The impact of ICT adoption and trade openness on youth unemployment in ASEAN: opportunity or challenge?

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Abstract

This study investigates the long-term impact of Information and Communication Technology (ICT) adoption and trade openness on youth unemployment in ASEAN countries over the period 2000–2023. Panel data are analyzed using the Fully Modified Ordinary Least Squares (FMOLS) estimation method. The empirical results indicate that trade openness reduces youth unemployment, particularly among male youth. However, its effect is relatively weaker and not consistently significant for female youth, suggesting the presence of gender disparities in labor absorption within tradable sectors. Furthermore, digital infrastructure plays a crucial role in mitigating youth unemployment. Both fixed broadband and mobile cellular subscriptions are found to significantly reduce youth unemployment rates, with broadband access exhibiting a stronger and more consistent effect across models. Overall, the findings suggest that ICT adoption and trade openness constitute important mechanisms for reducing youth unemployment in ASEAN countries.

Keywords: *ASEAN; FMOLS; ICT; Trade openness; Youth unemployment*

JEL Classification: C33, E24, F15, F43, O33

INTRODUCTION

The impact of Information and Communication Technology (ICT) on youth unemployment has become a prominent topic in empirical research, generating considerable debate in the literature. Several studies have demonstrated that ICT adoption can expand young people's access to employment opportunities by enhancing job search efficiency and fostering the development of digital skills (Listari et al., 2024). For example, research conducted in Cameroon found that ICT use significantly increased youth employment opportunities, particularly by expanding social networks and improving access to information (Nouffeussie et al., 2024). However, other studies have emphasized that, without adequate digital skills, young people may be left behind in an increasingly digitalized labor market (Idris & Maikomo, 2024).

This situation reflects the ambivalent role of ICT: on the one hand, it acts as an enabler, opening pathways to new employment opportunities; on the other hand, it may become a barrier for segments of the workforce that lack sufficient digital access or competence (Arifin & Heriqbaldi, 2023). Divergent findings in the literature suggest that

a country's digital infrastructure readiness significantly influences the effectiveness of ICT in addressing youth unemployment. Therefore, a deeper analysis of the interaction between ICT adoption and youth unemployment is essential.

In the ASEAN region, these dynamics become increasingly complex given the diversity in levels of digital economic development, the quality of ICT infrastructure, and disparities in access to and digital literacy among member countries (Hesda, 2023). In ASEAN, advances in digital infrastructure and internet penetration have created new opportunities for young people to participate in the digital economy. However, a paradox emerges when increased ICT adoption does not automatically translate into a reduction in youth unemployment rates (Riniati et al., 2022).

Countries such as Singapore and Malaysia have demonstrated significant progress in ICT integration, enabling greater youth participation in the digital economy and contributing to reductions in youth unemployment. In contrast, countries such as Cambodia, Laos, and Myanmar continue to face fundamental challenges in providing adequate infrastructure and digital skills training for young people, limiting their ability to address youth unemployment effectively. Meanwhile, Indonesia, the Philippines, and Vietnam exhibit strong potential as expanding digital markets but continue to grapple with inequalities in access to and the quality of vocational education, which do not yet fully align with the needs of ICT-based industries. Consequently, efforts to reduce youth unemployment in these countries have not been particularly effective.

Figure 1 compares digital infrastructure across ASEAN member countries during the pre-AEC (ASEAN Economic Community) period (2010–2014) and the AEC period (2015–2023). Four main indicators are used: fixed broadband subscriptions, fixed telephone subscriptions, mobile cellular subscriptions, and individuals using the Internet. The data are displayed in a tiered bar chart for each ASEAN country, providing a clear overview of digital disparities across the region.

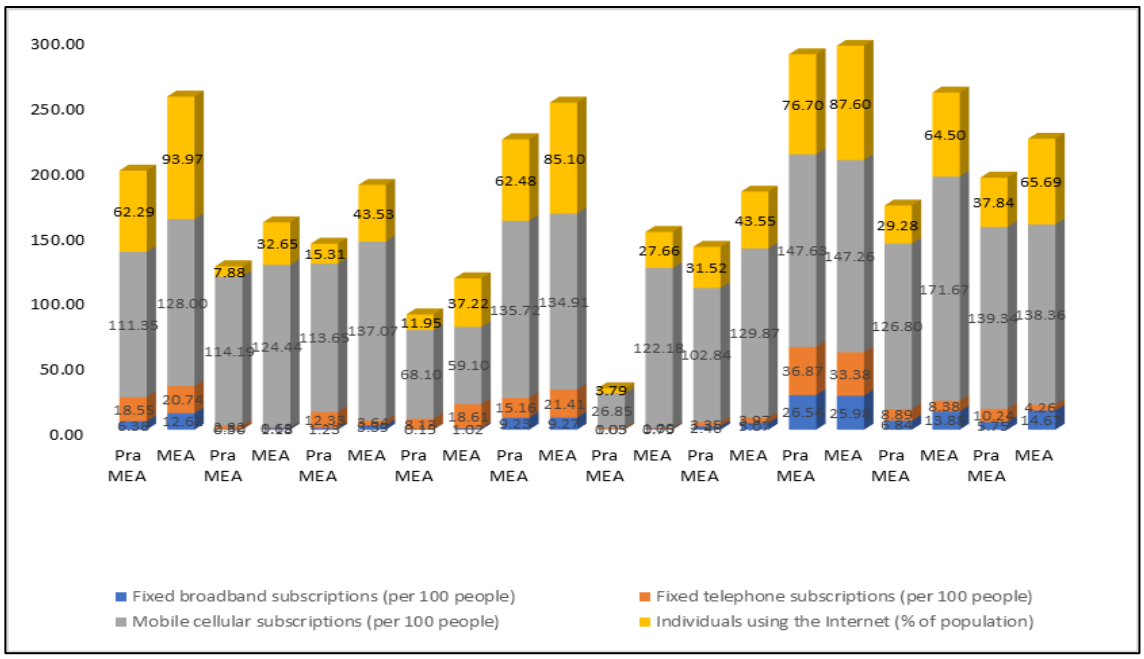

Figure 1. Digital infrastructure disparities 2010-2023 in ASEAN
Source: World Bank, 2023

Mobile cellular subscriptions (grey bars) represent the most widespread and dominant form of digital infrastructure across ASEAN countries, both before and after

the establishment of the AEC. Almost all countries record more than 100 mobile subscriptions per 100 inhabitants, indicating high penetration rates and broad access to cellular networks. This suggests that mobile telecommunications have become the backbone of digital connectivity in Southeast Asia.

However, substantial disparities are evident in the indicators for fixed broadband and fixed telephone subscriptions (orange bars). Countries such as Singapore and Malaysia demonstrate significantly higher adoption rates of fixed broadband and fixed telephony compared to countries such as Laos, Cambodia, and Myanmar. This disparity reflects gaps in wired digital infrastructure, which are typically associated with long-term infrastructure investment and national economic capacity (Juárez et al., 2023).

The indicator measuring Internet use also reveals striking differences. Singapore, Brunei, and Malaysia report very high internet penetration rates (approaching or exceeding 80 percent), whereas countries such as Laos, Myanmar, and Cambodia remain below 50 percent, even during the AEC period. This suggests that, beyond infrastructure availability, factors such as digital literacy, purchasing power, and government policy significantly influence internet adoption rates.

Overall, the figure illustrates that although the AEC aims to promote integration and more equitable development, digital disparities persist across the ASEAN region. Economically more advanced countries have experienced substantial improvements across all digital infrastructure indicators, while countries with limited resources and fiscal capacity continue to lag. Achieving the vision of inclusive digital connectivity in ASEAN, therefore, requires a regional strategy that emphasizes infrastructure investment, technological cooperation, and the development of human capital.

The evident digital disparities also have direct implications for youth unemployment in the ASEAN region. Figure 2 illustrates youth unemployment rates across ASEAN member countries, represented by blue bars for each country, with a horizontal red line indicating the ASEAN average youth unemployment rate of 6.4 percent. Notably, Brunei Darussalam records the highest youth unemployment rate in the region at 23.3 percent, substantially exceeding the regional average. This is followed by Indonesia (15.5 percent) and Malaysia (11.1 percent), two countries with large populations and rapidly evolving economic structures.

The elevated youth unemployment rates in these countries are likely attributable to a mismatch between the skills of young graduates and industry demands, limited access to high-quality job training, and a slow transition toward an inclusive digital economy (Arifin & Heriqbaldi, 2023). In contrast, countries such as Cambodia (0.7 percent), Lao PDR (3.6 percent), and Thailand (3.8 percent) report relatively low youth unemployment rates. However, these figures should be interpreted with caution, as they may reflect the predominance of informal employment and lower participation rates in higher education rather than genuinely favorable labor market conditions.

