The Effects of Digitalization, Energy Intensity, and the Demographic Dividend on Viet Nam's Economic Sustainability Goals

Ngo Thai Hung*

This research examines how the digital economy, energy efficiency, and demographic transition might help Viet Nam achieve more sustainable economic development. The causal association between digitalization, the demographic dividend, energy intensity, and long-term economic development has not been thoroughly investigated yet. Therefore, this paper aims to examine the asymmetric relationship between these indicators in Viet Nam, which is recognized as an emerging economy, using the relatively novel quantile-on-quantile regression and Granger causality approaches in different quantiles. The empirical findings suggest that the asymmetric interaction between digital innovation, energy intensity, demographic change, and economic growth in Viet Nam is primarily positive, even though there are slight differences across various quantiles of the selected indicators. In addition, the outcomes of Granger causality in quantile analysis uncover that, during the sample period, a bidirectional association exists between digitalization, the demographic dividend, and economic growth, while a unidirectional causality runs from energy intensity to economic growth.

Keywords: demographic dividend, digitalization, energy intensity, gross domestic product, quantile regression, Viet Nam

JEL codes: D04, J11, J14

*Ngo Thai Hung: Faculty of Economics and Law, University of Finance-Marketing, Ho Chi Minh City, Viet Nam. E-mail: hung.nt@ufm.edu.vn. The Asian Development Bank recognizes "China" as the People's Republic of China, "Turkey" as Türkiye, and "Vietnam" as Viet Nam.

Asian Development Review, Vol. 40, No. 2, pp. 399–425
DOI: 10.1142/S0116110523500129

I. Introduction

Viet Nam's *Doi Moi* strategy of economic reforms has significantly boosted the country's growth.[1] Since 2000, Viet Nam's economy has quickly expanded (Hung 2022b). A developing country, Viet Nam has been one of Asia's top performers over the last decade, with an average annual economic growth rate greater than 7% (Ha and Ngoc 2021). It is a developing economy with a large population and a positive demographic profile with the potential for continued rapid economic growth. With its steady economic growth, energy demand has increased significantly in recent years. And as energy demand has increased faster than gross domestic product (GDP), the government is attempting to meet this demand by undertaking various projects to increase energy intensity by 15%–20% by 2030 and 25%–30% by 2045. In addition, digital innovations have a significant influence on economic sustainability. Nevertheless, the study on the interplay between energy and other macroeconomic factors is limited in Viet Nam, although it has emerged as an important topic among contemporary researchers worldwide (Hung 2022b). This study investigates the asymmetric relationship between digitalization, energy intensity, demographic transition, and economic development in Viet Nam.

Taking Viet Nam as an example, even though it has not yet completed the industrialization and urbanization processes that accompany rapid economic growth, it has a large proportion of working-age individuals who are able to raise the growth rate, presenting an economic opportunity. In addition, energy usage and digitalization stimulate economic sustainability in Viet Nam. To achieve the goal of sustainable development, Viet Nam must take advantage of the demographic dividend through leveraging digitalization in the energy industry to increase economic performance in the digital economy. As a result, I take Viet Nam as a case study to explore the causal associations between digitalization, energy intensity, the demographic dividend, and economic development, and build a method for predicting long-term development.

In an age of digital technology, economic sustainability and energy efficiency are critical for achieving sustainable development, especially in light of demographic change (Olaniyan, Soyibo, and Lawanson 2012; Hosan et al. 2022). It is widely acknowledged that population aging may have a negative impact on economic dynamism, exacerbate generational inequality, and harm public finances (Mason, Lee,

[1] The Government of Viet Nam started the *Doi Moi* economic reforms during the Sixth National Congress in 1986. These changes gave market forces a larger role in coordinating economic activity between corporations and government agencies, as well as allowing for private ownership of small businesses and the establishment of a stock exchange for both state and nonstate enterprises.

and Park 2022). Demographic transition affects not only the demographic structure but also the social, economic, and political structure of any economy, and these wide-ranging impacts of demographic transition are gaining importance in the literature (see, for example, Misra 2015, Van Der Gaag and De Beer 2015). Because the global economy is transitioning via digitalization, researchers and policy makers have focused on promoting long-term development by making the most of the potential of the demographic dividend in all economic sectors (Hosan et al. 2022). Furthermore, while the demographic premium or dividend is necessary for economic growth, it is insufficient because it merely provides the economy with the essential labor force, with little or no regard for its quality (Jafrin et al. 2021).

Every country goes through a demographic transition (Joe, Kumar, and Rajpal 2018; Taketoshi 2020), and the effects of the transition on the economy vary from country to country, depending on how quickly the population structure changes. Since the middle of the 1970s, Viet Nam has seen rapid demographic change, with an increasing share of the working-age population and a fall in the dependency ratio (Wagstaff 2007). This demographic change creates ideal conditions for economic growth, resulting in economic benefits known as the demographic dividend.

In the digital age, the demographic transition has a substantial impact on the economy as a whole, while digital innovation changes the working-age population and labor market, promotes economic growth, and leads to more energy use (Baerlocher, Parente, and Rios-Neto 2019; Fang 2020; Gniniguè and Ali 2022). The digitalization process is moving swiftly in most emerging economies, with growth accelerating, the working-age population expanding, and energy efficiency being achieved (Rivza et al. 2019). Digital technologies are rapidly being utilized in manufacturing and service processes, and they are quickly becoming associated with modernity and innovation. As a result, digitalization and the implementation of the Industry 4.0 concept are becoming economic growth drivers for numerous firms, governments, and regions around the world (Brodny and Tutak 2022).[2] Generally, one of the channels through which the application of digital technologies affects growth refers to how information and communications technology (ICT) is reshaping ways of dealing via electronic commerce and online business, allowing for greater flexibility in banking operations and improved communications, resulting in increased productivity and economic growth. Since the early 2000s, digital innovation has played an essential role in developing countries by cutting communication costs (Habibi and Zabardast 2020).

[2] The Fourth Industrial Revolution, or Industry 4.0, refers to the fast pace of changes in technology, industries, and societal patterns and processes that are occurring in the 21st century as a result of increased interconnectivity and smart automation.

It directly affects the performance of Viet Nam's services and micro, small, and medium-sized enterprise sectors. Digitization directly impacts an economy's total trade volume because it increases the efficiency of any business. Information technology and information-technology-enabled services significantly impact the service sector and the micro, small, and medium-sized enterprise sector, both of which are known to be growth engines for any economy.

The energy sector is also critical to economic development. The continuous availability of sufficient energy inputs is required for sustainable economic growth, which can be achieved if energy intensity decreases with growth (Yaw Naminse and Zhuang 2018, Pan et al. 2019). The term "energy efficiency" refers to how efficiently available energy resources are used to produce goods and services. The energy sector is crucial to economic progress. Energy consumption rises when countries migrate from labor-intensive agriculture to capital- and energy-intensive industries (Díaz et al. 2019). As the structural transition continues, they will gradually migrate to information-intensive services. Therefore, energy intensity rises at first, then falls as incomes rise. The controversy over energy intensity trends continues: Some research suggests that energy intensity decreases as GDP rises. In contrast, others show that energy intensity rises and follows an inverted U-shaped pattern. The variations in results are due to the methodologies utilized, the sample economies studied, and the period examined (Agovino, Bartoletto, and Garofalo 2019).

