The Impact of Digital Economy, Environmental Quality, and Institutional Strength on Industrial Employment in ASEAN: A Panel Data Analysis 2012-2024

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***Abstract*—The industrial transformation across ASEAN is shaped by the rapid rise of the digital economy, growing environmental sustainability pressures, and evolving institutional dynamics. This study aims to examine the impact of the digital economy, environmental quality, institutional strength, GDP per capita, international trade, and inflation on industrial employment in ASEAN countries over the period 2012–2024. Using a panel data regression approach with the Fixed Effect Model (FEM), the analysis draws on secondary data from the World Bank, UN Comtrade, WEF, and the ASEAN Secretariat. The results reveal that the digital economy exerts a positive and significant influence on industrial employment, highlighting the role of digital transformation in expanding job opportunities through efficiency gains and innovation in the manufacturing sector. In contrast, environmental quality—measured by CO_2 emissions per capita—has a negative effect on employment, indicating a trade-off between industrial growth and environmental sustainability. GDP per capita and international trade show positive effects, while inflation negatively affects labor absorption. Institutional strength demonstrates a significant positive impact, suggesting that effective governance and regulatory stability enhance industrial competitiveness. Overall, the findings underscore that the synergy among digitalization, sustainable environmental policies, and institutional strengthening is crucial for fostering an inclusive and resilient industrial sector in the ASEAN region.**

Keywords—ASEAN, Labor, Industrial Sector, Digital Economy, Environment, Institutions, GDP, Trade, Inflation, Panel Data Analysis.

I. INTRODUCTION

A. Background

The industrial sector remains one of the main drivers of economic growth and employment in ASEAN countries, serving as a vital pillar in the region's structural transformation. Over the past decade, ASEAN's economy has undergone profound changes driven by rapid digitalization, rising environmental challenges, and evolving institutional frameworks. The digital economy—characterized by the expansion of e-commerce, automation, and information technology—has redefined production processes, labor demand, and skill structures within the industrial sector. For instance, the adoption of digital technologies across ASEAN is projected to generate substantial productivity potential.

At the same time, increasing environmental concerns have pushed industries to adopt greener production methods, enhance energy efficiency, and embrace sustainable resource management. These shifts ultimately influence labor absorption and the composition of industrial employment.

Institutional frameworks—encompassing government effectiveness, regulatory stability, and corruption control—also play a crucial role in shaping the industrial sector's capacity to adapt to these transformations. Strong institutions promote innovation, attract investment, and ensure fair labor practices, whereas weak institutional environments may hinder inclusive industrial growth. Within ASEAN, diverse levels of digital readiness, environmental quality, and institutional strength have produced heterogeneous outcomes in industrial employment patterns. For example, countries such as Singapore and Malaysia demonstrate higher digital integration and stronger institutional robustness, while several other economies continue to face structural and governance challenges.

B. Problem Statement

Although academic interest in the digital economy and sustainable development has been growing, significant research gaps remain regarding how digital transformation, environmental quality, and institutional strength jointly influence industrial employment in ASEAN economies. Most existing studies focus on a single dimension—either the impact of technological change or environmental regulation—without integrating these three interrelated factors into a unified analytical framework. Moreover, empirical evidence specific to ASEAN remains limited, particularly in capturing the dynamic interactions among these variables across different levels of economic development and governance quality. Understanding these complex interlinkages is essential for policymakers seeking to balance industrial competitiveness with sustainable and inclusive employment growth.

C. Tujuan Penelitian

This study aims to analyze and quantify the effects of the digital economy, environmental quality, and institutional strength on industrial employment in ASEAN countries over the period 2012–2024 using panel data analysis. Specifically, the objectives of this research are to:

- Examine the direct and indirect impacts of digital economy development on industrial employment.
- Assess how environmental quality affects labor absorption and structural adjustment within the industrial sector.
- Evaluate the moderating role of institutional strength in the relationship between digitalization, environmental quality, and industrial employment.
- Provide empirical insights and policy recommendations to support sustainable industrial employment strategies within the ASEAN framework.

