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ANALYZING THE TIME-FREQUENCY IMPACT OF DIGITAL TRANSFORMATION ON THE IMPROVEMENT OF SERVICE TRADE IN VIETNAM

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ABSTRACT

This study investigates the dynamic influence of digitalization (DG), gross domestic product (GDP), population (PO), and broad money supply (M2) on service trade (ST) in Vietnam from 1996 to 2022 using wavelet analysis and spectral Granger causality models. The results indicate that there is a positive nexus between variables during the sample period. While the relationship between broad money supply, population, and service trade is significant across different times and frequencies, the cases of ST-DG and ST-GDP are weak and insignificant at low frequencies. Moreover, Granger causality tests reveal that there exist bidirectional associations between the selected indicators. These findings suggest that Vietnam should focus on investment to enhance digitalization and expand the broad money supply, which would improve the service trade, attract foreign direct investment, and strengthen ties with other economies.

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1. Introduction

Today, digital technology and automation are popular, paralleling the trend of globalization and creating favorable conditions for every aspect of life. Digitalization has a profound impact on the economy, supporting development in all aspects and fostering increased productivity and sustainable development. The digital industrial revolution, known as the 4.0 Revolution, is gradually shaping the way we live, work, and operate the economy, including finance, trade in services, import-export, etc. (Ghobakhloo, 2020). Digital technology opens the door to innovation and creativity in products and services. Companies can quickly react and experiment with new ideas, from artificial intelligence to virtual reality. On the other hand, in economics, digital technology has transformed how businesses reach customers and advertise products. Online marketplaces and digital marketing strategies are now integral parts of many companies' business strategies. The development of digital technology has created many potential opportunities for growth in various fields and has also addressed numerous challenges, such as managing medical data during the COVID-19 pandemic and guiding national healthcare planners to enhance outbreak preparedness or improve public health education and communication (Ting et al., 2020). In this article, we will analyze the factors of digitalization and the positive impacts that help promote development in Vietnam's trade-in-service industry.

In economic terms, when evaluating a country's level of economic growth, people often focus on the Gross Domestic Product (GDP) index. GDP and social well-being are closely related, both implicitly and overtly, often used as a core index to assess a country's economic position over time or relative to other countries - and often used the popular alternative phrase 'standard of living' (Van den Bergh, 2009). By using market prices, various types of products are combined into a single value indicator. Market prices represent the amount consumers are willing to pay for different goods, accurately reflecting their value. GDP only includes products that are made and legally sold in the market, naturally excluding goods produced and sold illegally in the underground economy. The method for estimating annual and quarterly GDP is derived from data obtained from the annual economic survey and the population census, which includes manufacturing shipments, retail sales, and new house construction (Marcuss & Kane, 2007).

On the other hand, the financial sector can impact the digitalization process and significantly influence the Trade in Services industry by supporting investment in technological advances and serving as a source of economic development. Acquah and Ibrahim (2020), have demonstrated the impact of financial factors on a country's economic growth, while also predicting that Foreign Direct Investment (FDI) will have a similar effect. Therefore, to attract investors, a company or country must demonstrate optimal performance using financial statements that measure the company's performance and predict its prospects (Karamoy & Tulung, 2020). Other studies have also examined the impact of financial depth on economies, trade, and service sectors in various countries. These include Rahman (2017), Sumantri and Latifah (2019), Redmond and Nasir (2020), and Cheng (2020). The purpose of these studies is to contribute to the overall economic development of the world by analyzing the role of financial deepening in enhancing the productivity of the economies in question.

The role of population growth is to increase the labor force, thereby enhancing a country's productive capacity and significantly

improving productivity (Bui & Chen, 2017). However, there are also opinions suggesting that population growth can exert considerable pressure on economic activities by increasing market demand in the long run, thus placing significant strain on economic activities, imports, and exports (Martínez-Zarzoso et al., 2003; Bikker, 2010). Although the population factor can have various impacts on economic activity, it has not been proven or explained. Specifically, there is still no official study analyzing the demographic aspects affecting commercial activities in Vietnam, indicating a potential opportunity for future research.

