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The Moderating Effect of Female Labor Force Participation on Economic Growth in ASEAN

Tiya Rana Ammara [1], Sofyan Syahnur [1,*] and Srinita Srinita [1]

[1] Department of Economics, Faculty of Economics and Business, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia; ranatiyaa@gmail.com (T.R.A.); kabari_sofyan@usk.ac.id (S.S.1.); srinita@usk.ac.id (S.S.2.)

* Correspondence: kabari_sofyan@usk.ac.id

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Abstract

Despite ASEAN's rapid economic growth, persistent gender gaps in labor participation remained underexplored as determinants of regional development. This study aimed to analyze the effects of gross fixed capital formation, information and communication technology, human capital, labor, and female labor force participation on economic growth in eight ASEAN countries from 2000 to 2023. The Panel Autoregressive Distributed Lag (ARDL) method was employed. Additionally, this study examined the moderating effect of female labor force participation on labor's contribution to economic growth. The estimation results indicated that, in the long run, gross fixed capital formation positively affected economic growth, while information and communication technology and human capital showed positive and negative effects in different models. Labor had a negative and significant effect in the long run. The moderating effect of female labor force participation strengthened the impact of labor on economic growth. The findings of this study highlighted the importance of policies that enhanced human capital quality, developed workforce skills, increased digital literacy, and empowered women to promote sustainable economic growth in the ASEAN region.

1. Introduction

Economic growth, commonly measured by growth in gross domestic product (GDP), is a central indicator of development, as it is often associated with improvements in living standards, expanded public services, and greater employment opportunities [1, 2]. As a dynamic region, Southeast Asia's GDP grew steadily at an average annual rate of 4.1% from 1980 to 2023 [3], demonstrating resilience through major economic crises. However, growth patterns vary significantly across the region. The more developed ASEAN-5 nations (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) account for 83% of the region's GDP and have benefited from earlier industrialization. In contrast, Cambodia, Laos, Myanmar, and Vietnam have recently emerged as the fastest-growing economies, driven by exports of raw materials, services, and light manufactured goods [4].

The Solow model explains that long-term economic growth is influenced by technological progress and exogenous labor growth, whose values are determined by variables outside the model. Meanwhile, the rate of increase in output and capital accumulation is endogenous, with values determined by variables in the model [5]. Later, Romer [6] introduced the endogenous growth theory and argues that economic growth is driven by investment in knowledge and innovation in the economy, and that long-term growth comes from economic activities that create science and technology.

Endogenous growth theory focuses specifically on internal factors, such as human capital, that can be influenced by economic policies. This makes it possible to sustain long-term growth by strategically investing in education and training [7]. According to these theories, Barro and Sala-i-Martin [8] revealed that economic growth is determined by the accumulation of physical and human capital and labor, with technological progress serving as the main long-term driver.

Gross fixed capital formation is a component of GDP expenditure that reflects physical investment, which strengthens a country's production capacity and serves as an indicator of the level of investment in an economy [9, 10]. In advanced economies, fixed capital investment focuses on physical infrastructure as well as intellectual assets and digital technology. This accelerates the transition to a knowledge-based economy [11, 12]. Meanwhile, in the Association of Southeast Asian Nations (ASEAN), despite the acceleration of infrastructure investment, the transition to higher-quality investments and technology is still in the early stages, so the region's long-term growth potential has not been fully realized. Previous studies suggested that gross fixed capital formation is related to long-term growth [13, 14] and found that it has a positive effect on growth [15–17].

Information and communication technology (ICT) continues to expand and penetrate the world economy. Today, ICT plays an important role in driving globalization and economic growth, as well as facilitating cross-border communication and trade [18]. Nipo et al. [19] found that internet usage increased per capita income in 20 Asian countries. Ahn [20] found that internet usage significantly affected economic growth in the ASEAN-5 countries. Additionally, Suparta et al. [21] reported that internet access negatively impacted economic growth in Java and Sumatra, Indonesia. However, other technology-related variables had positive effects on growth.

Despite being a key focus of development in the region, human capital in ASEAN currently faces significant challenges. Key issues include unequal access to quality education and health problems such as stunting. There is also a lack of training and skills development that meet the needs of the modern labor market. Human capital can be measured by examining activities that improve specific capabilities. Zhang et al. [22] developed an economic model of human capital and analyzed the relationship between labor investment activities and income. Gulcemal [23] and Nogueira and Madaleno [24] found that human capital had a positive effect on growth. Cetinguc et al. [25] found that the Human Development Index (HDI) negatively impacted economic growth in the short term. However, they found that HDI positively impacted environmental sustainability, suggesting that human development fosters ecological awareness and environmentally friendly policies.

Labor is one of the main factors of production and plays a strategic role in driving economic growth, particularly in developing countries like those in the ASEAN region. An abundant labor force has the potential to significantly increase national output. A high labor force can boost production capacity, expand economic sectors, and increase the region's competitiveness in the global market. Jermsittiparsert et al. [26] found that labor had a positive effect on growth, while Kala et al. [27] found that labor had an insignificant effect.

In practice, however, the contribution of labor to economic growth in ASEAN countries has not been optimal. Structural issues, such as the dominance of the informal sector, low productivity, and limited skills, are the main obstacles. According to The ASEAN Secretariat report [28], most ASEAN countries still rely on low-cost, uneducated labor. The dominance of informal sector jobs absorbed more than 50% of the labor force in several countries, including Indonesia, Myanmar, and Cambodia [29].