Youth unemployment in ASEAN is also closely linked to the dynamics of trade openness in the region. On the one hand, trade openness can generate new employment opportunities through increased foreign direct investment, the expansion of the manufacturing sector, and the growth of services (American University of Central Asia & Rashidi, 2022). On the other hand, if not accompanied by efforts to strengthen the capacity and competitiveness of the young workforce, the benefits of free trade may accrue disproportionately to highly skilled or foreign workers. This imbalance has the potential to exacerbate youth unemployment, particularly in countries that have struggled to integrate young graduates into the global labor market or regional supply chains (Baliamoune-Lutz, 2023).

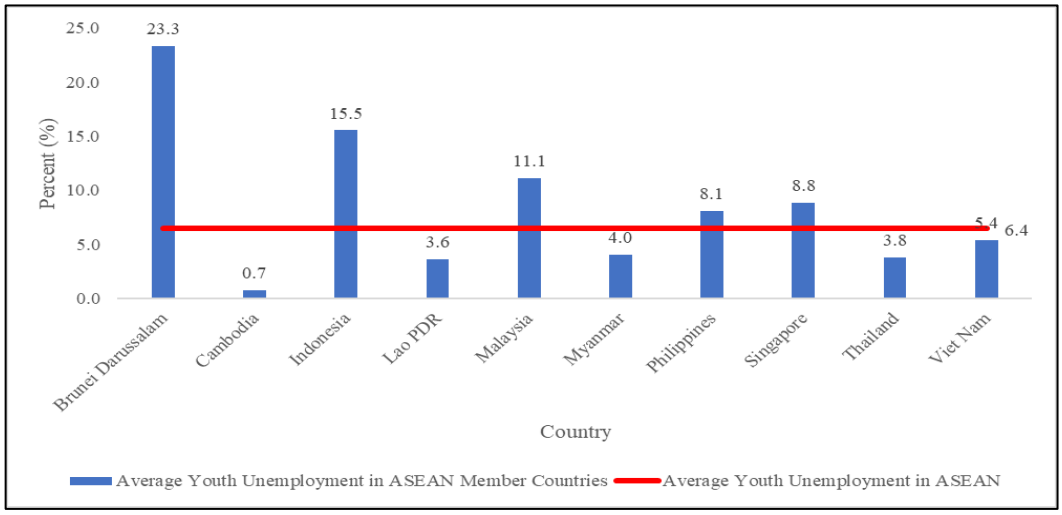

Figure 2. Average youth unemployment in ASEAN member countries 2010-2023
Source: World Bank, 2023

Figure 3 illustrates the relationship between youth unemployment rates in ASEAN and trade openness from 2010 to 2023. In the early period (2010–2014), trade openness in ASEAN was relatively high and stable, while youth unemployment remained at a comparatively elevated level of around 11–8 percent. This indicates that high levels of international trade do not automatically translate into greater employment absorption for young workers, particularly when they lack the skills demanded by global industries. During this period, although export markets expanded, structural transformation in the production sector was not fully inclusive of young workers with limited experience and digital competencies.

Between 2015 and 2020, trade openness declined significantly, particularly in 2019–2020, likely due to the global economic slowdown and the COVID-19 pandemic. During the same period, youth unemployment increased sharply, reaching peaks in 2017 and 2020. Restrictions on mobility, job losses, and economic uncertainty rendered young people especially vulnerable to the crisis. These findings reinforce the argument that during trade disruptions or economic contractions, young workers are often disproportionately affected.

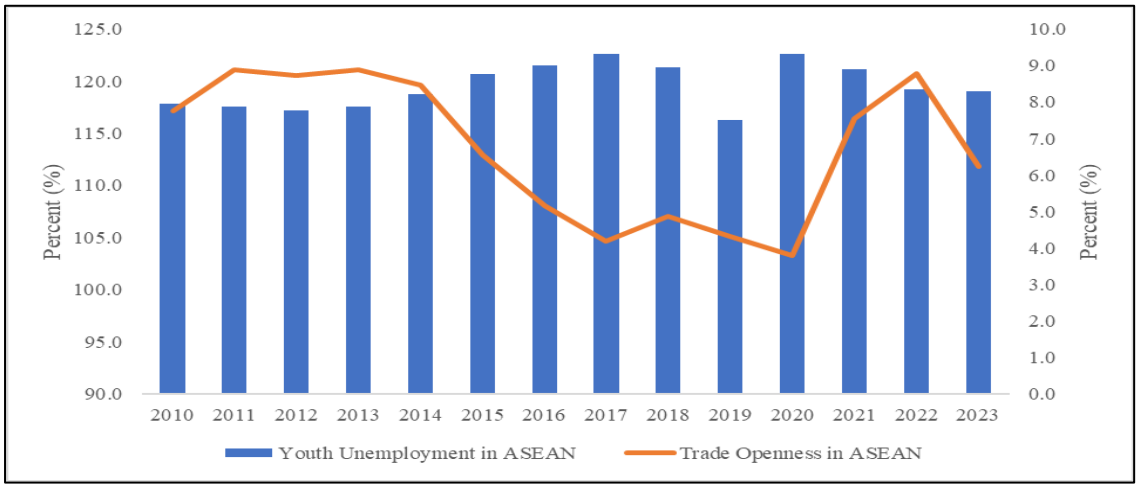

Figure 3. Youth unemployment and trade openness in ASEAN
Source: World Bank, 2023

In the post-pandemic period (2021–2022), trade openness recovered substantially, once again exceeding 80 percent. This recovery was accompanied by a gradual decline in youth unemployment, suggesting a positive association between trade recovery and renewed employment opportunities. Interestingly, although trade growth slowed in 2023, youth unemployment did not rise significantly. This may indicate structural adjustments, such as the expanding role of the digital economy, online employment, and youth entrepreneurship initiatives.

The issues surrounding youth unemployment, ICT, and trade openness outlined above underscore the importance of examining their interrelationships. ICT theory posits that increased adoption and penetration of information technology can reduce unemployment, particularly among young people, by generating new forms of digital employment and expanding access to online job opportunities (Kpognon et al., 2020). ICT enables the digital economy, opening pathways for youth entrepreneurship, gig economy platforms, and remote work models that are increasingly accessible to workers without conventional industry experience.

Although ICT is frequently viewed as a solution for expanding employment opportunities in the digital era, empirical evidence also suggests that it may intensify challenges of youth unemployment. Njiepue Nouffeussie et al. (2024) note that low levels of ICT utilization and economic structures that do not adequately support the technology sector have prevented lower-middle-income countries from fully benefiting from ICT development, thereby limiting their impact on reducing youth unemployment. Bhat & Beg (2023) emphasize that access to and the ability to utilize digital technologies remain unevenly distributed. In the context of youth employment, this inequality creates structural barriers, as many young people—particularly in developing countries—lack the foundational digital skills required in technology-driven labor markets. Furthermore, Listari et al. (2024) argue that ICT development tends to increase demand for highly skilled workers while displacing conventional jobs typically filled by young individuals with limited experience. Consequently, young people without adequate technological competencies may be excluded from emerging production systems, exacerbating youth unemployment.

Trade openness similarly presents both opportunities and risks. On the one hand, it can reduce unemployment by expanding access to broader labor markets and stimulating labor-intensive sectors such as manufacturing and export-oriented services (Gonese et al., 2023). Trade openness has also contributed to economic transformation in ASEAN by fostering a more integrated regional market (Wahyuningsih, 2021). On the other hand, its benefits for young workers depend heavily on the alignment between their skills and global industry requirements. Without appropriate competencies, young workers may not benefit from trade expansion. Moreover, trade liberalization can trigger economic restructuring, automation, and efficiency-driven production processes that may substitute technology for labor, including young workers (Nwosa et al., 2020). In such circumstances, trade openness may increase the risk of youth unemployment, particularly in countries that have not aligned trade policies with strategies to enhance human capital.

Nevertheless, trade openness can also serve as a strategic tool to address youth unemployment when supported by domestic policies that promote skills development and innovation. From classical and neoclassical economic perspectives, international trade enables countries to allocate resources more efficiently and access broader markets, thereby generating new labor demand, including for young workers (Bhat & Beg, 2023). As export sectors expand—particularly in labor-intensive and medium-technology

industries such as manufacturing, modern agribusiness, and digital services—employment opportunities for young workers may increase. Trade can also facilitate technology and knowledge transfer, which, if supported by vocational education and training, can enhance the competitiveness of young workers in global markets (Kpognon et al., 2020). In this context, trade openness may catalyze greater youth participation in the formal economy, especially when accompanied by policies that support youth entrepreneurship, industrial internships, and collaboration with the global private sector.

