

CONDITIONAL CONVERGENCE OF GDP PER CAPITA ACROSS VIETNAMESE PROVINCES: A SYSTEM GMM APPROACH

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ABSTRACT

Achieving long-term and sustainable economic development in developing countries requires overcoming the middle-income trap. This challenge is particularly important for transition economies seeking to promote balanced development across regions. This study applies the System Generalized Method of Moments (SYS-GMM) estimator to examine income convergence across Vietnam's 63 provinces and centrally governed cities. The empirical results provide no statistically significant evidence of absolute convergence among the examined localities. However, strong evidence of conditional convergence is identified. The estimated annual rate of conditional convergence is 3.08%, indicating that approximately 22.53 years would be required for provinces and cities to reduce by half the gap between their current income levels and their respective steady-state equilibria. The findings further suggest that accelerating economic growth requires substantial progress in industrial development. Nevertheless, such development should be aligned with Vietnam's long-term Net Zero commitments and accompanied by effective population policies, as higher population growth is found to have a negative effect on per capita economic growth.

Keywords: *economic convergence, Barro model, Vietnam, industrial development, population growth, GDP per capita*

1. INTRODUCTION

Vietnam is a Southeast Asian country that has made sustained efforts to transform itself from a low-income economy into a more prosperous and market-oriented society. Following approximately four decades of the Doi Moi economic renovation programme, which facilitated the transition from a centrally planned system to a market-oriented economy, Vietnam has achieved considerable economic and social progress. Vietnam is a developing country, transitioning towards upper-middle-income status, and is one of the fastest-growing e-commerce markets ([World Bank, 2026](#); [Fitrianti et al., 2026](#); [Shojaei et al., 2026](#)). Its annual GDP growth rate has remained relatively high, placing the country among the world's faster-growing economies. In 2023, Vietnam recorded a GDP growth rate of 5.05%, while the overall size of the economy had expanded approximately thirtyfold compared with three decades earlier.

Vietnam's economic structure has also undergone a significant transformation, gradually shifting away from agriculture, forestry, and fisheries toward industry and services. According to the National Statistics Office, based on GDP measured at constant 2010 prices, agriculture,

forestry, and fisheries accounted for approximately 10% of GDP in 2023. Industry contributed around 30%, while services represented approximately 44%. The remaining share consisted primarily of construction and product taxes less subsidies.

Industrial production plays a central role in Vietnam's economic development. The expansion of industrial activities stimulates demand for machinery, equipment, advanced technologies, and more efficient production processes. These developments contribute to the creation of new productive capacity, improvements in labour productivity, and the modernisation of the national economy. Industrial development can therefore be regarded as one of the principal drivers of sustained economic growth.

Nevertheless, rapid economic growth may be accompanied by widening income disparities across regions. Such disparities may be reflected in an increasing standard deviation of provincial GDP per capita or in persistent differences between economically advanced and less-developed regions (Phan & Coxhead, 2010; Vu, Hoang, & Nghiem, 2018; Nguyen, 2024). Examining economic convergence and the determinants of provincial growth is therefore important not only for promoting social equity and addressing the middle-income trap, but also for identifying sustainable sources of long-term development.

The growth framework developed by Barro and Sala-i-Martin (1990) provides one of the most widely used approaches for examining economic convergence. Analysing subnational regions within a single country offers several methodological advantages. Provinces and cities operate under a common legal and institutional framework, use the same currency, share broadly similar cultural and linguistic characteristics, and face few internal barriers to trade and factor mobility. In addition, statistical information is generally collected according to uniform national standards. National and international shocks, such as the COVID-19 pandemic, changes in energy prices, or fluctuations in external demand, are also likely to affect provinces within the same country through broadly comparable transmission mechanisms. These characteristics make Vietnam's provinces and centrally governed cities an appropriate setting for assessing regional income convergence using the Barro regression framework.

Economic growth is inherently dynamic, as present economic performance is partly influenced by past income and growth levels. Furthermore, several explanatory variables may be endogenous because economic growth can simultaneously influence, and be influenced by, investment, industrial development, population dynamics, and other structural factors. Under these conditions, conventional estimation techniques, including Ordinary Least Squares and standard fixed-effects estimators, may produce biased and inconsistent coefficients, particularly in panels with a relatively short time dimension (Nickell, 1981).

To address these methodological challenges, this study applies the System Generalized Method of Moments estimator for dynamic panel data. SYS-GMM combines equations expressed in first differences with equations estimated in levels and uses appropriate internal instruments to address unobserved heterogeneity, simultaneity, endogeneity, and the dynamic structure of the convergence model. Subject to the validity of the selected instruments and diagnostic tests, this approach can provide more consistent and reliable estimates than conventional static panel methods.

This study contributes to the existing literature in several respects. First, it provides updated empirical evidence on absolute and conditional income convergence across all 63 provinces and centrally governed cities in Vietnam. Second, it applies a dynamic panel-data framework that accounts for the persistence of provincial income and the potential endogeneity of its determinants. Third, it evaluates the roles of industrial development and population growth in shaping regional economic performance. Finally, it draws policy implications concerning the relationship between industrialisation, balanced regional development, population dynamics,

and Vietnam's long-term environmental commitments.

The remainder of the paper is organised as follows. Section 2 reviews the theoretical and empirical literature on economic growth and regional convergence. Section 3 presents the empirical model, describes the dataset and variables, explains the estimation methodology, and reports the results for Vietnam's 63 provinces and cities. Section 4 concludes the study and presents the principal policy recommendations.

2. LITERATURE REVIEW

2.1. THEORETICAL FOUNDATIONS OF ECONOMIC GROWTH AND CONVERGENCE

The foundations of modern economic growth theory can be traced to [Ramsey \(1928\)](#), who developed an intertemporal model in which households determine optimal levels of consumption and saving over time. Although Ramsey's contribution provided an important theoretical basis for the analysis of capital accumulation and long-run growth, its broader application remained limited until the development of neoclassical growth theory during the 1950s.

