, and tertiary levels has increased income convergence across countries, these variables did not significantly affect average GDP per capita growth. However, while not directly impacting growth rates, gross enrollment ratios play a crucial role in reducing income disparities. In the dynamic panel model, only the Sys-GMM estimator demonstrates superior results compared to the Diff-GMM estimator. Most variables in the Diff-GMM model are statistically insignificant. The AR(1) and AR(2) tests and the Hansen test confirm the absence of first-order and second-order serial correlation, indicating that the instrumental variables used in the model are valid. Based on Sys-GMM estimations, incorporating average years of schooling, gross enrollment ratio, and HCI as proxies for educational

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human capital significantly accelerates income convergence in ASEAN-8 countries, shown by the increasingly negative coefficient on the initial per capita GDP. When using average years of schooling as a proxy of human capital, income convergence increased by 0.013 percentage points, from -0.0106 to -0.0237. This finding aligns with the Augmented Solow model and the endogenous growth theory, which emphasize the role of education in human capital as a crucial factor in accelerating convergence.

Zhang and Wang (2021) investigate the diverse impacts of human capital, measured by average years of schooling, on economic development between developed and developing regions in China. Average years of schooling have the most significant impact on convergence at the early stages of economic development, but as regional development advances, its influence decreases. Furthermore, Zhang et al. (2023) found that cognitive human capital production, reflected by average years of schooling, positively impacted income convergence. Similarly, Teixeira and Queirós (2016) emphasized that countries with a higher average year of schooling tend to grow faster than others as a proxy of human capital stock. Breton (2015) also found that when average schooling attainment increases per year, the GDP of Japan rises by 20%.

In Columns 27 and 28, the gross enrollment ratios for primary and secondary education do not exhibit significant coefficients, indicating that increased participation at these levels does not directly impact GDP per capita growth. This finding aligns with Carillo (2024), who found that individuals with lower education may hinder technology adoption and postpone the shift from stagnation to growth. In contrast, Cardoso and Ravishankar (2015) showed that secondary education, as a proxy for human capital, positively contributes to income convergence. However, the gross enrollment ratio for tertiary education exhibits a positive and significant coefficient, indicating that increased access to higher education promotes an average per capita GDP growth rate. It can boost long-term economic growth and enhance workforce skills and innovation in the long run.

Moreover, including the gross tertiary enrollment ratio increases the rate of income convergence by 0.013 percentage points, as shown by the negative and significant coefficient of initial GDP per capita. Expanding tertiary education can accelerate income convergence by boosting human capital, productivity, and technology adoption in lower-income countries. Carillo (2024) further emphasizes that individuals with higher education tend to be the ones who drive technological innovation. Similarly, Muhamad et al. (2018) found a positive effect of tertiary enrollment on economic growth in the long term.

Based on the results in Column 30, income convergence increased by 0.014 percentage points, from -0.0106 to -0.0244, when using the HCI variable as a proxy for human capital. This result indicates that HCI has a greater impact on accelerating income convergence than the average years of schooling and gross tertiary enrollment ratio. HCI provides a more comprehensive measure of human capital based on average years of schooling (educational attainment) and rate of return to education. In contrast, the other two indicators only capture educational attainment. Using a similar human capital index comprised of years of schooling and returns to education, Ghatak (2021) showed that human capital, measured by the human capital index, plays an important role in convergence by reducing regional disparities.

Table 4. Conditional β-Convergence in ASEAN-8: A Comparison of the Basic and Augmented Solow Models with 5-Year Sub-Periods