Empirical evidence on the effects of ICT and trade openness on youth unemployment remains mixed. Ogbonna et al. (2023), using a dynamic Generalized Method of Moments (GMM) approach and a composite ICT index for 41 African countries (2003–2018), find that higher ICT usage reduces youth unemployment. In contrast, Arifin & Heriqbaldi (2023), employing System GMM (SysGMM) with panel data from 34 Indonesian provinces (2013–2022), report that digitalization—proxied by the ICT Development Index—positively and significantly increases youth unemployment.

Listari et al. (2024), using dynamic panel data across 33 Indonesian provinces (2010–2021), find that mobile phone and internet usage do not significantly affect youth unemployment. Idris & Maikomo (2024) conclude that the digital economy significantly influences youth unemployment in Nigeria. Hesda (2023), analyzing 57 countries (2015–2017), finds that ICT development reduces total unemployment by approximately 1 percent, particularly among individuals with medium levels of education; however, this effect is significant only in developed countries. The study suggests that developing countries must adopt cautious, adaptive strategies to respond to rapid ICT expansion. Başol et al. (2023), examining 27 European countries (2018–2021), find that the Digital Economy and Society Index (DESI) significantly reduces youth unemployment. Similarly, Mwesha et al. (2025), through a review of 20 studies (2019–2024), conclude that digital skills development enhances employability and that digital platforms promote youth entrepreneurship in Africa.

Regarding trade openness, Hasan and Sasana (2020) find, using a Least Squares Dummy Variable (LSDV) estimator on ASEAN panel data (2001–2017), that trade openness has a positive and significant effect on youth unemployment. Baliamoune-Lutz (2023), employing fixed effects (FE) and GMM for 89 developing and emerging countries (1990–2018), reports heterogeneous effects: trade openness significantly reduces youth unemployment in Latin America and the Caribbean. Still, it shows no significant effect in Asia and Sub-Saharan Africa. Gonese et al. (2023) conclude that trade openness reduces overall unemployment in the long run, although imports may increase unemployment where domestic industries lack competitiveness.

These divergent findings reveal a clear research gap. While some studies highlight the positive role of ICT and trade openness in reducing youth unemployment—particularly in countries with robust digital infrastructure and supportive institutions—others emphasize the risks of widening inequality and labor market exclusion due to skill mismatches and uneven access to digital technologies. The mixed, sometimes contradictory empirical results underscore the need for a more comprehensive, integrated approach to analyzing the combined effects of ICT and trade openness on youth unemployment.

This study, therefore, proposes an empirical panel-data approach to examine the impact of ICT usage and trade openness on youth unemployment in ASEAN countries, covering periods before, during, and after the COVID-19 pandemic, as well as before and

after the implementation of the AEC. It also investigates the moderating role of economic growth in the relationship between ICT and youth unemployment. By doing so, this study aims to contribute new empirical insights. Understanding how ICT and trade openness concretely affect youth unemployment will not only enrich the academic literature but also provide a robust foundation for designing inclusive, evidence-based policies to accelerate youth employment in the digital economy era.

METHODS

Data and variables

This study employs time-series data covering the period 2000–2023 for ASEAN countries. The early 2000s marked an important phase during which ASEAN countries became increasingly active in trade liberalization and regional integration. This period enables a longitudinal analysis of the impact of trade openness on youth unemployment. In addition, the 2000–2023 timeframe captures the rapid adoption of information technology in Southeast Asia, including internet penetration, mobile connectivity, and the expansion of the digital economy. It is therefore well-suited to examining the relationship between digitalization and youth unemployment.

The selected period also encompasses two major global shocks: the 2008 Global Financial Crisis and the COVID-19 pandemic. This broad coverage allows the study to evaluate how labor markets and digital sectors responded to economic pressures and how these responses influenced youth unemployment. ASEAN was selected because it has a large youth population and relatively high youth unemployment rates across many member countries, making the region particularly relevant for analyzing labor-market challenges and structural transformation.

The data used in this study were obtained from the World Bank. These secondary data are systematically collected and processed using reliable and standardized methodologies. Secondary data were chosen because they provide comprehensive information on economic and social indicators in a consistent format, thereby facilitating cross-country comparisons and analysis. Moreover, the use of secondary data enhances research efficiency in terms of both time and cost.

The dependent variables in this study are youth unemployment, male youth unemployment, and female youth unemployment. The primary independent variables are ICT and trade openness. The control variables include economic growth, foreign direct investment (FDI), and the birth rate. Economic growth and FDI are not the central focus of this study; however, they are included as control variables to avoid omitted variable bias in estimating the effects of ICT and trade openness on youth unemployment. The birth rate is incorporated because demographic dynamics influence the size of the youth labor force in the medium- and long-term. Controlling for this variable ensures that demographic pressures do not confound the estimated relationship between ICT and youth unemployment.

ICT is proxied by Mobile Cellular Subscriptions per 100 People and Fixed Broadband Subscriptions per 100 People. These two variables, along with the Crude Birth Rate (per 1,000 people), are transformed using the natural logarithm (ln). The logarithmic transformation reduces the influence of extreme values and outliers, thereby improving the robustness and reliability of the analysis.

Table 1 is a detailed description of the variables used in this study.

Table 1. Operational definition

Variable Name	Indicator/Proxy	Code	Operational Definition	Academic Justification
		Dependent Variable		
Youth Unemployment	Youth Unemployment Rate (ages 15–24)	yun	Percentage of the population aged 15–24 who are actively seeking work but are currently unemployed.	This variable represents one of the most vulnerable groups in the labor market and indicates potential mismatches between the education system and labor demand.
	Male Youth Unemployment Rate (ages 15–24)	yun_ male	Percentage of the male population aged 15–24 who are actively seeking work but are currently unemployed.	This variable reflects gender-specific vulnerability in the youth labor market.
	Female Youth Unemployment Rate (ages 15–24)	yun_ female	Percentage of the female population aged 15–24 who are actively seeking work but are currently unemployed.	This variable captures gender disparities in youth labor market outcomes.
		Independent Variables		
	Mobile Cellular Subscriptions per 100 People	ICT1	Number of active mobile cellular subscriptions (postpaid and active prepaid accounts used within the last three months) per 100 people in a country.	This indicator captures the level of mobile technology adoption and reflects the extent of digital connectivity and communication infrastructure within an economy.
	Fixed Broadband Subscriptions per 100 People	ICT2	Number of active fixed broadband subscriptions per 100 people in a country at a given time.	This variable measures access to fixed broadband internet and reflects the level of digital infrastructure supporting economic, educational, and governmental activities. Broadband access facilitates innovation, productivity, and digital inclusion.
Trade Openness	(Exports + Imports) / GDP	to	Ratio of total exports and imports of goods and services to Gross Domestic Product.	Trade openness may create employment opportunities but can also intensify competition and induce structural shifts in labor markets.
		Control Variables		
Economic Growth	GDP Growth (% annual)	eg	Annual percentage change in real GDP, representing overall economic performance.	According to Okun's law, higher economic growth is generally associated with lower unemployment, as increased labor demand reduces it.
Foreign Direct Investment	FDI Net (% of GDP)	fdi	Net inflows of foreign direct investment as a percentage of GDP.	FDI may generate employment opportunities and facilitate technology transfer, depending on whether the investment is labor-intensive or capital-intensive.
Fertility	Crude Birth Rate (per 1,000 people)	ber	Number of live births per 1,000 population in a given year.	This variable captures demographic pressure, as a youth bulge may increase youth unemployment if job creation does not keep pace with labor force growth.

Econometric methodology

The analytical technique employed in this study is Panel Fully Modified Ordinary Least Squares (FMOLS). Pedroni (2001) extended the concept of Fully Modified OLS (FMOLS), originally introduced by Phillips and Hansen (1990) in the context of time-series analysis, to the panel-data setting. The Panel FMOLS estimator is designed to provide consistent and efficient estimates of cointegrating relationships by correcting for endogeneity and serial correlation.

The estimation procedure begins by testing for panel data stationarity using unit root tests, such as the Levin–Lin–Chu (LLC) test developed by Levin et al. (2002). This step ensures that the variables are non-stationary at levels but become stationary after first differencing, indicating an integration of order one (I(1).

Levin et al. (2002) proposed a unit root testing approach for panel data under the assumption of a common unit root process across cross-sectional units. The Augmented Dickey–Fuller (ADF) specification underlying the LLC test is as follows:

$$\Delta y_{it} = \alpha_i + \rho y_{it-1} + \sum_{j=1}^{p} \beta_{ij}\, \Delta y_{it-j} + \varepsilon_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

In this equation, y_{it}represents the variable tested for stationarity, where $i$indexes cross-sectional units (e.g., countries) and $t$denotes time periods. The operator Δindicates the first difference, capturing changes from one period to the next. The key parameter of interest is ρ, which determines whether the series contains a unit root. If $\rho = 0$, the variable is considered non-stationary (i.e., it contains a unit root); if $\rho < 0$, the variable is stationary. The model allows for individual-specific intercepts (α_i) and includes lagged difference terms to account for serial correlation in the error term (Burdisso & Sangiácomo, 2016).