Goldin [30] explained the U-shaped relationship between women's labor force participation and economic development, influenced by the interaction between economic development, education, social norms, and changes in the structure of work. The income effect causes women to reduce their participation in the workforce because family income can "purchase" their time to stay home or do housework. However, as women become more educated and the office and industrial employment sectors expand, their participation increases. According to this hypothesis, female labor force participation declines with economic growth at low income levels, but above a certain level of growth, the relationship becomes positive [31].

Many studies found a positive correlation between higher female labor force participation and increased economic growth [32, 33]. Cuberes & Teignier [34] suggested that gender inequality in labor force participation could reduce per capita income in a country. Doepke & Tertilt [35] examined the impact of women's empowerment on economic growth, focusing on the effects of providing targeted assistance to women in a development context. They showed that women's empowerment through resource transfers did not necessarily have a positive impact on growth; rather, it depended on the structure of the economy and the extent of the gender gap in the labor market. The social norms of a region also influence women's participation in the labor market. The OECD's

Table 1. Definition of variables.

Status	Variable Name	Symbol	Variable Definition	Units	Data Sources
Dependent	Economic Growth	ECG	The annual GDP growth rate.	Percent	World Bank [36]
Independent	Capital	CAP	Percentage of gross fixed capital formation as a share of total GDP.	Percent	World Bank [36]
	Information and Communication Technology	ICT	The percentage of individuals using the internet out of the total population.	Percent	World Bank [36]
	Human Capital	HDI	Proxied by the Human Development Index (HDI), which is a composite index of life expectancy at birth, expected years of schooling, mean years of schooling, and a decent standard of living.	Scale, from 0 to 1	Asian Development Bank [37]
	Labor	LAB	The proportion of the working-age population that is employed or seeking employment, expressed as a percentage of the total population.	Percent	World Bank [36]
Moderator	Female Labor Force Participation	FLP	The female labor force participation rate is defined as the share of women aged 15–64 who are employed or actively seeking employment.	Percent	World Bank [36]

Social Institutions and Gender Index report [38] revealed that social norms in Southeast Asia restricted gender equality further between 2014 and 2022. Traditional views on gender roles strengthened during this period, including the belief that men should be prioritized for higher education and employment. Although there were improvements in some countries, such as Indonesia and Singapore, discrimination remained high. However, World Bank data [39] showed that women's labor force participation in ASEAN averaged 60%, raising questions about their contribution to the region's economy.

According to Barro and Sala-i-Martin's [8] economic growth theory, gross fixed capital formation, internet penetration (ICT), human capital, and labor are key determinants of economic growth. Consistent with this theory, Kurniawati [40] examined the impact of gross fixed capital formation, ICT, and labor on economic growth in 25 Asian countries using the FMOLS method. However, the study had limitations because it did not include human capital as a determining factor. Building on the theoretical framework of economic growth by Barro and Sala-i-Martin and extending previous research by Kurniawati, this study aims to provide a comprehensive analysis of economic growth determinants in the ASEAN region.

Through three key dimensions, this study first examines the dynamic influence of gross fixed capital formation, internet penetration, human capital, and labor force participation on economic growth, thereby addressing a critical gap in the existing literature by incorporating human capital as a key variable. Second, the study investigates gender dynamics in economic growth by analyzing (1) the direct effect of women's labor force participation in ASEAN's patriarchal context, and (2) its moderating role in enhancing the overall workforce's impact on economic growth. Third, employing advanced econometric techniques, particularly the Autoregressive Distributed Lag (ARDL) model, the study distinguishes between short-term fluctuations and long-term equilibrium effects, thereby offering temporal insights into growth mechanisms. By integrating these approaches, the study not only contributes to the development economics literature but also provides policymakers with evidence-based recommendations for fostering inclusive and sustainable economic growth in ASEAN.

2. Methodology

2.1. Data and Variable

This study investigates the effects of gross fixed capital formation, information and communication technology (ICT), human capital, and labor on economic growth in the Association of Southeast Asian Nations (ASEAN), while also assessing the moderating role of female labor force participation. Due to data availability, the analysis focuses on eight ASEAN member states: Brunei Darussalam, the Philippines, Indonesia, Cambodia, Malaysia, Singapore, Thailand, and Vietnam over the period 2000 to 2023. The variables include gross fixed capital formation (CAP) as a proxy for capital, internet users (ICT) as a proxy for ICT development, the Human Development Index (HDI) as a proxy for human capital, labor force (LAB), female labor force participation (FLP), and economic growth (ECG). A detailed description of these variables is provided in Table 1.

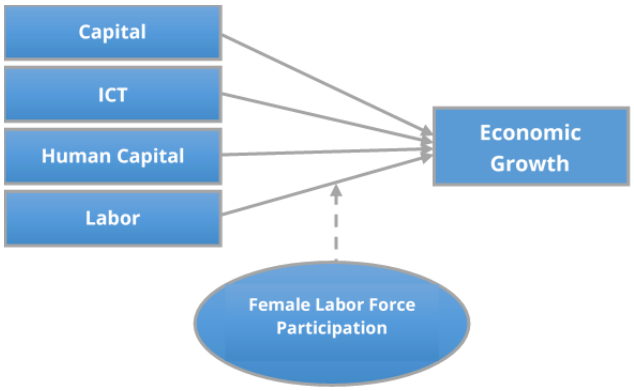

Figure 1. Conceptual framework.