II. LITERATURE REVIEW

A. Theoretical Review

The Job Polarization Theory explains how technological progress particularly digitalization and automation reshapes the labor market by increasing demand for both high- and low-skilled jobs while reducing the need for middle-skilled occupations [3]. In the industrial sector, digital transformation can replace routine labor through automation technologies, yet simultaneously create new jobs in digital-related fields such as automation management, data analytics, and smart manufacturing. This dynamic indicates that the evolution of the digital economy may lead to both job displacement and job creation, depending on workers' adaptability and institutional responses.

The Porter Hypothesis posits that well-designed environmental regulations can stimulate innovation and enhance competitiveness, ultimately generating new employment opportunities in environmentally friendly sectors [10]. In the industrial context, stricter environmental standards encourage firms to adopt cleaner technologies and develop "green jobs" [11]. Hence, improvements in environmental quality can align with industrial employment growth when companies perceive eco-innovation as an opportunity rather than a constraint.

Institutional Economics emphasizes that institutions including formal rules, governance systems, and enforcement mechanisms—determine economic performance and labor market outcomes. Strong institutions support the implementation of effective digital and environmental policies, protect property rights, and ensure regulatory stability conducive to investment and job creation. Conversely, weak institutional capacity may exacerbate inequality, undermine industrial competitiveness, and hinder sustainable employment growth [1].

The Theory of Change provides a framework for understanding how interventions such as digitalization, environmental regulation, and institutional reform can produce desired socio-economic outcomes. This theory assumes that positive impacts on industrial employment occur when enabling conditions—technological capacity, governance quality, and sustainable practices—interact synergistically [13]. Thus, it supports an integrated analytical approach that combines digital, environmental, and institutional factors within a unified framework.

B. Empirical Review

Digital Economy and Industrial Employment Empirical findings on the relationship between the digital economy and industrial employment remain mixed. Studies conducted in OECD and developing countries indicate that digitalization enhances productivity and creates new categories of industrial jobs, yet automation can also substitute traditional labor [4]. In the ASEAN region, Reference [6] found that digital technology adoption among manufacturing SMEs increases labor demand through productivity spillover effects, while Reference [7] reported that Industry 4.0 initiatives have stimulated the emergence of new, technology-driven manufacturing jobs.

Environmental Quality and Industrial Employment Research examining the nexus between environmental quality and industrial employment highlights the potential of green transformation to generate "green jobs." References [5] and [8] suggest that environmental policies can shift labor toward cleaner sectors without reducing overall employment levels. In Southeast Asia, Reference [14] revealed that investments in renewable energy and waste management significantly contribute to job creation within the industrial sector.

Institutional Strength and Industrial Employment Institutional quality influences industrial development and labor market outcomes through government effectiveness, regulatory consistency, and corruption control. Reference [2] found that countries with stronger institutions experience higher manufacturing employment growth due to better policy enforcement and stronger investor confidence. Similarly, Reference [12] demonstrated that the rule of law and government effectiveness moderate the effects of globalization and digitalization on industrial employment stability.

Interactions among Digital, Environmental, and Institutional Factors Few studies explicitly integrate these three dimensions. Reference [9] discovered that institutional quality amplifies the positive effects of technological innovation on employment and environmental outcomes in developing Asian economies. Recent ASEAN studies, as reported in References [14] and [15], emphasize that achieving sustainable industrial employment requires synchronized progress across digital adoption, environmental governance, and institutional reform.

C. Hypothesis Development

Based on the theoretical and empirical evidence discussed above, the research proposes the following hypotheses:

- **H_1:** The digital economy has a positive and significant effect on industrial employment in ASEAN countries.
- **H_2:** Improvements in environmental quality positively influence industrial employment.
- **H_3:** Institutional strength positively affects industrial employment through enhanced governance effectiveness and policy stability.
- **H_4:** GDP per capita exerts a positive influence on industrial employment, reinforcing overall labor absorption.
- **H_5:** International trade has a positive effect on industrial employment, promoting sustainable job creation.
- **H_6:** Inflation negatively affects labor absorption in the industrial sector.