This study investigates the impact of time-frequency digitalization on Vietnam's service trade. It seeks to understand how the timing complexities of digital transformation influence the nation's service trade dynamics. The empirical findings provide actionable policy insights, which are critical for advancing economic paradigms and strengthening various sectors. Vietnam has the potential to make significant progress by aligning with technologically advanced nations, fostering competitiveness, and ensuring robust growth through these informed efforts. Contribution to the relevant literature is made in a variety of ways. First, the Wavelet Coherence analysis stands as a potent tool for unveiling intricate dynamics in time-frequency domains, particularly in non-stationary signals. This method elucidates both local and global connections by evaluating the coherence of two signals across various frequency components. Its ability to identify frequency-specific relationships has been demonstrated in a variety of fields. Wavelet Coherence's robustness in capturing phase-locking patterns at various timescales has attracted attention, demonstrating its ability to discern not only linear but also nonlinear interactions across a wide frequency spectrum, thereby improving our understanding of complex systems. Second, the Granger causality regarding quantiles test introduced by Troster (2018), presents a sophisticated approach to examining intricate relationships among comparable quantiles within a given conditional distribution. Finally, to better understand the flow of service trade between Vietnam and countries worldwide, and to consider the factors affecting this flow, especially in the context of Vietnam's increasing promotion of regional and global economic integration, this study was conducted under the title: "Analyzing the time-frequency impact of digital transformation on the improvement of service trade in Vietnam". This aspect is worth attention because the quality of services provided by open countries can give them a competitive advantage internationally (Nordås & Rouzet, 2017). Following this, we will analyze empirical studies measuring how increased trade in services affects economic welfare, as per the WTO. This analysis will include a framework connected to new quantitative trading models that will be used to quantify the benefits of expanded trade in services (Arkolakis et al., 2012; Costinot et al., 2014). These findings serve as valuable additions to case studies demonstrating how trade in services drives economic expansion.

2. Literature review

2.1. Nexus between digitalization and service trade

In recent years, the nexus between digitalization and service trade has become a focal point of research, with studies offering valuable insights into the transformative impact of technological advancements on the global economic landscape. Vietnam, as a noteworthy example, has undergone a substantial metamorphosis driven by rapid digitalization, reshaping not only its economic dynamics but also significantly influencing the trajectory of its service trade sector.

Trade in services records the value of services exchanged between residents and non-residents of an economy, including services provided through foreign affiliates established abroad. This indicator is measured in millions of USD and as a percentage of GDP for exports, imports, and net trade (OECD). Trade in services has long been a topic of discussion, dating back to the works of Adam Smith, David Ricardo, and Karl Marx, who distinguished between goods and services when assessing worker productivity. According to François and Hoekman (2010), the use of knowledge-intensive commercial, financial, transportation, and communication services in industrial production is a positive driver of international trade in services.

Several studies have investigated the relationship between digitalization and service trade. Researchers such as Özso et al. (2022) using a GMM research model have delved into the impact of digitalization on a country's technology-intensive exports. Their panel data analysis from 2007 to 2017 suggests that developing nations aspiring to enhance high-tech exports should prioritize investments in information and communication technologies. Similarly, Zhang et al. (2022) focused on China's urban export transactions between 2005 and 2019, revealing a positive impact of digitalization on exports in urban areas.

Exploring the factors influencing digital service exports, Jiang and Jia (2022) employed the GPCA method and data from 71 nations (2005-2019), demonstrating a substantial global impact of digitalization on digital service trade exports. In Italy, Elia et al. (2021) explored digital export drivers, providing an opportunity for businesses to tap into the potential of their B2C digital marketing activities. They used a unique dataset of 102 enterprises of various sizes in three fields, with the results showing that companies, regardless of size, are more likely to export digital technology than traditional technology.

Zhang et al. (2022) offered a comprehensive analysis of digital service trade in the context of economic globalization and technological progress based on panel data from 40 countries/regions (2014-2020), emphasizing the positive influence of improved digital technology on digital service trade. Wen et al. (2023) examined the correlation between digital service trade and technological innovation, covering 131 countries (2005-2020), and revealing that economic growth, urban expansion, and demographic aging trigger changes in digital service trade innovation.

Maiti and Kayal (2017) focused on India's services sector and MSME segments (2000-2014), demonstrating the significant impact of digitization on India's inclusive economic growth and trade. Studies on the regional level, such as Abendin et al.'s (2022) examination of digitalization's influence on bilateral trade in ECOWAS (2000-2018), used POLS, GLS, and PPML models from 2000 to 2018. The research underscores a significant positive influence of digitalization on bilateral trade within the ECOWAS region.

Banga and Banga (2020) employed panel data methods like system GMM and random effects Tobit, and utilized Leontief's decomposition with data from the World Input-Output Dataset between 2000 and 2015 to demonstrate that India's industrial exports have a lower value added by digital services compared to other developing nations, highlighting digitalization as a critical factor affecting India's export competitiveness. Nath and Liu (2017) carried out a study using panel data for 49 countries between 2000 and 2013, showing that the rise of international trade in products and services has been significantly boosted by the development of ICT.

