DOI 10.15826/vestnik.2025.24.3.025 Original Paper

Analysis of Economic Development and Economic Interaction in ASEAN Countries: ARDL Model Approach

Setyo Wira Rizki ✉, ***Nikolay I. Didenko***
Peter the Great St. Petersburg Polytechnic University,
Saint-Petersburg, Russia
✉ *rizki.sv@edu.spbstu.ru*

Abstract. Regional economic integration within ASEAN aims to strengthen the economies of its member states, and this commitment has yielded positive results. Economic integration, particularly through tariff reduction, significantly impacts intra-regional exports, which serve as a key form of economic interaction among member states. Intra-export is viewed as the representation of economic integration and is projected to stimulate economic growth. This study examines the economic interaction indicators that influence economic development, hypothesizing that intra-exports have a significant effect on economic progress. To test this hypothesis, the Autoregressive Distributed Lag (ARDL) model was employed as the theoretical framework and analytical tool. The results confirm the hypothesis, demonstrating that intra-exports are a significant driver of economic development within the region. Forecasting of key economic indicators indicates an upward trend over the next decade, with average annual increases of approximately four percent. The approach proves to be highly effective for short-term forecasting. In summary, this study finds that economic interaction, as measured by intra-exports, positively contributes to economic development indicators such as GDP per capita, exports per capita, imports per capita, and population growth. The findings support neoclassical trade theory and build on previous research highlighting the critical role of intra-regional trade in fostering regional economic growth. The study's implications serve as valuable recommendations for policymakers aiming to enhance intra-export activities.

Key words: ASEAN; regional trade; ARDL model; trade openness; economic integration.

JEL C02, F15, F43

1. Introduction

Regional integration has become a popular trend in various regional areas. It aims to build a joint political and economic in a region by improving trade collaboration among member countries. The intra-trade is expected to contribute a positive impact on the economic growth of the regional organization. The intra-regional trade was thought to have significant and positive effects on per capita output growth. Nevertheless, in a study involving European union countries, the intra-regional trade had a smaller impact on output growth than the extra-regional trade [1]. However, the intra-regional trade is still being an interesting topic to investigate, especially in research involving the economic interaction in a regional organization.

Regional organizations could be a starting point for developing countries to promote international trade and investment. The ASEAN free trade area signed in 1992 was the important free trade agreements in the world and the Asia Pacific

  ISSN 2712-7435

region. This agreement was regarded as an initial commitment to achieve a competitive economic growth in Southeast Asia region. The economic growth is identified as a country's GDP per capita. It is frequently regarded as an assessment of a country's prosperity, even though it is incompatible with socially equitable signals [2]. The GDP is a principal indicator of welfare in the economic development. The entire government policies, designed at growing welfare, have purposed to improve GDP [3]. In addition, the volume of export and import could be also expected as a benchmark or parameter to measure the economic growth. The export and import provide a positive impact on economic development in developing nations [4]. In the ASEAN region, the intra-trade development under a trade agreement has given a positive and significant impact on an extensive quantity of products, including imported and exported goods [5].

ASEAN is a prominent regional organization. It has a significant performance in the Asian continent. In recent decades, the regional integration in Asia has increased since the 1990s with a priority on the domestic growth. It is reflected in several indicators such as trade flows, foreign direct investment, tourism, financial links, and output correlation. Further, it is regarded as a solid regional organization in the Asian region with most of its members are developing countries.

As a commitment to regional economic cooperation, the ASEAN economic community was established in 2015. It was considered as a foremost commitment to build a stronger economic integration. ASEAN has made optimal efforts in building the economic community, but it has required several challenges to internal laws or even national constitutions. This economic community has emerged as Asia's leading regional economic integration and achieved a significant progress in the most sectors [6]. Furthermore, the policy intervention of regional integration, aims to improve the population's welfare and life quality, is manifested on the economic development.

To reveal an analysis of the economic development and economic interaction, the researchers employed a mathematical model. A mathematical model is conducted generally on the economic growth cases. The mathematical model used is the autoregressive distributed lag (ARDL) model. This approach can be applied in a small sample. Thus, it produces an unbiased and efficient model. This model enable avoid the problem of autocorrelation, and obtain both of long-term and short-term estimation simultaneously. Further, this research is applied on the time series data during period 2000 to 2021. The endogenous variables are represented by GDP per capita, export per capita, import per capita and population. Those four endogenous variables could be considered as indicators measuring the economic development. Thus, intra-export, average of price deflator, total labor force, average of number of physicians per 1000 people, average of unemployment and average of life expectancy are expected as the variables influencing the economic development and assessing the economic interaction.

This study constructed four ARDL models such as model 1 is a composition of the GDP per capita as endogenous variable and the export per capita, the import

per capita, the population, the intra-export, the average of price deflator, the total labor force, the average of number of physicians per 1000 people, the average of unemployment and the average of life expectancy as exogenous variables; model 2 is a composition of the export per capita as endogenous variable and the GDP per capita, the import per capita, the population, the intra-export, the average of price deflator, the total labor force, the average of number of physicians per 1000 people, the average of unemployment and the average of life expectancy as exogenous variables; model 3 is a composition of the import per capita as endogenous variable and the GDP per capita, the export per capita, the population, the intra-export, the average of price deflator, the total labor force, the average of number of physicians per 1000 people, the average of unemployment and the average of life expectancy as exogenous variables; model 4 is a composition of the total population as endogenous variable and the GDP per capita, the export per capita, the import per capita, the intra-export, the average of price deflator, the total labor force, the average of number of physicians per 1000 people, the average of unemployment and the average of life expectancy as exogenous variables.

In this study, the economic interaction among the ASEAN countries is described as the intra-export variable which is one of the exogenous variables.

The purpose of the study is to find out the indicators of economic interaction that influence economic development in ASEAN.

The research question of this study is whether the intra-export has an impact on economic development in ASEAN.

The intra-export is expected to give a significant effect on the economic development. This expectation is considered as a novel thing and simple uniqueness. In the last, forecasting of the economic development indicators are carried out as the final result of the research. This research is expected to provide a new insight in assessing the future economic development by considering the economic interaction among member countries of the regional organization.

2. Literature review

International economic integration has played an important role in international economics since the 1950s [7]. The international economic integration is an agreement that provides opportunities and challenges for the member countries involved. Another goal of regional economic integration is to reduce poverty and achieve a sustainable inclusive development. This integration activity has been getting more diverse encompassing financial flows, business cycle synchronization, economic and social exchanges [8]. The regional economic integration is an effective way to overcome regional challenges in order to increase the economic growth in a region. The European community is the most significant and influential organization of these arrangements. In the recent decades, the regional integration in Asia has increased and approached to European level.

The Asian economy has experienced a rapid growth since the 1960s. Several aspects have supported the economic acceleration in Asian countries. Those are

such as having the potential to grow despite relatively low incomes, potential geography and structural characteristics, the demographic structure changes afterward World War II, and economic policy strategies supporting to sustainable growth. The more developed countries in Asia have recognized the importance of regional economic integration into the world economy. They have promoted the international trade through several strategic policies such as more flexible trade districts, easier currency convertibility, macroeconomic stability, tariff-free procedures, and investment. The economic growth in the East and Southeast Asian countries climbed efficiently during period 1965 to 1990. The top eight countries were Hong Kong, Singapore, Taiwan, Korea, China, Malaysia, Thailand, and Indonesia, reached their economy growth by approximately 5.5 % per year.

In Asia, there are several regional integration groups including ASEAN. It has contributed positively to improve the regional unity in Asia, although the institution has been learning and struggling in the direction of political stability [9]. This organization has emerged as an important catalyst of economical designs in Asia-Pacific's. Moreover, it settled as an inspiration in regional cooperation with a highly sought-after economic partner. Most of the member countries have developed stable and politically confident.

Andal [10] studied on the resilience level of the organization centrality as an implementation of economic integration in the Asia Pacific region. The study discovered that ASEAN is not strongly connected to other regions. This research contributed to give a significant consideration to trade policymakers about the trend of economic integration in the region.

More than a few previous studies of the worldwide economic integration have been accomplished. For instance, Türkcan, & Saygılı [11] studied on the effect of economic integration agreement among Turkey and its trading partners on machinery exports in the period 1998–2013 using the probit model. The study revealed that the economic integration agreements have enhanced the survival of export relationship initiated before the agreement.

Cyrus [12] studied on the reason of several countries to establish the regional trade agreements using bilateral data from 1950 to 2013. The study disclosed that the trade, the GDP per capita, the cultural similarities and the institutions have significant opportunity for the involved countries under the regional trade agreement. Thus, a higher frequency of bilateral trade in the previous times has improved the opportunity of two countries to join in the equivalent trade agreement.

Ruan et al. [13] studied on the trade relation among the ASEAN member states and China using the theory of ecological population evolution. The study indicated that the trade collaboration among those countries gives a low probability on the conflict and trade friction. It revealed that the trade relation among China and the ASEAN countries is mutually beneficial.

Furthermore, the regional economic cooperation is realized in a trade openness arrangement. It aims to increase export and import volume considered as economic development generator. Nguyen & Bui [14] studied on the nonlinear impact of

trade openness on the economic development by considering the volume of trade transaction in the ASEAN-6 countries. The study disclosed that there is a positive impact of trade openness on the economic growth.

Vogiatzoglou & Thi [15] studied on the short-run and long-run effects of the economic openness on the economic growth in the ASEAN-5 during a period 1980–2014. The study revealed that both of the import and export hold a significant short-run and long-run impacts on the economic growth.

Sermcheep [16] studied on the impact of service export on the economic growth in the ASEAN countries with panel data in a period 1980–2014. The study confirmed that the service export has generated the economic growth in ASEAN over the past few decades. Moreover, the modern service export has contributed to the gross domestic product with a less strong positive effect.

Mathematical modelling is a method frequently used in completely fields of research such as social, health, economics and humanities. The mathematical research conducted by the ASEAN researchers has increased over time. For instance, Ho-Le & Nguyen [17] studied on the mathematical research trend rooted from the ASEAN countries in the period 2006–2015. The study exposed that the ASEAN researchers published 9,890 papers in mathematics. Several studies have applied the ARDL model to analyse the economic development and economic interaction in ASEAN countries.

Numerous preceding studies have employed the ARDL model in economy fields. For instance, Ahmed & Delin [18] studied on the ARDL method applied to investigate the relationship of cotton cultivation area, profitability, quantity of cotton exports, cotton export prices in Egypt and American cotton export prices. Data stationarity was tested by Augmented Dickey-Fuller and Phillips-Perron unit root tests. The study indicated that profitability and the number of exports had a significant effect on the area of cotton cultivation in the long term.

Dell'Anno & Halicioglu [19] studied on the ARDL method to analyse the relationship between the unrecorded economy and the recorded gross domestic product in Turkey. The method was adjusted to estimate the size of the unrecorded economy based on a partial adjustment model.