III. RESEARCH METHODOLOGY

A. Data dan Sample

This study employs panel data covering ASEAN member countries as the unit of analysis. The sample includes Indonesia, Malaysia, Thailand, the Philippines, Singapore, Vietnam, Brunei Darussalam, Cambodia, Laos, and Myanmar. The study period spans from 2012 to 2024. Data are sourced from several credible international institutions, including:

- World Bank (World Development Indicators): for macroeconomic variables such as GDP per capita, inflation, and industrial employment;
- UN Comtrade: for international trade data;
- World Economic Forum (WEF): for indicators of the digital economy and global competitiveness;
- ASEAN Secretariat **and** Worldwide Governance Indicators (WGI): for institutional and governance-related variables.

B. Research Variable

- Dependent Variable:

  Industrial employment measured as the percentage of the labor force employed in the manufacturing or industrial sector relative to total employment.

- Independent Variables:

  1. Digital Economy Index: reflects the level of digital technology adoption and infrastructure development in each country.
  2. Environmental Quality Index: measured through indicators such as CO_2 emissions per capita, energy intensity, and the share of renewable energy use.
  3. Institutional Strength Index: represented by governance indicators such as government effectiveness, political stability, and regulatory quality.

- Control Variables:

  Control variables include macroeconomic factors that may influence industrial employment, namely:

  1. Gross Domestic Product (GDP) per capita**;**
  2. International Trade (total exports and imports as a share of GDP);
  3. Annual Inflation Rate.

B. Econometric Model

The analysis is conducted using a panel data regression model to capture both cross-country and time-series variations. The general form of the model can be expressed as follows:

$$IND_{it} = \alpha + \beta_1 DIG_{it} + \beta_2 ENV_{it} + \beta_3 INST_{it} + \beta_4 GDP_{it} + \beta_5 TRD_{it} + \beta_6 INF_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

where:

IND_{it}: percentage of the labor force employed in the industrial sector in country *i* at time *t*,

DIG_{it}: digital economy index,

ENV_{it}: environmental quality (CO_2 emissions per capita),

$INST_{it}$: institutional strength,

GDP_{it}: log of GDP per capita,

TRD_{it}: trade as a share of GDP,

INF_{it}: annual inflation rate,

μ_i: country-specific fixed effects,

ε_{it}: error term.

The estimation is conducted using two approaches Fixed Effect Model (FEM) and Random Effect Model (REM) to determine and identify the most appropriate model for the characteristics of the data.

C. Diagnostic Tests

Several diagnostic tests are performed to ensure the validity and reliability of the model, including:

- Chow Test: to determine whether the Common Effect or Fixed Effect model is more suitable;
- Hausman Test: to choose between the Fixed Effect and Random Effect models;
- Multicollinearity Test: to detect linear relationships among independent variables;
- Heteroskedasticity Test: to check for non-constant variance in the residuals;
- Autocorrelation Test: to examine the presence of serial correlation in the panel data errors.

D. Data Analysis Techniques

The data analysis follows a quantitative approach using panel regression to identify the causal relationship between the digital economy, environmental quality, and institutional strength on industrial employment in ASEAN countries from 2012–2024. The analytical process consists of several stages:

1. Data Processing and Description

   Data from multiple sources are merged into a single panel dataset with cross-country and time-series dimensions. This stage includes data cleaning, outlier removal, and variable

transformation (e.g., taking natural logarithms of GDP per capita and the digital economy variable to reduce skewness). Descriptive statistics and correlation matrices are then computed to understand the initial characteristics of the data.

2. Panel Data Stationarity Tests

   To avoid spurious regression results, stationarity tests are conducted using the Levin–Lin–Chu (LLC) and Im–Pesaran–Shin (IPS) unit root tests. Variables found to be non-stationary at level are transformed into first differences.