However, to my knowledge, no studies for Viet Nam provide straightforward insights into the scenario in which digitalization could contribute to decreasing material and energy consumption over the demographic dividend period. This paper will add to the knowledge on the asymmetric interplays between demographic change, digital innovation, and energy intensity that drive economic growth. Furthermore, insufficient information systematically explains the time-varying nexus between the demographic dividend, digitalization, energy intensity, and economic growth against the backdrop of Viet Nam's digital economy using traditional models (e.g., vector autoregression, ordinary least squares [OLS], Granger causality). As a result, this paper significantly contributes to the existing literature in that economic development and digitalization are incorporated into the energy efficiency research framework, taking into account the growth of the digital economy in conjunction with the process of a demographic transition, broadening the energy and environmental economics research opportunities.

This paper looks at the asymmetric association between demographic transition, digital innovation, energy intensity, and economic development in Viet Nam. My study adds to the literature on the impact of digitalization, energy intensity, and demographic change on economic sustainability in Viet Nam, which is characterized by both high energy use and significant demographic change. Firstly, to the best of my knowledge, no studies have explored the nexus between digitalization, energy intensity, demographic change, and GDP in Viet Nam—so I believe this work uncovers the actual condition of the time-varying nexus for the benefit of media and policy makers. Secondly, I employ the quantile-on-quantile regression developed by Sim and Zhou (2015) to highlight the different nexus between the examined indicators at divergent quantiles from 1996 to 2020. This technique also considers the problems of non-normality, heterogeneity, and asymmetry of the series (Hung, Trang, and Thang 2022). Thirdly, the Granger causality in quantiles proposed by Troster (2018) is also employed to capture the causal associations between every comparable quantile of a specific conditional distribution. This method applies to all quantiles, highlighting the nonlinearity of a quantile regression model. By doing so, the outcomes provide fresh insight for policy makers of this emerging Asian economy to formulate future energy and sustainable development policy implications at the national level. The empirical results demonstrate that the asymmetric interaction between digital innovation, demographic transition, energy intensity, and GDP in Viet Nam is primarily positive, even though there are slight differences across various quantiles of the selected indicators. In addition, the outcomes of Granger causality in quantiles analysis reveal that a bidirectional causal association exists between digitalization, demographic dividend, and economic growth, while a unidirectional causality runs from energy intensity to economic growth during the sample period.

This study is organized as follows. The relevant literature is reviewed in section II. The methodology and data are discussed in section III. Section IV presents the empirical results and discussion. Section V concludes with my policy recommendations.

II. Literature Review

A. Demographic Structure and Economic Growth

The relationship between demographic dividends and economic growth has become increasingly significant (Taketoshi 2020; Amornkitvikai, Harvie, and Karcharnubarn 2022). For instance, Misra (2015) documents that the interaction between the demographic structure and GDP rate is positive in BRICS countries.[3] Van Der Gaag and De Beer (2015) argue that increasing employment rates in European

[3] BRICS is an acronym for five major emerging economies: Brazil, the Russian Federation, India, the People's Republic of China (PRC), and South Africa.

countries can increase the likelihood of economic sustainability. Jafrin et al. (2021) look into this interdependence in Bangladesh, India, Nepal, Pakistan, and Sri Lanka, and provide evidence that the demographic dividend positively influences economic growth in these economies. Olaniyan, Soyibo, and Lawanson (2012) confirm that Nigeria's demographic structure can lead to more rapid growth in GDP if the right policies are implemented. Likewise, Joe, Kumar, and Rajpal (2018) reveal that during the period 1980–2010, the Indian economy reaped enormous gains from the ongoing demographic change, with dividend effects estimated to be above 1 percentage point each year in terms of economic growth. Nevertheless, to achieve high growth from demographic potential, various growth restrictions must be overcome. Recently, Baerlocher, Parente, and Rios-Neto (2019) found a significant impact of the demographic transition on economic growth in Brazil. Also, Taketoshi (2020) indicated that the demographic dividend has a considerable influence on economic development in the People's Republic China (PRC). In the same vein, Fang (2020) employed a population "echo effect" to build human capital at all ages, increase employees' ability to benefit from employment, and increase the labor participation rate of the elderly, thus improving their incomes and social security. Amornkitvikai, Harvie, and Karcharnubarn (2022) report that the labor force relative to the working-age population, as well as the growth of the actively employed population, all have a significant and positive impact on economic growth in Asia.

B. Digitalization and Economic Growth

Ivanović-Đukić, Stevanović, and Rađenović (2019) document that high-growth-expectations entrepreneurship and new-technology-development entrepreneurship contribute the most to economic growth in regions with higher rates of digitalization. Brodny and Tutak (2022) suggest a positive association between GDP and digitalization for European Union countries. Rivza et al. (2019) highlight the similarities and differences between digitalization and economic growth in each European Union country. However, Gniniguè and Ali (2022) demonstrate that digitalization was not a channel for transmitting the impacts of migrant remittances on economic growth in members of the Economic Community of East African States during the COVID-19 outbreak.

In the Indian context, Maiti and Kayal (2017) reveal the large impact of digitalization on the inclusive growth of India's trade and its overall economy. Sahoo, Nayak, and Behera (2022) report that the per capita GDP both of India and the PRC is positively affected by the Internet and mobile phone density, projected years of schooling, foreign direct investment inflows, gross capital formation, per capita energy power consumption, research and development expenditure, and the consumer price index.

Recently, Myovella, Karacuka, and Haucap (2020) explored the effect of digital innovation on economic development in Sub-Saharan Africa compared to economies in the Organisation for Economic Co-operation and Development (OECD) and reported a positive relationship between the two indicators in both economies. Specifically, when compared to OECD economies, broadband Internet is minimal and the effect of mobile telecommunications is greater in Sub-Saharan African economies. In a similar fashion, Habibi and Zabardast (2020) validate the findings of Myovella, Karacuka, and Haucap (2020) that ICT is positively associated with economic growth in the Middle East and OECD economies.

C. Energy Intensity and Economic Growth

Pan et al. (2019) point out that economic development and technological innovation impact energy intensity, whereas trade openness, financial development, and technological innovation significantly impact Bangladesh's economic development. Similarly, in the case of the PRC, Xin-gang and Fan (2019) found that there is a significant positive spatial autocorrelation for energy intensity among various regions in the PRC. They also confirm that the convergence of regional energy intensity could be aided by industry transfer and economic development. Yaw Naminse and Zhuang (2018) disclosed that economic growth is related to energy consumption. Li (2019) discovered that GDP, population, and the secondary and tertiary sectors significantly impact energy consumption.

According to some studies, the relationship between economic growth and energy intensity is significant. For example, Agovino, Bartoletto, and Garofalo (2019) uncovered a U-shaped relationship between total energy intensity and GDP. As per Emir and Bekun (2019), there is feedback causality between energy intensity and GDP, but in Romania, there is one-way causation between renewable energy usage and economic growth. Díaz et al. (2019) revealed that transitioning from fossil fuels to frontier renewables is also associated with increased growth. Deichmann et al. (2019) examined the interplay between GDP and energy intensity for 137 economies and found that energy intensity is negatively correlated with income growth. In the same vein, Mahmood and Ahmad (2018) explored the influence of GDP on energy intensity in European countries. Their results indicate that energy intensity decreases significantly in response to economic development even when the former is detrended.

The above observations disclose a lack of agreement among researchers on the relationship between the indicators of interest and, to the best of my knowledge, most studies that explain the interconnections between some of the examined indicators using the conventional econometric models such as autoregressive distributed lag, vector autoregression, Granger causality test, vector error correction model, generalized method of moments, and OLS. However, in this study, I employ quantile-on-quantile regression (QQR) and Granger causality in different quantiles to highlight the asymmetric impact of digitalization, demographic transition, and energy intensity on economic growth in Viet Nam. In fact, I was unable to find any previous work relating to these indicators in the case of Viet Nam, so I believe this study will provide further evidence to academia and policy makers of the actual state of dynamic interplays between digitalization, demographic transition, energy intensity, and GDP in Viet Nam.