2.2. Conceptual Framework

This study employs the endogenous growth theory framework to model economic growth, incorporating capital, human capital, and labor as key inputs in an augmented Cobb-Douglas production function, as specified in Equation 1.

$$Y = AK^{\alpha}H^{\beta}L^{Y} \quad (1)$$

Here, Y represents output, K represents capital, H represents human capital, and L represents labor. The parameters α, β, and Y denote the output elasticities of capital, human capital, and labor, respectively, while A represents total factor productivity (TFP), which reflects technology and efficiency in the production process.

Building on this foundation, the study introduces female labor force participation (FLP) as a moderating variable to capture the influence of gender dynamics on the relationship between labor inputs and economic output. As illustrated in Figure 1, the inclusion of an interaction term between labor and FLP allows the model to test whether the economic impact of workforce expansion depends on women's participation. This approach reflects the hypothesis that gender-inclusive labor markets enhance productivity through skill diversification, more efficient utilization of human capital, and innovation stemming from diverse perspectives. The empirical model is therefore expressed in Equation 2.

$$ECG_{it} = \beta_0 + \beta_1 CAP_{it} + \beta_2 ICT_{it} + \beta_3 HDI_{it} + \beta_4 LAB_{it} + \beta_5 FLP_{it} + \beta_6 LAB \times FLP_{it} + \varepsilon_{it} \quad (2)$$

Based on the model in Equation 2, the study formulates two hypotheses. First, capital, ICT, human capital, and labor are expected to exert a positive influence on economic growth in both the short run and the long run in ASEAN (H_1). Second, female labor force participation is hypothesized to moderate the effect of labor on economic growth across both time horizons, reflecting the potential role of gender inclusion in strengthening the growth process (H_2).

2.3. Autoregressive Distributed Lag (ARDL) Model

The Autoregressive Distributed Lag (ARDL) method was employed in this study. Originally developed by Pesaran et al. [41], the ARDL method enables the simultaneous analysis of short-run and long-run relationships among variables. It combines the autoregressive (AR) component, which incorporates past lags of the dependent variable, with the distributed lag (DL) component, which incorporates lags of the independent variables. Although the ARDL method was initially designed for time-series analysis, it has been rigorously extended to panel data through approaches such as the Pooled Mean Group (PMG) estimator, which constrains long-run coefficients to be homogeneous while allowing short-run coefficients and error variances to vary across groups.

The ARDL method is particularly flexible, as it can be applied to models with regressors integrated at levels I(0) or I(1), but it is not suitable for variables integrated at I(2). Equation 3 presents the general form of the ARDL model for examining both short-run and long-run effects.

$$\Delta y_{it} = \sum_{k=1}^{p-1} \lambda_{ik}^{*} \Delta y_{i,t-k} + \sum_{k=0}^{q-1} \delta_{ik}^{*\prime} \Delta x_{i,t-k} + \varphi_i y_{i,t-1} + \beta_i' x_{it} + \omega_i + \varepsilon_{it} \quad (3)$$

This study employed a nested regression approach rather than a single estimation model that incorporated all variables simultaneously. Nested hypotheses arise when comparing two or more regression equations that are identical except that one includes restrictions not imposed on the other [42]. The main advantage of this method is its ability to track changes in statistical significance and elasticity coefficients as variables are introduced incrementally, thereby isolating the influence of each group of variables.

Equation 4 specifies Model 1, which examines the effects of capital, ICT, human capital, and labor on economic growth. Equation 5 specifies Model 2, which introduces female labor force participation to assess its direct effect alongside the other variables. Equation 6 specifies Model 3, which incorporates an interaction term between labor and female labor force participation to evaluate its moderating role in the labor–growth relationship.

The error correction term (ECT) measures the speed of adjustment to equilibrium. For a valid long-run relationship among the study variables, the ECT coefficient must be negative and statistically significant. A significant ECT indicates how quickly deviations from long-run equilibrium in the dependent variable are corrected following shocks to the independent variables [43].

$$\Delta ECG_{it} = \alpha_1 + \sum_{k=1}^{p} \beta_1 \Delta ECG_{i,t-k} + \sum_{k=1}^{q} \delta_1 \Delta CAP_{i,t-k} + \sum_{k=1}^{q} \delta_2 \Delta ICT_{i,t-k} + \sum_{k=1}^{q} \delta_3 \Delta HDI_{i,t-k} + \sum_{k=1}^{q} \delta_4 \Delta LAB_{i,t-k} + \lambda ECT_{i,t-1} + \varphi_1 CAP_{i,t-1} + \varphi_2 ICT_{i,t-1} + \varphi_3 HDI_{i,t-1} + \varphi_4 LAB_{i,t-1} + \varepsilon_{it} \quad (4)$$

$$\Delta ECG_{it} = \alpha_1 + \sum_{k=1}^{p} \beta_1 \Delta ECG_{i,t-k} + \sum_{k=1}^{q} \delta_1 \Delta CAP_{i,t-k} + \sum_{k=1}^{q} \delta_2 \Delta ICT_{i,t-k} + \sum_{k=1}^{q} \delta_3 \Delta HDI_{i,t-k} + \sum_{k=1}^{q} \delta_4 \Delta LAB_{i,t-k} + \sum_{k=1}^{q} \delta_5 \Delta FLP_{i,t-k} + \lambda ECT_{i,t-1} + \varphi_1 CAP_{i,t-1} + \varphi_2 ICT_{i,t-1} + \varphi_3 HDI_{i,t-1} + \varphi_4 LAB_{i,t-1} + \varphi_5 FLP_{i,t-1} + \varepsilon_{it} \quad (5)$$