Marimuthu et al. [20] studied on the causal relationship between the government expenditure and government income, and its impact on economic growth in the ASEAN region using panel unit root tests and the ARDL panel cointegration. The study discovered that the government expenditure has a long-term relationship with the gross domestic product, significantly and positively related to the economic growth in the long term, while the government income is significant in the short term.

Caleb et al. [21] studied on the cointegration affiliation between the gross domestic product as an endogenous variable and the macroeconomic variables as exogenous variables. The study revealed that there is a long-term cointegration connection between the gross domestic product and it's the regression coefficients.

Didenko et al[1]. studied on the impact of economic interaction through mutual trade among the EAEU countries on the economic growth, based on the conceptual positions of integration. It was conducted in order to formulate a target program for the development of integration displayed by alternative graphs, which will allow selecting options for the integration development of the EAEU countries.

Table 1. **Framework of the previous studies and research gap**

Previous studies	Research gap
The positive impact of economic integration on the economic development including in Europe and Asia since 1950s. (El-Agraa [7], Capannelli et al. [8])	The advantage of regional economic integration in the modern world using the recent data.
ASEAN has contributed positive impacts and performance as a regional organization, but as a group, ASEAN is not strongly connected. (Taghizadeh-Hesary et al. [9])	ASEAN's role in improving the economic growth of its member countries in the modern world economy using more updated research data and approaches.
The bilateral trade has given a significant impact to economic development of countries involved. (Türkcan & Saygılı [11], Cyrus [12], Ruan et al. [13]) The impact of bilateral trade on the economic development involving sub group ASEAN-5 and ASEAN-6 (Nguyen & Bui [14], Vogiatzoglou & Thi [15]) Modern service exports have given a less significant to the GDP growth. (Sermcheep [16])	The impact of intra-export on the economic development. The intra-export is considered as a manifestation of the economic interaction activity among the ASEAN member countries with all export products.
The mathematical model including the ARDL model, which is generally used in the economic research and it discuss about economic growth, export and import. (Ho-Le & Nguyen [17], Ahmed & Delin [18], Dell'Anno & Halicioglu [19]). The use of unit root tests and ARDL panel cointegration to check short-run or long-run (Marimuthu & Bangash [20], Caleb et al. [21])	The study employs four ARDL models to represent the economic development indicators.
The impact of economic interaction through mutual trade among the EAEU countries on the economic growth. (Didenko et al.)	ASEAN as a research object.

Source: compiled by Authors

To enhance and expand the previous studies in term of the multinational economic interaction, the researchers observe the economic growth and economic interaction among the ASEAN nations. The research question of this study is whether

[1] *Didenko, N. I., Skripnyuk, J.F., Kikkas, K. N*. Mathematical model for analyzing the impact of economic interaction of the EAEU countries on the economic growth of the EAEU. The state and the market: the Eurasian dominant of development in the context of the formation of a multipolar world: collective monograph / ed. by prof. S. A. Dyatlov, prof. D. Yu. Miropolsky, prof. T. A. Selishcheva. St. Petersburg, 2023. 632 p.

the intra-export has an impact on the economic development in ASEAN. To support the research question, we conducted a hypothesis as following:

H1: The intra-export has an impact on the economic development in ASEAN.

To confirm the hypothesis, an alpha value has been determined to evaluate the error probability. The researchers have to consider whether to reject or accept the hypothesis. H1 will be accepted if the p-value is less than alpha.

3. Methods

3.1. Autoregressive distributed lags (ARDL) model for short-run

The autoregressive distributed lag model of order p and n, $ADL(p, n)$, is defined for a scalar variable Yt as [22]:

$$Y_t = \sum_{i=1}^{p} \theta_i Y_{t-i} + \sum_{i=0}^{n} \beta_i X_{t-i} + \varepsilon_t, \tag{1}$$

where ε_t is a scalar zero mean error term and X^t is K — dimensional column vector process. The coefficients θ_i are scalars while β_i are row vectors. Using the lag operator L applied to each component of a vector, $L^k X_t = X_{t-k}$, it is convenient to define the lag polynomial $\theta(L)$ and the vector polynomial $\beta(L)$. An econometric model in which the dependent variable Y can be expressed as a function of its past values including the current and lagged values of another independent variable X is called a dynamic model.

If we regress Y on its k-lagged values and the current and k-lagged values of the independent variable X, then the dynamic model is given by [23]:

$$Y_t = \delta + \theta_1 Y_{t-1} + \theta_2 Y_{t-2} + \ldots + \theta_k Y_{t-k} + \beta_0 X_t + \beta_1 X_{t-1} + \ldots + \beta_k X_{t-k} + \varepsilon_t, \tag{2}$$

Some examples of a dynamic model are as follows.

A model which includes only the current and the lagged values of the explanatory variable X of the type:

$$Y_t = \delta + \beta_0 X_t + \beta_1 X_{t-1} + \ldots + \beta_k X_{t-k} + \varepsilon_t. \tag{3}$$

Equation (3) is called a distributed-lag model.

A model which includes one or more lagged values of the dependent variable Y and the current value of the explanatory variable X of the type:

$$Y_t = \delta + \theta_1 Y_{t-1} + \theta_2 Y_{t-2} + \ldots + \theta_k Y_{t-k} + \beta_0 X_t + \varepsilon_t. \tag{4}$$

Equation (4) is called an autoregressive model. The dynamic model of this type is called an autoregressive distributed lag model.

3.2. ARDL model using R software

Statistical programming R is software used for data processing in the field of economics. R software is an open-source software easily obtained legally [24]. The R software has become quite popular in the last decades with various packages needed in econometrics. The paper on ARDL models with R presents the

ARDL model package in the statistical language R by displaying its main functions in a step-by-step guide discussed in detail [25].

There are 10 steps to analyses ARDL model using R software, as following.

1. *Indicating endogenous and exogenous variables*.

Indicators of Economic Development in the Association of Southeast Asian Nations (ASEAN): Y_t^1 — GDP per capita of ASEAN in the *t*-th year, USD/person[1]; Y_t^2 — volume of export per capita of ASEAN in the *t*-th year, USD/person[2]; Y_t^3 — volume of import per capita of ASEAN in the *t*-th year, USD/person; Y_t^4 — total population of ASEAN in the *t*-th year, person.

Indicators that influence the development of the ASEAN economy and assess the economic interaction of countries: X_t^1 — total intra-export among the ASEAN member states in the *t*-th year, USD; X_t^2 — average of price deflator in ASEAN in the *t*-th year, percentage/per year; X_t^3 — total labor force in ASEAN in the *t*-th year, number of employees; X_t^4 — average of number of physicians per 1000 people in ASEAN the *t*-th year, number of physicians[3]; X_t^5 — average of unemployment in ASEAN in the *t*-th year, percentage of number of employees; X_t^6 — average of life expectancy in ASEAN in the *t*-th year, years[4].

2. *Data transformation*.

3. *Stationery Checking*.

The ARDL model produces a consistent parameter estimation with a good long-term coefficient, even though the explanatory variables or regressors are at different levels I (0) or I (1) [26]. The augmented Dickey–Fuller statistic is a test employing negative numbers. The more negative value indicates the stronger rejection on the hypothesis at some confidence level. It examines the null hypothesis that a unit root is current in a time series sample.

The alternative hypothesis depends on the version of the test used, but it is usually stationarity or trend stationarity. The differencing process is needed to overcome non-stationary data and obtain stationary data. Let *Yt* is a non-stationery time series data. First differencing is defined as $\omega_t = Y_t - Y_{t-1} = (1-B)Y_t$. A higher order in *d*-th order is denoted as $\omega_t = (1-\mathrm{B})^d Y_t$ resulting stationery time series data.

The test is an efficient way to indicate time-series model having a unit root process. It provides three characteristics: type 0 (no drift, no trend), type 1 (with drift, no trend) and type 2 (with drift, and with trend).

4. *Multicollinearity test*.

Multicollinearity occurs when there is an abundant intercorrelation among several independent variables in a multiple regression model, which might give rise to inaccurate analysis results. The statistical model will investigate the effectiveness of every

[1] Data is retrieved from: https://kidb.adb.org (date of access: 08.01.2025).

[2] Ibid.

[3] Data is retrieved from. https://prosperitydata360.worldbank.org/en/indicator/UN+SDG+SH+MED+PHYS+ZS (date of access: 08.01.2025).

[4] Data is retrieved from. https://databank.worldbank.org/indicator/SP.DYN.LE00.IN/1ff4a498/Popular-Indicators# (date of access: 08.01.2025).

single independent variable used. A larger confidence interval due to multicollinearity causes the probability of the involvement of the independent variables to be less accurate. The variance inflation factor (VIF) value can measure the level of collinearity in a multiple regression model. The value of 1 represents uncorrelated, the value of 1 to 5 denotes moderately correlated and the value of 5 to 10 confirms highly correlated.

5. *Selecting lags of endogenous and exogenous variables*.

Akaike information criterion (*AIC*) value is employed to compare the suitability of time series models with varying numbers of lags. This value is used to determine the appropriate number of lags. In the most cases, it is effective on a high-frequency data with small sample [27, 28]. The model with the lowest value is the most appropriate model to use [29].

$$AIC = -2\left(\frac{1}{T}\right) + 2\left(k + T\right), \tag{5}$$

where T is number of observations; K is estimated parameter.

6. *Constructing equation system*.

$$\left\{\begin{array}{l} Y_t^1 = \varphi\left(Y_{t-p}^1, Y_t^2, Y_{t-p}^2, Y_t^3, Y_{t-p}^3, ..., X_t^k, X_{t-p}^k\right) \\ Y_t^2 = \varphi\left(Y_{t-p}^2, Y_t^1, Y_{t-p}^1, Y_t^3, Y_{t-p}^3, ..., X_t^k, X_{t-p}^k\right) \\ Y_t^3 = \varphi\left(Y_{t-p}^3, Y_t^1, Y_{t-p}^1, Y_t^2, Y_{t-p}^2, ..., X_t^k, X_{t-p}^k\right) \\ Y_t^4 = \varphi\left(Y_{t-p}^4, Y_t^1, Y_{t-p}^1, Y_t^2, Y_{t-p}^2, ..., X_t^k, X_{t-p}^k\right) \end{array}\right\}. \tag{6}$$

Where p — number of lags; $k = 1, 2, 3, 4, 5, 6$.

Model 1 is a composition of Y_t^1 as endogenous variable and $Y_{t-p}^1, Y_t^2, Y_{t-p}^2, Y_t^3, Y_{t-p}^3, ..., X_t^k, X_{t-p}^k$ as exogenous variables.

Model 2 is a composition of Y_t^2 as endogenous variable and $Y_{t-p}^2, Y_t^1, Y_{t-p}^1, Y_t^3, Y_{t-p}^3, ..., X_t^k, X_{t-p}^k$ as exogenous variables.

Model 3 is a composition of Y_t^3 as endogenous variable and $Y_{t-p}^3, Y_t^1, Y_{t-p}^1, Y_t^2, Y_{t-p}^2, ..., X_t^k, X_{t-p}^k$ as exogenous variables.