Dependent Variable: Average per capita GDP growth rate

Variables	Static Panel											
	OLS						FE					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Average per capita GDP growth rate (lag)												
Initial per capita GDP	-0.0124*** (0.0011)	-0.0153*** (0.0021)	-0.0122*** (0.0016)	-0.0142*** (0.0023)	-0.0126*** (0.0012)	-0.0153*** (0.0021)	-0.0026 (0.0074)	-0.0014 (0.0122)	-0.0021 (0.0076)	-0.0040 (0.0098)	-0.0028 (0.0150)	-0.0015 (0.0119)
FDI Inflow	0.0004* (0.0002)	0.0005 (0.0003)	0.0004 (0.0003)	0.0006** (0.0003)	0.0004* (0.0002)	0.0005 (0.0003)	-0.0004 (0.0004)	-0.0004 (0.0004)	-0.0004 (0.0004)	-0.0004 (0.0004)	-0.0004 (0.0003)	-0.0004 (0.0004)
Population growth	-0.0073*** (0.0020)	-0.0055** (0.0026)	-0.0074*** (0.0019)	-0.0060** (0.0025)	-0.0068*** (0.0021)	-0.0056** (0.0026)	-0.0060 (0.0035)	-0.0052 (0.0036)	-0.0065 (0.0038)	-0.0061 (0.0035)	-0.0055 (0.0034)	-0.0052 (0.0037)
Trade openness	0.0001*** (0.0000)	0.0001*** (0.0000)	0.0001*** (0.0000)	0.0001*** (0.0001)	0.0001*** (0.0000)	0.0001*** (0.0000)	0.0000 (0.0001)	0.0000 (0.0001)	0.0000 (0.0001)	0.0000 (0.0001)	0.0000 (0.0001)	0.0000 (0.0001)
Inflation	-0.0010* (0.0005)	-0.0009* (0.0005)	-0.0010* (0.0006)	-0.0009* (0.0005)	-0.0009 (0.0006)	-0.0010* (0.0005)	-0.0013** (0,0005)	-0.0014** (0.0006)	-0.0013** (0.0005)	-0.0014** (0.0005)	-0.0013** (0.0005)	-0.0014** (0.0006)
Average years of schooling		0.0025* (0.0013)						0.0013 (0.0021)				
Gross enrolment ratio												
- Primary education			0.0001 (0.0003)						-0.0001 (0.0001)			
- Secondary education				0.0002 (0.0001)						-0.0000 (0.0001)		
- Tertiary education					0.0001 (0.0001)						0.0003 (0.0004)	
HCI						0.0116* (0.0064)						0.0065 (0.0100)
Observations	40	40	40	40	40	40	40	40	40	40	40	40
R-squared	0.6736	0.7060	0.6741	0.6898	0.6753	0.7051	0.4117	0.4190	0.4159	0.4132	0.4295	0.4204
Breusch-Pagan LM test	*p-value = 0.2777* (Model without human capital) *p-value = 0.4131* (Model with human capital: average years of schooling indicator)						*p-value = 0.2878* (Model with human capital: gross enrolment ratio – primary) *p-value = 0.4117* (Model with human capital: gross enrolment ratio – secondary)					
Hausman test	*p-value = 0.0669* (Model without human capital) *p-value = 0.3614* (Model with human capital: average years of schooling indicator)						*p-value = 0.1384* (Model with human capital: gross enrolment ratio – primary) *p-value = 0.2568* (Model with human capital: gross enrolment ratio – secondary)					
AR(1)												
AR(2)												
Hansen test												

Robust standard errors are in parentheses. Statistically significant at ***1%, **5%, *10

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Table 4 Conditional β-Convergence in ASEAN-8: A Comparison of the Basic and Augmented Solow Models with 5-Year Sub-Periods (continued)

Dependent Variable: Average per capita GDP growth rate

Variables	Static Panel						Dynamic Panel					
	RE						Diff-GMM					
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Average per capita GDP growth rate (lag)							**-0.2478**	**-0.3010**	**-0.2327**	**-0.2481**	**-0.2116**	**-0.3042**
							(0.2021)	**(0.2558)**	**(0.2284)**	**(0.2077)**	**(0.2084)**	**(0.2426)**
Initial per capita GDP	-0.0122***	-0.0151***	-0.0120***	-0.0134***	-0.0127***	-0.0150***	0.0045	0.0166	0.0038	0.0119	0.0104	0.0165
	(0.0009)	(0.0023)	(0.0012)	(0.0018)	(0.0010)	(0.0023)	(0.0174)	(0.0185)	(0.0170)	(0.0172)	(0.0119)	(0.0162)
FDI Inflow	0.0004*	0.0003	0.0004**	0.0005**	0.0003	0.0003	-0.0003	0.0003	-0.0004	0.0000	0.0005	0.0004
	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0008)	(0.0028)	(0.0016)	(0.0016)	(0.0019)	(0.0029)
Population growth	-0.0079***	-0.0062**	-0.0082***	-0.0075***	-0.0072***	-0.0063**	-0.0040	-0.0036	-0.0034	-0.0035	-0.0020	-0.0035
	(0.0027)	(0.0027)	(0.0026)	(0.0024)	(0.0026)	(0.0027)	(0.0031)	(0.0045)	(0.0044)	(0.0040)	(0.0043)	(0.0045)
Trade openness	0.0001***	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	-0.0000	-0.0001	-0.0001	-0.0000	-0.0001	-0.0001
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Inflation	-0.0011**	-0.0013**	-0.0012**	-0.0012**	-0.0012**	-0.0013**	-0.0006***	-0.0007**	-0.0006***	-0.0006***	-0.0006***	-0.0007**
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0001)	(0.0004)	(0.0002)	(0.0002)	(0.0002)	(0.0003)
Average years of schooling		0.0025*						-0.0025				
		(0.0015)						(0.0058)				
Gross enrolment ratio												
- Primary education			0.0000						-0.0002			
			(0.0002)						(0.0003)			
- Secondary education				0.0001						-0.0002		
				(0.0001)						(0.0002)		
- Tertiary education					0.0001						-0.0003	
					(0.0001)						(0.0003)	
HCI						0.0116						-0.0109
						(0.0072)						(0.0244)
Observations	40	40	40	40	40	40	24	24	24	24	24	24
R-squared	0,6712	0.6958	0.6677	0.6790	0.6645	0.6947						
Breusch-Pagan LM test	*p-value = 0.2300* (Model with human capital: gross enrolment ratio – tertiary) *p-value = 0.4037* (Model with human capital - HCI indicator)											
Hausman test	*p-value = 0.1595* (Model with human capital: gross enrolment ratio – tertiary) *p-value = 0.3538* (Model with human capital - HCI indicator)											
AR(1)							0.743	0.611	0.809	0.825	0.735	0.596
AR(2)							0.453	0.446	0.425	0.263	0.427	0.430
Hansen test							0.282	0.121	0.242	0.330	0.371	0.118