[Solow \(1956\)](#) and [Swan \(1956\)](#) subsequently developed the neoclassical growth model, in which output is determined by capital and labour, commonly represented through a Cobb–Douglas production function characterised by constant returns to scale and diminishing marginal returns to individual production factors. In the basic Solow–Swan framework, the saving rate, population growth rate, and rate of technological progress are treated as exogenous. The economy gradually moves toward a steady-state equilibrium in which capital per worker and output per worker stabilise.

One of the central implications of the Solow–Swan model is that economies with lower initial levels of capital and income per capita may grow faster than wealthier economies because of the diminishing marginal productivity of capital. This mechanism provides the theoretical foundation for the concept of economic convergence. However, in the absence of sustained technological progress, long-run growth in output per capita eventually approaches zero once the economy reaches its steady state. Continuous improvements in technology are therefore necessary to support sustained increases in living standards over the long term.

[Harrod \(1937\)](#) argued that if the ratio between average output per unit of labor and average capital per unit of labor is the same before and after technological change, then the marginal values of output with respect to average capital must also remain constant, in which case the production function takes the following general form:

$$Y(t) = F(K(t); L(t); A(t)) = F[K(t); L(t).A(t)] \quad (1)$$

Where $K(t)$, $L(t)$, $A(t)$ are capital, labor, and technology at time t , respectively.

Let $Y/L = y$ represent output per unit of labor, and $K/L = k$ denote capital per unit of labor. Applying the neoclassical theory of Solow and Swan, substituting into above equation, we obtain

$$y = F(k; A) \quad (2)$$

Let s be the investment rate, δ be the depreciation rate of capital:

$$K'_t = I(t) - \delta K(t) = s.Y(t) - \delta K(t) = sF(K; L.A) - \delta K(t) \quad (3)$$

$$\Rightarrow k'(t) = \frac{dk}{dt} = \frac{d(K/L)}{dt} = \frac{K'.L - K.L'}{L^2} = \frac{K'}{L} - \frac{K}{L} \cdot \frac{L'}{L} \quad (4)$$

Let the labor force growth rate be n and $x = \frac{A'}{A}$ be the growth rate of technology, combine the two equations above, it follows that:

$$\dot{k}' = [sF(k; A) - \delta k] - k.n = sF(k; A) - (\delta + n)k \quad (5)$$

Let $\tilde{y} = \frac{Y}{L.A} = \frac{y}{A}$ be output per unit of effective labor:

$$\tilde{y} = \frac{1}{A} F(k; A) = F\left(\frac{k}{A}; 1\right) = f\left(\frac{k}{A}\right) = f(\tilde{k}) \quad (6)$$

Where $\tilde{k} = \frac{K}{L.A} = \frac{k}{A}$ is average capital per unit of effective labor. Combining (5) and (6), we have:

$$\tilde{k}' = sf(\tilde{k}) - (n + x + \delta)\tilde{k} \quad (7)$$

Therefore, the economy is in a steady state when $\tilde{k}' = 0$

$$\Rightarrow sf(\tilde{k}) - (n + x + \delta)\tilde{k} = 0 \quad (8)$$

Let $\tilde{k}^*$ be the solution to equation (8), then $\tilde{k} = \text{const} = \tilde{k}^*$

$$\text{From equation (7)} \Rightarrow \frac{\tilde{k}'}{\tilde{k}} = s \frac{f(\tilde{k})}{\tilde{k}} - (n + x + \delta) \quad (9)$$

Take the logarithm of both sides of equation (6) and differentiating with respect to t yields:

$$\frac{\tilde{y}'}{\tilde{y}} = \frac{\partial f(\tilde{k}) / \partial t}{f(\tilde{k})} = \frac{\frac{df(\tilde{k})}{d\tilde{k}} \cdot \frac{d\tilde{k}}{dt}}{f(\tilde{k})} = \frac{f'(\tilde{k})}{f(\tilde{k})} \cdot \tilde{k}' = \frac{\tilde{k}f'(\tilde{k})}{f(\tilde{k})} \cdot \frac{\tilde{k}'}{\tilde{k}} = Sh(\tilde{k}) \cdot \frac{\tilde{k}'}{\tilde{k}} \quad (10)$$

$$(\text{Where } Sh(\tilde{k}) = \frac{\tilde{k}f'(\tilde{k})}{f(\tilde{k})})$$

Substitute (9) into the above equation, we obtain:

$$\frac{\tilde{y}'}{\tilde{y}} = Sh(\tilde{k}) \cdot [s \frac{f(\tilde{k})}{\tilde{k}} - (n + x + \delta)] = Sh(\tilde{k}) \cdot s \cdot \frac{f(\tilde{k})}{\tilde{k}} - (n + x + \delta)Sh(\tilde{k}) \quad (11)$$

$$\Leftrightarrow \frac{\tilde{y}'}{\tilde{y}} = sf'(\tilde{k}) - (n + x + \delta)Sh(\tilde{k}) \quad (12)$$

$$\text{On the other hand, } y = \frac{Y}{L} = \tilde{y} \cdot A \Rightarrow \frac{y'}{y} = \frac{(\tilde{y}A)'}{\tilde{y}A} = \frac{\tilde{y}'A + A'\tilde{y}}{\tilde{y}A} = \frac{\tilde{y}'}{\tilde{y}} + \frac{A'}{A} = \frac{\tilde{y}'}{\tilde{y}} + x \quad (13)$$

Substituting from equation (12) into (13) gives:

$$\frac{y'}{y} = x + sf'(\tilde{k}) - (n + x + \delta)Sh(\tilde{k}) \quad (14)$$

Consider a Cobb–Douglas production function: $Y = K^\alpha (LA)^{1-\alpha}$

$$\Rightarrow \frac{y'}{y} = x + s \cdot \alpha \cdot A^{\frac{1-\alpha}{\alpha}} \cdot e^{\frac{\alpha-1}{\alpha} \ln y} - (n + x + \delta)\alpha \quad (15)$$