Model 4 is a composition of Y_t^4 as endogenous variable and $Y_{t-p}^4, Y_t^1, Y_{t-p}^1, Y_t^2, Y_{t-p}^2, ..., X_t^k, X_{t-p}^k$ as exogenous variables.

7. *Transforming the structural form of the model to the reduced form using linear*.

8. *Considering the identifiability of the equation system*.

9. *Finding the coefficient of equations and transitioning to non-normalized values*.

10. *Forecasting endogenous variable values with a t-years prospect*.

4. Results

The correlation coefficient value indicates how close the linear relationship of variables. The correlation calculation indicates that a number of variables have a close relationship as indicated by a value exceed of 0.75. A high correlation causes multicollinearity. It has a potential to cause problems such as unstable

estimation and increased standard error. The correlation values are calculated as an initial step to detect multicollinearity. The VIF test is required to determine the independent variables used in a model represented in Table 2.

Table 2. **The VIF values of models**

Model 1 $\boldsymbol{Y_t^1}$	VIF	Model 2 $\boldsymbol{Y_t^2}$	VIF	Model 3 $\boldsymbol{Y_t^3}$	VIF	Model 4 $\boldsymbol{Y_t^4}$	VIF
Y_t^4	5.43	Y_t^4	5.43	X_t^1	6.37	X_t^1	6.37
X_t^1	6.73	X_t^1	6.73	X_t^2	3.05	X_t^2	3.05
X_t^2	3.18	X_t^2	3.18	X_t^4	2.01	X_t^4	2.01
X_t^4	2.09	X_t^4	2.09	X_t^5	3.84	X_t^5	3.84
X_t^5	3.60	X_t^5	3.60	X_t^6	5.73	X_t^6	5.73

Source: Author's calculation

This research tolerates the VIF values in range of 0 to10 to choose appropriate variables as the exogenous variables in the model. The calculation guides the researchers to make decisions in building the models. Several checking steps are conducted to remove exogenous variables having the VIF value of more than 10 from the model. There are four appropriate models obtained as model 1 combines Y_t^1 as an endogenous variable and $Y_t^4, X_t^1, X_t^2, X_t^4, X_t^5$ as exogenous variables; model 2 combines Y_t^2 as an endogenous variable and $Y_t^4, X_t^1, X_t^2, X_t^4, X_t^5$ as exogenous variables; model 3 combines Y_t^3 as an endogenous variable and $X_t^1, X_t^2, X_t^4, X_t^5, X_t^6$ as exogenous variables; and model 4 combines Y_t^4 as an endogenous variable and $X_t^1, X_t^2, X_t^4, X_t^5, X_t^6$ as exogenous variables.

Table 3 reveals that whole variables are stationary at level or at first difference because of *p*-value less than 5 %. It confirms to accept the hypothesis at least once in the different type and level. This condition is still suitable because the coefficients remain robust and stable even when the variables are at different stationarity levels.

Table 3. **Stationery test using augmented Dicky-Fuller Test**

VAR	Stationery at	Type (1): no drift, no trend	Type (2): with drift, no trend	Type (3): with drift, with trend
Y_t^1	I (1)	Yes at lag 0, p-value = 0.0296	Yes at lag 0, p-value = 0.0109	Yes at lag 0, p-value = 0.010
Y_t^2	I (1)	Yes at lag 0, p-value = 0.0100 at lag 1, p-value = 0.0187	Yes at lag 0, p-value = 0.0100 at lag 1, p-value = 0.0183	Yes at lag 0, p-value = 0.0100 at lag 1, p-value = 0.0188

End of table 3

VAR	Stationery at	Type (1): no drift, no trend	Type (2): with drift, no trend	Type (3): with drift, with trend
Y_t^3	I (1)	Yes at lag 0, p-value = 0.0100 at lag 1, p-value = 0.0114	Yes at lag 0, p-value = 0.0100 at lag 1, p-value = 0.0156	Yes at lag 0, p-value = 0.0100 at lag 1, p-value = 0.0189
Y_t^4	I (0)	No	Yes at lag 0, p-value = 0.0100 at lag 1, p-value = 0.0115	No
X_t^1	I (0)	No	Yes at lag 2, p-value = 0.0441	No
X_t^2	I (0)	No	No	Yes at lag 1, p-value = 0.0184
X_t^3	I (0)	No	Yes at lag 0, p-value = 0.0203	No
X_t^4	I (1)	Yes at lag 0, p-value = 0.0100	Yes at lag 0, p-value = 0.010	Yes at lag 0, p-value = 0.010
X_t^5	I (1)	Yes at lag 0, p-value = 0.0100	Yes at lag 0, p-value = 0.0122	Yes at lag 0, p-value = 0.0199
X_t^6	I (1)	Yes at lag 0, p-value = 0.010	Yes at lag 0, p-value = 0.0254	Yes at lag 0, p-value = 0.0121

Source: Author's calculations.

The lag selection is decided based on the smallest AIC value. Based on the calculation, optimal lag chosen is lag 2 for all models. We attained the four best models. Those are the model 1→ARDL (2,2,2,2,2,2) with the smallest value of –139.96, the model 2 → ARDL (2,2,2,2,2,2) with the smallest value of –116.30.96, the model 3 → ARDL (2,2,2,2,2,2) with the smallest value of –97.86, and the model 4 → ARDL (2,2,2,2,2,2) with the smallest value of –251.97 (Table 4).

Table 4. **Estimated coefficients calculation of exogenous variables**

M1 Y_t^1	Estimated coefficient	M2 Y_t^2	Estimated coefficient	M3 Y_t^3	Estimated coefficient	M4 Y_t^4	Estimated coefficient
Intercept	–3.950641	Intercept	–5.30105	Intercept	–2.25180	Intercept	–0.3047267
Y_{t-1}^1	1.223409	Y_{t-1}^2	2.14901	Y_{t-1}^3	0.70383	Y_{t-1}^4	0.6984571
Y_{t-2}^1	–0.513661	Y_{t-2}^2	–0.44775	Y_{t-2}^3	0.15819	Y_{t-2}^4	0.2115841
Y_t^4	–5.232756	Y_t^4	–16.84210	X_t^1	0.91696	X_t^1	0.0054287
Y_{t-1}^4	–5.835043	Y_{t-1}^4	27.36822	X_{t-1}^1	–0.67298	X_{t-1}^1	–0.0017709

End of table 4

M1 Y_t^1	Estimated coefficient	M2 Y_t^2	Estimated coefficient	M3 Y_t^3	Estimated coefficient	M4 Y_t^4	Estimated coefficient
Y_{t-2}^4	12.027605	Y_{t-2}^4	–10.49882	X_{t-2}^1	–0.14097	X_{t-2}^1	–0.0003963
X_t^1	0.316904	X_t^1	0.82243	X_t^2	–0.62935	X_t^2	–0.0142990
X_{t-1}^1	–0.374954	X_{t-1}^1	–1.81883	X_{t-1}^2	0.13968	X_{t-1}^2	0.0020883
X_{t-2}^1	0.249865	X_{t-2}^1	0.43955	X_{t-2}^2	0.06930	X_{t-2}^2	–0.0015351
X_t^2	–0.562210	X_t^2	0.06545	X_t^4	0.12365	X_t^4	0.0012774
X_{t-1}^2	0.309743	X_{t-1}^2	0.28006	X_{t-1}^4	–0.05872	X_{t-1}^4	–0.0002593
X_{t-2}^2	–0.182715	X_{t-2}^2	1.00570	X_{t-2}^4	0.01277	X_{t-2}^4	–0.0002683
X_t^4	0.006161	X_t^4	–0.09223	X_t^5	0.05648	X_t^5	0.0067226
X_{t-1}^4	–0.030479	X_{t-1}^4	–0.45262	X_{t-1}^5	–0.41862	X_{t-1}^5	–0.0092994
X_{t-2}^4	0.082562	X_{t-2}^4	–0.14731	X_{t-2}^5	0.39611	X_{t-2}^5	0.0035530
X_t^5	–0.210732	X_t^5	–0.16990	X_t^6	–11.52715	X_t^6	0.0053260
X_{t-1}^5	0.112600	X_{t-1}^5	–1.00318	X_{t-1}^6	0.49279	X_{t-1}^6	–0.1750734
X_{t-2}^5	0.248848	X_{t-2}^5	1.13762	X_{t-2}^6	11.99964	X_{t-2}^6	0.3855459
MSE: 0.0001353 MAPE: 1.16 %		MSE: 0.0000261 MAPE: 1.09 %		MSE: 0.0000657 MAPE: 1.74 %		MSE: 2.96 E-08 MAPE: 0.04 %	

Source: Author's calculations.

Mean squared error value is used to measure the quality of the estimator. The mean squared error value is around to zero indicating that the model is effective to use. Mean absolute percentage error is calculated to measure the prediction accuracy of the forecasting model. The mean absolute percentage error value discloses that the model is affective and accurate with the value of around 1 %. From Table 4, we obtained the best models of the ARDL (2,2,2,2,2,2).

4.1. Equation of Model 1 ARDL (2,2,2,2,2,2)

The equation of model 1 is:

$$\begin{aligned} Y_t^1 = &-3.950641 + 1.223409Y_{t-1}^1 - 0.513661Y_{t-2}^1 - 5.232756Y_t^4 - \\ &- 5.835043Y_{t-1}^4 + 12.027605Y_{t-2}^4 + 0.316904X_t^1 - 0.374954X_{t-1}^1 + \\ &+ 0,249865X_{t-2}^1 - 0.562210X_t^2 + 0.309743X_{t-1}^2 - 0.182715X_{t-2}^2 + \\ &+ 0.006161X_t^4 - 0.030479X_{t-1}^4 + 0.082562X_{t-2}^4 - 0.210732X_t^5 + \\ &+ 0.112600X_{t-1}^5 + 0.248848X_{t-2}^5 + 0.002512. \end{aligned} \quad (7)$$

Intercept of –3.950641 is the variation in the GDP per capita value when exogenous variables of 0. It describes that the GDP per capita will decrease to –3.950641 units if the total population, the total intra-export, the average of price deflator, the average of number of physicians per 1 000 people and the average of unemployment at current year of 0. An analogous description for the coefficient at the time *t*–1 and *t*–2.

Coefficient of the total population at current year of –5.232756, it signifies that the GDP per capita will decrease as much 5.232756 units if the total population at current year of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The total population at *t*–1 and *t*–2 contribute to affect the GDP per capita. If all coefficients are added jointly, the result will be positive and the GDP per capita will continue to increase with changes in the total population of 1 unit.

Coefficient of the total intra-export at current year of 0.316904, it implies that the GDP per capita will increase as much 0.316904 unit if the total intra-export at current year of 1unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The total intra-export at *t*–1 and *t*–2 contribute to affect the GDP per capita. If all coefficients are added jointly, the result will be positive and the GDP per capita will continue to increase with changes in the total intra-export of 1 unit.