Robust standard errors are in parentheses. Statistically significant at ***1%, **5%, *10

Table 4 Conditional β-Convergence in ASEAN-8: A Comparison of the Basic and Augmented Solow Models with 5-Year Sub-Periods (continued)

Dependent Variable: Average per capita GDP growth rate

Variables	Dynamic Panel					
	Sys-GMM					
	(25)	(26)	(27)	(28)	(29)	(30)
Average per capita GDP growth rate (lag)	0.0366 (0.3454)	-0.7757 (0.5715)	-1.5733 (1.3944)	-0.7119 (0.5464)	-0.9935 (0.7591)	-0.8420 (0.5958)
Initial per capita GDP	-0.0106** (0.0048)	-0.0237*** (0.0077)	-0.0270** (0.0132)	-0.0217*** (0.0081)	-0.0238** (0.0093)	-0.0244*** (0.0081)
FDI Inflow	0.0006 (0.0010)	0.0012* (0.0007)	0.0020 (0.0014)	0.0015* (0.0009)	0.0014 (0.0009)	0.0012* (0.0007)
Population growth	-0.0060 (0.0037)	-0,0043* (0.0024)	-0.0068** (0.0031)	-0.0048** (0.0021)	-0.0043* (0.0026)	-0.0042* (0.0024)
Trade openness	0.00004 (0.0000)	0.0001* (0.0001)	0.0001 (0.0001)	0.0001 (0.0000)	0.0001 (0.0000)	0.0001* (0.0001)
Inflation	-0.0006* (0.0003)	-0.0005** (0.0002)	-0.0003 (0.0002)	-0.0005*** (0.0002)	-0.0003 (0.0002)	-0.0005** (0.0002)
Average years of schooling		0.0032** (0.0016)				
Gross enrollment ratio - Primary education			0.0002 (0.0004)			
- Secondary education				0.0002 (0.0002)		
- Tertiary education					0.0003* (0.0002)	
HCI						0.0149* (0.0077)
Observations	32	32	32	32	32	32
R-squared						
Breusch-Pagan LM test						
Hausman test						
AR(1)	0.850	0.433	0.242	0.387	0.725	0.479
AR(2)	0.633	0.189	0.107	0.595	0.154	0.118
Hansen test	0.505	1.000	1.000	1.000	1.000	1.000

Robust standard errors are in parentheses. Statistically significant at ***1%, **5%, *10

Furthermore, Zhang et al. (2023) found that a human capital quality index contributes to faster economic growth convergence. In contrast, Sharma and Sharma (2022) show different results, indicating the absence of conditional convergence in some developing countries. Sharma and Sharma (2022) also showed that human capital, measured by the education index, does not significantly affect the growth process.

The process of income convergence is linked to efforts to achieve equitable income distribution and reduce income inequality. Enhancing the quality of human capital through education is crucial in accelerating convergence and reducing income inequality. Munir and Kanwal (2020) summarize their research findings in five key points: (1)

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Inequality in education and average years of schooling increase income inequality; (2) Primary and tertiary education significantly reduce income inequality, whereas secondary education tends to increase it; (3) Educational inequality is inversely correlated with per capita income; (4) Gender inequality in secondary and tertiary education reduces per capita income; (5) Unequal access to education between boys and girls heightens educational inequality and reduces per capita income at the secondary and tertiary education levels. However, Luo and Hu (2024) found that the relationship between human capital and income inequality between urban and rural areas follows a U-shaped pattern due to disparities in the quality and scale of higher education. Therefore, improving access to education, primarily secondary and tertiary education, for underprivileged populations is crucial in reducing the negative impacts of unequal educational quality. In addition, increasing the number of public schools can assist governments in reducing income inequality (Arčabić et al., 2021).