2.2. Nexus between gross domestic product (GDP) and service trade

Michelis and Zestos (2004) investigated the causal relationship between exports, imports, and GDP in six member states of the European Union (Belgium, France, Germany, Greece, Italy, and the Netherlands) during the period between the 1950s and 1990s. The empirical results indicated strong Granger causality from the foreign sector to GDP in all countries studied. Additionally, there was strong bi-directional causality between GDP and exports/imports in all countries, except for the Netherlands, where the evidence was weaker.

Saaed and Hussain (2015) investigated the impact of exports and imports on Tunisia's economic development from 1977 to 2012. Employing both Granger causality and Johansen cointegration approaches, the study revealed a one-way causal relationship between exports and imports, as well as between exports and economic growth. Turan and Karamanaj (2014) indicated that there exists a long-term equilibrium relationship between exports, imports, and GDP in Albania by using the Economic Views statistical package and World Bank annual data from 1984 to 2012.

In Egypt, Sulaiman et al. (2019) employed the Autoregressive Distributed Lag (ARDL) model to reveal a long-term relationship between Egypt's GDP, exports, import demand, economic growth, export and import prices, and exchange rate volatility from 1980 to 2010. Examining the factors influencing the GDP of developing nations, Kira (2013) specifically looked at Tanzania from 1970 to 2009. Utilizing the Keynesian Model, the research revealed that Tanzania's GDP is affected by consumption and exports, emphasizing the consistent stability of GDP with insignificant fluctuations attributed to certain dormant factors. Abdulla et al. (2019) explored the causal link between Iraq's economic growth, exports, and imports using annual time series data from 1980 to 2017. Johansen cointegration analysis was employed to identify long-term relationships among these variables, while Granger causality tests helped determine the direction of causality. The study found a long-term association between exports, imports, and GDP.

In East Asia, Zang & Baimbridge (2012) constructed a Vector Autoregression (VAR) model to show that there is evidence of a bidirectional causal relationship between imports and economic growth in South Korea and Japan. Amid the COVID-19 pandemic, Velayutham et al. (2022) examined India's foreign trade performance during the pandemic and showed a significant decline in both exports and imports due to the global pandemic and economic closure, with a gradual but incomplete recovery, also identifying a bidirectional correlation between India's GDP and imports during the pandemic.

In Saudi Arabia, Ali et al. (2023) analyzed the influence of international trade on Saudi Arabia's economy by testing data from 2002 to 2021 using index numbers, ANOVA, and Post Hoc analysis. The research revealed a connection between Saudi Arabia's exports, imports, and GDP.

Lastly, Moussaoui (2022) examined the influence of trade on Tanzania's economic development by analyzing annual time series data from World Development Indicators (WDI) covering the period from 1962 to 2019, utilizing vector autoregression models within the framework of linear regression techniques. The causality test revealed that GDP is influenced by both imports and exports, indicating a two-way causal relationship with imports and a one-way causal link with exports.

2.3. Nexus between broad money and service trade

The relationship between broad money and service trade has drawn a lot of interest from

researchers. Rahman (2017) investigated the short-run and long-run dynamics between the export performance of Bangladesh and selected macroeconomic variables, including interest rates, inflation rates, broad money (M2), exchange rates, and the quantum index of industrial production. Using various econometric tools and analyzing monthly data from July 2011 to June 2016, the study discovered a long-term relationship between Bangladesh's export performance and the selected macroeconomic variables, but no short-term dynamics were found. Redmond and Nasir (2020) explored the impacts of natural resource abundance, international trade, financial development, trade openness, and institutional quality on economic development proxies in a panel of 30 countries using data from 1990 to 2016. The results indicated that international trade and broad money negatively influenced economic development, while trade openness had a stronger positive impact than institutional quality.

In a Southeast Asian context, Djalo et al. (2023) investigated the impact of export and import values, the rupiah exchange rate, and inflation on foreign debt in the post-reform era of Indonesia. Utilizing quantitative methods and data spanning from 1998 to 2021, the research found that all independent variables (exports, imports, exchange rates, and inflation) collectively had a significant impact on foreign debt.

Moving to South America, Casas et al. (2023) exploited the variation in foreign currency debt maturity structure among firms following a significant depreciation in Colombia. They found that debt revaluation reduced imports due to higher delinquencies and interest rates, while exports remained unaffected. Shifting the focus to the impact of currency devaluation on US services trade, Cheng (2020) examined quarterly data from 1999 to 2015 and revealed that currency devaluation could enhance the long-term growth of service exports and reduce imports, but its short-term impact was limited. Similarly, Dao et al. (2020) used quarterly data from 2000 to 2018 and the ARDL-ECM model, indicating that the real effective exchange rate had a short-term negative impact on the trade balance, while the broad money supply had a weak positive effect on the trade balance, persisting in the long run for Vietnam's trade balance. Harighi et al. (2022) pointed out that export diversification was positively impacted by indicators of financial growth using the Arellano-Bover/ Blundell-Bond two-step dynamic panel data (DPD) method based on the generalized method of moments (GMM) with 54 developing countries between 2005 and 2018.