Coefficient of the average of price deflator at current year of –0.562210, it indicates that the GDP per capita will decrease as much 0.562210 when the average of price deflator of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of price deflator at *t*–1 and *t*–2 contribute to affect the GDP per capita. If all coefficients are added jointly, the result will be negative and the GDP per capita will continue to decrease with changes in the average of price deflator of 1unit.

Coefficient of the average of number of physicians per 1 000 people at current year of 0.006161, it implies that the GDP per capita will increase as much 0.006161unit if the average of number of physicians per 1 000 people at current year of 1unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of number of physicians per 1 000 people at *t*–1 and *t*–2 contribute to affect the GDP per capita. If all coefficients are added jointly, the result will be positive and the GDP per capita will continue to increase with changes in the average of number of physicians per 1000 people of 1 unit.

Coefficient of the average of unemployment at current year of –0.210732, it indicates that GDP per capita will decrease as much 0.210732 when the average of unemployment of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of unemployment at *t*–1 and *t*–2 contribute to affect the GDP per capita. If all coefficients are added jointly, the result will be positive and the GDP per capita will continue to increase with changes in the average unemployment of 1 unit.

4.2. Equation of Model 2 ARDL (2,2,2,2,2,2)

The equation of model 2 is:

$$\begin{aligned} Y_t^2 = &-5.30105 + 2.14901Y_{t-1}^2 - 0.44775Y_{t-2}^2 - 16.84210Y_t^4 + \\ &+ 27.36822Y_{t-1}^4 - 10.49882Y_{t-2}^4 + 0.82243X_t^1 - 1.81883X_{t-1}^1 + \\ &+ 0.43955X_{t-2}^1 + 0.06545X_t^2 + 0.28006X_{t-1}^2 + 1.00570X_{t-2}^2 - \\ &- 0.09223X_t^4 - 0.45262X_{t-1}^4 - 0.14731X_{t-2}^4 - 0.16990X_t^5 - \\ &- 1.00318X_{t-1}^5 + 1.13762X_{t-2}^5 - 5.2288E^{-08}. \end{aligned} \quad (8)$$

Intercept of –5.30105 is the variation in the volume of export per capita value when exogenous variables of 0. It describes that the volume of export per capita will decrease to as much 5.30105 units if the total population, the total intra-export, the average of price deflator, the average of number of physicians per 1 000 people and the average of unemployment at current year of 0. An analogous description for the coefficient at the time *t*–1 and *t*–2.

Coefficient of the total population at current year of –16.84210, it signifies that the volume of export per capita will decrease as much 16.84210 units if the total population at current year of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The total population at *t*–1 and *t*–2 contribute to affect the volume of export per capita. If all coefficients are added jointly, the result will be positive and the volume of export per capita will continue to increase with changes in the total population of 1 unit.

Coefficient of the total intra-export at current year of 0.82243, it implies that the volume of export per capita will increase as much 0.82243 unit if the total intra-export at current year of 1unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The total intra-export at *t*–1 and *t*–2 contribute to affect the volume of export per capita. If all coefficients are added jointly, the result will be negative and the volume of export per capita will continue to decrease with changes in the total intra-export of 1 unit.

Coefficient of the average of price deflator at current year of 0.06545, it indicates that the volume of export per capita will increase as much 0.06545 when the average of price deflator of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average price deflator at *t*–1 and *t*–2 contribute to affect the volume of export per capita. If all coefficients are added jointly, the result will be positive and the volume of exports per capita will continue to increase with changes in the average of price deflator of 1 unit.

Coefficient of the average of number of physicians per 1 000 people at current year of –0.09223, it implies that the volume of export per capita will decrease as much 0.09223 unit if the average of number of physicians per 1 000 people at current year of 1unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of number of physicians per 1 000 people at *t*–1 and *t*–2 contribute to affect the volume of export per capita. If all coefficients are added

jointly, the result will be negative and the volume of export per capita will continue to decrease with changes in the average of number of physicians per 1 000 people of 1 unit.

Coefficient of the average of unemployment at current year of –0.16990, it indicates that the volume of export per capita will decrease as much 0.16990 when the average of unemployment of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of unemployment at *t*–1 and *t*–2 contribute to affect the volume of export per capita. If all coefficients are added jointly, the result will be negative and the volume of export per capita will continue to decrease with changes in the average of unemployment of 1 unit.

4.3. Equation of Model 3 ARDL (2,2,2,2,2,2)

The equation of model 3 is:

$$\begin{aligned} Y_t^3 = &-2.25180 + 0.70383Y_{t-1}^3 + 0.15819Y_{t-2}^3 + 0.91696X_t^1 - \\ &- 0.67298X_{t-1}^1 - 0.14097X_{t-2}^1 - 0.62935X_t^2 + 0.13968X_{t-1}^2 + \\ &+ 0.06930X_{t-2}^2 + 0.12365X_t^4 - 0.05872X_{t-1}^4 + 0.01277X_{t-2}^4 + \\ &+ 0.05648X_t^5 - 0.41862X_{t-1}^5 + 0.39611X_{t-2}^5 - 11.52715X_t^6 + \\ &+ 0.49279X_{t-1}^6 + 11.99964X_{t-2}^6 - 7.4468E^{-07}. \end{aligned} \quad (9)$$

Intercept of –2.25180 is the variation in the volume of import per capita value when exogenous variables of 0. It describes that the volume of import per capita will decrease to –2.25180 units if the total of intra-export, the average of price deflator, the average of number of physicians per 1 000 people, the average of unemployment and the average of life expectancy at current year of 0. An analogous description for the coefficient at the time *t*–1 and *t*–2.

Coefficient of the total intra-export at current year of 0.91696, it implies that the volume of import per capita will increase as much 0.91696 unit if the total intra-export at current year of 1unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The total intra-export at *t*–1 and *t*–2 contribute to affect the volume of import per capita. If all coefficients are added jointly, the result will be positive and the volume of import per capita will continue to increase with changes in the total intra-export of 1 unit.

Coefficient of the average of price deflator at current year of –0.62935, it indicates that the volume of import per capita will decrease as much 0.62935 when the average of price deflator of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of price deflator at *t*–1 and *t*–2 contribute to affect the volume of import per capita. If all coefficients are added jointly, the result will be negative and the volume of import per capita will continue to decrease with changes in the average of price deflator of 1 unit.

Coefficient of the average of number of physicians per 1 000 people at current year of 0.12365, it implies that the volume of import per capita will increase as much

0.12365 unit if the average of number of physicians per 1 000 people at current year of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of number of physicians per 1 000 people at *t*–1 and *t*–2 contribute to affect the volume of import per capita. If all coefficients are added jointly, the result will be positive and the volume of import per capita will continue to increase with changes in the average of number of physicians per 1 000 people of 1 unit.

Coefficient of the average of unemployment at current year of 0.05648, it indicates that the volume of import per capita will increases as much 0.05648 when the average of unemployment of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of unemployment at *t*–1 and *t*–2 contribute to affect the volume of import per capita. If all coefficients are added jointly, the result will be positive and the volume of import per capita will continue to increase with changes in the average of unemployment of 1 unit.

Coefficient of the average of life expectancy at current year of –11.52715, it signifies that the volume of import per capita will decrease as much 11.52715 units if the average of life expectancy at current year of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of life expectancy at *t*–1 and *t*–2 contribute to affect the volume of import per capita. If all coefficients are added jointly, the result will be positive and the volume of import per capita will continue to increase with changes in the average of life expectancy of 1 unit.

4.4. Equation of Model 4 ARDL (2,2,2,2,2,2)

The equation of model 4 is:

$$\begin{aligned} Y_t^4 = &-0.3047267 + 0.6984571Y_{t-1}^4 + 0.2115841Y_{t-2}^4 + 0.0054287X_t^1 - \\ &- 0.0017709X_{t-1}^1 - 0.0003963X_{t-2}^1 - 0.0142990X_t^2 + 0.0020883X_{t-1}^2 - \\ &- 0.0015351X_{t-2}^2 + 0.0012774X_t^4 - 0.0002593X_{t-1}^4 - 0.0002683X_{t-2}^4 + \\ &+ 0.0067226X_t^5 - 0.0092994X_{t-1}^5 + 0.0035530X_{t-2}^5 + 0.0053260X_t^6 - \\ &- 0.1750734X_{t-1}^6 + 0.3855459X_{t-2}^6 + 3.5648E^{-07}. \end{aligned} \quad (10)$$

Intercept of –0.3047267 is the variation in the total population value when exogenous variables of 0. It describes that the total population will decrease as much 0.3047267 units if the total intra-export, the average of price deflator, the average of number of physicians per 1000 people, the average of unemployment and the average of life expectancy at current year of 0. An analogous description for the coefficient at the time *t*–1 and *t*–2.

Coefficient of the total intra-export at current year of 0.0054287, it implies that the total population will increase as much 0.0054287 unit if the total intra-export at current year of 1unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The total intra-export at *t*–1 and *t*–2 contribute to affect the total population. If all coefficients are added jointly, the result will be positive and the total population will continue to increase with changes in the total intra-export of 1 unit.

Coefficient of the average of price deflator at current year of –0.0142990, it indicates that the total population will decrease as much 0.0142990 when the average of price deflator of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of price deflator at *t*–1 and *t*–2 contribute to affect the total population. If all coefficients are added jointly, the result will be negative and the total population will continue to decrease with changes in the average of price deflator of 1 unit.

Coefficient of the average of number of physicians per 1 000 people at current year of 0.0012774, it implies that the total population will increase as much 0.0012774 unit if the average of number of physicians per 1000 people at current year of 1unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of number of physicians per 1 000 people at *t*–1 and *t*–2 contribute to affect the total population. If all coefficients are added jointly, the result will be positive and the total population will continue to increase with changes in the average of number of physicians per 1 000 people of 1 unit.

Coefficient of the average of unemployment at current year of 0.0067226, it indicates that the total population will increases as much 0.0067226 when the average of unemployment of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of unemployment at *t*–1 and *t*–2 contribute to affect the total population. If all coefficients are added jointly, the result will be positive and the total population will continue to increase with changes in the average of unemployment of 1 unit.

Coefficient of the average of life expectancy at current year of 0.0053260, it signifies that the volume of import per capita will increase as much 0.0053260 units if the average of life expectancy at current year of 1 unit. An analogous description for the coefficient at the time *t*–1 and *t*–2. The average of life expectancy at *t*–1 and *t*–2 contribute to affect the volume of import per capita. If all coefficients are added jointly, the result will be positive and the volume of import per capita will continue to increase with changes in the average of life expectancy of 1 unit.

The delay multiplier figures reveal the delay multiplier calculation for 22 periods. The delay multiplier illustrates the impact on the dependent variable in period $t+s$, caused by an instantaneous shock to the independent variable in period t. The figures 1 to 4 illustrate the endogenous variables after the shock for each exogenous variable.