$$\Delta ECG_{it} = \alpha_1 + \sum_{k=1}^{p} \beta_1 \Delta ECG_{i,t-k} + \sum_{k=1}^{q} \delta_1 \Delta CAP_{i,t-k} + \sum_{k=1}^{q} \delta_2 \Delta ICT_{i,t-k} + \sum_{k=1}^{q} \delta_3 \Delta HDI_{i,t-k} + \sum_{k=1}^{q} \delta_4 \Delta LAB_{i,t-k} + \sum_{k=1}^{q} \delta_5 \Delta FLP_{i,t-k} + \sum_{k=1}^{q} \delta_6 \Delta (LAB \times FLP)_{i,t-k} + \lambda ECT_{i,t-1} + \varphi_1 CAP_{i,t-1} + \varphi_2 ICT_{i,t-1} + \varphi_3 HDI_{i,t-1} + \varphi_4 LAB_{i,t-1} + \varphi_5 FLP_{i,t-1} + \varphi_6 (LAB \times FLP)_{i,t-1} + \varepsilon_{it} \quad (6)$$

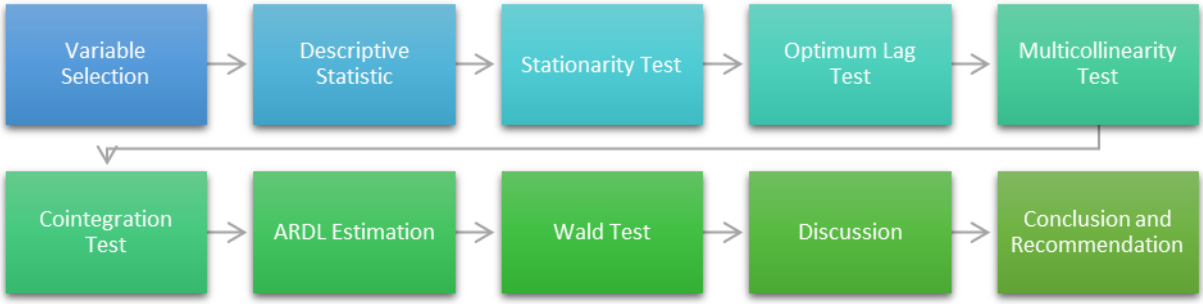

Figure 2. Research flow.

Table 2. Descriptive statistics.

Statistic	ECG (Percent)	CAP (Percent)	ICT (Percent)	HDI (Index)	LAB (Percent)	FLP (Percent)	FLP×LAB (Percent)
Mean	4.56	25.66	42.22	0.73	50.89	62.54	3236.91
Median	5.07	25.06	41.00	0.72	50.43	59.96	3047.45
Maximum	14.52	40.90	99.00	0.95	62.08	84.78	4870.58
Minimum	-9.52	15.20	0.05	0.43	37.26	44.50	1689.02
Std. Dev.	3.44	5.11	30.92	0.11	6.31	11.20	893.47
Observations	191	191	191	191	191	191	191

2.4. Research Flow

As shown in Figure 2, the analysis began with a statistical description to identify the characteristics of the research variables, including the mean, median, maximum, minimum, and standard deviation. A stationarity test was then conducted to assess whether the time-series data exhibited constant mean, variance, and covariance over time. This step employed several unit root tests, namely the Levin, Lin, and Chu (LLC) test, the Im, Pesaran, and Shin (IPS) test, and the ADF-Fisher chi-square test.

Following this, a cointegration test was performed to evaluate the existence of a long-run relationship between the dependent and independent variables, as well as the potential causal relationships among them. The Autoregressive Distributed Lag (ARDL) method was subsequently applied to estimate both short-run and long-run dynamics simultaneously. The ARDL approach integrates the autoregressive (AR) component, which accounts for lags of the dependent variable, with the distributed lag (DL) component, which incorporates lags of the independent variables. The optimal lag length for the ARDL model was determined using the Akaike Information Criterion (AIC).

3. Results and Discussion

3.1. Descriptive Statistics

Table 2 summarizes the descriptive statistics for 191 observations across the eight ASEAN countries. The average annual GDP growth rate is 4.56 percent, with Singapore recording the maximum of 14.52 percent and the Philippines the minimum of -9.52 percent. The relatively high standard deviation (3.50) indicates considerable variation across countries. Gross fixed capital formation averages 25.66 percent of GDP, ranging from 15.20 percent to 40.90 percent in Brunei Darussalam, with a moderate level of variation (standard deviation of 5.11). Internet penetration shows far greater disparity, averaging 42.22 percent, with a high of 99 percent in Brunei Darussalam and a low of 0.05 percent in Cambodia. The large standard deviation (30.92) underscores the significant digital divide in the region.

Human capital, measured by the Human Development Index, has an average value of 0.73, ranging from 0.95 in Singapore to 0.43 in Cambodia. The relatively low standard deviation (0.11) suggests values are clustered around the mean. Labor force participation averages 50.89 percent, with Singapore at the upper bound (62.08

Table 3. Results of stationarity test.

Variable	Level/1st Diff.	Prob.			Conclusion
		Levin, Lin & Chu	Im, Pesaran & Shin	ADF	
ECG	Level	0.0000***	0.0000***	0.0000***	I(0)
	1st Diff.	0.0000***	0.0000***	0.0000***	
CAP	Level	0.0653*	0.0958*	0.1812	I(1)
	1st Diff.	0.0000***	0.0000***	0.0000***	
ICT	Level	0.6307	0.9961	0.9410	I(1)
	1st Diff.	0.0063***	0.0164**	0.0000***	
HDI	Level	0.0000***	0.1451	0.0481**	I(1)
	1st Diff.	0.0039***	0.0000***	0.0000***	
LAB	Level	0.1395	0.5512	0.4850	I(1)
	1st Diff.	0.0000***	0.0000***	0.0000***	
FLP	Level	0.2362	0.0955*	0.0599*	I(1)
	1st Diff.	0.0000***	0.0000***	0.0000***	
FLP×LAB	Level	0.1739	0.3226	0.4343	I(1)
	1st Diff.	0.0000***	0.0000***	0.0000***	

Note: ***, ** and * denote significance levels at 1%, 5% and 10%, respectively.