Moving to Nigeria, Gatawa et al. (2017) utilized a VAR Model and Granger Causality test within an error correction framework, revealing that in the long run, broad money supply positively influenced economic growth, whereas inflation and interest rates exerted negative effects from 1973 to 2013. Aslam (2016) conducted research spanning from 1959 to 2013, aiming to prove the hypothesis that money supply positively affects economic growth, providing evidence of such a positive impact on Sri Lanka's economic growth.

Finally, Sumantri and Latifah (2019) researched how macroeconomic variables (loan rates, money supply, inflation, and consumer price index) influenced imports and exports from 2012 to 2018. The findings revealed that all factors influenced both imports and exports, except for the Consumer Price Index, which had little impact.

2.4. Nexus between population and service trade

Herzer (2017) employs panel time-series techniques across five decades, from 1960 to 2010, encompassing a sample of 74 countries to show that international trade has a robust

positive long-term effect on health, particularly in less developed countries with higher taxes on income, profits, and capital gains, as well as less restrictive business and labor market regulations. Lei et al. (2009) examined the connection between population carrying capacity and trade, with Macao City as a case study from 1977 to 2004, using the Ecological Footprint Analysis framework. The findings revealed that international trade can compensate for domestic ecological resource shortages and increase population carrying capacity.

Moving to the analysis of export strategies and social development, Didenko et al. (2015) delved into Russia's resource-oriented export strategy from 1990 to 2012. They found that when demand for energy resources is on the rise, exporting raw materials can significantly boost the development of Russia's social sector.

In Pakistan, Ahmad and Luqman (2012) clarified the correlation between variables such as inflation, investment, population, exports, and GDP, showing the positive effects of investment, exports, population, economic growth, and inflation. Becchetti et al. (2007) demonstrated that export productivity is affected differently by regions with different populations by collecting population data from Italian enterprises and the Italian Statistical Institute's ASIA database. They pointed out that enterprises in high-population industrial zones export more and have higher value-added than firms located elsewhere. Bui and Chen (2017) utilized the gravity model to identify key determinants, including GDP, price, population, and exchange rates, emphasizing the multifaceted factors influencing Vietnam's rice trade dynamics.

Wu et al. (2021) examined the influence of population aging on renovated exports in developing countries recently. Using the method of instrumental variables, the research revealed that population aging primarily slows down innovation, the development of human skills, and the improvement of exports. Addressing Indonesia's crude palm oil (CPO) exports from 1999 to 2018, Rosyadi et al. (2021) employed panel regression and the basic gravity model. The results revealed that Indonesia's CPO export intensity is positively affected by the importer's higher GDP and export volume, while it is negatively influenced by the exporter's GDP and economic distance. Limaei et al. (2011) identified positive relationships between wood trade and population, GDP, domestic wood production, and world oil prices using multivariable regression analysis (MRA) and a first-order autoregressive model.

Todshki and Ranjbaraki (2016) delved into the macro factors influencing steel exports and imports in Iran from 1975 to 2011. Using Youhanson long-term convergence and Granger causality tests, they found that Iran's macroeconomic variables, including population, have a positive impact on steel exports and imports. Dao et al. (2014) examined factors affecting total trade in services, service exports, and service imports between Vietnam and the European Union between 2002 and 2011 using a gravity model estimated with panel data. The results showed that factors such as the GDP per capita gap between Vietnam and partner countries, the population of partner countries, the real exchange rate, and colonial relationships have affected total trade in services.

Finally, Emikönel (2022) analyzed China's trade with 97 significant partner countries from 2008 to 2019 using an extended gravity model and identified the factors influencing this trade. The study revealed that Chinese trade is positively linked to GDP and population growth in both dependent and independent countries, with trade negatively affected by increasing distances.

3. Methodology

In this study, we will use the Wavelet method in the following order: First, we use the Continuous Wavelet Transform to represent fluctuations in local variance. By translating the initial series into a time and frequency function, the continuous wavelet transform enlarges the time series into a time-frequency plane. Then, the Cross-Wavelet is applied to transform to illustrate the evolution of local variance and covariance in a two-time series. After that, we use Wavelet Coherence to demonstrate the co-motion correlation of two variables in the time-frequency domain. The localized correlation coefficient in the time-frequency space is a wavelet coherence's definition. In addition to the time and frequency components, it presents the correlation strength between xt and yt in a three-dimensional manner. Delays and synchronizations between xt and yt are described by the phase difference. The wavelet coherence value is positive; hence, it is computed between positive and negative correlations and lead-lag connections (Vukovic et al. 2021). Finally, we use the Breitung-Candelon test (2006) for Granger causality to evaluate the level of reliability between selected variables.