Figure 1 reveals that the population (POP), the total intra-export (TIE), the average of price deflator (APD), the average of number of physicians (ANP), the average of unemployment (AUE) have varying effects on the GDP per capita. The population, the average price deflator, the average of number of physicians, and the average of unemployment contribute collectively a negative impact in first several periods. Thus, those exogenous variables give a positive impact on the endogenous variable in the following periods. The total intra-export gives a high positive impact in first period and provides a positive impact in the next period consistently on the GDP per capita. A whole exogenous variables tend to give a neutral effect after the 15th period to the last period.

Figure 2 discloses that the population, the total intra-export, the average of price deflator, the average of number of physicians, and the average of unemployment give similar impacts on the volume of export per capita. Those exogenous variables have provided a neutral effect to the endogenous variable from the beginning to the end of period.

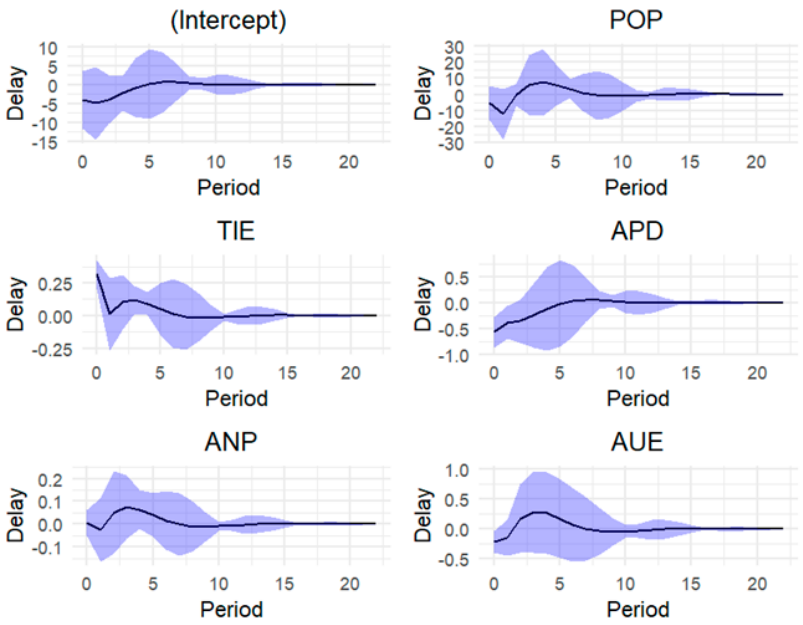

Figure 1. The delay multiplier of model 1

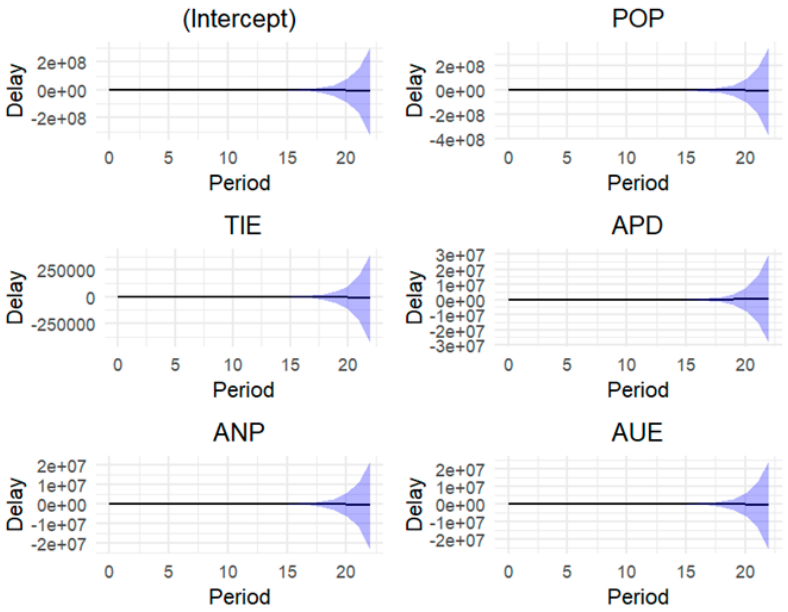

Figure 2. The delay multiplier of model 2

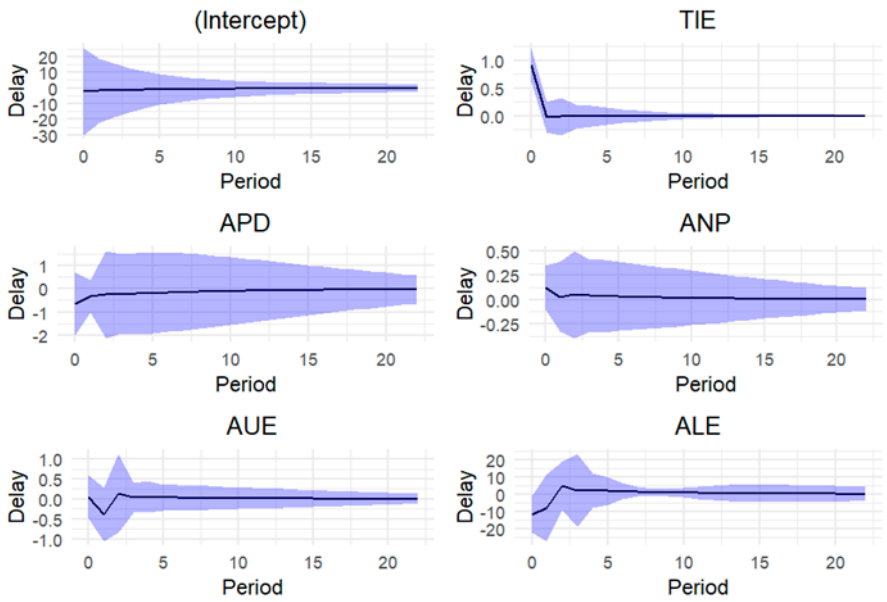

Figure 3. The delay multiplier of model 3

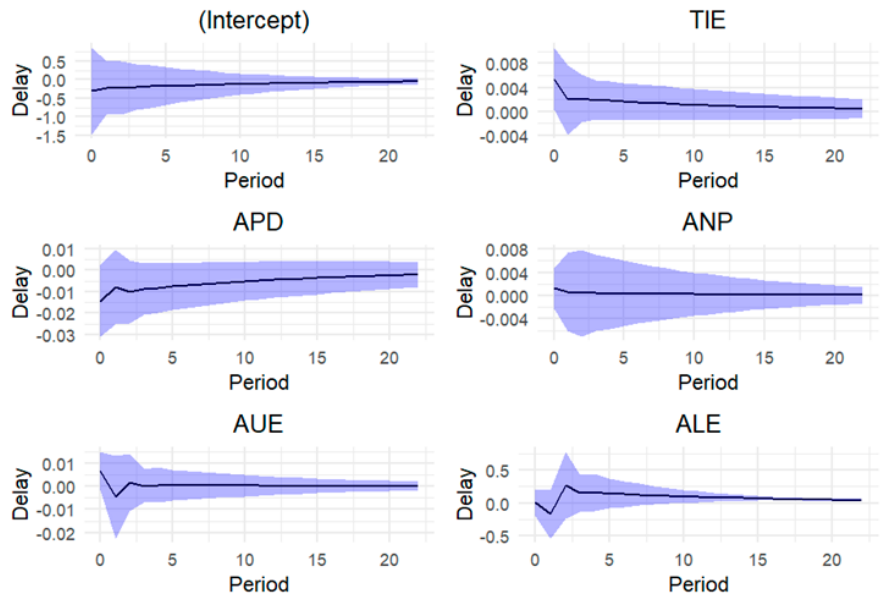

Figure 4. The delay multiplier of model 4

Figure 3 exposes that the total intra-export and the average of number of physicians deliver a positive impact on the volume of import per capita in a first period and a neutral impact in the remained periods. The average of price deflator, the average of unemployment and the average of life expectancy (ALE) distribute a negative impact on the volume of import per capita in a first period and a neutral impact in the continued periods.

Figure 4 reveals that the total intra-export and the average of number of physicians offer a negative effect on total population in a first period and a neutral impact in the following periods. The average of price deflator gives a positive effect in a first period and a neutral effect in the remained periods. The average of unemployment and the average of life expectancy distribute a negative and positive impact on the population in several first period and a neutral impact in the continual periods.

Table 5 presents the analysis results of the four models employed in this study. Model 1 is a composition of the GDP per capita as endogenous variable and the population, the total intra-export, the average of price deflator, the average of number of physicians per 1 000 people, and the average of unemployment as exogenous variables.

Table 5. **Significance effect of exogenous variables to endogenous variable**

Model 1 Y_t^1	Pr (> |t|)	Model 2 Y_t^2	Pr (> |t|)	Model 3 Y_t^3	Pr (> |t|)	Model 4 Y_t^4	Pr (> |t|)
Intercept	0.4220	Intercept	0.34087	Intercept	0.8877	Intercept	0.660
Y_{t-1}^1	0.0190 *	Y_{t-1}^2	0.27512	Y_{t-1}^3	0.3231	Y_{t-1}^4	0.218
Y_{t-2}^1	0.2636	Y_{t-2}^2	0.43524	Y_{t-2}^3	0.8695	Y_{t-2}^4	0.599
Y_t^4	0.4351	Y_t^4	0.37831	X_t^1	0.0277 *	X_t^1	0.177
Y_{t-1}^4	0.4690	Y_{t-1}^4	0.33621	X_{t-1}^1	0.2980	X_{t-1}^1	0.736
Y_{t-2}^4	0.2601	Y_{t-2}^4	0.50985	X_{t-2}^1	0.8568	X_{t-2}^1	0.892
X_t^1	0.0294 *	X_t^1	0.00764 **	X_t^2	0.4634	X_t^2	0.231
X_{t-1}^1	0.0798.	X_{t-1}^1	0.26287	X_{t-1}^2	0.6633	X_{t-1}^2	0.786
X_{t-2}^1	0.0879.	X_{t-2}^1	0.32648	X_{t-2}^2	0.8643	X_{t-2}^2	0.843
X_t^2	0.0656.	X_t^2	0.72025	X_t^4	0.3959	X_t^4	0.550
X_{t-1}^2	0.1400	X_{t-1}^2	0.59351	X_{t-1}^4	0.7439	X_{t-1}^4	0.930
X_{t-2}^2	0.2572	X_{t-2}^2	0.26665	X_{t-2}^4	0.8608	X_{t-2}^4	0.883
X_t^4	0.8546	X_t^4	0.52694	X_t^5	0.8544	X_t^5	0.247
X_{t-1}^4	0.5819	X_{t-1}^4	0.28119	X_{t-1}^5	0.2958	X_{t-1}^5	0.429
X_{t-2}^4	0.0815.	X_{t-2}^4	0.35441	X_{t-2}^5	0.5096	X_{t-2}^5	0.789
X_t^5	0.1485	X_t^5	0.57834	X_t^6	0.1719	X_t^6	0.964
X_{t-1}^5	0.3420	X_{t-1}^5	0.31074	X_{t-1}^6	0.9693	X_{t-1}^6	0.389
X_{t-2}^5	0.6021	X_{t-2}^5	0.28160	X_{t-2}^6	0.4676	X_{t-2}^6	0.143

End of table 5

Model 1 Y_t^1	Pr (> |t|)	Model 2 Y_t^2	Pr (> |t|)	Model 3 Y_t^3	Pr (> |t|)	Model 4 Y_t^4	Pr (> |t|)
Significance codes: '***' means under 0.001 or alpha 0.1 %, '**' means under 0.01 or alpha 1 %, '*' means under 0.05 or alpha 5 %, '.' means under 0.1 or alpha 10 %							
R-squared: 1 Adj. R-squared: 0.9996		R-squared: 0.9997 Adj. R-squared: 0.9976		R-squared: 0.9995 Adj. R-squared: 0.9952		R-squared: 1 Adj. R-squared: 0.9999	

Source: Author's calculations.