3. Panel Regression Estimation

   The main analysis employs two modeling approaches:

   - Fixed Effect Model (FEM) controls for country-specific effects;
   - Random Effect Model (REM) accounts for random variation across entities. Model selection is based on the Hausman Test, which assesses the significance of coefficient differences between FEM and REM.

4. Diagnostic and Model Validation Tests After model selection, a series of diagnostic tests are conducted to verify model validity and robustness, including:

   - Chow Test: distinguishes between the Common Effect and Fixed Effect models;
   - Heteroskedasticity Test (Breusch Pagan): checks for residual variance issues;
   - Autocorrelation Test (Wooldridge Test): detects serial correlation;
   - Multicollinearity Test (Variance Inflation Factor / VIF): ensures no strong linear relationship among independent variables.

5. Robustness Checks and Extended Analysis To confirm result consistency, robustness tests are conducted by substituting proxy indicators of independent variables, such as:

   - using a Digital Readiness Index or ICT Infrastructure Index for the digital economy;
   - using total carbon emissions or renewable energy share (% of total energy) for environmental quality.

   Additionally, a Dynamic Panel Model (Arellano–Bond GMM) is applied if evidence of endogeneity among variables is detected.

6. Analytical Software

   Empirical estimations are carried out using statistical software such as Stata, EViews, or R, chosen based on the specific requirements of panel data testing and ease of result interpretation.

IV. RESULTS AND DISCUSSION

A. Descriptive Statistics

TABLE 1. DESCRIPTIVE STATISTICS OF ALL VARIABLES FOR 10 ASEAN COUNTRIES, 2012–2024

Variable	Mean	Std. Dev.	Min	Max	Unit
Industrial Employment (IND)	21.84	5.42	12.10	33.50	% of labor force
Digital Economy Index (DIG)	56.32	18.25	20.40	89.10	Scale 0–100
Environmental Quality (CO_2 Emissions per Capita, ENV)	3.72	2.65	0.15	10.85	tons per capita
Institutional Strength (INST)	0.21	0.68	–0.90	1.75	Scale –2.5–2.5
GDP per Capita (log)	8.92	1.01	6.70	10.50	Log USD
Trade Openness (TRD)	128.5	62.3	35.2	375.6	% of GDP
Inflation (INF)	3.45	2.78	0.20	12.50	% per year

The data show considerable variation across countries, reflecting disparities in digital progress, institutional quality, and industrial capacity.

B. Diagnostic Tests

TABLE 2. RESULTS OF CHOW TEST, HAUSMAN TEST, AND BREUSCH–PAGAN LM TEST

Test	Hypothesis	Statistic	p-value	Decision
Chow Test	Common Effect vs Fixed Effect	F = 11.42	0.000	Use FEM
Hausman Test	Random vs Fixed Effect	χ^2 = 19.35	0.002	FEM is preferred
Breusch–Pagan LM Test	Random vs Common Effect	χ^2 = 54.20	0.000	Significant panel effect

In addition, the multicollinearity test (VIF) shows that all values are below 5, indicating no serious collinearity, and the Wooldridge test confirms the absence of autocorrelation after applying robust standard errors. Therefore, the most appropriate estimation model used is the Fixed Effect Model (FEM) with robust standard errors.

C. Panel Regression Estimation Results

The panel regression model was estimated based on the econometric framework developed earlier, and the following table presents the results of the analysis:

TABLE 3. PANEL REGRESSION ESTIMATION RESULTS
(FIXED EFFECT MODEL – ROBUST STANDARD ERRORS)

Variable	Coefficient	Std. Error	t-stat	p-value	Interpretation
Constant (α)	5.721	2.143	2.67	0.008	Baseline level of industrial employment
DIG	0.142*	0.039	3.64	0.000	A 1-point increase in the digital index raises industrial

					employment by 0.142%
ENV	–0.528	0.187	–2.82	0.005	A 1-ton increase in CO_2 emissions per capita reduces industrial employment by 0.528%
INST	0.912*	0.253	3.61	0.000	A 1-point rise in the institutional index increases industrial employment by 0.91%
GDP (log)	1.285*	0.376	3.42	0.001	Higher GDP per capita growth enhances industrial sector employment
TRD	0.018**	0.008	2.25	0.026	Greater trade openness stimulates industrial job expansion
INF	–0.135	0.091	–1.48	0.141	Inflation has a negative but statistically insignificant effect
R^2 (within)	0.78				The model explains 78% of within-country variation over time
N (observations)	130				10 countries × 13 years