Table 4. Determination of ARDL optimum lag.

ARDL Model	LogL	AIC	BIC	HQ	Specification
1	-208.82	4.0360	6.1383	4.8898	ARDL(4,2,2,2,2)
2	-171.29	3.7744	6.2078	4.7627	ARDL(4,2,2,2,2,2)
3	-261.72	4.3003	5.8122	4.9143	ARDL(2,1,1,1,1,1,1)

Table 5. Results of cointegration test.

Test	Panel PP		Panel ADF	
	Stat.	Prob.	Stat.	Prob.
Pedroni	-7.4812	0.0000***	-6.0343	0.0000***
Kao	n/a	n/a	-5.9043	0.0000***

Note: *** denotes significance level at 1%; 'n/a' indicates not applicable.

percent) and the Philippines at the lower bound (37.26 percent), reflecting a distribution close to normal (standard deviation of 6.31). Female labor force participation averages 62.54 percent, but with substantial cross-country variation, ranging from 44.5 percent in the Philippines to 84.8 percent in Cambodia (standard deviation of 11.20). Finally, the interaction between female labor force participation and total labor averages 3,236.91 percent, with a wide spread from 1,689.02 to 4,870.58, as indicated by a large standard deviation of 893.43.

3.2. Preliminary Tests

3.2.1. Stationarity Test

The results of the stationarity test presented in Table 3 indicate that the variables in this study are integrated at different levels. Economic growth is stationary at level, while gross fixed capital formation, ICT, human capital, labor, female labor force participation, and the interaction between female labor force participation and labor are non-stationary at this level. After transformation into first differences, these variables become stationary, confirming their integration of order one.

3.2.2. Determination of Optimum Lag

An optimum lag test is employed to identify the appropriate number of lags for the ARDL model and to minimize the risk of specification errors. This study adopts the Akaike Information Criterion (AIC) as the basis for lag selection. The results presented in Table 4 show that the optimal lag structures for Models 1, 2, and 3 are ARDL(4,2,2,2,2), ARDL(4,2,2,2,2,2), and ARDL(2,1,1,1,1,1,1), respectively. These specifications are subsequently applied in the ARDL estimation.

3.2.3. Cointegration Test

Before applying the ARDL method, it is necessary to establish the existence of a long-run relationship among the variables through cointegration testing. This study employs the Pedroni Residual Cointegration Test and the Kao Residual Cointegration Test for panel data. The results, presented in Table 5, indicate that the Pedroni test in both the PP and ADF statistic panels yields probability values of 0.0000, which are below the 5 percent significance level. Similarly, the Kao test produces a t-statistic of -5.9044 with a probability value of 0.0000, also below the 5 percent threshold. These findings confirm the presence of cointegration,

Table 6. Results of Pairwise correlation matrix.

Independent Variable	CAP	ICT	HDI	LAB	FLP
CAP	1				
ICT	0.1927	1			
HDI	0.0855	0.7444	1		
LAB	0.3345	0.2952	0.2954	1	
FLP	0.2528	-0.0793	-0.2702	0.7736	1

Note: A value below 0.8 indicates no high multicollinearity.

Table 7. Results of ARDL estimation for model 1.

Dynamics	Variable	Coef.	Std. Er.	t-Stat.	Prob.
Short-run	COINTEQ01	-2.2075	0.3919	-5.6335	0.0000***
	D(ECG(-1))	1.0482	0.2429	4.3152	0.0000***
	D(ECG(-2))	0.5158	0.1681	3.0682	0.0029***
	D(ECG(-3))	0.5071	0.1989	2.5495	0.0126**
	D(CAP)	0.2265	0.2801	0.8085	0.4211
	D(CAP(-1))	-0.0943	0.2093	-0.4505	0.6535
	D(ICT)	-0.0163	0.0792	-0.2061	0.8372
	D(ICT(-1))	-0.0199	0.0927	-0.2152	0.8302
	D(HDI)	244.74	132.58	1.8461	0.0684*
	D(HDI(-1))	70.546	82.350	0.8567	0.3941
	D(LAB)	0.8605	0.6921	1.2433	0.2172
	D(LAB(-1))	0.1317	0.8079	0.1630	0.8709
	C	7.9902	2.0891	3.8246	0.0003***
Long-run	CAP	0.1058	0.0164	6.4375	0.0000***
	ICT	-0.0214	0.0036	-5.8635	0.0000***
	HDI	6.8282	3.7974	1.7981	0.0758*
	LAB	-0.1260	0.0453	-2.7818	0.0067***

Note: ***, ** and * denote significance levels at 1%, 5% and 10%, respectively.

suggesting that economic growth maintains a long-run equilibrium relationship with the independent variables in the model.

3.2.4. Multicollinearity Test

The multicollinearity test is conducted using the correlation coefficient to examine the relationships among the independent variables. If the correlation coefficient is below 0.85, the variables are considered free from multicollinearity. Based on the results presented in Table 6, all correlation coefficients fall below the 0.85 threshold, indicating no strong relationships among the independent variables. Therefore, it can be concluded that the model is free from multicollinearity.