When considering other control variables, including average years of schooling and HCI, have led to the significance of FDI inflow, population growth, and trade openness in the Sys-GMM estimation. Conversely, incorporating the gross tertiary enrollment ratio led only to the significance of population growth but caused insignificant inflation. Population growth consistently exerts negative effects on per capita income growth. Implying that higher population growth can lead to slower per capita GDP growth. A 1% increase in population growth can reduce the average per capita GDP growth rate by 0.004%.

On the other hand, FDI inflows, as a proxy for investment levels, show a positive and significant coefficient in the model (Columns 26, 28, and 30). This result indicates that net FDI inflows, as a percentage of GDP, positively affect the average per capita GDP growth rate. These findings support the Solow growth theory, showing a positive relationship between per capita income growth and investment levels. Nayak and Sahoo (2022) and Das (2019) also support these findings. Nayak and Sahoo (2022) found that FDI inflows can increase growth in all regions of India. Meanwhile, Das (2019) found evidence of conditional convergence in BRICS countries where FDI inflows can increase the average per capita GDP growth rate.

Furthermore, trade openness also positively impacts the average per capita GDP growth rate (Columns 26 and 30). An increase in the volume of exports and imports can significantly increase economic growth, especially in developing countries within the ASEAN region (Nam & Ryu, 2024). This result is consistent with the ASEAN member states' actions in 1992 to create the ASEAN Free Trade Area (AFTA). AFTA was established by six countries: Thailand, Malaysia, Indonesia, the Philippines, Singapore, and Brunei Darussalam. AFTA was formed to reduce development disparities and enhance trade integration among less-developed ASEAN countries. ASEAN countries can stimulate economic growth and promote income convergence by enhancing trade openness and attracting foreign direct investment.

Our results confirm the Augmented Solow model, which provides more substantial evidence of convergence in countries with varying levels of human capital. Human

capital accumulation is included as an additional explanatory variable in the cross-country regressions of the Augmented Solow model. Furthermore, our findings align with the Augmented Solow model, showing that per capita income growth is a positive function of human capital (average years of schooling, gross enrollment ratio, and HCI) and investment in physical capital (FDI) and a negative function of initial per capita income (GDP) and population growth. These findings are also supported by Kostakis and Theodoropoulou (2017) that show the significant role of human capital in accelerating a country's convergence;). According to Kostakis and Theodoropoulou (2017), conditional convergence is shown by human capital's positive and significant impact on economic growth.

ASEAN-8 countries, characterized by similar structural and economic features, except for Singapore, should prioritize enhancing human capital through education and promoting the equalization of human capital quality to optimize income convergence within the region. This is crucial to avoid the 'low-level equilibrium trap' arising from low investment in human capital. Hembram et al. (2019) prove the 'low-level equilibrium trap' hypothesis, showing that regions with similar structural characteristics (low human capital investment) and low initial income tend to remain grouped at a lower income level over time. The same applies to regions with high income.

CONCLUSION

The findings of this study confirm that human capital, measured by average years of schooling, the gross tertiary enrollment ratio, and the Human Capital Index (HCI), significantly accelerates income convergence among ASEAN-8 countries. Absolute and conditional β-convergence indicates that poorer ASEAN-8 nations are catching up with richer ones, with human capital playing a crucial role in this process. These results align with the Augmented Solow model and are robust across OLS, RE, and Sys-GMM estimation techniques, particularly Sys-GMM, which provides consistent and significant findings. Across all models based on the Sys-GMM estimator, the negative coefficient of initial GDP per capita confirms the presence of convergence. However, the magnitude of this negative coefficient, a key indicator of income convergence, varies across different human capital indicators. The Human Capital Index (HCI) contributes more significantly to the convergence process (-0,0244) compared to average years of schooling (-0,0237) and gross tertiary enrollment ratio (-0,0238).

Based on these empirical findings, ASEAN-8 governments should focus on improving the overall quality of human capital, particularly in education, to enhance income convergence within the ASEAN-8 countries. Expanding access to education, particularly at the tertiary level, will help increase school enrollment and educational attainment. Tertiary education has been shown to play a more significant role in enhancing income convergence than primary and secondary education. Addressing disparities in educational access, particularly for underprivileged populations, can ensure a more equitable distribution of human capital and prevent a low-level equilibrium trap.

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Future research could expand the analysis by incorporating alternative human capital indicators and extended observation periods to obtain more comprehensive results.

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