Consider the function $G(\ln y; A)$:

$$G(\ln y; A) = s \cdot \alpha \cdot A^{\frac{1-\alpha}{\alpha}} \cdot e^{\frac{\alpha-1}{\alpha} \ln y} - (n + x + \delta)\alpha = \alpha \cdot [s \cdot A^{\frac{1-\alpha}{\alpha}} \cdot e^{\frac{\alpha-1}{\alpha} \ln y} - (n + x + \delta)] \quad (16)$$

Expanding the above function as a Taylor series around $(\ln y^*; T)$, where

$y^* = A \cdot \tilde{y}^* = A \cdot f(\tilde{k}^*)$ with $\tilde{k}^*$ being the solution to equation (8), we obtain:

$$G(\ln y; A) \approx G(\ln y^*; A) + G'_{\ln y}(\ln y^*; A) \cdot (\ln y - \ln y^*) \quad (17)$$

Since $\tilde{k}^*$ is the solution to equation (8) therefore $G(\ln y^*; A) = 0$

$$G'_{\ln y}(\ln y^*; A) = s \cdot \alpha \cdot A^{\frac{1-\alpha}{\alpha}} \cdot e^{\frac{\alpha-1}{\alpha} \ln y^*} \cdot \frac{\alpha-1}{\alpha} = (\alpha-1) \cdot s \cdot (\tilde{k}^*)^{\alpha-1} = (\alpha-1) \cdot \frac{sf(\tilde{k}^*)}{\tilde{k}^*} \quad (18)$$

Substituting from (8) into the above equation:

$$G'_{\ln y}(\ln y^*; A) = (\alpha-1) \cdot (x+n+\delta) \quad (19)$$

Substituting (19) into equation (17):

$$G(\ln y; A) \approx (\alpha-1) \cdot (x+n+\delta) \cdot (\ln y - \ln y^*) \quad (20)$$

$$\text{Substituting into equation (15)} \Rightarrow \frac{y'}{y} = x + (\alpha-1)(x+n+\delta)(\ln y - \ln y^*) \quad (21)$$

$$\text{Let } \lambda = (1-\alpha) \cdot (x+n+\delta) \Rightarrow \frac{y'}{y} = x - \lambda(\ln y - \ln y^*) \quad (22)$$

- When $y = y^*$, the economy is in a steady state, and the growth rate of y is exactly the growth rate x of technology.
- With $\lambda > 0$, when $y > y^*$, the growth rate of y is lower than the growth rate of technology, but when $y < y^*$, the growth rate of y is higher than x . This explains why, under the same level of technology, regions with lower income experience higher growth rates.

From the equation (22) and $\frac{y'}{y} = \frac{d(\ln y)}{dt} \approx \ln y_{t+1} - \ln y_t$

$$\Rightarrow \ln y_{t+1} = (x + \lambda \ln y_t^*) + (1-\lambda) \ln y_t \quad (23)$$

$$\Leftrightarrow \ln(A_{t+1} \tilde{y}_{t+1}) = [x + \lambda \ln(A_t \tilde{y}_t^*)] + (1-\lambda) \ln(A_t \tilde{y}_t) \quad (24)$$

$$\Leftrightarrow \ln \tilde{y}_{t+1} = x + \lambda \ln \tilde{y}_t^* + (1-\lambda) \ln \tilde{y}_t - \ln(x+1) \text{ (since technology grows at rate } x) \quad (25)$$

On the other hand, when x is small, $\ln(1+x) \approx x$, substituting into the above equation, we obtain:

$$\ln \tilde{y}_{t+1} = (1-\lambda) \ln \tilde{y}_t + \lambda \ln \tilde{y}_t^* \quad (26)$$

Since $\tilde{y}^* = (\tilde{k}^*)^\alpha$ with $k^* = \text{const}$, therefore $\tilde{y}_t^* = \text{const} = \tilde{y}^* = \tilde{y}_0^*$, substituting into the above equation, we have:

$$\ln \tilde{y}_{t+1} = (1-\lambda) \ln \tilde{y}_t + \lambda \ln \tilde{y}_0^* \quad (27)$$

Applying to the solution form of the difference equation (27), we obtain:

$$\ln \tilde{y}_t = e^{-\lambda t} \ln \tilde{y}_0 + (1-e^{-\lambda t}) \ln \tilde{y}_0^* \quad (28)$$

$$\Rightarrow \ln \frac{y_t}{A_t} = e^{-\lambda t} \ln \frac{y_0}{A_0} + (1-e^{-\lambda t}) \ln \frac{y_0^*}{A_0} \quad (29)$$

$$\Rightarrow \ln y_t = e^{-\lambda t} \ln y_0 + (1-e^{-\lambda t}) \ln y_0^* + xt \quad (30)$$

$$\Rightarrow \frac{\ln y_t - \ln y_0}{t} = x - \frac{e^{-\lambda t} - 1}{t} \ln y_0^* + \frac{e^{-\lambda t} - 1}{t} \ln y_0 \quad (31)$$

Setting $t = \text{constant} = T$, we have:

$$\frac{\ln y_T - \ln y_0}{T} = x - \frac{e^{-\lambda T} - 1}{T} \ln y_0^* + \frac{e^{-\lambda T} - 1}{T} \ln y_0 \quad (32)$$

Since $x - \frac{e^{-\lambda T} - 1}{T} \ln y_0^* = \text{const} = \beta_0$; $\frac{e^{-\lambda T} - 1}{T} = \text{const} = \beta_1$

$$\Rightarrow \frac{1}{T} \ln \left(\frac{y_T}{y_0} \right) = \beta_0 + \beta_1 \ln y_0 \quad (33)$$

For N countries sharing the same steady state:

$$\frac{1}{T} \ln \left(\frac{y_{i,T}}{y_{i,0}} \right) = \beta_0 + \beta_1 \ln y_{i,0} + \varepsilon_{i,0} \quad \text{with } \beta_1 < 0 \text{ and } \varepsilon_{i,0} \text{ distributed as } N(0; \sigma^2) \quad (34)$$

The regression from equation (34) is precisely the Barro regression proposed by **Barro and Sala-i-Martin (1990)**, where technology is treated as an endogenous variable. From the original Barro regression, according to **Sala-i-Martin (2002)**, economists have developed an extended form of the Barro regression as follows:

$$\gamma_{i,t,t+T} = \beta X_{i,t} + \varepsilon_{i,t}$$

Where $\gamma_{i,t,t+T} = \frac{1}{T} \ln \left(\frac{y_{i,t+T}}{y_{i,t}} \right)$ is the average growth rate over the period from t to $t+T$;

the variables $X_{i,t}$ reflect the determinants of long-term growth.