3.3. ARDL Estimation

3.3.1. Results of ARDL for Model 1

ARDL Model 1 estimates the effects of gross fixed capital formation, information and communication technology (ICT), human capital, and labor on economic growth in eight ASEAN countries. As reported in Table 7, the error correction term (ECT), represented by COINTEQ01, has a coefficient of -2.2076, which is significant at the 1 percent level (p = 0.0000). The negative and significant value confirms model stability and indicates cointegration, suggesting that the system adjusts toward long-run equilibrium. In the event of a crisis or recession, the adjustment speed is approximately 221 percent per period. Economic growth in the current period is positively influenced by its own past values at lags -1, -2, and -3, with the effect at lag -3 significant at the 5 percent level. This implies that past economic growth continues to positively influence present growth dynamics.

In the short run, gross fixed capital formation does not significantly affect economic growth. However, in the long run it has a positive and significant impact, with a coefficient of 0.1058 (p = 0.0000), indicating that a 1 percent increase in gross fixed capital formation raises economic growth by about 0.11 percent. ICT shows no effect in the short run, but exerts a negative long-run effect, where a 1 percent increase in internet users reduces economic growth by 0.02 percent. Human capital has a significant positive short-run effect, though lagged values are insignificant. In the long run, human capital exerts a positive effect at the 10 percent significance level, with a coefficient of 6.8282, meaning a 1-point increase in the human development index enhances economic growth by about 6.8 percent. Labor shows no short-run impact, but in the long run it has a negative and significant effect at the 1 percent level, with a coefficient of -0.1260 (p = 0.0067), indicating that a 1 percent

Table 8. Results of ARDL estimation for model 2.

Dynamics	Variable	Coef.	Std. Er.	t-Stat.	Prob.
Short-run	COINTEQ01	-2.3444	0.5484	-4.2750	0.0001***
	D(ECG(-1))	1.1381	0.3748	3.0365	0.0034***
	D(ECG(-2))	0.6540	0.1744	3.7495	0.0004***
	D(ECG(-3))	0.6163	0.2971	2.0743	0.0420**
	D(CAP)	0.1525	0.2265	0.6734	0.5030
	D(CAP(-1))	-0.2322	0.3017	-0.7696	0.4442
	D(ICT)	0.0397	0.0632	0.6278	0.5323
	D(ICT(-1))	0.0160	0.0808	0.1984	0.8434
	D(HDI)	224.90	112.48	1.9995	0.0497**
	D(HDI(-1))	16.463	100.88	0.1632	0.8709
	D(LAB)	3.3265	0.9028	3.6846	0.0005***
	D(LAB(-1))	-0.5257	2.1807	-0.2411	0.8102
	D(FLP)	-1.7748	0.5237	-3.3892	0.0012***
	D(FLP(-1))	-0.0032	0.7643	-0.0042	0.9966
	C	11.578	3.8554	3.0032	0.0038***
Long-run	CAP	0.0881	0.0197	4.4969	0.0000***
	ICT	-0.0145	0.0037	-3.9332	0.0002***
	HDI	11.536	3.1799	3.6277	0.0006***
	LAB	-0.4296	0.0518	-8.2884	0.0000***
	FLP	0.1800	0.0398	4.5235	0.0000***

Note: *** and ** denote significance levels at 1% and 5%, respectively.

increase in the labor force reduces economic growth by approximately 0.12 percent.

3.3.2. Results of ARDL for Model 2

Model 2 incorporates female labor force participation to assess its direct effect alongside the other variables. As shown in Table 8, the error correction term (ECT), COINTEQ01, has a coefficient of -2.3444, which is significant at the 1 percent level (p = 0.0001). The negative and significant value confirms the presence of cointegration and model stability, with the system returning to long-run equilibrium at a rate of approximately 234 percent per period. Economic growth in the previous period, as well as at lags -1 and -2, exerts a positive and significant influence. Growth at lag -3 also contributes positively at the 5 percent significance level, indicating that past growth continues to play an important role in shaping current growth.

Gross fixed capital formation shows no effect on economic growth in the short run, but in the long run it has a positive and significant impact (coefficient = 0.0887; p = 0.0000), implying that a 1 percent increase in physical capital raises growth by about 0.09 percent. ICT has no short-run effect but negatively affects growth in the long run (coefficient = -0.0145; p = 0.0002), where a 1 percent increase in internet users reduces growth by 0.01 percent. Human capital positively influences growth in both the short and long run, with a coefficient of 224.90 (p = 0.0497) in the short run and 11.536 (p = 0.0006) in the long run, suggesting that improvements in the human development index strongly promote growth.

Labor positively and significantly affects growth in the short run (coefficient = 3.3265; p = 0.0005), but in the long run it has a negative effect (coefficient = -0.4296; p = 0.0000), indicating that a 1 percent increase in labor reduces growth by about 0.43 percent. Finally, female labor force participation negatively affects economic growth in the short run but contributes positively in the long run (coefficient = 0.1800; p = 0.0000), where a 1 percent increase in women's participation raises economic growth by 0.18 percent.

3.3.3. Results of ARDL for Model 3

Model 3 estimates the effects of all independent variables, including the interaction between female labor force participation and labor, on economic growth. As shown in Table 9, the error correction term (ECT), COINTEQ01, has a coefficient of -1.1594, which is significant at the 1 percent level (p = 0.0000). The negative and significant value confirms cointegration and adjustment toward long-run equilibrium, with the system returning to equilibrium at a rate of approximately 116 percent per period. Economic growth in the previous period (lag -1) has a positive but insignificant effect.