D. Conceptual Framework

The existing literature discusses three different perspectives on the interplay between demographic change and economic growth: Population growth can either boost, stifle, or be unconnected to economic development. According to Polyzos, Kuck, and Abdulrahman (2022), it is necessary to examine a specific region or single country to avoid biases that may appear when analyzing a global sample. In the seminal study, Malthus (1798) demonstrated that rising population rates could increase labor supply, thereby decreasing real wages. In addition, his analysis indicated that if corresponding levels of economic growth do not accompany population growth, it can lead to poverty, inflation, and even famine. My work is based on a positive view of the connection between demographic transition and economic growth, which is widely supported in the literature.

In the neoclassical growth model, capital accumulation, population growth, and technological progress are all exogenous explanations for long-term economic development (Solow 1956). Nevertheless, in contrast to the Solow growth model, which considers technology to be exogenous, a new growth model that believes technological progress to be endogenous has arisen (Myovella, Karacuka, and Haucap 2020). Additionally, it is said that modern technology rates influence not only growth and development rates but also outcomes such as life expectancy, democratic levels, health outcomes, poverty rates, and literacy rates (Myovella, Karacuka, and Haucap 2020; Sahoo, Nayak, and Behera 2022). Some scholars illustrate that the pace of output growth is influenced not just by computing equipment but also by other forms of capital, labor, and multifactor productivity. More importantly, technological advancements help spur economic growth by meeting the demand for digital items such as communication equipment, computers, and software, increasing productivity and investment in ICT-reliant industries. Hence, many studies have focused on the influence of digital innovation on the economic sustainability of advanced and emerging countries.

Energy is a valuable resource that catalyzes economic growth. Energy intensity is a common metric used by scholars to assess a country's energy consumption level. Lower energy intensity indicates that the country is making better use of its energy resources in manufacturing. Because divergent determinants and variables influence energy intensity, finding the causal link between energy intensity and economic indicators has become a much-debated issue among scholars and policy makers. Their results enable us to deduce the consequences of a wide range of energy, economic, and financial policies to attain economic development.

III. Methodology

I employ the following techniques in my research. First, I evaluate if the quantiles of the distribution follow the unit root process devised by Koenker and Xiao (2004) in their quantile autoregression unit root test. Next, I utilize the cointegration test introduced by Xiao (2009) to test the null hypothesis of constant cointegrating coefficients after the null hypothesis of a unit root is not rejected. After that, QQR, as developed by Sim and Zhou (2015), was employed to investigate the relationship between the variables under consideration. Finally, Granger causality in a quantiles test developed by Troster (2018) is used to capture the casual associations between the interested indicators. Figure 1 shows the framework of analysis.

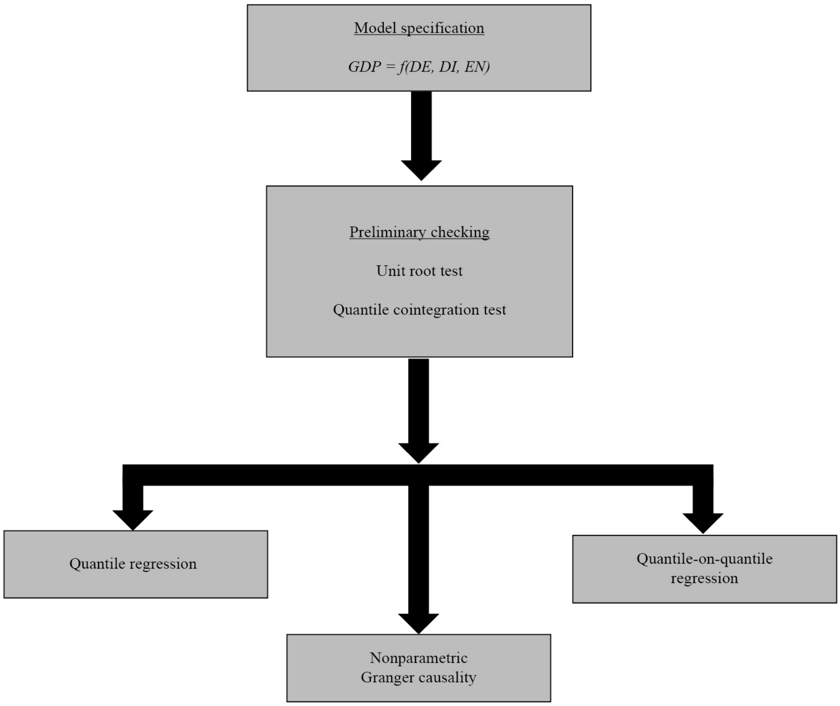
A. The Quantile-on-Quantile Approach

I employ QQR to investigate the effect of the quantiles of digitalization (DI), demographic dividend (DE), and energy intensity (EN) on the quantiles of economic growth (GDP). The nonparametric quantile regression model is used to start the process:

$$\mathrm{GDP}_t = \beta^{\theta}(X_t) + u_t^{\theta}, \tag{1}$$

where X_t shows the interested indicators (DI, DE, and EN) at period t, θ is the θth quantile of the conditional distribution of GDP_t, and u_t^{θ} is the error quantile whose θth conditional quantile is made up to be 0, and $\beta^{\theta}(\cdot)$ demonstrates the slope of this relationship.

Figure 1. **Analysis Framework**



DE = demographic dividend, DI = quantiles of digitalization, EN = energy intensity, GDP = gross domestic product.
Source: Author's illustration.

Equation (4) can be extended by a first-order Taylor expansion of a quantile of X_t as follows:

$$\beta^{\theta}(X_t) \approx \beta^{\theta}(X^{\tau}) + \beta^{\theta'}(X^{\tau})(X_t - X^{\tau}), \tag{2}$$

where $\beta^{\theta'}$ presents the partial derivative of $\beta^{\theta}(X_t)$, as the slope indicates a minimal effect. Obviously, θ is the functional form of $\beta^{\theta}(X^{\tau})$ and $\beta^{\theta'}(X^{\tau})$, while τ is the functional form of X and X^{τ}, therefore θ and τ are the functional forms of $\beta^{\theta'}(X^{\tau})$ and $\beta^{\theta}(X^{\tau})$, respectively. If I write $\beta^{\theta}(X^{\tau})$ and $\beta^{\theta'}(X^{\tau})$, respectively, as $\beta(\theta,\tau) \rightarrow \beta_0(\theta,\tau)$ and $\beta_1(\theta,\tau)$ as follows:

$$\beta^{\theta}(X_t) \approx \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(X_t - X^{\tau}), \tag{3}$$

then equation (2) can be replaced by fundamental QQR equation (1):

$$\text{GDP}_t = \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(X_t - X^{\tau}) + u_t^{\theta}, \tag{4}$$

where part of equation (4) is the conditional quantile of θth of GDP. The link between GDP quantiles and other metrics is shown in these equations. As in OLS, a similar minimization is applied to arrive at the following equation:

$$\min_{b_0,b_1}\sum_{i=1}^{n}\rho_\theta\left[\text{GDP}_t-b_0-b_1(X_t-X^\tau)\right]K\left(\frac{F_n(X_t)-\tau}{h}\right), \tag{5}$$

where $\rho_\theta(u)$ is the quantile loss function showing as $\rho_\theta(u)=u(\theta-I(u<0))$, $K(\cdot)$ is the kernel density function, and h illustrates the kernel density function's bandwidth parameter. A prime bandwidth is required to confirm the stability of disparity and estimate bias caused by a smaller or larger interval of $K(\cdot)$. Choosing the optimum bandwidth is a difficult challenge in empirical analysis (Razzaq et al. 2020). A bigger bandwidth results in a higher bias but a lower variation of the estimations. If I use a smaller bandwidth, the estimates have a lower bias but a higher variance. Therefore, this study utilizes a bandwidth parameter of $h=0.05$ for the estimation based on Sim and Zhou (2015); Razzaq et al. (2020); and Hung, Trang, and Thang (2022).