Many other studies, such as those by **Mankiw, Romer and Weil (1992)**, **Islam (1995)**, **Caselli, Esquivel and Lefort (1996)**, **Hoeffler (2000)**, **Bond, Hoeffler and Temple (2001)** employ the Barro regression form:

$$\gamma_{i,t} = \beta_0 + \beta_1 \ln y_{i,t-1} + \beta_2 X_{i,t} + \eta_i + v_{i,t} \quad (35)$$

Where:

$\gamma_{i,t}$ is the average growth rate in each period.

$y_{i,t-1}$ is the initial output value at the beginning of the period.

$\varepsilon_{i,t} = \eta_i + v_{i,t}$ is the error term with $E(\eta_i) = E(v_{i,t}) = E(\eta_i, v_{i,t}) = 0$

Previous studies employing conventional econometric techniques, including Ordinary Least Squares, fixed-effects, and random-effects estimators, have generally identified conditional convergence rates of approximately 2% per year.

Barro and Sala-i-Martin (1992) examined income convergence across 48 US states using personal income data extending back to 1840 and gross state product data available from 1963 onward. Their analysis was based on cross-sectional datasets constructed for different sub-periods. When personal income was used as the dependent variable, the estimated convergence parameter, λ , for the longest period, 1880–1988, based on 47 observations, was 0.0175. The results also revealed a strong negative relationship between the average growth rate and the logarithm of initial income, with an estimated coefficient of -0.93, providing evidence of income convergence.

In the specification based on per capita gross state product, calculated by deflating nominal GSP and dividing it by population, the estimated λ coefficient varied considerably across sub-periods. It ranged from -0.0285 during 1975-1981 to 0.1130 during 1981–1986. The change in

both the magnitude and sign of the coefficient suggests that the convergence process was unstable and not robust across all periods. However, once differences in sectoral structure were incorporated into the model, the study concluded that both personal income and per capita GSP exhibited conditional convergence, provided that sectoral composition remained stable. For five- or six-year periods, the estimated annual convergence rate of per capita GSP ranged from 1.57% to 2.97%, with an average rate of approximately 2.22% over the 1963–1986 period.

Mankiw, Romer, and Weil (1992) examined several groups of countries, including oil-producing economies, an intermediate sample of countries, and 22 OECD members over the period 1960–1985. Their augmented neoclassical growth model provided evidence of conditional convergence, with estimated annual convergence rates ranging from 1.37% to 2.03%.

Latzko (2002) analysed income convergence across counties in Pennsylvania. These sub-regional units operated under relatively homogeneous conditions, including similar institutional arrangements, market access, and socioeconomic environments. The empirical analysis found no evidence of absolute convergence in per capita income. Nevertheless, the fixed-effects estimates indicated conditional convergence at an annual rate of approximately 2%.

Bonnefond (2013) investigated regional convergence in China using panel data for 29 provinces and centrally governed cities over the period 1995–2009. Applying the system GMM estimator developed by **Blundell and Bond (1998)**, the study found strong evidence of conditional convergence. The estimated speed of convergence increased substantially after 2004, which the author associated with government policies aimed at reducing regional disparities. Depending on the model specification, the annual convergence rate ranged from approximately 3.4% to 7.0% for the full 1995–2009 period and from 4.1% to 7.4% for the 2004–2009 sub-period.

Caselli, Esquivel, and Lefort (1996) estimated several cross-country growth regressions using the difference GMM estimator introduced by **Arellano and Bond (1991)**. Their findings suggested that per capita income converged toward its steady state at a rate of approximately 10% per year. This estimate was substantially higher than the frequently reported convergence rate of around 2%, indicating that the estimated speed of convergence is highly sensitive to the econometric methodology employed.

Similarly, **Eftimoski (2020)** applied GMM estimation to a sample of 20 countries in Central, Eastern, and Southeastern Europe. The results supported the existence of absolute convergence among the examined economies. The conditional convergence specification further indicated an annual convergence rate of approximately 2.8%.

The sensitivity of convergence estimates to methodological choices was also demonstrated by **Abreu, de Groot, and Florax (2005)**. Their meta-analysis synthesised approximately 600 estimates from 48 empirical studies of β -convergence. Across 619 reported estimates, the average convergence rate was 4.3%, while the estimated values generally ranged from 1.43% to 8.34%. The authors also found substantial variation associated with differences in model specification, sample composition, data structure, and estimation technique.

Within the Vietnamese context, **Minh and Khanh (2014)** applied the classical Barro model, an extended Barro specification, and a Markov-chain approach to GDP and per capita income data for 59 provinces over the period 1990–2007. The results obtained from the classical Barro model were sensitive to the selected time period. Convergence was detected in only two of the four sub-periods, namely 1990–1996 and 2002–2007, whereas no convergence was identified for the full 1991–2007 period.

By contrast, the extended Barro model indicated an income convergence coefficient of 0.010558, with provincial income moving toward an estimated steady-state level of VND 163,748,000. For GDP per capita, the estimated convergence coefficient was 0.011115, with

an implied steady-state level of VND 1,562,172,595. Based on these estimates, the authors suggested that the convergence process would be extremely slow, requiring several centuries. The evidence of convergence was broadly consistent with the results obtained from the Markov-chain analysis.

Bentzen and Tung (2021) found no strong evidence of nationwide absolute income convergence in Vietnam during the period 1990–2012. However, their time-series analysis indicated that approximately half of the provinces exhibited a tendency to converge toward the income level of Ho Chi Minh City. Considerable regional heterogeneity was nevertheless evident. Provinces in the southern region and the Red River Delta tended to catch up more rapidly, whereas northern mountainous provinces, the Central Highlands, and several central coastal provinces displayed either slow convergence or no convergence. The study also documented a widening income gap between richer and poorer regions after 2010.