After confirming that the variables are integrated of the same order, the next step is to test for cointegration. The Kao cointegration test is used to determine whether a long-run equilibrium relationship exists among the panel's variables. This test extends traditional time-series cointegration tests to a panel framework and was developed by Kao (1999).

The hypotheses of the Kao test are as follows (Mushtaq, 2011):

H_0 (Null Hypothesis): No cointegration (the residuals contain a unit root and are non-stationary).

H_1 (Alternative Hypothesis): Cointegration exists (the residuals are stationary).

If the residuals are found to be stationary (i.e., the p-value is less than the chosen significance level), this indicates that the dependent and independent variables share a long-term equilibrium relationship and are therefore cointegrated.

The cointegration test employed in this study is the Kao Residual Cointegration Test. Kao & Chiang (2001) distinguish between two residual-based cointegration tests: the Dickey–Fuller (DF) and Augmented Dickey–Fuller (ADF) tests. Kao (1999) applied both DF and ADF statistics to examine cointegration in panel data, following the conventional Engle–Granger two-step procedure adapted to a panel framework. In this approach, the first step is to estimate the long-run regression, and the second is to test the residuals' stationarity.

Kao (1999) developed panel versions of the DF and ADF test statistics to assess whether the residuals from the cointegrating regression contain a unit root. If the residuals are stationary, the null hypothesis of no cointegration is rejected, indicating the existence of a long-run equilibrium relationship among the variables.

$$\text{ADF } t = \frac{t_{\text{ADF}} + \frac{\sqrt{6N}\hat{\sigma}_\nu}{2\hat{\omega}_\nu}}{\sqrt{\frac{\hat{\omega}_\nu^2}{2\hat{\sigma}_\nu^2} + \frac{3\hat{\sigma}_\nu^2}{10\hat{\omega}_\nu^2}}} \quad \text{.....(2)}$$

Following the confirmation of cointegration, the long-run equilibrium relationship among the variables is estimated using the panel Fully Modified Ordinary Least Squares (FMOLS) approach developed by Pedroni (2001). This estimator corrects for endogeneity and serial correlation inherent in cointegrated panel data models, thereby producing consistent and efficient long-run parameter estimates.

Model specification and robustness check

The empirical models estimated in this study are specified as follows:

Model 1

$$\text{Yun}_{it} = \alpha_{11} + \alpha_{12}\text{ICT1}_{it} + \alpha_{13}\text{Ln(ICT2)}_{it} + \alpha_{14}\text{TO}_{it} + \alpha_{15}\text{FDI}_{it} + \alpha_{16}\text{EG}_{it} + \alpha_{17}\text{Ln(BR)}_{it} + e_{1it} \ldots\ldots (3)$$

Model 2

$$\text{Yun\_Male}_{it} = \alpha_{21} + \alpha_{22}\text{ICT1}_{it} + \alpha_{23}\text{Ln(ICT2)}_{it} + \alpha_{24}\text{TO}_{it} + \alpha_{25}\text{FDI}_{it} + \alpha_{26}\text{EG}_{it} + \alpha_{27}\text{Ln(BR)}_{it} + e_{2it} \ldots. (4)$$

Model 3

$$\text{Yun\_Female}_{it} = \alpha_{31} + \alpha_{32}\text{ICT1}_{it} + \alpha_{33}\text{Ln(ICT2)}_{it} + \alpha_{34}\text{TO}_{it} + \alpha_{35}\text{FDI}_{it} + \alpha_{36}\text{EG}_{it} + \alpha_{37}\text{Ln(BR)}_{it} + e_{3it}. (5)$$

In these equations, *Yun*, *Yun_Male*, and *Yun_Female* represent youth unemployment, male youth unemployment, and female youth unemployment, respectively, as the dependent variables. *ICT1* and *ICT2* denote Mobile Cellular Subscriptions per 100 People and Fixed Broadband Subscriptions per 100 People, respectively. *TO* represents trade openness, *FDI* refers to net inflows of foreign direct investment as a percentage of GDP, *EG* indicates economic growth, and *BR* denotes the birth rate.

The subscript i refers to ASEAN member countries, and $t$represents the time period from 2000 to 2023. The term $e$denotes the error term, while *Ln* indicates the natural logarithm transformation. The parameters α_{11}, α_{21}, and α_{31}represent the intercepts of each model, whereas the remaining αcoefficients correspond to the estimated effects of the explanatory and control variables.

The primary objective of the robustness check is to ensure that the relationships identified in the baseline model are not coincidental or driven by a specific model specification. This procedure involves re-estimating the model using alternative approaches, such as employing different estimation techniques (e.g., replacing panel FMOLS with DOLS or CCR), modifying the set of control variables, using alternative country subsamples, or applying different variable transformations. If the estimated coefficients remain consistent in terms of direction and statistical significance across these alternative specifications, the results can be considered robust. Therefore, robustness checks function as an important validation mechanism to strengthen the credibility and empirical reliability of the econometric findings.

In this study, robustness is assessed by modifying the control variables by including a dummy variable for the ASEAN Economic Community (AEC) implementation period. The estimated models are specified as follows:

$$\text{Yun}_{it} = \beta_{11} + \beta_{12}\text{ICT1}_{it} + \beta_{13}\text{Ln(ICT2)}_{it} + \beta_{14}\text{TO}_{it} + \beta_{15}\text{FDI}_{it} + \beta_{16}\text{EG}_{it} + \beta_{17}\text{Ln(BR)}_{it} + \beta_{18}D_{MEA} + e_{1it} \ldots\ldots (6)$$

$$\text{Yun\_Male}_{it} = \beta_{21} + \beta_{22}\text{ICT1}_{it} + \beta_{23}\text{Ln(ICT2)}_{it} + \beta_{24}\text{TO}_{it} + \beta_{25}\text{FDI}_{it} + \beta_{26}\text{EG}_{it} + \beta_{27}\text{Ln(BR)}_{it} + \beta_{28}D_{MEA} + e_{2it} \quad (7)$$

$$\text{Yun\_Female}_{it} = \beta_{31} + \beta_{32}\text{ICT1}_{it} + \beta_{33}\text{Ln(ICT2)}_{it} + \beta_{34}\text{TO}_{it} + \beta_{35}\text{FDI}_{it} + \beta_{36}\text{EG}_{it} + \beta_{37}\text{Ln(BR)}_{it} + \beta_{38}D_{MEA} + e_{3it} \quad (8)$$

The variable D_MEA represents a dummy variable for the ASEAN Economic Community (AEC). It takes a value of 0 for the pre-AEC period (2000–2014) and 1 for the AEC implementation period (2015–2023). This specification allows the analysis to capture potential structural differences in youth unemployment dynamics before and after the establishment of the AEC.

RESULTS AND DISCUSSION

Descriptive statistics

Table 2 presents the descriptive statistics for the variables used in this study. Based on 240 observations, the average youth unemployment rate (*yun*) is 8.55 percent, with considerable variation (standard deviation of 6.77). The minimum value is 0.38 percent, while the maximum reaches 30.81 percent. When disaggregated by gender, the female youth unemployment rate (*yun_female*) is higher, averaging 9.54 percent, compared to 7.87 percent for males (*yun_male*). This indicates the presence of a gender gap in youth unemployment, with females being more adversely affected.

Economic growth (*eg*) averages 5.04 percent but exhibits substantial variability (standard deviation of 3.86), reflecting fluctuations across countries and time periods. The minimum value of −12.02 percent indicates episodes of economic contraction in certain countries or years. Meanwhile, foreign direct investment (*fdi*) records an average of −3.23 percent of GDP, with a similar standard deviation (3.86). The minimum value of −18.66 percent suggests that several countries experienced significant FDI outflows, pointing to periods of instability in the foreign investment climate.

Table 2. Descriptive statistics results for the full sample

Variable	Mean	Std. Dev.	Min	Max	Observations (N)
yun (%)	8.547	6.768	0.375	30.809	240
yun_female (%)	9.540	7.581	0.423	33.313	240
yun_male (%)	7.865	6.329	0.296	29.572	240
eg (%)	5.036	3.863	-12.016	14.520	240
fdi (%)	-3.233	3.863	-18.656	4.576	240
to (%)	118.848	95.554	0.000	437.327	240
ber (per 1,000 people)	2.267	0.699	0.970	4.429	240
ICT1 (per 100 People)	87.052	53.527	0.029	181.767	240
ICT2 (per 100 People)	5.503	7.663	0.000	28.539	240

Trade openness (*to*) is notably high, with an average ratio of 118.85 percent of GDP and substantial dispersion (standard deviation of 95.55). The maximum value of 437.33 percent indicates that some economies in the sample are highly dependent on international trade. Fertility rates (*ber*) are relatively moderate, with an average of 2.27 and a standard deviation of 0.70, reflecting ongoing demographic transitions in most ASEAN countries.