Gross fixed capital formation has no effect on growth in the short run, but exerts a positive and significant influence in the long run (coefficient = 0.0770; p = 0.0074). Across the three estimated models, gross fixed capital formation consistently contributes positively in the long run, while its short-run effect is insignificant. ICT has no short-run effect but positively influences growth in the long run at the 10 percent significance level (coefficient = 0.0168; p = 0.0934). Human capital positively affects

Table 9. Results of ARDL estimation for model 3.

Dynamics	Variable	Coef.	Std. Er.	t-Stat.	Prob.
Short-run	COINTEQ01	-1.1594	0.1527	-7.5928	0.0000***
	D(ECG(-1))	0.2257	0.1633	1.3823	0.1696
	D(CAP)	0.1983	0.1743	1.1381	0.2575
	D(ICT)	-0.0721	0.0875	-0.8237	0.4118
	D(HDI)	202.07	86.418	2.3383	0.0211**
	D(LAB)	20.960	25.573	0.8196	0.4142
	D(FLP)	15.623	21.221	0.7362	0.4631
	D(FLP×LAB)	-0.3111	0.4227	-0.7360	0.4633
	C	76.876	10.791	7.1240	0.0000***
Long-run	CAP	0.0770	0.0282	2.7266	0.0074***
	ICT	0.0168	0.0100	1.6920	0.0934*
	HDI	-11.175	8.5846	-1.3018	0.1956
	LAB	-1.7367	0.2873	-6.0443	0.0000***
	FLP	-0.3892	0.1619	-2.4038	0.0179**
	FLP×LAB	0.0173	0.0034	5.0665	0.0000***

Note: ***, ** and * denote significance levels at 1%, 5% and 10%, respectively.

Table 10. Results of Wald test.

Model	Test Statistic	Stat.	Prob.
Model 1	F-Stat.	56.638	0.0000***
	Chi-square	226.55	0.0000***
Model 2	F-Stat.	137.45	0.0000***
	Chi-square	687.26	0.0000***
Model 3	F-Stat.	29.036	0.0000***
	Chi-square	174.21	0.0000***
Interaction	t-Stat.	1.7901	0.0761*
	F-Stat.	3.2045	0.0761*
	Chi-square	3.2045	0.0734*

Note: *** and * denote significance levels at 1% and 10%, respectively.

growth in the short run (p = 0.0211), but in the long run its effect is negative and insignificant. This short-run result is consistent across all three models, suggesting that improvements in human capital support growth only in the near term.

Labor shows no short-run effect, but in the long run it has a strong negative effect (coefficient = -1.7367; p = 0.0000), consistent across all models. Female labor force participation has no short-run effect, but in the long run it negatively affects growth (coefficient = -0.3892; p = 0.0179). The interaction between labor and female labor force participation is insignificant in the short run, yet in the long run it has a positive and significant effect (coefficient = 0.0173; p = 0.0000). This indicates that female labor force participation moderates the effect of labor on growth in the long run, functioning as a quasi-moderator, while in the short run it remains a non-moderator.

3.4. Wald Test

The Wald test is employed to assess whether the independent variables in the model significantly affect the dependent variable. As presented in Table 10, the results show that the independent variables in Models 1, 2, and 3 have a significant effect on economic growth. The probability value of the F-statistic is 0.0000, which is significant at the 1 percent level. The consistently high significance across all three models confirms that variables such as capital formation, ICT adoption, and human capital are substantive drivers of economic growth rather than mere statistical correlations. Model 2 records the strongest F-statistic value of 137.45, indicating that its specification, particularly with regard to human capital and technology, captures the most influential mechanisms of growth, thereby making it especially relevant for policy considerations.

The interaction between labor and female labor force participation yields a probability value significant at the 10 percent level, which remains acceptable. This finding suggests that the impact of labor on economic growth depends on the extent of female workforce engagement. The result implies a complementary relationship, where higher female labor force participation enhances the positive contribution of labor to economic growth, potentially through improved gender diversity in skills and productivity. This also implies that policies fostering women's inclusion in the labor market can amplify the growth-enhancing effects.

Table 11. Summary of the effects of independent variables on economic growth.

Independent Variable	Model 1		Model 2		Model 3	
	Short-run	**Long-run**	**Short-run**	**Long-run**	**Short-run**	**Long-run**
Capital	Positive but insignificant	Positive and significant	Positive but insignificant	Positive and significant	Positive but insignificant	Positive and significant
ICT	Negative but insignificant	Negative and significant	Positive but insignificant	Negative and significant	Negative but insignificant	Positive and significant
Human Capital	Positive and significant	Positive and significant	Positive and significant	Positive and significant	Positive and significant	Negative but insignificant
Labor	Positive but insignificant	Negative and significant	Positive and significant	Negative and significant	Positive but insignificant	Negative and significant
Female Labor Force Participation	-	-	Negative and significant	Positive and significant	Positive but insignificant	Negative and significant
Female Labor Force Participation × Labor	-	-	-	-	Negative but insignificant	Positive and significant

3.5. Discussion

In all three models, gross fixed capital formation has a positive and significant effect on long-run economic growth. This finding is consistent with previous studies. Saragih et al. [16] found a significant short-run effect, while Adebayo & Beton Kalmaz [15] and Thinagar et al. [17] reported long-run positive effects. Rani and Kumar [13] identified a one-way causal relationship from capital formation to growth. These results support endogenous growth theory, which argues that physical capital investment drives output and economic expansion.