Nguyen (2024) examined all 63 provinces and centrally governed cities in Vietnam over the period 2010–2020. The findings provided no evidence of nationwide economic convergence. Nevertheless, the study identified seven distinct convergence clubs among 61 provinces and cities. The income gaps between these clubs widened during the study period, suggesting that regional income inequality became increasingly pronounced.

Against this background, the present study examines economic convergence across all 63 provinces and centrally governed cities in Vietnam using more recent data. Since economic growth models are inherently dynamic, the inclusion of a lagged dependent variable generates correlation between that variable and the disturbance term. **Nickell (1981)** demonstrated that eliminating unit-specific fixed effects does not fully remove this correlation in short panels, resulting in biased fixed-effects estimates, commonly referred to as Nickell bias.

To address this problem, the study first compares the results obtained from conventional panel-data estimators and then applies the system GMM approach developed by **Blundell and Bond (1998)**. This estimator is particularly suitable for dynamic panels because it can account for the endogeneity of the lagged dependent variable, unobserved province-specific effects, simultaneity, and other potential sources of endogeneity. The use of SYS-GMM is therefore expected to produce more consistent and reliable estimates of the speed and determinants of regional economic convergence in Vietnam.

3. DATA, MODEL AND RESEARCH RESULTS

The study employs a balanced panel dataset covering Vietnam's 63 provinces and centrally governed cities over the period 2012–2023. Although preliminary information is available for some variables for 2024, these observations are excluded to ensure consistency and comparability across the entire dataset. The resulting panel therefore contains 756 province-year observations.

The principal variable of interest is real gross domestic product per capita. Provincial nominal GDP per capita data are obtained from the National Statistics Office of Vietnam. Following the general approach adopted in the convergence literature, including **Barro and Sala-i-Martin (1992)**, nominal provincial GDP per capita is converted into real terms using the national GDP deflator published by the World Bank. Real GDP per capita is subsequently transformed using the natural logarithm and is denoted by *lnGDPCapita*.

The study period includes several substantial macroeconomic disturbances, most notably the COVID-19 pandemic. Such shocks may simultaneously affect economic activity across all provinces and cities. Year-fixed effects are therefore included in the empirical specifications to control for common national and international shocks, policy changes, inflationary pressures, energy-price fluctuations, and other time-specific influences shared by all cross-sectional units.

During the 2012–2023 period, which witnessed economic shocks such as the COVID-19 pandemic, this study employs year-fixed effects (year dummies) to isolate the impact of common aggregate shocks affecting all 63 provinces and cities.

A panel data model for equation (34) with a one-year time lag is employed. The basic models including Random Effects (RE), Fixed Effects (FE), and Pooled Ordinary Least Squares (POLS) were tested. The Breusch and Pagan Lagrangian Multiplier (LM) test for random effects and the Hausman test both favor the FE model. However, the within R^2 of 0.29 but the overall R^2 approximately 0.09 indicate that the model has low explanatory power. Furthermore, the correlation coefficient $\text{corr}(u_p, X_\beta) = -0.9231$, signaling a serious omitted variable bias. This result indicates that absolute economic convergence does not exist in Vietnam. Therefore, to address the omitted variable issue, the study proceeds to test the conditional convergence hypothesis and augments the model with measures of change in industrial capacity and labor size, as these two factors respectively reflect the role of industrial structure and labor market size in shaping per capita output.

In Vietnam, the method of measuring labor quantity changed starting in 2021 due to the adoption of the ICLS 19 guidelines (19th International Conference of Labour Statisticians) issued by the International Labour Organization (ILO), while data before 2021 were measured under the previous ICLS 13 guidelines. Due to the inconsistency in measurement methods, the study uses population size as a proxy measure. The population size variable captures both labor supply and agglomeration effects, which influence growth through productivity and resource allocation. The variable $GPop$ is used, calculated as the annual change in the natural logarithm of the average annual population, which represents the annual population growth rate. The National Statistics Office of Vietnam publishes the Index of Industrial Production (IIP), which captures changes in the scale of industrial output relative to a fixed base year (base year = 100). The IIP captures year-on-year fluctuations in industrial real value-added. The variable used in the model is $GIIP$, transformed from the original IIP (with the base year equal to 100). $GIIP$ is the growth rate of the entire industry compared to the base year, it is included in the model as a control variable to account for contemporaneous industrial dynamics. Descriptive statistics for these variables are presented in Table 1.

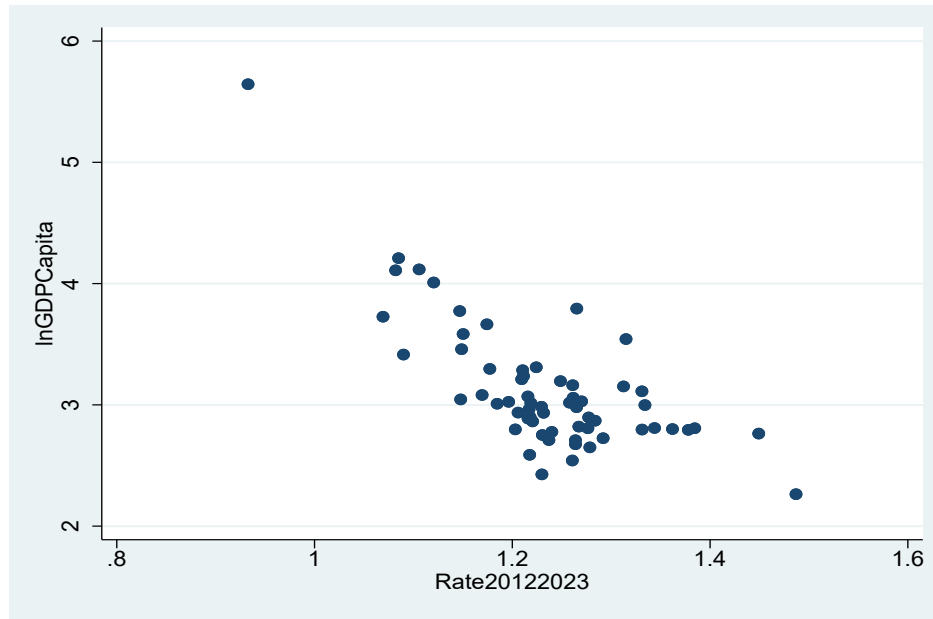
Table 1. Descriptive statistics of variables