It is argued that asymmetry in economic and financial data exists as a result of structural changes, policy shifts, economic reforms, financial crises, and other determinants (Hung, Trang, and Thang 2022). Based on these factors, this research employs QQR, as proposed by Sim and Zhou (2015). This method combines the benefits of both the nonparametric and quantile regression approaches (Irfan et al. 2022). It regresses the quantiles of DI, DE, and EN on GDP to capture the asymmetric and spatial properties of the model over time (Razzaq et al. 2020). Sim and Zhou (2015) contend that QQR provides more information and comprehensive findings than OLS and classical quantile regression.

B. Granger Causality in Quantiles

A series Z_t does not Granger cause another series Y_t, according to Granger (1969), if past Z_t does not assist in forecasting Y_t given past Y_{t-1}. Assume that $I_t\equiv(I_t^Y,I_t^Z)'\in R^d, d=s+q$ is an explanatory vector, and I_t^Z is the historical information set of $Z_t, Z_t, I_t^Z := (Z_{t-1},\ldots,Z_{t-q})\in R^q$. From Z_t to Y_t, the null hypothesis of Granger noncausality is

$$H_0^{Z\nrightarrow Y}: F_Y(y|I_t^Y,I_t^Z)=F_Y(Y|I_t^Y),\quad \text{for all } y\in\mathbb{R}, \tag{6}$$

where $F_Y(\cdot\,|\,I_t^Y,I_t^Z)$ is the Y_t given (I_t^Y,I_t^Z) conditional distribution function. Z_t does not Granger cause Y_t in mean if

$$E(Y_t|I_t^Y,I_t^Z)=E(Y_t|I_t^Y) \tag{7}$$

The means of $F_Y(\cdot|I_t^Y, I_t^Z)$ and $F_Y(\cdot|I_t^Y)$ are $E(Y_t|I_t^Y, I_t^Z)$ and $E(Y_t|I_t^Y)$, respectively. If $Q_\tau^{Y,Z}(\cdot|I_t^Y, I_t^Z)$ is the τ-quantile of $F_Y(\cdot|I_t^Y, I_t^Z)$, then equation (6) can be rewritten as follows:

$$H_0^{QC:Z\nrightarrow Y}: Q_\tau^{Y,Z}(Y_t|I_t^Y, I_t^Z) = Q_\tau^{Y}(Y_t|I_t^Y), \quad \text{a.s. for all } \tau \in \mathcal{T}, \tag{8}$$

where $\mathcal{T}$ is a compact set such that $\mathcal{T} \subset [0,1]$ is satisfied, and Y_t's conditional τ-quantiles satisfy the following constraints:

$$\begin{aligned} &\Pr\{Y_t \leq Q_\tau^{Y}(Y_t|I_t^Y)|I_t^Y\} := \tau, \quad \text{a.s. for all } \tau \in \mathcal{T}, \\ &\Pr\{Y_t \leq Q_\tau^{Y,Z}(Y_t|I_t^Y, I_t^Z)|I_t^Y, I_t^Z\} := \tau, \quad \text{a.s. for all } \tau \in \mathcal{T}. \end{aligned} \tag{9}$$

Given an explanatory vector I_t, then $\Pr\{Y_t \leq Q_\tau(Y_t|I_t)|I_t\} = E\{1[Y_t \leq Q_\tau(Y_t|I_t)]|I_t\}$. The null hypothesis of Granger noncausality is equivalent to

$$E\{1[Y_t \leq Q_\tau^{Y,Z}(Y_t|I_t^Y, I_t^Z)]|I_t^Y, I_t^Z\} = E\{1[Y_t \leq Q_\tau^{Y}(Y_t|I_t^Y)]|I_t^Y\}, \quad \text{a.s. for all } \tau \in \mathcal{T}. \tag{10}$$

C. Data

Motivated by the research objectives, the present paper explores the influence of digital innovation, energy intensity, and demographic change on economic development in Viet Nam by using annual data from 1996 to 2020. The time frame was chosen based on the availability of data. Furthermore, the study period includes *Doi Moi* in Viet Nam, which refers to the economic reforms that began in 1990 with the goal of creating a "socialist-oriented market economy" (Nguyen et al. 2021, Hung 2022b). The indicator employed in this study (DI) comprises the people utilizing the Internet as digitalization (Hosan et al. 2022). Moreover, GDP is the proxy for economic growth and has been employed as a measure of macroeconomic growth in many recent articles (Agovino, Bartoletto, and Garofalo 2019; Emir and Bekun 2019; Hosan et al. 2022; Polyzos, Kuck, and Abdulrahman 2022). Using per capita values allows cross-country comparison, while the expression in constant 2010 United States dollars provides inflation-adjusted values. This measure is selected in lieu of the yearly percentage of economic growth because the rapid demographic shifts the sample economies are experiencing account for the GDP per capita (Hosan et al. 2022; Polyzos, Kuck, and Abdulrahman 2022). DE represents a demographic transition. By altering the age structure as a result of the transition from high to low birth and death rates, demographic change may produce a demographic dividend. This results in the expansion of the working-age population as a whole, which may result in economic

Table 1. **Summary of Indicators and Data Sources**

Indicator	Symbol	Description	Note	Data Source
Demographic dividend	DE	Working-age population (age 15–64 years) as share of the total population	%	World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022)
Economic growth	GDP	GDP is measured in US dollars per capita (constant 2010 US dollars)	$\ln(GDP_t) - \ln(GDP_{t-1})$	World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022)
Energy intensity	EN	Total energy supply over GDP measured in constant 2011 US dollars	ln(EN)	World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022)
Digitalization	DI	Individual using Internet as share of the total population	%	World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022)

GDP = gross domestic product, US = United States.
Source: Author's compilation.

benefits for companies seeking labor (Polyzos, Kuck, and Abdulrahman 2022). The energy intensity (EN) is calculated by dividing gross energy use by GDP. The gross inland consumption of energy is computed by adding the gross inland consumption of coal, electricity, oil, natural gas, and renewable energy. Table 1 illustrates the details of all the indicators and their summary, definition, and data sources.

The interpolation technique known as the quadratic match-sum approach is used to transform my annual data into the quarterly frequency so as to increase the number of observations (Sharif et al. 2020; Hung 2022a, 2022b). The strategy facilitates the correction of seasonal variations in the data in this method.

IV. Results

The descriptive statistics for GDP, DE, DI, and EN are shown in Table 2. Interestingly, all the concerned variables have a positive mean. Digitalization has the highest standard deviation, whereas GDP and energy intensity have the lowest volatility. Additionally, all variables are normally distributed according to the Jarque–Bera statistic tests.