3.1. Continuous wavelet transform (CWT)

The continuous wavelet transform (CWT) facilitates our ability to examine the overall level of volatility exhibited by a time series, including analysis spanning both frequency and time dimensions, thereby providing a more thorough understanding of the data's fluctuation patterns. It can be defined as:

$$\mathrm{Wx(s)}=\int_{-\infty}^{\infty} x(t)\,\frac{1}{\sqrt{s}}\psi * \left(\frac{t}{s}\right) \qquad (1)$$

Where, * stands for the complex conjugate and the scale parameter s indicates whether the wavelet may detect higher or lower components of the series x(t), which may be the case if the admissibility condition is met.

The wavelet power spectrum is also referred to as the scalogram or the wavelet periodogram and can be defined as:

$$\mathrm{WPSx\ (a,\ b) = |Wx\ (a,\ b)^2|} \qquad (2)$$

It displays the local variance of x(t) at various frequencies. WPS plots are represented in color with the highest cardinality shades implying periods of the highest volatility.

3.2. Cross-wavelet power transform

According to Hudgins et al. (1993) and Torrence and Compo (1998), Covariance contribution is measured in the time-frequency space using cross-wavelet power. The cross-wavelet of two series x(t) and y(t) can be defined as:

$$W_n^{XY}(u,s) = W_n^{X}(u,s)W_n^{Y*}(u,s) \qquad (3)$$

Where, u denotes the position, s is the scale, and * denotes the complex conjugate. The local covariance between two time-series at each time and frequency is represented by the cross-wavelet power, which we label as |Wxy n (u,s)|.

3.3. Wavelet coherence

Wavelet coherence (WTC) can be conceptualized as the local correlation between two time series, both in terms of time and frequency. It is defined as "the ration of the cross-spectrum to the product of the spectrum of each series" (Aguiar-Conraria et al., 2008). The wavelet coherence that captures the co-movement of the two-time series is defined as follows by Torrence and Webster (1999):

$$R_n^2(u,s) = \frac{S(s^{-1}\left|W_n^{XY}(u,s)\right|^2)}{S(s^{-1}|W_X(u,s)|^2)S(s^{-1}|W_Y(u,s)|^2)} \qquad (4)$$

Where, S represents a smoothing parameter on both a temporal and scale. The range of R2(u,s) values is 0 to 1, where a high or low value indicates a strong or weak co-movement. This co-movement can be present in the range

$0 \leq R2(u,s) \leq 1$. If its value is closer to 0, it shows that the interdependence is weaker and vice versa.

3.4. Discrete wavelet transform

A time series y(t) can be broken down into different temporal scales:

$$y(t) = \sum_k SJ,k\phi J,k(t) + \sum_k dJ,k\psi J,k(t) + \sum_k dJ\text{-}1,k\psi J\text{-}1,k(t) + \ldots + \sum_k d1,k\psi 1,k(t) \quad (5)$$

This decomposition is expressed mathematically by the sum of products of smooth (low-frequency) and detail (high-frequency) wavelet coefficients, denoted by $S_{J,k}$ and $d_{J,k}$, with the corresponding father and mother wavelet functions $\phi_{J,k}(t)$ and $\psi_{J,k}(t)$. Equation (1) consolidates this representation, illustrating the multi-resolution analysis of the signal.

As a result, the time series y(t) can be expressed in a different form:

$$y(t) = Sj(t) + Dj(t) + Dj\text{-}1(t) + \ldots + D1(t) \quad (6)$$

The manuscript simplifies this relationship into a summation of smooth signals $S_j(t)$ and detail signals $D_j(t)$ across different scales, as depicted in equation (2). It specifies that $S_j(t)$ is the highest-level approximation and represents the smooth aspect of the signal, while $D_1(t)$, $D_2(t)$,..., $D_j(t)$ correspond to details reflecting various oscillation lengths.

The study utilizes daily data and selects a multi-resolution level J = 8, justifying this choice with references to past studies that have demonstrated moderate filters' effectiveness in financial data analysis (Fernández-Macho, 2012; Reboredo et al., 2017). This choice underscores the relevance of choosing an appropriate level of detail for analyzing financial time series data.