Variable	Obs.	Mean	Std. dev.	Min	Max
$\ln\text{GDPCapita}$	756	3.4859	0.5123	2.2642	5.6443
$GIIP$	756	0.0964	0.1456	-0.5670	2.228
$GPop$	756	0.0094	0.0093	-0.0139	0.0628

Source: Author's calculations

The $GIIP$ variable has a very large coefficient of variation. With a $CV \approx 151\%$, this indicates substantial differences across provinces and over time. Separate checks for each year reveal consistently high CV values, with the range of variation always spanning both negative and positive values. The correlation coefficient between the growth rate and per capita GDP in the initial year is $\rho \approx -0.73$, which suggests a tendency for lower growth in provinces with higher initial income levels (Figure 1).

Figure 1. Correlation between the logarithm of GDP per capita in 2012 and growth during 2012-2023



Source: Author's calculations

The panel data reveals a potential correlation among observations within the same unit (province) over time. Therefore, when using POLS, the study estimates the model with the option of cluster-robust standard errors clustered by province to ensure higher reliability for statistical inference results. However, neither POLS nor FE model adequately addresses potential endogeneity, particularly given that IIP may correlate with the error term or be driven by reverse causation from growth. To ensure robustness, this study proceeds in three stages. First, cross-sectional regressions for each year are conducted to test the temporal stability of the relationship. Second, the RE model is reported alongside POLS and FE as a supplementary check. Third, to account for possible endogeneity due to omitted variables or bidirectional causality, this study employs the system Generalized Method of Moments estimator. GMM effectively handles endogeneity and growth dynamics, and delivers consistent estimates given a relatively short time dimension ($T = 12$) and a sufficiently large cross-section ($N = 63$).

The results of cross-sectional models for the respective years are presented in Table 2a and Table 2b:

Table 2a. Results of estimation models

Variable	2013	2014	2015	2016	2017	2018
	Coef. (Std. err.)	Coef. (Std. err.)	Coef. (Std. err.)	Coef. (Std. err.)	Coef. (Std. err.)	Coef. (Std. err.)
lnGDPCapita(-1)	-0.0042 (0.0165)	-0.0278** (0.0087)	-0.1108*** (0.0306)	-0.0726 (0.0380)	0.0273 (0.0172)	-0.0132 (0.0212)
GIIP	0.1936 (0.1285)	0.0723*** (0.0105)	0.1790* (0.0830)	0.1970*** (0.0547)	0.0406 (0.0461)	0.1467** (0.0528)
Gpop	-0.0336 (0.0170)	-0.6318 (0.4425)	0.0158 (0.0178)	3.8515** (1.2581)	-0.4587 (0.6204)	-2.5126* (1.2489)
Cons.	0.0575 (0.0563)	0.1531*** (0.0298)	0.2666* (0.1084)	0.3912*** (0.0864)	-0.0435 (0.0542)	0.1706* (0.0702)
R-squared	0.17	0.26	0.38	0.32	0.12	0.19
Number of Obs.	63	63	63	63	63	63

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

Source: Author's calculations

Table 2b. Results of estimation models

Variable	2019	2020	2021	2022	2023
	Coef. (Std. err.)	Coef. (Std. err.)	Coef. (Std. err.)	Coef. (Std. err.)	Coef. (Std. err.)
$\ln\text{GDPCapita}(-1)$	-0.0110 (0.0135)	-0.0524** (0.0194)	0.0255 (0.0156)	0.0356** (0.0112)	-0.0493*** (0.0129)
$GIIP$	0.3271*** (0.0307)	0.2978*** (0.0641)	0.3284*** (0.0450)	0.1515* (0.0624)	0.2927*** (0.0354)
$Gpop$	-0.2583 (0.4097)	0.5356 (0.5686)	-0.0559 (0.5270)	-2.3531*** (0.3756)	-0.1640 (0.6641)
Cons.	0.0666 (0.0437)	0.1995** (0.0646)	-0.0792 (0.0562)	-0.0561 (0.0419)	0.2246*** (0.0452)
R-squared	0.68	0.53	0.51	0.42	0.62
Number of Obs.	63	63	63	63	63

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

Source: Author's calculations

The coefficients of $GIIP$ across years are all positive and most are statistically significant. This finding predicts the role of industry in considering economic convergence. The coefficient of $\ln\text{GDPCapita}(-1)$ is negative and most are statistically significant in 8 out of 11 years, confirming the conditional convergence hypothesis. However, in 2017 and 2021, the coefficient turns positive but is not significant. The coefficient is positive and significant in the 2022 cross-sectional data. This is the year that begins after the end of the COVID-19 pandemic period. Although a general pattern is observed across the short-term cross-sectional snapshots, the results remain inconsistent due to year-specific shocks and potential unobserved endogeneity. Therefore, panel data models utilize year dummies (D_t) to control for time-specific factors that affect all observations identically. Table 3 presents the estimation results from the FE, RE, POLS and the Generalized Method of Moments. To ensure robustness, the two-step system GMM estimator with the finite-sample correction proposed by Windmeijer (2005) is adopted, this method provides more reliable inference than the one-step estimator in the presence of heteroskedasticity. The lagged of $\ln\text{GDPCapita}$ and $GIIP$ are treated as predetermined and instrumented with their lags 2 to 4 using the 'collapse' option to limit instrument proliferation. $GPop$ is treated as endogenous and instrumented with its first to third lags. Year dummies are treated as strictly exogenous and used as standard instruments. The 'small' option is appropriately incorporated to fit the characteristics of short panels.