Model 2 is a composition of the export per capita as endogenous variable and the population, the total intra-export, the average of price deflator, the average of number of physicians per 1 000 people, and the average of unemployment as exogenous variables. Model 3 is a composition of the import per capita as endogenous variable and the total intra-export, the average of price deflator, the average of number of physicians per 1000 people, the average of unemployment and the average of life expectancy as exogenous variables. Model 4 is a composition of the total population as endogenous variable and the total intra-export, the average of price deflator, the average of number of physicians per 1 000 people, the average of unemployment and the average of life expectancy as exogenous variables.

To confirm and approve the hypothesis which states that the intra-export has an impact on the economic development in ASEAN, an alpha value is determined. The hypothesis is accepted because of p-value less than alpha.

From the model 1, the GDP per capita in a previous year and the intra-export in a current year give a strong impact on GDP per capita under a significance *alpha* = 5 %. Those are indicated by *p-values* of 0.0190 and 0.0294, respectively. The GDP per capita also depends significantly on the GDP per capita and the intra-export at lags, the average of price deflator at current year and the average of number of physicians at second lag in significance *alpha* = 10 %. The adjusted R-squared value of 0.9996 indicates that the GDP per capita in a previous year, the intra-export, the average of price deflator at current year and the average of number of physicians at second lag can explain and influence to the GDP per capita at current year of 99.96 % in significance *alpha* = 10 %. The R-squared of 1 explains that all combinations of the exogenous variables give effects on the GDP per capita of 100 %.

From the model 2, the intra-export at current year gives a very strong impact to the export per capita. It is indicated by *p-value* as 0.007764 under significance *alpha* = 1 %. The adjusted R-squared value of 0.9976 discloses that the intra-export at current year can explain and give impact to the export per capita at current year as much 99.76 % in significance *alpha* = 1 %. The R-squared of 0.9997 describes that whole exogenous variable combinations give impacts on the export per capita of 99.97 %.

From the model 3, the intra-export at current year gives a strong impact to the import per capita. It is indicated by *p-value* as 0.0277 under significance *alpha* = 5 %. The adjusted R-squared value as 0.9952 discloses that the intra-export at current year can explain and give impacts on the import per capita at current year as much 99.52 % in significance *alpha* = 5 %. The R-squared of 0.9995 describes that each combination of exogenous variable gives effect on the import per capita of 99.95 %.

From the model 4, the total population is affected normally by all exogenous variables as the populations at previous years, the intra-export, the average of price deflator, the average number of physicians, the average of unemployment and the average of life expectancy. It indicates by R-squared as 1. It means that all exogenous could explain and affect the total population variable normally as 100 %.

The forecasting results of the endogenous variables display an upward trend in the next 10 years. These are represented in Table 6.

The GDP per capita, the export per capita, the import per capita, and the total population are projected to obtain a fairly smooth growth. It will increase of around 4.5 % in the first four years and 3.3 % in the following years. The longer forecasting period causes the smaller percentage increase. This model is quite effective for short forecasting times. The small error values indicate the effectiveness and accuracy of the model (Fig. 5–8).

Table 6. **Forecasting of economic development indicators in ASEAN**

Year	Forecasting results			
	GDP per capita ($)	Export per capita ($)	Import per capita ($)	Total population (million)
2022	5320.805	2562.776	2402.899	675.4475
2023	5569.083	2679.357	2511.627	681.7344
2024	5817.361	2795.938	2620.355	688.0213
2025	6065.640	2912.519	2729.083	694.3082
2026	6313.918	3029.100	2837.811	700.5951
2027	6562.196	3145.681	2946.539	706.8820
2028	6810.475	3262.261	3055.267	713.1689
2029	7058.753	3378.842	3163.995	719.4558
2030	7307.031	3495.423	3272.723	725.7427
2031	7555.309	3612.004	3381.451	732.0296

Source: Author's calculation.

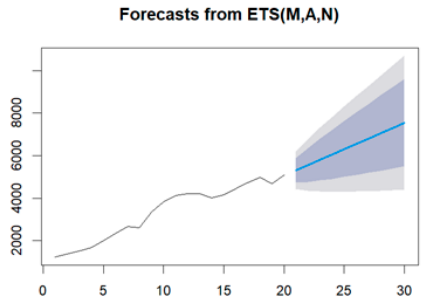

Figure 5. Forecasting of GDP per capita indicator

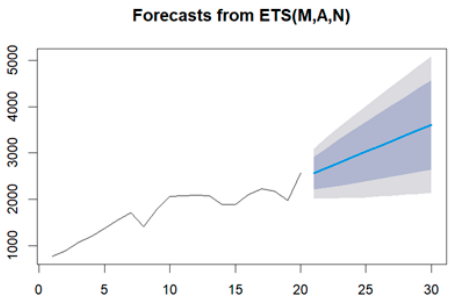

Figure 6. Forecasting of export per capita indicator

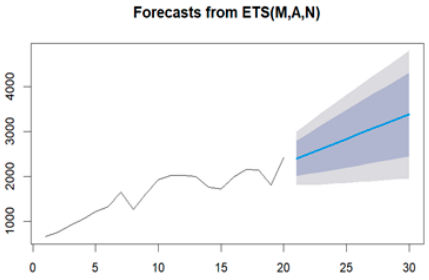

Figure 7. Forecasting of import per capita indicator

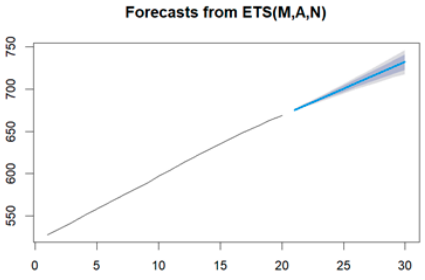

Figure 8. Forecasting of population indicator

The forecasting results of the ARDL model (2,2,2,2,2,2) for all models display a significant and gradual upward trend on the economic development indicators in ASEAN. The GDP per capita, the export per capita, the import per capita and the population are projected gradually growth in the one-decade forthcoming.

5. Discussion

This study reveals that the economic interaction has contributed to the economic development. The intra-export variable represents the economic interaction among the ASEAN countries. This variable gives impact on the GDP per capita, the export per capita, the import per capita and the population. The analysis result answers the research question of whether the intra-export has an impact on economic development. The analysis result also confirms and strengthen the hypothesis states that the intra-export has impact on the economic development in ASEAN.

An alpha value is applied to test the hypothesis. The hypothesis is accepted because of *p*-value less than the alpha. The analysis result discloses several important points. The intra-export contributes a strong impact on the GDP per capita under significance *alpha* = 5 % and *p-values* of 0.0294. The intra-export contributes a very strong impact on the volume of export per capita under significance *alpha* = 1 % and *p-value* of 0.9976. The intra-export contributes a strong impact on the volume of import per capita under significance *alpha* = 5 % and *p-value* as 0.0277, but the total population is affected normally by the intra-export.

This study supports several previous works such as a study of the factors influencing the ASEAN economic growth and integration by Nurjannah et al. [30]. That study revealed that the intra-regional trade gives an impact of 0.014 % on the economic growth. Further, Anwar et al. [31] showed that the international trade effects represented by imports and exports in the ASEAN region has an impact on the economic growth. The results specifically disclosed that the intra-import and the intra-export has impact on the GDP. Furthermore, a study by Matondang et al. [32] disclosed that the international trade is a gathering point to increase productivity and efficiency on the national economic sustainability.

Moreover, Diater & Higgot [33] suggested that ASEAN needs to take more attention to intra-export policies projected to strengthen ASEAN's international trade. Based on these findings, it is necessary to strengthen the economy through increasing the intra-trade in the ASEAN region. It is to answer the challenges resulted from Diaeter's study about the theory of monetary regionalism on regional projects in Asia which provides insight that this regional economy does not have the material strength of larger competitors.

In addition, this study supports the theory of neoclassical trade stated that trade has an impact on the economic development. For instance, the study of neoclassical growth conducted by Deardoff [34] provided an explanation that international trade has an impact on a country's prosperity. Thus, Ben-David & Loewy [35] explored on extending the traditional neoclassical exogenous growth model with multi-country long-run analysis and revealed that the degree of trade liberalization among countries can affect the level of economic growth. A study conducted by Singh [36] revealed that trade is a catalyst for productivity and aggregate economic growth.

Another point to consider, the ASEAN economic interaction needs to be further enhanced to encourage equal prosperity for whole member countries. Policies related to improve the intra-trade volume needs to be continuously monitored and updated along with technological development in the modern economic world. It refers to an empirical analysis of the regional economic interaction system in spatial econometrics and numerical calibration conducted by Behren & Thisse [37] showed that the emergence of trade blocks and the gradual elimination of state borders are important in the modern economic world. This situation needs to be supported by the formation of a well-developed regional economy to optimize economic integration and its potential consequences.

Furthermore, a study on the main functional-hierarchical model of central places in the reproduction of economic interaction with an analysis of the regional export conducted by Dzurkha [38] revealed that the income is generated by the export. The study also disclosed that the inter-regional interaction determines the level of intra-regional connectivity. Ultimately, this discussion describes that the economic interactions manifested in international trade across a regional economic area have a significant impact on the economic development. The significance of this study is to recommend new insights for policy makers to decide a strategic action in improving intra-trade among the ASEAN countries.

6. Conclusion

The ASEAN economy has increased rapidly in accordance to the Asia-Pacific economic strategy. In 2022, this regional economic growth reached more than 5 %. The economic interaction has been considered as an important stimulant for this regional economic development. The economic interaction among the member countries is manifested in intra-trade which shows an upward trend in the last two decades. In this study, the ARDL model has proven the hypothesis that the intra-export has an impact on the economic development. The analysis results disclose that the intra-trade has an impact on the GDP per capita, the export per capita, the import per capita and the population.