Technology adoption and digital access display marked disparities. The average number of mobile cellular subscriptions (*ICT1*) is 87.05 per 100 people, with a high standard deviation (53.53) and a maximum of 181.77, indicating multiple device ownership in some countries. In contrast, fixed broadband subscriptions (*ICT2*) remain relatively low, averaging only 5.50 per 100 people, with a maximum of 28.54, suggesting limited fixed digital infrastructure across the region.

Correlation analysis

The correlation matrix (Table 3) reveals several noteworthy relationships among youth unemployment, macroeconomic indicators, and ICT variables. Total youth unemployment (*yun*) is strongly and positively correlated with female youth unemployment (0.842) and male youth unemployment (0.811). The correlation between female and male youth unemployment is also high (0.765). These strong associations are expected, as total youth unemployment structurally comprises both male and female unemployment. However, including all three variables simultaneously in a regression model may raise concerns about multicollinearity due to their strong interdependence.

Table 3. Correlation

Variabel	yun (%)	yun_ female (%)	yun_ male (%)	eg (%)	fdi (%)	to (%)	ber (per 1,000 people)	ICT1 (per 100 People)	ICT2 (per 100 People)
yun (%)	1.000	0.842	0.811	-0.421	-0.388	-0.355	-0.472	-0.514	-0.536
yun_female (%)	0.842	1.000	0.765	-0.398	-0.361	-0.334	-0.448	-0.497	-0.518
yun_male (%)	0.811	0.765	1.000	-0.402	-0.349	-0.327	-0.429	-0.485	-0.503
eg (%)	-0.421	-0.398	-0.402	1.000	0.544	0.512	0.436	0.473	0.491
fdi (%)	-0.388	-0.361	-0.349	0.544	1.000	0.587	0.458	0.532	0.556
to (%)	-0.355	-0.334	-0.327	0.512	0.587	1.000	0.421	0.495	0.517
ber (per 1,000 people)	-0.472	-0.448	-0.429	0.436	0.458	0.421	1.000	0.559	0.582
ICT1 (per 100 People)	-0.514	-0.497	-0.485	0.473	0.532	0.495	0.559	1.000	0.429
ICT2 (per 100 People)	-0.536	-0.518	-0.503	0.491	0.556	0.517	0.582	0.429	1.000

Economic growth (*eg*) exhibits a moderate negative correlation with youth unemployment: −0.421 for total youth unemployment, −0.398 for female youth unemployment, and −0.402 for male youth unemployment. These findings are consistent with economic theory, particularly Okun's Law, which posits that higher economic growth is associated with lower unemployment. Economic growth is also positively correlated with FDI (0.544), trade openness (0.512), fertility (0.436), ICT1 (0.473), and ICT2 (0.491), suggesting that stronger economic performance is generally associated with greater openness and higher levels of digital development.

Foreign direct investment (*FDI)* shows a moderate negative correlation with youth unemployment (ranging from −0.349 to −0.388), suggesting that greater capital inflows may create employment opportunities for young workers. FDI is also positively correlated with trade openness (0.587) and ICT indicators (0.532 with ICT1 and 0.556 with ICT2), indicating that more globally integrated economies tend to exhibit more advanced digital infrastructure and technological diffusion.

Similarly, trade openness shows a moderate negative association with youth unemployment (approximately −0.33 to −0.36) and positive correlations with ICT variables (0.495 with ICT1 and 0.517 with ICT2). This pattern suggests that globalization and digitalization tend to evolve concurrently and may jointly improve labor market outcomes.

Fertility (*ber*) is moderately negatively correlated with youth unemployment (−0.472) and positively associated with ICT1 (0.559) and ICT2 (0.582). The correlation between ICT1 and ICT2 is 0.429, indicating a moderate but not excessive relationship. Importantly, all correlations involving ICT variables remain below 0.6, suggesting that multicollinearity among the digital indicators is not severe and poses no substantial concern for the econometric analysis.

Descriptive comparison: Pre-AEC and AEC period

Table 4 indicates that the youth unemployment rate (yun) changed only marginally between the pre-AEC and AEC periods. The average rate was 8.446 percent before the

implementation of the ASEAN Economic Community (AEC) and 8.106 percent during the AEC period, with standard deviations that were relatively similar. A comparable pattern is observed for yun_female and yun_male. Although these changes are not substantial, they indicate that the implementation of the AEC has not been associated with a marked reduction in youth unemployment at the descriptive level.

Table 4. Descriptive statistics before and during the AEC Period

Variable	Pra MEA (N=150)				MEA (N=80)			
	Mean	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**
yun (%)	8.446	6.828	0.598	26.301	8.106	6.612	0.375	30.809
yun_female (%)	9.479	7.741	0.423	30.670	9.659	7.300	0.461	33.313
yun_male (%)	7.725	6.280	0.767	23.492	8.076	6.340	0.296	29.572
eg (%)	5.917	3.433	-3.901	14.520	3.385	4.240	-12.016	9.691
fdi (%)	-2.776	3.278	-13.647	4.431	-4.029	4.747	-18.656	4.576
to (%)	124.156	99.040	0.000	437.327	109.632	89.929	0.000	332.981
ber (per 1,000)	2.429	0.749	1.150	4.429	1.974	0.498	0.970	2.744
ICT1 (per 100)	62.522	49.582	0.029	154.035	129.058	29.463	51.546	181.767
ICT2 (per 100)	3.287	6.160	0.0001	27.730	9.509	8.534	0.000	28.539

Economic growth declined during the same period. Before the AEC, the average growth rate was 5.917 percent, but it fell to 3.385 percent during the AEC period. This suggests that the implementation of the AEC did not generate a sustained boost in domestic economic performance and may have coincided with structural adjustments and intensified competition among ASEAN member states.

Foreign direct investment (FDI) also declined from −2.776 percent to −4.029 percent, indicating net capital outflows during the AEC period. Trade openness decreased from 124.156 percent to 109.632 percent, a somewhat paradoxical outcome given that the AEC was designed to promote regional trade liberalization. Meanwhile, the fertility rate fell in line with broader demographic transition trends.

By contrast, substantial improvements in digital infrastructure are evident during the AEC period. Mobile cellular subscriptions increased significantly, and fixed broadband penetration expanded considerably. These developments reflect strong digital expansion, although this progress has not yet fully translated into stronger aggregate economic performance or lower youth unemployment.

Panel unit root and cointegration tests

Based on the results of the panel stationarity test using the Levin–Lin–Chu (LLC) method, all variables in the model—both the dependent variables (*yun, yun_female, yun_male*) and the independent variables (*fdi, eg, to, lnber, lnICT1,* and *lnICT2*)—are non-stationary at the level form (Table 5). This is indicated by p-values exceeding 0.10, suggesting insufficient evidence to reject the null hypothesis of unit roots in the variables.

Table 5. Unit root test using the Levin-Lin-Chu (LLC)

Variable	Integrated	**p-value**	**Note**	**Variable**	Integrated	**p-value**	Note
yun	Level	0.6591	Not Stationer	D.yun	First Diff.	0.000***	Stationer
yun_female	Level	0.4455	Not Stationer	D.yun_female	First Diff.	0.000***	Stationer
yun_male	Level	0.5900	Not Stationer	D.yun_male	First Diff.	0.000***	Stationer
fdi	Level	0.7934	Not Stationer	D.fdi	First Diff.	0.000***	Stationer
eg	Level	0.9885	Not Stationer	D.eg	First Diff.	0.000***	Stationer
to	Level	0.8850	Not Stationer	D.to	First Diff.	0.000***	Stationer
lnber	Level	0.9876	Not Stationer	D.lnber	First Diff.	0.000***	Stationer
lnICT1	Level	0.9463	Not Stationer	D.lnICT1	First Diff.	0.000***	Stationer
lnICT2	Level	0.7499	Not Stationer	D.lnICT2	First Diff.	0.000***	Stationer

The non-stationarity problem is addressed by transforming the variables into first

differences. After first differencing, all variables become statistically significant at conventional levels, with p-values of 0.0000. This finding indicates that each variable requires only one differencing to achieve stationarity. In econometric terms, all variables are integrated of order one, I(1).

Following confirmation that the variables are integrated of the same order, the Pedroni panel cointegration test is applied to examine the existence of long-run relationships among the variables. The results provide strong evidence of cointegration across all three models (Table 6).