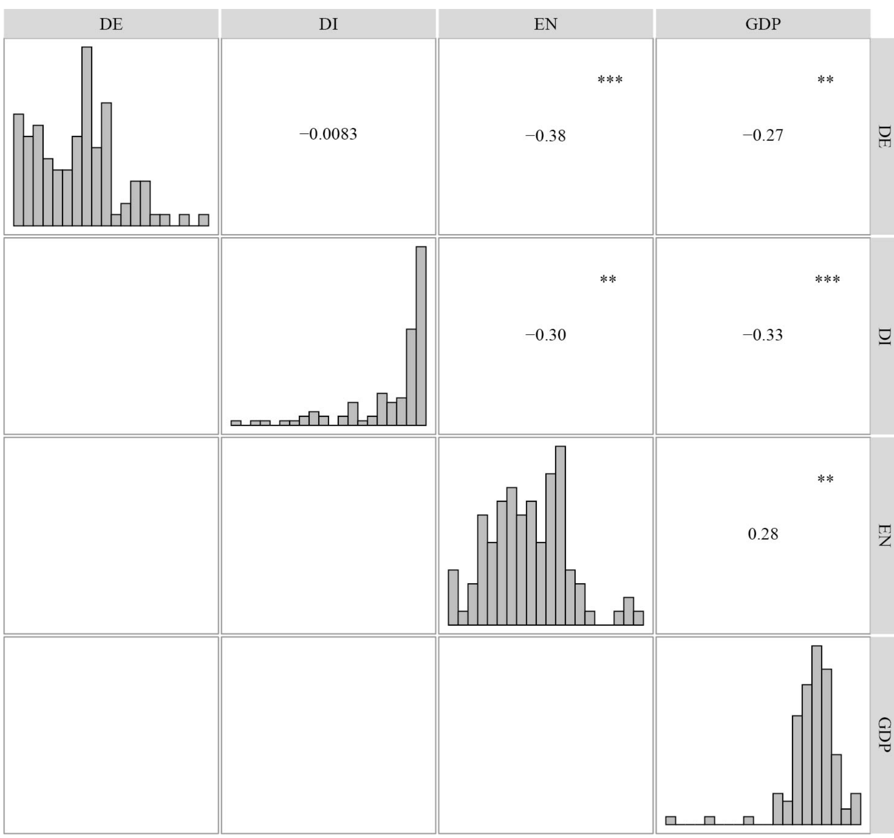
Figure 2 represents the distribution and pair-wise unconditional correlation among Viet Nam's GDP, DI, DE, and EN. The outcomes indicate that GDP has a significant relationship with DE and DI. The correlation coefficients of these pairs fall

Table 2. **Descriptive Statistics**

Variables	Mean	Minimum	Maximum	Std. Dev	Jarque–Bera
GDP	0.071899	0.031911	0.094411	0.016856	1.743012***
DE	81.84440	80.60000	83.85000	0.840233	0.918501***
DI	26.52493	0.000135	70.29000	24.23094	2.012545***
EN	1.776694	1.726111	1.844414	0.025812	0.638235***

DE = demographic dividend, DI = quantiles of digitalization, EN = energy intensity, GDP = gross domestic product, Std. Dev = standard deviation.
Note: *** indicates statistical significance at the 10% level.
Source: Author's calculations based on the World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022).

Figure 2. **Plots of Distribution and the Pair-Wise Correlations of Indicators**



Note: *** and ** mean rejection of the null hypothesis at the 1% and 5% levels, respectively.
DE = demographic dividend, DI = quantiles of digitalization, EN = energy intensity, GDP = gross domestic product.
Source: Author's calculations based on the World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022).

Table 3. **Quantile Autoregression Unit Root Analysis**

τ	GDP		DI		DE		EN	
	$\hat{\alpha}$	*t*-statistic	$\hat{\alpha}$	*t*-statistic	$\hat{\alpha}$	*t*-statistic	$\hat{\alpha}$	*t*-statistic
0.05	–3.3316	–4.3154	–2.3100	–9.8719	–2.3100	2.7337	–2.8875	**4.0116**
0.10	–3.3571	1.9451	–2.3100	1.0930	–2.7689	0.4222	–3.2794	–1.8992
0.15	–3.4100	0.5411	–2.3100	0.0463	–2.9307	0.6654	–3.4100	–1.7321
0.20	–3.4049	0.6653	–2.3100	–0.1560	–3.0375	0.9740	–3.4100	–1.1791
0.25	–3.4100	0.5701	–2.3100	–0.3518	–3.1622	2.3410	–3.4100	–1.5788
0.30	–3.3253	0.4170	–2.4218	–3.3670	–3.1665	2.8740	–3.4100	–1.4487
0.35	–3.3250	0.5179	–2.3899	–3.5834	–3.3133	2.7385	–3.4100	–1.2239
0.40	–3.3133	0.2441	–2.5727	**–5.3478**	–3.3860	2.8171	–3.4100	–1.5637
0.45	–3.1960	–0.0814	–2.5087	**–4.2055**	–3.4100	2.8406	–3.4100	–0.9404
0.50	–3.1911	–0.5476	–2.4489	**–5.0734**	–3.4100	2.7404	–3.4100	–1.3976
0.55	–3.0813	–1.4957	–2.4937	**–5.6194**	–3.4100	2.9005	–3.4100	–0.8820
0.60	–2.9835	–2.4606	–2.4315	**–7.4037**	–3.4100	3.2130	–3.4100	–0.9214
0.65	–2.8704	–2.6872	–2.4491	**–6.9331**	–3.4100	2.5345	–2.8463	–0.5006
0.70	–2.8614	–2.5960	2.3100	**11.1503**	–3.4100	1.9414	–3.4100	–0.5325
0.75	–2.6588	–2.2104	–2.3100	**9.3417**	–3.3154	2.6841	–3.4100	–0.2232
0.80	–2.5777	–2.5883	–2.3100	**6.7199**	–3.2969	3.1401	–3.4100	–0.4386
0.85	–2.4528	–2.1894	–2.3100	**8.6945**	–3.1634	3.1815	–3.4100	–0.2276
0.90	–2.4757	–0.9881	–2.3100	**8.4942**	–2.9370	0.6839	–3.0213	0.1651
0.95	–2.3100	2.4049	–2.3100	**13.7240**	–3.2914	–1.2453	–2.8729	–1.1240

DE = demographic dividend, DI = quantiles of digitalization, EN = energy intensity, GDP = gross domestic product.
Note: The table displays point estimates and bold values of *t*-statistics at the 5% significance level.
Source: Author's calculations based on the World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022).

in the range from –0.33 to 0.98. I also observe the interaction between the variables in scatter plots.

Table 3 presents the findings of the quantile unit root test, which examines the stationarity of the model parameters. This approach provides the values of persistence $\hat{\alpha}$ and *t*-stats values for the grid of 19 quantiles (0.05–0.95). Additionally, the null hypothesis for all 19 quantiles is that $H_0 : \hat{\alpha}(\tau) = 1$, which indicates that all variables are nonstationary. Bold values of *t*-statistics demonstrate the rejection of the null hypothesis $H_0 : \hat{\alpha}(\tau) = 1$ at the 5% significance level. Overall, the examined indicators GDP, DE, EN are nonstationary at all quantiles of distribution. Nevertheless, at the 5% significance level, I reject the null hypothesis of unit root for digitalization at the middle and higher quantiles of the conditional distribution.