The forecasting of economic development indicators reveals a rising trend over the one decade ahead. Those indicators are the GDP per capita, the export per capita, the import per capita, and the total population. The economic development indicators are projected to grow steady at a relatively constant rate of 4 %. This model is very effective for a short-time forecasting, because a longer period has caused the lower percentage increase. The more projection interval gives the more modest percentage growth. The small and significant error values indicate the effectiveness and accurateness of model. Moreover, the error values assess the effectiveness of the parameter estimation and determine the forecasting model's prediction accuracy.

The intra-export is a significant factor influencing the economic development indicators. The regional committee is recommended to regenerate policies relating to increase the intra-export volume. It also must be supported by the quantity and quality of production goods needed by the destination countries. To increase the quantity and quality of production, the investment funding is certainly needed in the modern economic world. Thus, investment policy is an important factor in this case. It is recommended to consider the investment factor as a research variable in next study.

Furthermore, the population has increased every year could be considered as a potential human resource to increase production volume. To support it, the availability of educated and work-ready human resources is a crucial Issue on the economic development in this regional economy. This situation is a complicated Issue involving the level of literacy and education in society. It is relatively being a crucial Issue in several member countries. In another hand, the member countries have several potentials that can support the economic development in ASEAN, such as diverse natural resources, human resources, a stable political situation, natural and cultural tourism.

In summary, our study has validated and supported the theory of 'neoclassical trade' which states that the international trades and flows lead to increase income distribution among the involved countries in the international trade. In addition, this study has supported and enhanced several previous works that the factors influencing the economic development and regional integration.

References

1. Islam, S.M.N., Clarke, M. (2002). The Relationship between Economic Development and Social Welfare: A New Adjusted GDP Measure of Welfare. *Social Indicators Research,* Vol. 57, 201–229. https://doi.org/10.1023/A:1014481414637

2. Raghutla, C., Chittedi, K.R. (2020). Is there an export- or import-led growth in emerging countries? A case of BRICS countries. *Journal of Public Affairs,* Vol. 20, Issue 3, e2074. https://doi.org/10.1002/pa.2074

3. Okabe, M., Urata, S. (2014). The impact of AFTA on intra-AFTA trade. *Journal of Asian Economics,* Vol. 35, 12–31. https://doi.org/10.1016/j.asieco.2014.09.004

4. Menon, J., Melendez, A.C. (2017). Realizing An ASEAN Economic Community: Progress and Remaining Challenge. *Singapore Economic Review,* Vol. 62, No. 3, 681–702. https://doi.org/10.1142/S0217590818400052

5. Adrangi, B., Kerr, L. (2022). Sustainable Development Indicators and Their Relationship to GDP: Evidence from Emerging Economies. *Sustainability,* Vol. 14, Issue 2, 658. https://doi.org/10.3390/su14020658

6. Anis, T.B., Mamun, M., Rahman, Md.M. (2021). ASEAN Economic Community (AEC): An Empirical Impact Analysis. *South Asian Journal of Social Studies and Economics,* Vol. 12, Issue 4, 338–353. https://doi.org/10.9734/sajsse/2021/v12i430340

7. El-Agraa, A.M. (1989). *The Theory and Measurement of International Economic Integration.* London, Palgrave Macmillan, 388 p.. https://doi.org/10.1007/978-1-349-10203-7

8. Capannelli, G., Lee, J.W., Petri, P.A. (2010). Economic interdependence in Asia: Developing indicators for regional integration and cooperation. *Singapore Economic Review,* Vol. 55, No. 1, 125–161. https://doi.org/10.1142/S021759081000364X

9. Taghizadeh-Hesary, F., Yoshino, N., Ju Kim, C., Morgan, P.J. (2020). Regional Economic Integration in Asia: Challenges and Recommended Policies. *Journal of Economic Integration,* Vol. 35, Issue 1, 1–9. https://doi.org/10.11130/jei.2020.35.1.1

10. Andal, E.G.T. (2017). ASEAN centrality amidst economic integration in the Asia Pacific region. *Journal of the Asia Pacific Economy,* Vol. 22, Issue 2, 273–290. https://doi.org/10.1080/13547860.2016.1239394

11. Türkcan, K., Saygılı, H. (2018). Economic Integration Agreements and the Survival of Exports. *Journal of Economic Integration,* Vol. 33, Issue 1, 1046–1095. https://doi.org/10.11130/jei.2018.33.1.1046

12. Cyrus, T.L. (2021). Why Do Countries Form Regional Trade Agreements? A Discrete-Time Survival Analysis. *Open Economies Review,* Vol. 32, 417–434. https://doi.org/10.1007/s11079-020-09603-5

13. Ruan, W.X., Yu, X., Wang, S.Y., Zhao, T.C., Liu, Y.Z. (2023). Exploration of China — ASEAN Trade Relations in the Context of Sustainable Economic Development — Based on the Lotka-Volterra Model. *Sustainability,* Vol. 15, Issue 1, 517. https://doi.org/10.3390/su15010517

14. Nguyen, M.L.T., Bui, T.N. (2021). Trade openness and economic growth: A study on ASEAN-6. *Economies,* Vol. 9, Issue 3, 113 https://doi.org/10.3390/economies9030113

15. Vogiatzoglou, K., Thi, N. (2016). Economic openness and economic growth: A cointegration analysis for ASEAN-5 countries. *The European Journal of Applied Economics,* Vol. 13, Issue 2, 10–20. https://doi.org/10.5937/ejae13-11311

16. Sermcheep, S. (2019). Services Export and Economic Growth in ASEAN Countries. *Journal of Asian Economic Integration,* Vol. 1, Issue 2, 163–182. https://doi.org/10.1177/2631684619883443

17. Ho-Le, T.P., Nguyen, T.V. (2018). Mathematics Research in Association of Southeast Asian Nations Countries: A Scientometric Analysis of Patterns and Impacts. *Frontiers in Research Metrics and Analytics,* Vol. 3, 3. https://doi.org/10.3389/frma.2018.00003

18. Ahmed, Y.N., Delin, H. (2019). Current Situation of Egyptian Cotton: Econometrics Study Using ARDL Model. *Journal of Agricultural Science,* Vol. 11, No. 10, 88. https://doi.org/10.5539/jas.v11n10p88

19. Dell'Anno, R., Halicioglu, F. (2010). An ARDL model of unrecorded and recorded economies in Turkey. *Journal of Economic Studies,* Vol. 37, No. 6, 627–646. https://doi.org/10.1108/01443581011086666

20. Marimuthu, M., Khan, H., Bangash, R. (2021). Fiscal Causal Hypotheses and Panel Cointegration Analysis for Sustainable Economic Growth in ASEAN. *Journal of Asian Finance, Economics and Business,* Vol. 8, Issue 2, 99–109. https://doi.org/10.13106/jafeb.2021.vol8.no2.0099

21. Caleb, G., Mazanai, M., Dhoro Netsai, L. (2014). Relationship between international trade and economic growth: A cointegration analysis for Zimbabwe. *Mediterranean Journal of Social Sciences,* Vol. 5, No. 20, 621–627. https://doi.org/10.5901/mjss.2014.v5n20p621

22. Hassler, U., Wolters, J. (2006). Autoregressive distributed lag models and cointegration. *Allgemeines Statistisches Arch,* Vol. 90, 59–74. https://doi.org/10.1007/s10182-006-0221-5

23. Hossain, S. (2024). *Econometric Analysis: An Applied Approach to Business and Economics.* Cambridge Scholars Publishing. Available at: https://www.cambridgescholars.com/resources/pdfs/978-1-5275-6337-7-sample.pdf

24. Henningsen, A., Henningsen, G. (2019). Analysis of panel data using R. *In: Panel Data Econometrics: Theory.* Edited by M. Tsionas. Elsevier, 345–396 https://doi.org/10.1016/B978-0-12-814367-4.00012-5

25. Natsiopoulos, K., Tzeremes, N.G. (2023). ARDL: An R Package for ARDL Models and Cointegration. *Computational Economics,* Vol. 64, 1757–1773. https://doi.org/10.1007/s10614-023-10487-z

26. Ardiansyah, M., Djuraidah, A., Sumertajaya, I.M., Wigena, A.H., Fitrianto, A. (2021). Development of the Panel ARDL by Adding Space-Time effect to Modeling Monthly Paddy Producer Price in Java. *Journal of Physics: Conference Series,* Vol. 1863, 012053. https://doi.org/10.1088/1742-6596/1863/1/012053

27. Li, Z., Han, J., Song, Y. (2020). On the forecasting of high-frequency financial time series based on ARIMA model improved by deep learning. *Journal of Forecasting,* Vol. 39, Issue 7, 1081–1097. https://doi.org/10.1002/for.2677

28. Polyzos, E., Siriopoulos, C. (2024). Autoregressive Random Forests: Machine Learning and Lag Selection for Financial Research. *Computational Economics,* Vol. 64, 225–262. https://doi.org/10.1007/s10614-023-10429-9

29. Ding, J., Tarokh, V., Yang, Y. (2018). Model Selection Technique. *IEEE Signal Processing Magazine,* 1–21. https://doi.org/10.48550/arXiv.1810.09583

30. Nurjannah, N., Masbar, R., Majid, M.S.A., Suriani, S. (2023). Inter-regional trade and economic growth of ASEAN low middle income: Are corruption control and HDI important? *Cogent Economics and Finance,* Vol. 11, Issue 2, 2230733. https://doi.org/10.1080/23322039.2023.2230733

31. Anwar, A., Mifrahi, M.N., Ahmad Kusairee, M.A.B.Z. (2024). International trade and economic growth in ASEAN. *Jurnal Kebijakan Ekonomi Dan Keuangan,* Vol. 3, Issue 1, 109–115. https://doi.org/10.20885/jkek.vol3.iss1.art14

32. Matondang, K.A., Silalahi, H.H.B., Naibaho, H.S.D., Safitri, L., Siregar, A.N. (2024). The Role of International Trade in Increasing the Rate of Economic Growth in Indonesia: A Literature Review. *International Journal of Education, Social Studies, And Management (IJESSM),* Vol. 4, No. 2, 278–290. https://doi.org/10.52121/ijessm.v4i2.238

33. Dieter, H., Higgott, R. (2003). Exploring alternative theories of economic regionalism: From trade to finance in Asian co-operation? *Review of International Political Economy,* Vol. 10, Issue 3, 430–454. https://doi.org/10.1080/09692290308422

34. Deardorff, A.V. (2001). Rich and Poor countries in Neoclassical Trade and Growth. *The Economic Journal,* Vol. 111, Issue 470, 277–294. https://doi.org/https://doi.org/10.1111/1468-0297.00608

35. Ben-David, D., Loewy, M.B. (2003). Trade and the Neoclassical Growth Model Trade and the Neoclassical Growth Model. *Journal of Economic Integration,* Vol. 18, Issue 1, 1–16. https://doi.org/10.11130/jei.2003.18.1.1

36. Singh, T. (2010). Does international trade cause economic growth? A survey. *World Economy,* Vol. 33, Issue 11, 1517–1564. https://doi.org/10.1111/j.1467-9701.2010.01243.x