In Model 1, all test statistics are highly significant. The Modified Phillips–Perron (PP) t-statistic is 2.6615 (p-value = 0.0039), the Phillips–Perron t-statistic is −7.6029 (p-value = 0.0000), and the Augmented Dickey–Fuller (ADF) t-statistic is −4.8878 (p-value = 0.0000). These results indicate a stable long-run equilibrium relationship between the dependent and independent variables in Model 1.

Table 6. Cointegration test using Pedroni

Model	Cointegration Approach	p-value	Conclusion
Model 1	Modified Phillips–Perron t	0.0039	Cointegration exists
	Phillips–Perron t	0.0000	Cointegration exists
	Augmented Dickey–Fuller t	0.0000	Cointegration exists
Model 2	Modified Phillips–Perron t	0.0023	Cointegration exists
	Phillips–Perron t	0.0000	Cointegration exists
	Augmented Dickey–Fuller t	0.0003	Cointegration exists
Model 3	Modified Phillips–Perron t	0.0797	Cointegration exists
	Phillips–Perron t	0.0000	Cointegration exists
	Augmented Dickey–Fuller t	0.0000	Cointegration exists

In Model 2, all cointegration statistics are likewise statistically significant. The Modified PP t-statistic is 2.8387 (p-value = 0.0023), the PP t-statistic is −4.5405 (p-value = 0.0000), and the ADF t-statistic is −3.4105 (p-value = 0.0003). These findings confirm the presence of a statistically significant long-run relationship in Model 2, reinforcing the validity of the estimated equilibrium relationship.

For Model 3, two of the three test statistics are highly significant. The Phillips–Perron t-statistic (−7.1678) and the ADF t-statistic (−6.3234) both have p-values of 0.0000. However, the Modified Phillips–Perron t-statistic yields a value of 1.4068 with a p-value of 0.0797, which is not statistically significant at the 5 percent level.

Nevertheless, since two of the three principal statistics indicate strong significance, there remains substantial evidence of cointegration in Model 3. However, the evidence is slightly weaker than in Models 1 and 2.

Overall, the Pedroni test results confirm the existence of long-run equilibrium relationships among the variables in all three models. Therefore, estimating long-run coefficients using panel FMOLS is methodologically appropriate for further analysis.

FMOLS long-run estimation results

Based on the FMOLS estimation results presented in Table 7, distinct relationships emerge between the dependent variables—total youth unemployment, female youth unemployment, and male youth unemployment—and the explanatory variables. With 233 degrees of freedom and a critical t-value of 1.96 at the 5 percent significance level, the results indicate that economic growth exerts a negative and statistically significant effect on youth unemployment, both in aggregate and by gender. This finding is consistent with Okun's Law, which posits that increased economic activity raises labor demand and reduces unemployment. When ASEAN economies expand, higher aggregate demand

encourages firms to increase production capacity, thereby generating greater demand for labor, including young workers (Hasan & Sasana, 2020).

Table 7. Result full sample

Independent Variable	Dependent Variable								
	Model 1			Model 2			Model 3		
	yun (Total)	t-stat	SE	yun_female	t-stat	SE	yun_male	t-stat	SE
eg	-0.42	-3.82	0.11	-0.51	-4.25	0.12	-0.36	-3.00	0.12
fdi	-0.18	-2.57	0.07	-0.22	-3.14	0.07	-0.14	-2.00	0.07
to	-0.09	-2.25	0.04	-0.07	-1.75	0.04	-0.12	-2.40	0.05
lnICT2	-0.31	-3.10	0.10	-0.44	-3.67	0.12	-0.19	-2.11	0.09
lnber	0.27	3.00	0.09	0.34	3.40	0.10	0.21	2.33	0.09
lnICT1	-0.15	-2.50	0.06	-0.21	-3.00	0.07	-0.11	-1.83	0.06

In the ASEAN context, economic growth driven by the expansion of manufacturing, modern services, tourism, and the digital economy has generated employment opportunities that are relatively more accessible to young people, who typically exhibit higher labor mobility and adaptability than older cohorts. The statistical significance of economic growth in explaining youth unemployment also reflects the role of business cycles in shaping the school-to-work transition. During periods of robust economic expansion, firms tend to increase hiring, including fresh graduates and young workers with limited experience. Conversely, during economic downturns, young people are often among the first groups to be adversely affected by declining labor demand. These findings therefore underscore that stable, sustained economic growth is a crucial determinant of reducing youth unemployment in the ASEAN region.

From a gender perspective, the estimation results indicate that the effect of economic growth in reducing youth unemployment is stronger for young women than for young men. This pattern may be attributed to the expanding role of the service sector, labor-intensive industries, and the digital economy in ASEAN, which tend to be more inclusive of female labor force participation. The growth of these sectors has broadened formal and semi-formal employment opportunities for young women while gradually reducing structural barriers that have traditionally constrained their access to the labor market. Economic growth thus functions not only as a driver of job creation but also as a mechanism for enhancing gender inclusiveness in employment.

Moreover, the negative relationship between economic growth and youth unemployment reflects improvements in the quality of labor absorption. Growth accompanied by rising investment, technological adoption, and trade expansion is likely to generate higher-productivity employment, thereby strengthening the economy's capacity to absorb young workers. In the medium term, this dynamic may mitigate the scarring effect associated with early unemployment, which refers to the long-term adverse consequences for future earnings and employment stability.

The net FDI variable also shows a negative, statistically significant effect on youth unemployment across all models. This finding suggests that higher net inflows of foreign direct investment help reduce youth unemployment by creating jobs, fostering capital accumulation, and facilitating technology transfer. Since net FDI reflects the balance between inflows and outflows, a positive net position indicates that foreign investment entering the economy exceeds domestic investment abroad, thereby expanding productive capacity. The estimated coefficient is relatively larger for young women, implying that foreign investment in ASEAN economies tends to absorb female labor more intensively, particularly in labor-intensive manufacturing and service sectors. This result supports the view that multinational enterprises may offer greater employment opportunities for young women than domestic firms, especially in export-oriented industries.

Theoretically, the negative association between FDI and youth unemployment can be explained through both direct and indirect employment channels. Greenfield FDI promotes the establishment of new factories, production facilities, and service centers that directly employ young workers. In addition, FDI generates spillover effects through backward and forward linkages, increasing labor demand in supporting domestic industries such as logistics, business services, and trade. These mechanisms expand employment opportunities for youth, who are generally more adaptable to evolving labor market requirements. Empirical evidence by Setyanti and Wahyudi (2021) supports this interpretation, showing that FDI inflows Granger-cause improvements in youth employment in most ASEAN-5 countries, suggesting that FDI precedes job creation rather than merely responding to it.

Concerning trade openness, a coefficient of 0.01 implies that a 1 percent increase in trade openness—measured as the ratio of exports plus imports to GDP—is associated with a 0.01 percentage-point reduction in youth unemployment, holding other factors constant (*ceteris paribus*). Although the magnitude appears modest, it reflects a systematic and economically meaningful relationship. At the macroeconomic level, even small percentage-point reductions in unemployment can translate into substantial job gains in large populations.

This negative association suggests that deeper integration into international markets can enhance employment opportunities for young people. Greater trade openness may stimulate production expansion, strengthen export competitiveness, and attract investment, thereby increasing labor demand. For young workers in particular, export-oriented sectors—such as manufacturing, digital services, and other tradable industries—often generate entry-level positions that require adaptability and foundational skills rather than extensive prior experience. Consequently, trade integration can facilitate young people's transition into the labor market, provided that complementary policies in education and skills development are in place.

Moreover, trade openness may indirectly reduce youth unemployment by boosting productivity and fostering knowledge spillovers. Exposure to global competition encourages firms to innovate and adopt new technologies, thereby improving efficiency and potentially stimulating higher output growth. As firms expand production to meet international demand, labor demand increases, including for young individuals entering the labor market.

However, the relatively small estimated coefficient suggests that trade openness alone is not a dominant determinant of youth employment outcomes. Its effectiveness likely depends on complementary factors such as the quality of human capital, labor market flexibility, digital infrastructure, and institutional capacity. Thus, although deeper trade integration helps lower youth unemployment, its impact is gradual and operates within broader structural and policy frameworks.

In addition, FDI reduces youth unemployment not only through job creation but also through technology transfer and human capital upgrading. Multinational enterprises introduce advanced production standards, technologies, and managerial practices, thereby facilitating skill development among local workers. Young people, who generally adapt more quickly to technological change, are particularly well positioned to benefit from these developments. Consequently, FDI increases not only the quantity of employment opportunities but also the quality and productivity of jobs available to young workers.