I investigate the likelihood of cointegration between the variables using the quantile cointegration test conceptualized and introduced by Xiao (2009), which validates the cointegration nexus between the indicator changes over the distribution. Table 4 shows the outcomes of quantile cointegration of GDP with DI, DE, and EN in

Table 4. **Quantile Cointegration Test**

Model	Coefficient	Supτ $|V_n(\tau)|$	CV1	CV5	CV10
GDP-DE	β	4,226.92	549,988.31	418,260.50	358,472.88
	γ	578.58	48,147.82	33,755.95	24,163.04
GDP-DI	β	16.38	11.56	8.11	6.73
	γ	0.82	0.38	0.25	0.19
GDP-EN	β	6,021.83	9,996.54	6,927.9	5,616.72
	γ	7,455.95	12,071.30	8,601.61	6,844.70

DE = demographic dividend, DI = quantiles of digitalization, EN = energy intensity, GDP = gross domestic product.
Note: CV1, CV5, and CV10 represent the critical values of statistical significance at the 1%, 5%, and 10% levels, respectively.
Source: Author's calculations based on the World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022).

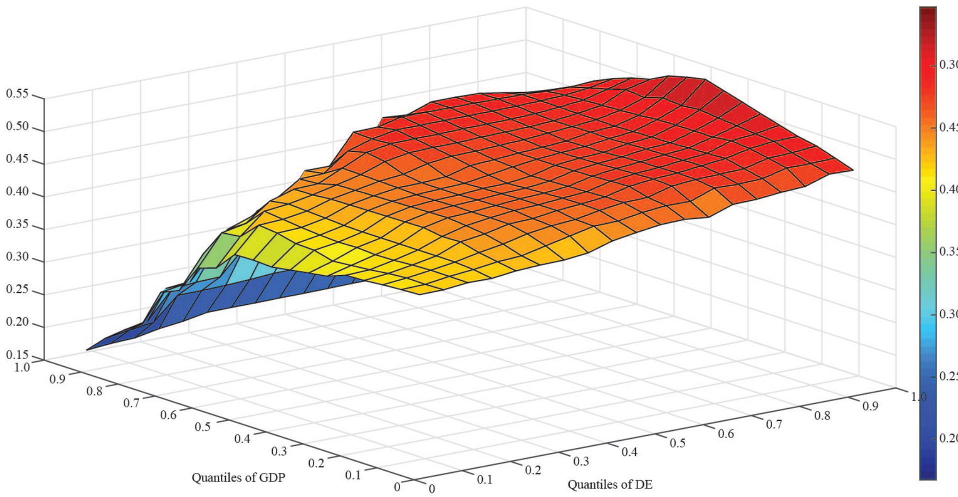
Viet Nam, illustrating the values of supremum norm β and coefficients γ along with their critical values—CV1, CV5, and CV10—at the 1%, 5%, and 10% significance levels, respectively. The table clearly shows that the values of supremum norm β and γ coefficients are greater than all the critical values at the 1%, 5%, and 10% significance levels, which demonstrates that there is a significant long-term association between GDP, DI, DE, and EN in Viet Nam. Put in another way, there is a statistically nonlinear cointegration nexus between the quantiles of GDP, DI, DE, and EN at the 1% significance level.

Following the illustration of a long-term association between digitalization, demographic structure, energy intensity, and economic growth in Viet Nam, the present study utilizes the quantile-on-quantile regression proposed by Sim and Zhou (2015) to explore the influence of these factors on economic growth in Viet Nam from 1996 to 2020. The slope coefficients of QQR are represented in three-dimensional plots. The regressor effect (x-axis) on economic growth (y-axis) is described in each graph. Overall, the empirical results of the QQR estimates uncover that the relationship between the selected variables has heterogeneity in each state.

The demographic dividend's influence on GDP in Viet Nam is described in Figure 3. The coefficient of the slope ranges from –3.5 to 1.0. In the lower tail (0.1–0.3) of DE and higher quantiles (0.8–0.95) of GDP, the impact of DE is weak and negative. Nevertheless, in the middle and higher quantiles of DE and GDP, the effect of DE is strong and positive. In general, the effect of DE on GDP is significantly positive across quantiles, which means that an increase in GDP is caused by an increase in the demographic dividend in Viet Nam for all quantiles.

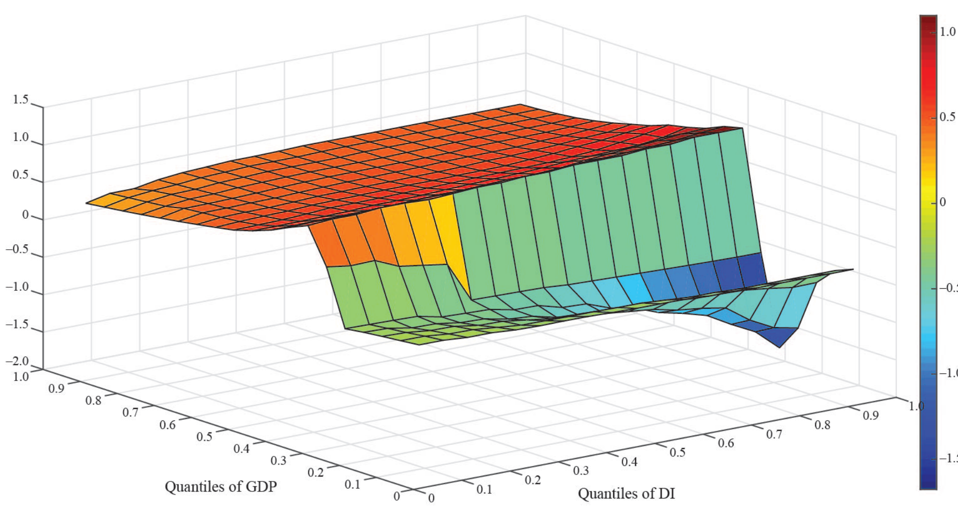
Furthermore, the DI effect on GDP in Viet Nam is described in Figure 4. The slope coefficients span from –20 to 80. In the lower and higher tails of both GDP and

Figure 3. **Effects of the Demographic Dividend on Economic Growth in Viet Nam**



DE = demographic dividend, GDP = gross domestic product.
Source: Author's calculations based on the World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022).

Figure 4. **Effects of Digitalization on Economic Growth in Viet Nam**

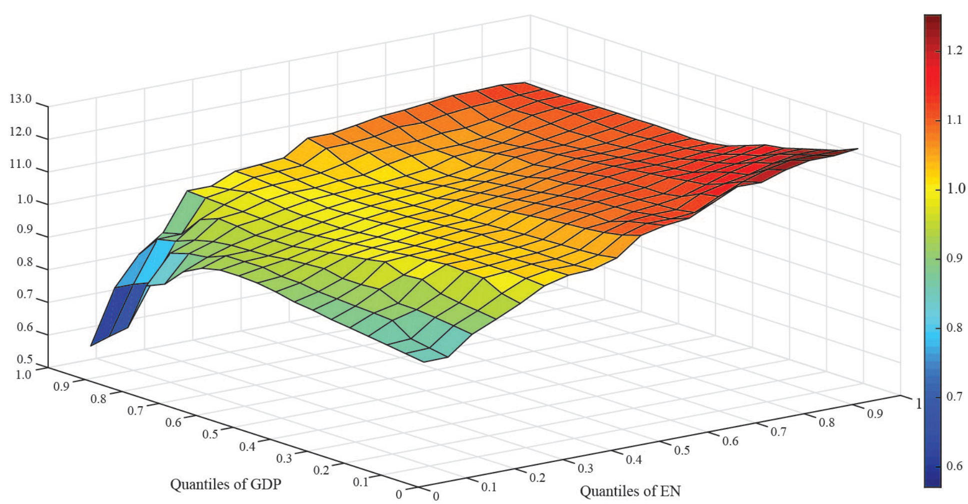


DI = digitalization, GDP = gross domestic product.
Source: Author's calculations based on the World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022).