3.5. Data

The data used in this article were collected and compiled from various sources from 1996 to 2022, including World Bank Development Indicators and the DiGiX digitalization database for the variables being studied. The selection of this time frame was chosen because it is presently available. Financial reform was introduced in 1990 to improve the performance of Vietnam's financial institutions (Shahbaz et al., 2019; Nguyen Xuan Phuong et al., 2021). This study investigates the relationship between Service Trade (ST), digitalization (DG), economic growth (GDP), broad money (M2), and population (PO) in Vietnam. Service Trade will be measured by its profitability in the industry (US Dollar); the Digitalization index measures countries' digital adoption across aspects of the economy (total social, political, and economic digitalization); economic growth, GDP measures a country's economic performance (in US dollars per capita); broad money M2 calculates the money supply of a country (US dollars) and population statistics the number of people in Vietnam over the years (number of people). This study looks into the connections between service trade (ST), digitalization (DG), economic growth (GDP), broad money (M2), and population (PO) in Vietnam. The Service Trade (ST) variable is derived evenly by adding the sum of the two indices Export and Import. Table 1 lists the tested indicators' descriptions, units of measurement, and sources.

Table 1. Data description

Variable	Abbreviation	Measurement	Source
Service Trade	ST	US dollar	WDI
Digitalization	DG	Index	DiGiX index
Economic Growth	GDP	US dollar per capita	WDI
Broad Money	M2	US dollar	WDI
Population	PO	number of people	WDI

We applied the quadratic match sum strategy and a widely recognized interpopulation methodology to increase the number of observations in the data set. As noted by Ngo Thai Hung (2023), and Shahbaz et al. (2018), we also modified the annual data frequency to quarterly. All series are logarithmically converted to eliminate the variable variance issue (*see Appendix 1 online)*. As can be seen clearly, Broad money (M2) has the greatest average of the variables studied, at 33.48%. Meanwhile, Digitalization (DG) has the smallest average among the variables studied, at only 1.96%. However, the DG variable has the highest standard deviation, with a value of 2.52, indicating that it is the most volatile of the remaining variables. PO has the smallest standard deviation, which indicates that values are less likely to deviate from the mean. The Jarque-Bera test results reveal that the series has a non-normal distribution.

The overall distribution of the relevant time series and pairwise correlations between indicators helps us see their structure and the relationship between them (*see Appendix 2 online)*. The correlation between variables is described through the degree of color displayed between them: the darker the color of the cell tends to become, the more positive the correlation it shows; On the contrary, if the color of the cell tends to become darker and redder, it shows that there is more and more negative correlation between each other. And if the color of the cell is white then there will be no correlation between them. In general, there is a very strong correlation between variables with no correlation below 0.9. That proves there is a strong positive relationship between service trade, digitalization, GDP, broad money, and population in Vietnam.

4. Results and discussions

Wavelet coherence (WTC) is used because it offers a valid measurement for synchronizing the indicators under examination over a long period and across frequency bands and because wavelet intelligibility guides further research thanks to the clear and distinct findings. The wavelet intelligibility analysis generates the limited association coefficient between two-time series. Wavelet clarity can be relied upon to offer the co-movements and lead-lag correlations between series over various investment horizons. The results are shown in Appendix 3, Appendix 4, Appendix 5, and Appendix 6 (*see Appendix 3, 4, 5 and 6 online)*. The color represents the degree of co-movement between two indicators, with the horizontal line denoting the time component and the vertical line denoting the frequency component (quarters). The interdependence of economic series with dense red regions is stronger than those with light blue islands. The regions that are statistically significant at the 5% level, are shown by the thick black outline computed using a Monte Carlo simulation.

The WTC and phase differences for four sets of indicator pairs—ST and DG, ST and GDP, ST and M2, and ST and PO—are shown in Figure 2, Figure 3, Figure 4 and Figure 5. Directional relationships are shown by the arrow. The right (left) arrow indicates that the series is in (out of) phase, while the up (down) arrow indicates that the first (second) series leads to another series. Data on wavelet coherence and phase differences corroborate our predictions.

The wavelet coherence between ST and DG In the short-term period, from 1996 to 2000 and 2022, the red color shows a strong correlation, and the arrow in this area points to the right, showing a positive correlation. However, in 2000-2020, the blue area appeared, proving that the correlation here is weaker, but there is still almost a positive correlation. Figure 2 can point out that the pair was out of phase in 2015 at the short frequency (0-4 quarters) because while the other periods of the short frequency all have arrows pointing to the right,

indicating a positive correlation, there is only The 2015 area again that has arrows pointing left. This means there is a negative relationship between ST and DG on a short-term scale around 2015, showing that an increase in DG reduces ST. Similarly, this also happens in the medium term but in the middle period in 2003 and around 2005-2015, the arrows tend to move in the upper right direction. That proves the dependent variable is leading. However, in long and very long periods, this pair shows a positive influence on each other when even the correlation strength tends to slide down a slope and slowly climb, always showing a positive correlation. These results confirm the economic theory of a positive correlation between Service Trade and a country's digitalization. This is also demonstrated in reality, where the fourth industrial revolution's rapid advancement, the COVID-19 epidemic's effects, and shifting consumer preferences serve all powerful catalysts for the transformation process. It is thought that a trend will emerge where digitalization happens more swiftly in the services and commerce fields.