The stronger impact of FDI in reducing female youth unemployment reflects the structural characteristics of FDI inflows in the ASEAN region. A substantial share of foreign investment is concentrated in labor-intensive manufacturing and modern service sectors—such as textiles and garments, electronics, business process outsourcing,

tourism, and retail—which traditionally employ a higher proportion of female workers (Nguyen, 2022). These sectors often offer employment opportunities that are more compatible with the skills, flexibility, and working conditions sought by young women, particularly compared with informal-sector employment (Wahyuningsih, 2021).

Furthermore, foreign-owned firms tend to implement more formal and inclusive labor practices, including non-discriminatory hiring policies, structured training programs, and clearer career development pathways. Such practices enhance participation and engagement among young female workers, who have historically faced structural constraints in domestic labor markets. FDI, therefore, serves as an important mechanism for narrowing gender disparities in youth employment across ASEAN. Nevertheless, the effectiveness of FDI depends critically on its sectoral composition and quality. Capital-intensive, high-technology investments with limited domestic linkages may yield weaker employment effects. Accordingly, investment policies in ASEAN countries should prioritize labor-intensive, export-oriented FDI with strong domestic linkages to maximize its contribution to youth employment.

The estimation results also indicate that trade openness exerts a negative, statistically significant effect on overall youth unemployment and male youth unemployment during the 2000–2023 period. In contrast, its effect on female youth unemployment is not statistically significant. This suggests that the employment gains associated with trade expansion are not evenly distributed across genders and tend to benefit young men more substantially.

From a theoretical perspective, trade openness enhances resource allocation efficiency by promoting specialization and expanding sectors in which countries have a comparative advantage. In many ASEAN economies, rapidly expanding tradable sectors—such as heavy manufacturing, automotive production, electronics, agro-industry, logistics, and transportation—are male-dominated, particularly in occupations that require physical strength, high mobility, or extended working hours. As a result, increased exports and imports are more likely to raise labor demand for young men than for young women, contributing to the observed gender differences in the impact of trade openness on youth unemployment.

Moreover, trade openness encourages the restructuring of industrial systems and global value chains (GVCs). ASEAN's integration into regional and global production networks increases labor demand in upstream and downstream activities, such as warehousing, distribution, and assembly manufacturing, which empirically exhibit a gender bias toward male workers. Young men tend to have higher participation rates in these sectors and therefore respond more strongly to trade expansion.

The absence of a statistically significant effect of trade openness on female youth unemployment reflects persistent structural and social barriers that limit young women's access to employment in tradable sectors. Constraints such as restricted mobility, prevailing social norms, occupational segregation in non-tradable sectors (e.g., education, health, and domestic services), and gaps in technical and vocational skills reduce young women's capacity to benefit from employment opportunities generated by trade liberalization. Consequently, even as international trade expands, its positive effects on female youth employment remain comparatively limited.

Empirical findings in the literature remain mixed. Prasetyo and Zaka (2022), in their study on trade openness, financial openness, and unemployment in ASEAN, report that while economic growth and inflation significantly reduce unemployment, trade openness increases overall unemployment, including among youth. In contrast, Rashidi (2023) finds that trade openness reduces total unemployment in highly trade-oriented economies such as Singapore and Malaysia. These divergent findings suggest that the impact of trade

openness on youth unemployment may differ from its effect on aggregate unemployment, potentially due to sectoral composition and skill mismatches.

These results may also be linked to the evolving structure of ASEAN trade, which has become increasingly integrated with technology and automation. Many export-oriented sectors with medium- and high-technology intensity are capital-intensive and require specialized technical skills that are still more commonly possessed by young men. This structural characteristic may further explain the gender-differentiated effects observed in the estimation results.

Overall, the findings confirm that although trade openness reduces youth unemployment, its effects are gender-selective. To enhance the benefits of trade expansion for young women, ASEAN countries should complement trade liberalization with gender-responsive labor market and education policies. These may include technology-oriented vocational training, greater female participation in industrial and logistics sectors, and the removal of structural barriers that restrict women's access to employment in tradable industries.

The digital infrastructure variable, proxied by fixed broadband subscriptions, has a negative, statistically significant effect on youth unemployment across all estimated models, both in aggregate and by gender. This finding indicates that improved broadband access plays a crucial role in reducing youth unemployment in ASEAN during the 2000–2023 period. Conceptually, broadband access expands young people's opportunities to obtain education, acquire skills, and access labor market information. High-speed internet enables youth to participate in online learning, obtain digital certifications, and engage in technology-based training aligned with evolving labor market demands. Consequently, broadband functions as a catalyst for enhancing employability and mitigating skill mismatches, which are widely recognized as key drivers of youth unemployment in developing economies.

Empirical evidence supports this interpretation. Hesda (2023) finds that fixed broadband subscriptions are positively associated with the employment-to-population ratio, particularly when accompanied by adequate digital skills and productivity levels. Similarly, Listari et al. (2024) suggest that broadband investment increases aggregate employment but may not generate substantial youth-specific employment spillovers when digital readiness remains low.

Furthermore, broadband infrastructure reduces job search costs by enabling faster and broader access to vacancy information, online recruitment platforms, and professional networks. For young individuals who often lack work experience and established networks, enhanced access to information is particularly important in facilitating the school-to-work transition. Higher broadband penetration, therefore, shortens the duration of unemployment and increases the probability of securing formal employment.

The stronger impact of broadband on female youth unemployment highlights the role of digital infrastructure in mitigating gender-based structural constraints. Internet access enables young women to engage in remote work, freelancing, and digital entrepreneurship, offering flexibility that helps them overcome mobility limitations, household responsibilities, and restrictive social norms. In ASEAN countries where gender gaps in labor force participation persist, broadband access thus serves as an important instrument for promoting inclusiveness and expanding employment opportunities for young women.

Furthermore, the expansion of broadband infrastructure stimulates the growth of the digital economy, including e-commerce, digital services, and platform-based employment—sectors that are relatively more accessible to young workers. These sectors

generate not only direct employment opportunities but also support self-employment and digital entrepreneurship among youth. Thus, broadband reduces youth unemployment not only through conventional wage employment channels but also through non-traditional and innovation-driven job creation.

From a medium- to long-term perspective, improved broadband access contributes to higher productivity and enhanced job quality. The integration of digital technologies into production processes and service delivery accelerates structural transformation toward higher value-added economic activities. Young people, who tend to adapt more rapidly to technological change, are likely to benefit disproportionately from this transformation.

The fertility rate has a positive, statistically significant effect on youth unemployment across all estimated models, both in aggregate and by gender. This finding indicates that rising fertility increases demographic pressure on the labor market by expanding the size of the youth cohort entering working age. When growth in youth labor supply is not matched by sufficient job creation, youth unemployment increases.

From a theoretical standpoint, the positive relationship between fertility and youth unemployment can be explained by demographic pressure and the youth bulge phenomenon. High fertility in earlier periods produces large youth cohorts in subsequent years. In many ASEAN countries, the formal labor market is often insufficient to absorb the influx of young workers, as competition intensifies among young job seekers, unemployment and underemployment increase, and participation in low-productivity informal employment increases.

The stronger impact of fertility on female youth unemployment reflects structural vulnerabilities and persistent gender inequalities in labor markets. A growing number of young women entering the workforce often face additional constraints, including restrictive social norms, domestic responsibilities, limited mobility, and discriminatory hiring practices. Under conditions of heightened competition driven by demographic pressure, young women are typically in a weaker position than young men, increasing their vulnerability to unemployment.

In addition, high fertility is frequently associated with lower per-child investment in education and health, commonly described as the quantity–quality trade-off. In larger households, limited resources reduce investment in human capital per child. This constraint adversely affects the skills and employability of young people upon entering the labor market, particularly young women, who in some contexts continue to face lower educational prioritization than men. Consequently, female youth from high-fertility environments may encounter greater difficulty in securing formal employment.

High fertility may also reinforce the intergenerational transmission of disadvantage. Children raised in resource-constrained households often have limited access to quality education and training. Upon reaching working age, they are more likely to face barriers to productive employment. Over time, this dynamic may prolong unemployment spells and increase the risk of structural unemployment, especially among young women.

These findings carry important policy implications. Reducing youth unemployment in ASEAN requires not only employment-generation strategies but also integrated demographic and human capital policies. Expanding access to family planning, increasing investment in girls' and women's education, and improving child health and educational outcomes are essential to mitigating demographic pressure. Simultaneously, gender-responsive labor market policies—such as childcare provision, flexible work arrangements, and stronger enforcement of anti-discrimination regulations—are necessary to reduce the vulnerability of young women in competitive labor markets.

The mobile cellular subscriptions variable has a negative, statistically significant

effect on overall youth unemployment and female youth unemployment, but its effect on male youth unemployment is statistically insignificant. This suggests that mobile phone penetration is particularly effective in enhancing employment access for young women in the ASEAN context.