Information and communication technology, measured by internet use, shows a negative effect on economic growth in model 1 and 2. This aligns with Suparta et al. [21], who found that internet use in Java and Sumatra negatively affected growth, likely because usage was not productivity-oriented. In developing countries, digital infrastructure alone does not stimulate growth; complementary policies are needed to improve digital skills and productivity. However, in Model 3, ICT has a positive and significant effect once the interaction of female labor participation and the total labor force is included. This suggests that gender-inclusive labor dynamics strengthen ICT's growth impact. These results are consistent with Nair et al. [44] and Ahn [20], who showed that internet adoption can foster growth.

The human development index, as a proxy for human capital, has a positive and significant effect on economic growth in both the short and long run in model 1 and 2. This is consistent with Gulcemal [23] and Nogueira and Madaleno [24], who emphasized the role of human capital in sustaining growth. However, in Model 3, human capital has a negative and insignificant effect, similar to Cetinguc et al. [25], who found negative impacts in developing countries. This indicates that the growth contribution of education and health depends on each country's stage of development. Abdu [45] also showed that spending on health and education did not boost growth in Nigeria.

Labor has a positive but insignificant short run effect in general and a consistent negative significant long run effect on economic growth based on all three models. A large workforce without adequate employment opportunities hinders growth. In Model 3, the negative role of human capital further strengthens labor's negative effect. Amelia et al. [46] found that HDI reduced employment opportunities in North Sumatra. Other explanations include measurement errors, declining capital per worker, low allocative efficiency, sectoral shifts, and weaker human capital [47]. In the US, population aging has slowed labor productivity and overall growth [48].

Model 2 includes female labor participation, which shows no significant short-run effect but a positive significant long-run effect on economic growth, supporting Appiah [32], who argued that women's participation stimulates growth. By contrast, Model 3 finds a negative relationship, in line with Forgha & Mbella [49] and Thaddeus et al. [50]. This may reflect women's concentration in informal or low-wage sectors, or demographic factors. Sulaiman et al. [51] found that female participation, education, and longevity support growth, but high life expectancy can make labor participation less growth-enhancing.

Finally, the interaction between female participation and total labor shows a positive and significant effect on economic growth in both the short and long run. This indicates that women's participation plays a moderating role. While labor and female participation separately have negative effects, their interaction enhances overall efficiency. This supports endogenous growth theory, which highlights the importance of labor dynamics and social structures, including gender, in driving growth.

Overall, as summarized in Table 11, the findings highlight the complex relationships between capital formation, technology adoption, human capital, and labor dynamics in shaping economic growth in ASEAN. While physical capital and human development remain robust long-run growth drivers, the role of ICT and female labor participation is more nuanced, depending on how effectively they are integrated into the broader labor market and institutional context. The interaction between labor and female participation underscores that inclusive labor markets can enhance efficiency and amplify growth benefits. These results suggest that policies aimed at fostering investment, strengthening human capital, and promoting gender-inclusive labor participation, alongside measures to ensure productive ICT use, are crucial for sustaining long-term economic development in ASEAN.

4. Conclusions and Policy Recommendations

The findings reveal that gross fixed capital formation consistently promotes long-term economic growth in ASEAN, although it has no significant short-term effect. Information and communication technology, measured by internet usage, negatively influences long-term economic growth in Models 1 and 2 but exerts a positive effect in Model 3. Human capital, proxied by the Human Development Index (HDI), contributes positively to economic growth in both the short and long run across most models, although it turns negative in the long-run estimation of Model 3. Labor, by contrast, significantly constrains long-term economic growth, likely due to insufficient employment opportunities. Female labor force participation shows mixed effects, contributing positively in Model 2 but negatively in Model 3, possibly reflecting the influence of high birth rates and persistent gender inequality. Importantly, female labor force participation acts as a quasi-moderator, amplifying the impact of labor on economic growth.

Sustained investment in gross fixed capital formation remains crucial for ASEAN's long-term economic growth, particularly through infrastructure development and policies that stimulate private sector participation. At the same time, expanding digital infrastructure, encouraging firm-level digital adoption, and integrating digital literacy into education and training systems are essential for transforming ICT into a source of productivity rather than consumption. Human capital development requires aligning education and healthcare systems with labor market needs, broadening access in underserved regions, and ensuring adequate budgetary commitments, with effective implementation supported by public–private collaboration and robust monitoring mechanisms.

Labor market reforms should prioritize vocational training, stronger industry partnerships, and policies that reduce structural inefficiencies. Particular emphasis must be placed on female labor force participation, which strengthens the contribution of labor to economic growth. Governments can support this through equal pay enforcement, affordable childcare provision, parental leave schemes, and targeted tax incentives for firms that recruit and retain female workers. Expanding access to education and vocational training for women, especially in STEM and digital fields, will further enhance productivity. Together, these measures not only improve overall labor market efficiency but also ensure that gender-inclusive participation amplifies the growth potential of ASEAN economies.

Despite the value of its findings, this study has several limitations. ICT adoption is measured only by internet penetration, which does not distinguish between productive and non-productive uses, potentially obscuring its link to economic growth. Employment data are not disaggregated by sector or status, and women's participation includes the informal sector, where productivity is typically low. Future research should address these gaps by grouping ASEAN countries by income levels, incorporating indicators of ICT productivity such as digital adoption and R&D, and conducting more detailed analyses of labor productivity and human capital quality. Greater attention should also be given to women's economic participation and gender disparities to capture the interactions between technology adoption, productivity, and social inclusion in the region.

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