Figure 3 describes the WTC between ST and GDP. The red indicates a very strong correlation between the two variables, ST and GDP, for a short period (4 quarters) from 1996 to around 2000. The red area's arrows all pointed to the right, indicating a positive correlation. However, between 2000-2002 and 2020, blue and green zones began to appear. This demonstrates that the ST variable and GDP have a weaker correlation between these years. It is still a positive correlation. Thus, we see red areas displaying a strong and positive correlation in 2022. In general, the two variables ST and GDP show a positive correlation in the short term. In the medium term, it can be seen that ST and GDP are still positively correlated. However, from 2015 to 2018, despite a strong correlation, the two variables had a negative relationship. By 2022, the two variables ST and GDP were strongly and positively correlated again. Generally, the two variables ST and GDP are still strongly correlated during a medium-term period of 4 to 8 quarters. However, the variables are positively correlated in 1996-2002 and 2020-2022 but are negatively correlated between 2015-2018. In the long-term period, from 8 quarters to 16 quarters and 16 quarters to 32 quarters, most of the arrows point to the right, proving that the two variables ST and GDP are positively correlated The majority of the arrows point to the right during the long term period, from 8 quarters to 16 quarters and 16 quarters to 32 quarters, demonstrating that the two variables ST and GDP are positively associated. Overall, the two variables ST and GDP have a strong and positive correlation in all periods; only in the medium term, from 2015 to 2018, do they have a negative correlation. They all have a positive relationship in both the short and long term.

Additionally, Figure 4 depicts the WTC between ST and PO. We observe that the relationship between these two series varies across time and frequency domains. There was a strong correlation from 1996 to nearly 1998, in the small frequency category (from 0 to 4 quarters) before a weak correlation occurred that lasted more than 2 decades and became stronger again from around 2022 onward. The good news is that in all time points, whether strongly or weakly correlated, observations show that there is always a positive correlation between the two variables ST and PO. Moving to mid-frequency, we will see more diverse changes in this correlation relationship. Almost similar to low frequencies, we will see strong correlations at the beginning and end of the observation series as well as weak long-term correlations in the middle of the series. The special thing is that in the middle of the weak correlation series, there was a significant increase in the correlation between the variables from 0 to approximately 0.5 from 2005 to nearly 2015.

Furthermore, amongst this increasing interval, the arrow moves right down, showing that the chosen independent variables are leading. It is seen that the expansion of the labor market has impacted the number of migrants and increased the need for human resources. Similarly, the large period also fluctuates in correlation with the increasing trend at the beginning and end of the time series and decreasing in the middle. However, it can be seen that the weak correlations have narrowed and made the fluctuations in this period much more balanced. And in the entire time series, they all show a positive correlation between the two variables but in the period of very large correlation, it is the most disproportionate stage. Since the 2000s, the fluctuations between the two variables have always been weak and have continued until today. In recent years the chosen independent variables are represented by right-down arrows. In general, the relationship between ST and PO is always a positive correlation even though the correlation between them is strong and weak.

The findings related to the ST-M2 pair consistently demonstrate specific patterns across various time frames. In short-term frequencies, there is a distinct shift of arrows to the right, indicating a substantial interconnection between 1996 and 1998. Notably, during this time frame, the arrows for the ST-M2 pair pointed simultaneously upwards and to the left. Importantly, starting from 2022 and onward, the arrows for the ST-M2 pair shifted to the right again, signaling a positive influence, and correlation significantly strengthened by the end of this period. Moving to higher frequencies (4-8 quarters), the 1996-1999 period exhibited a strong connection, although the arrows pointed to the right. However, there was a noticeable shift in the right-down direction observed from 1997 to 1999. Furthermore, between 2000 and the early months of 2022, the arrows consistently followed the right direction, while the correlation for ST-M2 remained relatively weak. Particularly noteworthy is the remarkably strong connection in ST-M2 during this period, with the arrows constantly pointing downward. Subsequently, the arrows reverted to the right, accompanied by a strengthening correlation. In terms of 8-16 quarters, the arrows consistently pointed to the right from 1996 to 2000, demonstrating robust inter-correlation. Moreover, from 2000 to 2022, the arrows continued to point to the right, despite the correlation showing an upward trend, albeit with a brief period of weak correlation in 2005. In the long term, a strong association is observed within the ST-M2 pair, aligning with the overarching trend of arrows pointing to the right from 1996 to 2022. After nearly two decades of observation, a persistent pattern of weak correlation emerges.The wavelet coherence results for three key time periods: short, medium, and long-term (see *Appendix 7 online)*.