In many ASEAN countries—especially developing and archipelagic economies such as Indonesia, the Philippines, and Vietnam—mobile phones constitute the most inclusive form of digital infrastructure, given the limited availability of fixed broadband in remote areas. Increased mobile penetration reduces information asymmetries in labor markets, particularly for young women who often face mobility constraints and limited professional networks (Arifin & Heriqbaldi, 2023). Through mobile devices, young women can access job vacancies, online recruitment platforms, mobile-based training, and professional networking opportunities without relocating.

Empirical evidence from other regions supports the employment-enhancing role of digital technologies. Idris and Maikomo (2024) find that the digital economy significantly affects youth unemployment in Nigeria. Başol et al. (2023) show that improvements in the Digital Economy and Society Index (DESI) reduce youth unemployment in European countries. Mwesha et al. (2025) conclude that digital skills development and digital platforms enhance youth employability and entrepreneurship in African contexts.

The stronger impact of mobile subscriptions on female youth unemployment also reflects the capacity of mobile technology to mitigate structural and social barriers. Mobile access enables young women to search for employment, participate in online interviews, and engage in income-generating activities from home, including gig work, e-commerce, and online micro-enterprises. In this sense, mobile technology serves as a tool for economic empowerment.

Moreover, mobile penetration facilitates the expansion of informal and semi-formal digital employment, which may be more accessible to young women. Activities such as online retail, remote customer service, digital content creation, and administrative support are often compatible with flexible working arrangements. This helps explain why increases in mobile subscriptions significantly reduce female youth unemployment but have weaker effects on male youth unemployment.

The insignificant effect on male youth unemployment may be attributed to sectoral employment structures. Young men in ASEAN are more concentrated in traditional sectors—such as construction, heavy manufacturing, transportation, and agriculture—that rely less on mobile technology for recruitment and daily operations. Consequently, marginal increases in mobile access may not directly translate into greater employment opportunities for young men.

Overall, these findings suggest that mobile technology functions as a partial gender equalizer in ASEAN youth labor markets. As access to digital tools expands, employment gaps between young men and women may narrow, particularly through technology-enabled service and platform-based occupations. However, the benefits of mobile penetration depend critically on digital literacy and complementary skills. Without adequate capabilities, the employment effects of mobile technology remain limited.

From a policy perspective, these results underscore the importance of gender-responsive digital inclusion strategies. Expanding affordable mobile access should be accompanied by investments in digital skills training, support for digital entrepreneurship, and regulatory frameworks that protect platform workers—especially young women. Integrating labor-market, education, and digital-transformation policies is essential to fully harness the potential of mobile technology to reduce youth unemployment and promote inclusive growth in ASEAN.

Robustness check: AEC (MEA) dummy

The estimation results in Table 8 indicate that the MEA dummy variable has a negative, statistically significant effect on total youth unemployment, female youth unemployment, and male youth unemployment. This finding suggests that the post-implementation period of the ASEAN Economic Community (AEC), 2015–2023, is statistically associated with lower youth unemployment rates compared to the pre-AEC period (2000–2014).

Table 8. FMOLS using MEA dummy (robustness check)

Independent Variable	Model 1			Model 2			Model 3		
	yun (Total)	t-stat	SE	yun_female	t-stat	SE	yun_male	t-stat	SE
eg	-0.42	-3.21	0.13	-0.63	-4.47	0.14	-0.48	-3.20	0.15
fdi	-0.20	-2.18	0.09	-0.36	-3.29	0.11	-0.33	-2.72	0.12
to	-0.16	-1.98	0.08	-0.11	-1.63	0.07	-0.26	-2.86	0.09
lnICT2	-0.30	-2.48	0.12	-0.52	-3.97	0.13	-0.43	-2.25	0.19
lnber	0.17	2.45	0.07	0.35	3.85	0.09	0.14	2.73	0.05
lnICT1	-0.23	-2.05	0.11	-0.38	-3.15	0.12	-0.12	-1.99	0.06
MEA Dummy	-0.98	-4.26	0.23	-1.05	-3.89	0.27	-0.93	-3.57	0.26

From an economic perspective, the negative coefficient of the MEA dummy reflects structural adjustments in youth labor markets following the implementation of the AEC. Regional economic integration—through trade liberalization, increased investment flows, and stronger cross-border production networks—appears to have expanded labor demand for young workers, particularly in export-oriented manufacturing, modern services, and the digital economy. Although this effect is observed across genders, it is stronger for young women, as indicated by the larger coefficient in the female youth unemployment model.

The statistical significance of the MEA variable in the female model suggests that the AEC may have contributed to reducing structural barriers to labor market participation among young women. The expansion of service industries, labor-intensive manufacturing, and ICT-based employment—sectors that tend to be more gender-inclusive—has likely enhanced young women's access to employment. In addition, increased market liberalization and the growing presence of multinational enterprises during the post-AEC period may have promoted more formalized and skill-oriented employment practices, thereby facilitating greater integration of young women into regional labor markets.

Although the MEA coefficient for male youth unemployment is slightly smaller in magnitude than that for females, it remains negative and statistically significant. This indicates that the benefits of regional integration are not gender-exclusive, although young women appear to benefit relatively more from the structural transformation associated with the AEC (Listiana & Sariyani, 2024). The difference in magnitude may also reflect a gradual shift in employment opportunities from traditional to more modern, service-oriented sectors, which often absorb young women with secondary-level education.

Overall, these findings suggest that the ASEAN Economic Community has functioned as an effective regional policy framework for reducing youth unemployment in ASEAN, primarily through job creation, enhanced factor mobility, and expanded access to regional production networks (Pramesty & Kistanti, 2025). However, the sustainability of this impact depends critically on each member country’s ability to align its education system, vocational training programs, and labor market institutions with the evolving demands of regional economic integration. Without such alignment, the potential employment gains from the AEC may not be fully realized by young people

across the region.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study confirms that economic growth, foreign direct investment (FDI), digital infrastructure, and regional economic integration significantly reduce youth unemployment in ASEAN, while demographic pressure increases it. These findings indicate that expanding economic activity and attracting productive investment enhance labor demand for young workers across the region.

Trade openness also contributes to reducing youth unemployment, particularly among male youth, although its impact is weaker and not consistently significant for female youth. This pattern suggests persistent gender disparities in labor absorption within tradable sectors and highlights the importance of complementary gender-responsive labor market policies.

Digital infrastructure plays a pivotal role in lowering youth unemployment. Both fixed broadband and mobile cellular subscriptions are associated with reductions in youth unemployment rates, with broadband access exhibiting a stronger and more consistent effect across models. Reliable internet connectivity expands access to employment opportunities, education, and digital-based economic activities, particularly for young women who may face structural mobility constraints.

In contrast, fertility exerts a positive and statistically significant effect on youth unemployment, reflecting demographic pressures that increase the number of young entrants into the labor force. The adverse impact is more pronounced for female youth, underscoring the interaction between demographic dynamics and gender inequality. Moreover, the negative and significant coefficient of the ASEAN Economic Community (AEC/MEA) dummy variable indicates that the post-AEC period is associated with lower youth unemployment, suggesting that regional economic integration has contributed to improved youth labor market outcomes in ASEAN.

Recommendations

From a policy perspective, several implications emerge. ASEAN countries should prioritize sustaining inclusive, stable economic growth while attracting high-quality, labor-intensive FDI that creates broad-based employment opportunities for young people. Trade liberalization should be complemented by gender-responsive labor-market and human capital policies, particularly by strengthening technical and vocational education and training (TVET) in technology-oriented and export-related sectors to enhance young women's access to employment in tradable industries.

At the same time, accelerating digital infrastructure development should be accompanied by investments in digital literacy, job-matching platforms, and youth entrepreneurship programs to maximize the employment benefits of technological transformation. Managing demographic pressures through improved access to education and family planning services, alongside policies that promote female labor force participation, is also essential to achieving sustainable reductions in youth unemployment across the ASEAN region.

Beyond these policy implications, several limitations should be acknowledged. The analysis relies on aggregate macroeconomic indicators, which may not fully capture sectoral employment dynamics and industry-specific skill mismatches. ICT is proxied only by mobile and broadband subscriptions, which do not directly measure digital skills, platform participation, or the intensity of technology adoption at the firm level. In addition, the use of panel FMOLS focuses on long-run equilibrium relationships and does

not explicitly capture short-run dynamics or potential cross-country spillover effects within ASEAN.

Future research may extend this analysis by employing dynamic panel models, incorporating sector-specific employment data, or including institutional and human capital variables such as education quality, vocational alignment, and labor market regulations. Further investigation into digital skills readiness, participation in the platform economy, and gender-specific labor market barriers would also enrich understanding of how digital transformation and trade integration shape youth employment outcomes in ASEAN.

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CONFLICT OF INTEREST

The authors declare no conflict of interest

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