Table 3. Results of estimation panel models

Variable	FE	RE	POLS	GMM
	Coef. (Std. err.)	Coef. (Std. err.)	Coef. (Std. err.)	Coef. (Std. err.)
$\ln\text{GDPCapita}(-1)$	-0.1897*** (0.0250)	-0.0261** (0.0089)	-0.0249*** (0.0088)	-0.0303** (0.0105)
$GIIP$	0.1024*** (0.0271)	0.1297*** (0.0237)	0.1319*** (0.0239)	0.1122*** (0.0316)
$GPop$	0.0104 (0.0170)	-0.0495* (0.0197)	-0.0541* (0.0220)	-0.0434* (0.0168)
Cons.	0.6447*** (0.0821)	0.1329*** (0.0280)	0.1291*** (0.0277)	0.1501*** (0.0361)
R-squared	Within = 0.34 Overall = 0.12	Between = 0.40 Overall = 0.28	0.28	

Variable	FE	RE	POLS	GMM
F-statistic				61.38***
AR(1) test (p-value)				0.000
AR(2) test (p-value)				0.089
Hansen J-test (p-value)				0.406
Number of instruments				59
Number of groups	63	63	63	63
Number of Obs.	693	693	693	693

Note: ***, ** and * indicate significance respectively at 1%, 5%, 10% . Year dummy coefficients are omitted from the table for brevity, 63 obs. lost from lags.

Source: Author's calculations

A substantial difference is observed between the fixed-effects estimates and those obtained from the pooled OLS, random-effects, and system GMM models. This discrepancy is not unexpected, as the fixed-effects estimator may be affected by Nickell bias when applied to dynamic panels with a relatively short time dimension. In particular, the inclusion of the lagged dependent variable creates a correlation between the transformed lagged outcome and the transformed error term, leading to biased and inconsistent fixed-effects estimates.

By contrast, the coefficients obtained from the pooled OLS, random-effects, and system GMM estimators are broadly similar in magnitude and direction. Nevertheless, pooled OLS and random-effects estimators do not adequately address the dynamic structure of the model, unobserved province-specific heterogeneity, or the potential endogeneity of the explanatory variables. The two-step system GMM estimator is therefore adopted as the preferred specification.

The diagnostic tests indicate that the estimated system GMM model satisfies the principal validity conditions. The Arellano–Bond test detects statistically significant first-order serial correlation in the first-differenced residuals, with a p-value of 0.000. This result is expected in a correctly specified dynamic panel model. More importantly, the test does not reject the null hypothesis of no second-order serial correlation, as the corresponding p-value is 0.089, which exceeds the 5% significance threshold. The absence of second-order serial correlation supports the validity of the lagged variables used as instruments.

The Hansen test of overidentifying restrictions also produces a statistically insignificant result, with a p-value of 0.406. Consequently, the null hypothesis that the instrument set is jointly valid cannot be rejected. The validity of the additional instruments used in the level equation was further examined through the Difference-in-Hansen test. The test yields a p-value of 0.397 and therefore fails to reject the null hypothesis that these instruments are exogenous.

In addition, the total number of instruments is lower than the number of cross-sectional groups, reducing concerns regarding instrument proliferation and the potential weakening of the Hansen test. Taken together, the Arellano-Bond, Hansen, and Difference-in-Hansen test results support the adequacy of the model specification and the validity of the selected instrument set.

Accordingly, the two-step system GMM estimates are treated as the principal empirical results of the study. This estimator controls for time-invariant province-specific heterogeneity through internal instruments, addresses the possible reverse-causality relationship between industrial production and economic growth, and corrects the dynamic-panel bias arising from the inclusion of the lagged dependent variable in a panel with a short time dimension.

The results from this adjusted model are presented in equation (36):

$$\hat{y}_{i,t} = 0.1501 - 0.0303 \ln y_{i,t-1} + 0.1122 GIIP_{i,t} - 0.0434 GPop_{i,t} + \sum_{i=2}^{11} \alpha_i D_i \quad (36)$$

All variables are statistically significant. The results indicate that population growth in Vietnam over the past period has hindered GDP per capita growth, directly leading to a decline in average income per capita. Specifically, a 1 percentage point increase in the growth rate of population

leads to an average decrease of 0.0434 percentage points in GDP per capita growth. According to data from the [United Nations \(2026\)](#) and [World Bank \(2025\)](#), Vietnam's population has surpassed 102 million in 2026, with a density of 330 people/km², making it the 38th most densely populated country in the world as of 2023. This indicates that Vietnam currently experiences high population density, which is further compounded by its geographical characteristics, featuring a vast mountainous terrain. Consequently, the population is unevenly distributed between flat plains and rugged mountainous regions, as well as between urban and rural areas. The results provide evidence of a negative impact from an uncontrolled population growth rate in Vietnam. Another variable with a substantial impact is industrial production growth. A one-unit increase in *GIIP*—which signifies an increase in industrial output equal to that of the base year—leads to an average increase of 0.1122 in economic growth. This sizable effect strongly underscores the pivotal role of the industrialization process.

The significantly negative coefficient β_1 provides strong evidence of conditional economic convergence among provinces in Vietnam. Under the condition that the *GIIP* and *GPop* indices remain stable, the convergence rate across provinces is $\lambda = -\ln(1 + \beta_1) \approx 3.08\%$ per year. This implies that each year, the gap between the current state of the economy and its long-run steady state is narrowed by 3.08%. The half-life convergence period, denoted as

$\theta = \frac{\ln 2}{-\ln(1 + \beta_1)} \approx 22.53$ years. At this pace, it will take poorer localities approximately 22.53 years to cover half the distance toward their steady state. These findings are consistent with the studies by [Bonnefond \(2013\)](#) across 29 Chinese provinces from 1995 to 2009, by [Sala-i-Martin \(1996\)](#) using panel data for 47 Japanese prefectures from 1955 to 1990, reflecting a conditional convergence rate that aligns with the statistical analyzed by [Abreu et al. \(2005\)](#).