DI, the DI effect on GDP is weak and negative, suggesting that DI plays an important role in declining GDP. Specifically, in the middle quantiles of GDP (0.5–0.8), the DI influence on GDP is strong and positive, indicating that DI contributes to economic growth in Viet Nam in the middle tail. Overall, the beneficial impact of digitalization on GDP in Viet Nam is better established than the negative impact.

Similarly, for the pair of GDP and EN (Figure 5), the overall influence of energy intensity on GDP in Viet Nam is positive. In the lower tail (0.1–0.3) of EN and the higher tail (0.8–0.95) of GDP, the impact of EN on GDP is weak and negative. Nevertheless, in the low and middle tails of GDP, the effect of EN on GDP is strong and positive. Generally, energy intensity impacts GDP in Viet Nam positively. The possible reason for this positive interplay between GDP and EN in Viet Nam, as pointed out in several other studies, may be due to the fact that the positive sign associated with economic growth is connected with the branch of the hyperbole of modern energy intensity in which modern energy intensity outperforms traditional energy intensity. In addition, the possible reasons for increased energy intensity in Viet Nam are the growing adoption of energy-saving technology in both the manufacturing and residential sectors and the shift in the proportion of economic growth toward energy-intensive industries such as the service sectors. The existence of an increasing trend as well as the positive nexus between EN and GDP reveals that the variations in technology and product mix are dramatically associated with economic growth in Viet Nam.

Figure 5. **Effects of Energy Intensity on Economic Growth in Viet Nam**



EN = energy intensity, GDP = gross domestic product.
Source: Author's calculations based on the World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022).

Figures 3, 4, and 5 show that the digitalization and demographic dividend have a remarkable positive (and statistically significant) influence on GDP in Viet Nam for almost all quantiles. These outcomes are in line with the studies of Misra (2015); Joe, Kumar, and Rajpal (2018); Ivanović-Đukić, Stevanović, and Rađenović (2019); Rivza et al. (2019); Myovella, Karacuka, and Haucap (2020); and Jafrin et al. (2021)—suggesting that increased DI and a larger DE stimulate economic progress in emerging countries. More precisely, these findings indicate that in the era of digitalization, a relatively larger working-age population and the faster expansion of a skilled labor force positively impact Viet Nam's economic performance, which supports the outcomes of past studies by Taketoshi (2020) and Fang (2020). A larger and more skilled working-age population results in positive externalities, such as generations of young people with new technological knowledge and capabilities. Younger generations are more likely to utilize the Internet and advanced technologies to stay current in the digital world. Therefore, a population of young workers with such knowledge can influence both energy consumption and economic performance. Besides, energy intensity is a metric used to assess an economy's energy efficiency, with low EN being the desired outcome. It is reasonable to expect increased energy intensity and an expanding GDP to be strongly connected during a country's early development stages because energy-intensive activities—such as road construction, automobile manufacturing, infrastructure development, and industrial growth—require more energy. It is true for Viet Nam that increasing EN is significant for economic development because it has already emerged from its development stages and related increasing energy intensity levels. However, this outcome is not consistent with the results of Hosan et al. (2022), suggesting that energy intensity is negatively associated with economic development. This may be the case because emerging market economies are expanding quickly while frequently ignoring sustainability issues.

Following the QQR estimations, it is necessary to investigate the causal relationships between the quantiles of indicators included in the model. In this regard, I used Granger causality in different quantiles as introduced by Troster (2018), the empirical results of which are reported in Table 5. The findings suggest that there is a bidirectional relationship between digitalization and economic development at all quantiles, which validates the significant impact of digitalization on GDP in Viet Nam during the review period. In a similar fashion, there exists a lead-lag association between demographic dividend and economic growth at the low and middle quantiles, and this relationship is statistically significant at the 10% level. The Granger causality indicators of DI and DE have a causal association with GDP, which affirmed the feedback effect between economic development, demographic dividend, and digitalization in Viet Nam. As digitalization exacerbated energy intensity and impacted economic growth, I inquired whether there was a causal link between GDP

Table 5. **Granger Causality in Quantile Test Results**

Quantiles	GDP → DE	DE → GDP	GDP → DI	DI → GDP	GDP → EN	EN → GDP
0.05	0.0151**	1.0000	0.0606	0.5303	1.0000	1.000
0.10	0.0151**	0.6818	0.0151**	0.6818	0.1363	0.6818
0.15	0.0151**	0.7878	0.0151**	0.7878	0.0151**	0.7878
0.20	0.0151**	0.1060**	0.0151**	0.1060	0.0151**	0.1060
0.25	0.0151**	0.0151**	0.0151**	0.0151**	0.0151**	0.0151**
0.30	0.0151**	0.0454***	0.0151**	0.0606***	0.0303***	0.0454***
0.35	0.0151**	0.0151**	0.0151**	0.0151**	0.5909	0.0151**
0.40	0.6363	0.0151**	0.0606	0.0151**	0.3030	0.0151**
0.45	0.0151**	0.0151**	0.0151**	0.0151**	0.7727	0.0151**
0.50	0.0151**	0.0757***	0.0151**	0.0606***	1.0000	0.0758***
0.55	0.0151**	0.6363	0.0151**	0.5000	0.8030	0.6363
0.60	0.0151**	0.2727	0.0151**	0.2272	0.1667	0.2727
0.65	0.0151**	0.0151**	0.0151**	0.0151**	0.2424	0.0151**
0.70	0.0151**	0.0454***	0.0151**	0.0454***	0.0303***	0.0455***
0.75	0.0151**	0.1818	0.0151**	0.1818	0.0151**	0.1818
0.80	0.0454***	0.2727	0.0151**	0.2273	0.0151**	0.2727
0.85	0.3333	0.5606	0.0151**	0.5606	0.0151**	0.5606
0.90	0.7272	0.8787	0.0151**	0.8788	0.3788	0.8788
0.95	0.0303***	0.0151**	0.0151**	0.0151**	1.0000	0.0151**

DE = demographic dividend, DI = quantiles of digitalization, EN = energy intensity, GDP = gross domestic product.
Note: ** and *** represent rejection of the null hypothesis at the 5% and 10% levels, respectively.
Source: Author's calculations based on the World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022).

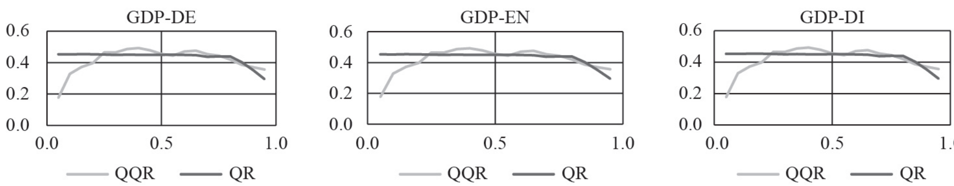
and EN. Nevertheless, the findings document that there is a unidirectional causality running from EN to GDP at the middle quantiles of EN. In addition, I also observe a feedback nexus between EN and GDP. Overall, the empirical results uncover that digitalization, the demographic dividend, and energy intensity predict significant fluctuations in economic development across different quantiles, which has crucial implications for Vietnamese policy makers.