5. Conclusion and implications

5.1. Conclusion

This research explores how digitalization, GDP, population, and broad money interact to influence the development of service trade in Vietnam. We analyze their dynamic relationship across different periods from 1996 to 2022, by employing wavelet frameworks and wavelet-based Granger causality tests using quarterly data on digitalization, GDP, population, and financial depth (represented by broad money) which serve as a proxy for economic growth and opportunities for Vietnam's service trade.

About how the digitalization trend and accompanying factors will impact Vietnam's Trade and Services industry: By examining the frequency domain, we identify patterns of contagion and intercorrelation. We found that higher timescales are associated with contagion, while lower timescales are linked to interrelations. Our analysis reveals a positive connection between service trade, digitalization, GDP, population, and broad money over medium and long-term periods.

Regarding the importance of developing the dynamic interaction of digitalization and factors influencing service trade in Vietnam: The wavelet-based Granger causality analysis indicates a significant bidirectional relationship between digitalization (DG) and service trade (ST). However, no significant links were found between GDP, population (PO), and service trade (ST). The interaction between digitalization (DG) and M2 money supply displays a complex relationship with varying short- and long-term effects over time. This underscores the importance of targeted policies to support service trade and investment in digital skills. Focusing on digitalization, GDP growth, M2 money supply expansion, and population strategy development can significantly enhance Vietnam's service trade and overall economic prosperity.

Propose solutions for sustainable development: The findings above have key policy implications for the government and policymakers, who propose various policy ideas to help improve investment capital flows to expand the service trade industry and Vietnam's future potential. Policies to promote digitalization should be applied to improve and develop the e-commerce industry, opening up many opportunities for the industry. Industry development in Vietnam also attracts foreign investment resources that will help this country's economy stronger.

5.2. Policy recommendations

Our results indicate the time-frequency relationship between (Service Trade, Digitalization, Economic Growth, Broad Money, and Population) studied in Vietnam between 1996 and 2022. According to our research's first finding, higher timescales are related to contagion, while lower timescales are related to interrelationships. In the pursuit of digitalization within the service commerce sector, it is imperative to implement a series of interconnected policy recommendations. These recommendations are carefully designed not only to stimulate economic growth (GDP), but also to engage the entire population, foster digitalization, and influence the measurement of Broad Money M2.

To begin, the enforcement of data privacy and security regulations is crucial. When people have faith in the security of their digitalization, they are more likely to adopt digital services, which leads to increased digitalization rates. The fintech integration solutions into the digital commerce ecosystem is a pivotal step. Encouraging businesses to incorporate fintech solutions for digital payments can have a two-fold impact, influencing both the measurement of Broad Money M2 and the facilitation of seamless digital transactions. Simultaneously, supporting Vietnamese small and medium-sized enterprises (SMEs) in their digital technology adoption is another essential policy measure. By enhancing the competitiveness of SMEs, we contribute to their growth, thereby positively affecting GDP. In addition, governments should develop comprehensive e-government services to streamline public services and reduce bureaucracy. An efficient government not only reduces costs but also makes a notable contribution to GDP growth. Investing in digital infrastructure is equally critical. This is particularly relevant for underserved areas, as it not only accelerates digitalization but also broadens the reach to a larger population. Furthermore, providing tax incentives and benefits for businesses that invest in digitalization can significantly influence GDP by stimulating digital commerce. Enhancing the population's digital skills through training and educational programs positively affects both GDP and the digitalization rate. This ensures the availability of a skilled workforce, fostering digital economic activities. Finally, promoting cross-border digital trade agreements offers businesses access to larger markets, ultimately contributing to GDP growth.

These policy recommendations should be customized to the specific circumstances of each country or region. By considering their potential impact on GDP, population engagement, digitalization, and Broad Money M2, governments and policymakers can create an environment conducive to successful digital transformation within the service trade sector, leading to economic growth and increased digitalization.

5.3. Limitations

Although the study's findings are solid, they have several limitations. The scope of the study was confined to Vietnam, and only a few indicators were included for measuring the impact of digitalization on the service trade business. This can make comparing Vietnam's domestic policies with other regions more complicated. Therefore, the suggestions when applied may be correct in Vietnam and other countries with similar development conditions but may be misleading and ineffective when applied in other countries. Furthermore, the scope of the study does not include all variables affecting service trade, so other potential variables may be missed.

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