In the long run, the aggregate impact of common shocks across provinces is neutralized. The model supports the view that managing population growth toward stabilization or reduction and maintaining industrial expansion are positively associated with long-term growth in the Vietnamese context.

4. CONCLUSION AND RECOMMENDATIONS

The empirical results provide no evidence of absolute convergence in GDP per capita across Vietnam's provinces and centrally governed cities. However, once differences in industrial production, population growth, and common time-specific shocks are taken into account, the findings support the existence of conditional convergence. This implies that, other factors being held constant, provinces with lower initial levels of GDP per capita tend to grow more rapidly than relatively richer provinces.

The estimated annual convergence rate is approximately 3.08%, corresponding to a convergence half-life of around 22.53 years. In practical terms, this means that provinces would require slightly more than two decades to reduce by half the distance between their current income levels and their respective steady-state positions. This adjustment period is not excessively long in the context of regional economic development and suggests that conditional convergence may gradually contribute to narrowing provincial disparities in GDP per capita.

Nevertheless, conditional convergence does not imply that all provinces will ultimately reach the same income level. Rather, each province converges toward its own steady state, which is determined by its structural, demographic, institutional, and productive characteristics. In the present model, the level of the province-specific steady state is influenced particularly by industrial-production dynamics and population growth. Provinces with stronger industrial performance and more favourable demographic conditions may therefore converge toward higher long-run income levels, while structurally weaker provinces may remain trapped at

comparatively lower steady states.

The stationarity of industrial-production growth was examined using the Harris–Tzavalis panel unit-root test (Harris & Tzavalis, 1999) without a deterministic time trend. The estimated autoregressive coefficient for (GIIP) is 0.1024, and the associated test statistic is highly significant, with a p-value of 0.0000. The null hypothesis of a unit root is therefore rejected at the 1% significance level, indicating that the (GIIP) series is stationary over the study period.

This result suggests that shocks to industrial-production growth are temporary and that the variable tends to return relatively quickly toward its long-run mean. However, panel stationarity should be interpreted as a property of the panel as a whole and does not necessarily establish that every individual provincial series follows an identical adjustment process.

The estimated coefficient of (GIIP) is positive and highly statistically significant, demonstrating that stronger industrial-production growth is associated with higher provincial economic growth. This finding highlights the importance of industrial development as a central driver of productivity enhancement, capital accumulation, technological upgrading, and structural transformation.

Accordingly, policies aimed at accelerating economic growth should place particular emphasis on strengthening industrial capacity, supporting technological innovation, modernising production processes, and improving industrial productivity. However, the expansion of industrial activity must be consistent with Vietnam’s long-term environmental commitments, particularly its objective of achieving Net Zero emissions.

Industrialisation should therefore be directed toward low-carbon, resource-efficient, technologically advanced, and environmentally sustainable sectors. Stronger environmental regulation, cleaner production technologies, renewable-energy integration, energy-efficiency improvements, and effective monitoring of industrial emissions will be essential. This policy orientation is consistent with Decision No. 896/QĐ-TTg, which approved Vietnam’s National Strategy on Climate Change to 2050 and established objectives related to greenhouse-gas reduction and climate-change adaptation.

The Harris–Tzavalis test was also applied to the population-growth variable, (GPop), without including a deterministic time trend. The estimated autoregressive coefficient is -0.4959 , with a p-value of 0.0000. The unit-root null hypothesis is therefore rejected at the 1% significance level, confirming the stationarity of the population-growth series.

The negative autoregressive coefficient indicates a strong corrective adjustment pattern, whereby deviations in population growth tend to be followed by movements in the opposite direction. Nevertheless, this result should not be interpreted as evidence that the negative economic effect of population growth automatically disappears. Stationarity merely indicates that shocks to the population-growth rate are not permanent and that the variable tends to return toward its long-run equilibrium.

The estimated coefficient of (GPop) is negative, indicating that faster population growth is associated with lower growth in GDP per capita, other factors being constant. This result may reflect capital dilution, pressure on infrastructure and public services, insufficient employment creation, lower capital availability per worker, and challenges related to the efficient allocation of economic resources.

The policy implication is not that population growth should be reduced mechanically, but rather that demographic policy should be coordinated with economic capacity, employment creation, human-capital development, and the provision of public services. Emphasis should be placed on improving population quality through education, healthcare, professional skills, labour productivity, and adaptability to technological change, rather than relying on population expansion as a source of growth.

A central strategic priority for Vietnam should therefore be to promote a major transforma-

tion in industrial production while preserving environmental quality. Future industrial policy should focus on green manufacturing, clean technologies, digitalised production, renewable energy, circular-economy practices, and sectors with high technological and knowledge content. Such a transition could enable Vietnam to raise productivity and provincial income levels without intensifying environmental degradation.

At the same time, demographic policy must respond to the country's changing population structure. Vietnam is gradually moving beyond the period associated with a favourable demographic dividend and is expected to experience a more pronounced ageing process in the coming years. Rather than attempting to reverse this structural transition through short-term measures alone, policymakers should prepare appropriate social-protection, healthcare, pension, employment, and lifelong-learning systems.

Particular attention should be given to extending healthy working lives, improving labour-force participation, increasing productivity, adapting workplaces to older employees, and strengthening social-welfare sustainability. Vietnam may also benefit from examining the experiences of countries that have already undergone population ageing, while adapting those lessons to its own institutional, cultural, and economic circumstances.

Overall, the findings indicate that regional convergence in Vietnam is conditional rather than automatic. Lower-income provinces can catch up, but the speed and final level of convergence depend on their productive structures and demographic conditions. Policies aimed at reducing regional disparities should therefore combine industrial upgrading, green transformation, technological progress, population-quality improvement, human-capital development, and proactive preparation for population ageing.

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Data Availability Statement

The data that support the findings of this study are publicly available from the National Statistics Office of Vietnam ([PX Web – National Statistics Office of Vietnam](#)), along with the 2018 Statistical Yearbooks, and from the World Bank ([GDP deflator: linked series \(base year varies by country\) - Viet Nam | Data](#)).

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Conflicts of Interest

The author declares no conflicts of interest.

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