A. Robustness Analysis

I compare the coefficients gained from traditional quantile regression and the average estimates of QQR to validate the findings of the quantile-on-quantile model. The slope coefficient of QQR—which demonstrates the impact of digitalization, demographic change, energy intensity, and economic growth presented by $\gamma(\theta)$—can be written as follows:

$$\gamma(\theta) = \frac{1}{S} \sum_{\tau} \hat{\beta}(\theta, \tau), \tag{11}$$

Figure 6. **Comparison of Quantile Regression and Quantile-on-Quantile Regression Estimates**



DE = demographic dividend, DI = quantiles of digitalization, EN = energy intensity, GDP = gross domestic product, QR = standard quantile regression, QQR = quantile-on-quantile regression.
Source: Author's calculations based on the World Bank. https://data.worldbank.org/country/VN (accessed 3 May 2022).

where $S = 19$ is the total number of quantiles $\tau = (0.05, 0.10, 0.15,\ldots, 0.95)$ utilized in the study.

As shown in Figure 6, the beta value of the QQR technique is nearly indistinguishable from the standard quantile regression outcomes, regardless of quantiles.

In all quantiles, the digitalization, demographic dividend, and energy intensity effects on GDP are positive. There is also clear similarity between the slope coefficients of the standard quantile regression and QQR. Overall, the findings of the standard quantile regression validate the estimates of QQR and Granger causality in different quantiles.

B. Discussion

The shifting pattern of age-related features significantly impacts a country's economic success. The presence of a strong interaction between demographic dividend and economic growth is highlighted in this paper, which confirms the demographic dividend hypothesis and coincides with other findings such as Van Der Gaag and De Beer (2015); Baerlocher, Parente, and Rios-Neto (2019); Amornkitvikai, Harvie, and Karcharnubarn (2022); and Polyzos, Kuck, and Abdulrahman (2022).

The social consequence of digitalization is subject to a number of limitations. If basic requirements are not satisfied at lower levels of development, the contribution of digitalization to population well-being will be reduced. High levels of digitalization can improve social equality, human growth, and access to essential services once these prerequisites are realized. Therefore, these development goals will not be accomplished unless traditional economic and social development policies are combined with digitalization promotion.

The positive impact of access to the Internet on economic development in Viet Nam is consistent with the findings of Maiti and Kayal (2017) for India; Brodny and Tutak (2022) for European Union countries; and Sahoo, Nayak, and Behera (2022) for the PRC. On the other hand, some of the negative effects of digitalization on economic growth were found by Gninigué and Ali (2022). The interaction between digitalization and economic growth in Viet Nam might be explained by the large investment in broadband Internet subscriptions in the country. As a result, Internet access is represented as a channel for transmitting the effect of digital innovation on economic sustainability in Viet Nam.

The convergence of energy intensity can be aided by an expanding GDP. The influence of economic growth on regional energy intensity convergence becomes more significant as per capita GDP rises, which in the Vietnamese context suggests that the economy grew faster than the country's energy usage. Therefore, as can be observed, GDP and energy usage in Viet Nam eventually decoupled as a result of structural adjustments to the economy. The increase in energy intensity may be the result of economic structural changes toward sectors associated with more energy intensity. For example, an increasing proportion of GDP devoted to services, all else being equal, could explain the rise in energy intensity since it takes much more energy to produce the same amount of GDP in the service sector as in the manufacturing industry. Energy intensity significantly impacts economic growth, which supports the findings found by Yaw Naminse and Zhuang (2018), Pan et al. (2019), and Xin-gang and Fan (2019), among others. Hence, my hypothesis is proved for a less energy-dependent economy such as Viet Nam (Pan et al. 2019). More importantly, a unidirectional causality runs from energy intensity to GDP because a highly energy-dependent economy suggests the causality is directed from energy consumption to income (Mahmood and Ahmad 2018, Deichmann et al. 2019, Li 2019).

V. Conclusion and Policy Insights

Viet Nam has been noted for its quick growth and industrialization; nevertheless, its current economic trajectory may become unsustainable without policy action. Therefore, present policies in this country will need to be revised to better deal with the problems of attaining sustainable development goals. This research contributes by tackling policy challenges such as demographic transmission, long-term digitalization growth, and energy efficiency. By doing so, the current study explores the asymmetric association between digital innovation, energy intensity, demographic change, and economic sustainability in Viet Nam from 1996 to 2020 using a novel approach: QQR developed by Sim and Zhou (2015) and Granger causality in quantiles introduced by Troster (2018). Based on the QQR model, I demonstrate how the quantiles of digitalization, energy intensity, and demographic structure affect the quantiles of economic growth. As a result, my work provides a straightforward insight into the comprehensive dependence structure between the concerned indicators compared to traditional econometric models such as quantile or OLS regressions.

The empirical findings suggest that the asymmetric interaction between digital innovation, demographic structure, energy intensity, and GDP in Viet Nam is primarily positive, even though slight differences exist across various quantiles of the country's selected indicators and economic growth. The heterogeneity in the impact of digital innovation, demographic change, and energy intensity on economic sustainability can be attributed to disparities in the importance of digitalization, demographic structure, and energy as inputs for economic development in Viet Nam. In addition, the outcomes of Granger causality in quantiles analysis uncover that, during the review period, a bidirectional causal association exists between digitalization, demographic dividend, and economic growth, while a unidirectional causality runs from energy intensity to GDP.

The clear evidence has significant implications for policy makers, who should consider it throughout a given stage of the economic cycle when designing policies related to demographic transition, energy conservation, digital innovation, and economic sustainability in Viet Nam. More importantly, new digital gadgets and services should also be considered by policy makers, like expanding the use of smart homes and consumer devices, which have the ability to boost energy consumption. Further, the Government of Viet Nam must shift its focus to more efficient technologies that encourage the development of skills and human knowledge, resulting in a progressive increase in the country's human capital. The government also needs to enhance green technologies that have the potential to boost economic growth.

My research uses an inclusive and current methodology to examine the asymmetric relationship between digital innovation, demographic structure, energy intensity, and GDP in Viet Nam. Nevertheless, there are some limitations, and future studies can be directed to include other measures of economic factors such as financial development, urbanization, foreign direct investment, and tourism revenue. Additionally, future studies can also take into account empirical research in regional and economic blocs such as the Association of Southeast Asian Nations and the BRICS.

My findings illustrate that energy intensity, demographic transition, and digital innovation each has a remarkable influence on GDP in Viet Nam. Thus, the current study has several significant implications for identifying the drivers of digitalization and demographic structure in emerging economies in general and their impacts on economic sustainability in Viet Nam in particular. My research confirms that energy intensity, demographic structure, and digitalization all play critical roles in increasing employment opportunities for educated and young workers, as well as in maintaining Viet Nam's present high-growth economic trajectory. The findings can serve as the foundation for a roadmap for Viet Nam to achieve long-term development objectives by embracing digitalization and productive-sector energy efficiency.

Using evidence from my work, I recommend the following set of policies to help attain the Sustainable Development Goals. My empirical findings show that Viet Nam should enhance digital innovation in all productive industries to attract and retain a youthful and tech-savvy workforce, while also reducing energy intensity to achieve sustainable economic development. Furthermore, a national strategy for digitalization and a clean energy transition pertinent to merging the digital and green sectors must be devised to effectively capitalize on the demographic dividend for economic development.

Policy influences the relationship between demographic transition and economic sustainability. Governments need to strike a balance between fiscal sustainability and protecting and meeting the needs of aging population groups, which will necessitate careful policy formulation and implementation. Therefore, Viet Nam should develop policies to improve and strengthen the education system, economic policy, medical services, and governance to enhance economic sustainability in the digital economy by realizing the demographic dividend. To reap the advantages of the demographic transition, the promotion of a young, educated work force and the centralized implementation of emerging technologies—such as public transportation management, robotics, and artificial intelligence—are required.

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