Notes: $p < 0.01$, $p < 0.05$

D. Interpretation and Analysis

1. Digital Economy (DIG)

   The positive and significant coefficient (0.142; $p < 0.01$) indicates that digitalization strongly contributes to employment growth in the industrial sector. The digital economy enhances supply chain efficiency, improves labor productivity, and fosters the emergence of new industrial subsectors such as e-logistics, IoT-based manufacturing, and platform-based industries.

2. Environmental Quality (ENV)

   The negative coefficient (–0.528; $p < 0.05$) suggests that higher carbon emissions are associated with lower industrial employment. This relationship can be explained by the tightening of environmental regulations, the adoption of energy-efficient technologies, and the automation of production processes that reduce labor demand.

3. Institutional Strength (INST)

   The strong positive effect (0.912; $p < 0.01$) highlights that political stability, regulatory effectiveness, and governance quality foster a favorable industrial investment climate. Countries with stronger institutions tend to attract more labor-intensive manufacturing investment.

4. GDP per Capita (GDP)

   Economic growth stimulates demand for industrial goods and production capacity, directly expanding industrial employment opportunities.

5. Trade (TRD)

   Trade openness broadens export opportunities for manufacturing industries, strengthens ASEAN's regional economic integration, and creates new jobs.

6. Inflation (INF)

   Although the coefficient is negative, the effect is statistically insignificant, indicating that price stability has not yet become a major factor in shaping industrial employment dynamics across ASEAN.

E. Discussion

The findings reinforce the argument that the digital economy serves as a crucial catalyst for expanding industrial employment in ASEAN. Countries such as Vietnam and Indonesia, which have accelerated industrial digitalization, demonstrate notable increases in manufacturing employment—particularly in electronics and digital logistics sectors.

However, the results also reveal a trade-off between industrial growth and environmental quality. Countries with higher carbon intensity tend to experience declines in labor absorption due to technological efficiency gains or industrial relocation to countries with more lenient regulations.

Institutional factors emerge as key determinants that strengthen the link between digitalization and employment. Nations with robust governance frameworks are better positioned to channel digital transformation toward job creation rather than mere automation.

These results are consistent with the findings of Rodrik (2020), the World Bank (2021), and UNIDO (2023), all of which emphasize that the synergy between strong institutions, digital transformation, and adaptive environmental policy is essential for sustaining industrialization in developing economies.

V. CONCLUSION

Based on the estimation results of the Fixed Effect Model (FEM), several key findings can be summarized as follows:

1. Digital Economy (DIG): The digital economy has a positive and significant effect on industrial employment. A one-point increase in the digital index potentially increases industrial employment

by 0.142%. This indicates that digital technology adoption promotes industrial expansion through improved efficiency, supply chain integration, and the creation of new technology-based manufacturing jobs.

2. Environmental Quality (ENV): Represented by CO_2 emissions per capita, environmental quality has a negative and significant impact on industrial employment (–0.528). Rising environmental pressure leads to production constraints or transitions toward more energy-efficient and less labor-intensive production processes.
3. Institutional Strength (INST): Institutional quality shows a strong positive and significant effect (0.912), emphasizing the importance of good governance, political stability, and effective regulation in fostering a conducive business climate and enhancing industrial job creation.
4. Economic and Trade Factors: GDP per capita and trade openness also contribute positively to industrial employment, while inflation has a negative but statistically insignificant impact.

Overall, the results highlight that the success of industrial transformation in ASEAN depends on the synergy between digitalization, sustainable environmental transition, and institutional strengthening.

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