37. Behrens, K., Thisse, J.F. (2007). Regional economics: A new economic geography perspective. *Regional Science and Urban Economics,* Vol. 37, Issue 4, 457–465. https://doi.org/10.1016/j.regsciurbeco.2006.10.001

38. Dzhurka, N.G. (2024). Interregional Economic Interactions in Light of the Central Place Theory. *Regional Research of Russia,* Vol. 14, 126–142. https://doi.org/10.1134/S2079970524600070

INFORMATION ABOUT AUTHORS

Setyo Wira Rizki

Post-Graduate Student, Institute of Industrial Management, Economics and Trade, Peter the Great St. Petersburg Polytechnic University, Saint-Petersburg, Russia (195251, Saint-Petersburg, Polytechnicheskaya street, 29); ORCID https://orcid.org/0000-0003-0829-9767 e-mail: rizki.sv@edu.spbstu.ru

Nikolay Ivanovich Didenko

Doctor of Economics, Professor, Institute of Industrial Management, Economics and Trade, Peter the Great St. Petersburg Polytechnic University, Saint-Petersburg, Russia (195251, Saint-Petersburg, Polytechnicheskaya street, 29); ORCID https://orcid.org/0000-0001-8540-7034 e-mail: didenko.nikolay@mail.ru

FOR CITATION

Rizki, S.W., Didenko, N.I. (2025). Analysis of Economic Development and Economic Interaction in ASEAN Countries: ARDL Model Approach. *Journal of Applied Economic Research,* Vol. 24, No. 3, 754–785. https://doi.org/10.15826/vestnik.2025.24.3.025

ARTICLE INFO

Received March 24, 2025; Revised May 19, 2025; Accepted June 20, 2025.

УДК 339.9

Анализ экономического развития и экономического взаимодействия в странах ASEAN на основе модели ARDL

С. В. Ризки ✉, ***Н. И. Диденко***

Санкт-Петербургский политехнический университет Петра Великого,

г. Санкт-Петербург, Россия

✉ *rizki.sv@edu.spbstu.ru*

Аннотация. Региональная экономическая интеграция ASEAN направлена на укрепление экономик ее стран-членов, и такая установка демонстрирует положительные результаты. Соответствие экономической интеграции, с точки зрения соглашения о снижении тарифов, дает значительный результат по внутриэкономическому экспорту как форме экономического взаимодействия между странами — членами ASEAN. Экономическое взаимодействие представлено как внутриэкономический экспорт, который увеличивает экономический рост. Целью данного исследования является определение показателей экономического взаимодействия, влияющих на экономическое развитие стран — членов ASEAN. Гипотеза данного исследования заключается в том, что внутриэкономический экспорт оказывает влияние на экономическое развитие стран-членов. Модель ARDL используется в качестве теоретической основы и процедуры проверки гипотезы. После проверки теоретических процедур результат показывает, что гипотеза принимается. Она объясняет, что внутриэкономический экспорт является значительным фактором, влияющим на показатели экономического развития этой региональной интеграции. Прогнозирование показателей экономического развития отражает тенденцию к их росту в течение следующего десятилетия. Прогнозируется, что эти показатели будут расти сравнительно устойчивыми темпами со средним ростом в 4 %. Используемый методологический подход исключительно эффективен в краткосрочных прогнозах. Также исследование показывает, что экономическое взаимодействие, представленное переменной внутриэкономического экспорта, способствовало экономическому развитию: ВВП на душу населения, экспорта и импорта на душу населения. Это исследование поддерживает неоклассическую теорию торговли и обогащает предыдущие работы, в которых утверждается, что торговля в рамках интеграционного объединения оказывает значительное влияние на региональный экономический рост. Исследование формулирует рекомендации для разработки политики, направленной на увеличение внутриэкономического экспорта.

Ключевые слова: Ассоциация государств Юго-Восточной Азии; региональная торговля; модель ARDL; открытость торговли; экономическая интеграция.

Список использованных источников

1. *Islam S. M.N., Clarke M.* The Relationship between Economic Development and Social Welfare: A New Adjusted GDP Measure of Welfare // Social Indicators Research. 2002. Vol. 57. Pp. 201–229. https://doi.org/10.1023/A:1014481414637

2. *Raghutla C., Chittedi K. R.* Is there an export- or import-led growth in emerging countries? A case of BRICS countries // Journal of Public Affairs. 2020. Vol. 20, Issue 3. e2074. https://doi.org/10.1002/pa.2074

3. *Okabe M., Urata S.* The impact of AFTA on intra-AFTA trade // Journal of Asian Economics. 2014. Vol. 35. Pp. 12–31. https://doi.org/10.1016/j.asieco.2014.09.004

4. *Menon J., Melendez A. C.* Realizing an ASEAN Economic Community: Progress and Remaining Challenge // Singapore Economic Review. 2017. Vol. 62, No. 3. Pp. 681–702. https://doi.org/10.1142/S0217590818400052

5. *Adrangi B., Kerr L.* Sustainable Development Indicators and Their Relationship to GDP: Evidence from Emerging Economies // Sustainability. 2022. Vol. 14, Issue 2. 658. https://doi.org/10.3390/su14020658

6. *Anis T. B., Mamun M., Rahman Md.M.* ASEAN Economic Community (AEC): An Empirical Impact Analysis // South Asian Journal of Social Studies and Economics. 2021. Vol. 12, Issue 4. Pp. 338–353. https://doi.org/10.9734/sajsse/2021/v12i430340

7. *El-Agraa A. M.* The Theory and Measurement of International Economic Integration. London: Palgrave Macmillan, 1989. 388 p. https://doi.org/10.1007/978-1-349-10203-7

8. *Capannelli G., Lee J. W., Petri P. A.* Economic interdependence in Asia: Developing indicators for regional integration and cooperation // Singapore Economic Review. 2010. Vol. 55, No. 1. Pp. 125–161. https://doi.org/10.1142/S021759081000364X

9. *Taghizadeh-Hesary F., Yoshino N., Ju Kim C., Morgan P. J.* Regional Economic Integration in Asia: Challenges and Recommended Policies // Journal of Economic Integration. 2020. Vol. 35, Issue 1. Pp. 1–9. https://doi.org/10.11130/jei.2020.35.1.1

10. *Andal E. G.T.* ASEAN centrality amidst economic integration in the Asia Pacific region // Journal of the Asia Pacific Economy. 2017. Vol. 22, Issue 2. Pp. 273–290. https://doi.org/10.1080/13547860.2016.1239394

11. *Türkcan K., Saygılı H.* Economic Integration Agreements and the Survival of Exports // Journal of Economic Integration. 2018. Vol. 33, Issue 1. Pp. 1046–1095. https://doi.org/10.11130/jei.2018.33.1.1046

12. *Cyrus T. L.* Why Do Countries Form Regional Trade Agreements? A Discrete-Time Survival Analysis // Open Economies Review. 2021. Vol. 32. Pp. 417–434. https://doi.org/10.1007/s11079-020-09603-5

13. *Ruan W. X., Yu X., Wang S. Y., Zhao T. C., Liu Y. Z.* Exploration of China — ASEAN Trade Relations in the Context of Sustainable Economic Development — Based on the Lotka-Volterra Model // Sustainability. 2023. Vol. 15, Issue 1. 517. https://doi.org/10.3390/su15010517

14. *Nguyen M. L.T., Bui T. N.* Trade openness and economic growth: A study on ASEAN-6 // Economies. 2021. Vol. 9, Issue 3. 113. https://doi.org/10.3390/economies9030113

15. *Vogiatzoglou K., Thi N.* Economic openness and economic growth: A cointegration analysis for ASEAN-5 countries // The European Journal of Applied Economics. 2016. Vol. 13, Issue 2. Pp. 10–20. https://doi.org/10.5937/ejae13-11311

16. *Sermcheep S.* Services Export and Economic Growth in ASEAN Countries // Journal of Asian Economic Integration. 2019. Vol. 1, Issue 2. Pp. 163–182. https://doi.org/10.1177/2631684619883443

17. *Ho-Le T. P., Nguyen T. V.* Mathematics Research in Association of Southeast Asian Nations Countries: A Scientometric Analysis of Patterns and Impacts // Frontiers in Research Metrics and Analytics. 2018. Vol. 3. 3. https://doi.org/10.3389/frma.2018.00003

18. *Ahmed Y. N., Delin H.* Current Situation of Egyptian Cotton: Econometrics Study Using ARDL Model // Journal of Agricultural Science. 2019. Vol. 11, No. 10. 88. https://doi.org/10.5539/jas.v11n10p88

19. *Dell'Anno R., Halicioglu F.* An ARDL model of unrecorded and recorded economies in Turkey // Journal of Economic Studies. 2010. Vol. 37, No. 6. Pp. 627–646. https://doi.org/10.1108/01443581011086666

20. *Marimuthu M., Khan H., Bangash R.* Fiscal Causal Hypotheses and Panel Cointegration Analysis for Sustainable Economic Growth in ASEAN // Journal of Asian Finance, Economics and Business. 2021. Vol. 8, Issue 2. Pp. 99–109. https://doi.org/10.13106/jafeb.2021.vol8.no2.0099

21. *Caleb G., Mazanai M., Dhoro Netsai L.* Relationship between international trade and economic growth: A cointegration analysis for Zimbabwe // Mediterranean Journal of Social Sciences. 2014. Vol. 5, No. 20. Pp. 621–627. https://doi.org/10.5901/mjss.2014.v5n20p621

22. *Hassler U., Wolters J.* Autoregressive distributed lag models and cointegration // Allgemeines Statistisches Arch. 2006. Vol. 90. Pp. 59–74. https://doi.org/10.1007/s10182-006-0221-5

23. *Hossain S.* Econometric Analysis: An Applied Approach to Business and Economics. Cambridge Scholars Publishing, 2024. URL: https://www.cambridgescholars.com/resources/pdfs/978-1-5275-6337-7-sample.pdf

24. *Henningsen A., Henningsen G.* Analysis of panel data using R // In: Panel Data Econometrics: Theory. Edited by M. Tsionas. Elsevier, 2019. Pp. 345–396. https://doi.org/10.1016/B978-0-12-814367-4.00012-5

25. *Natsiopoulos K., Tzeremes N. G.* ARDL: An R Package for ARDL Models and Cointegration // Computational Economics. 2023. Vol. 64. Pp. 1757–1773. https://doi.org/10.1007/s10614-023-10487-z

26. *Ardiansyah M., Djuraidah A., Sumertajaya I. M., Wigena A. H., Fitrianto A.* Development of the Panel ARDL by Adding Space-Time effect to Modeling Monthly Paddy Producer Price in Java // Journal of Physics: Conference Series. 2021. Vol. 1863. 012053. https://doi.org/10.1088/1742-6596/1863/1/012053

27. *Li Z., Han J., Song Y.* On the forecasting of high-frequency financial time series based on ARIMA model improved by deep learning // Journal of Forecasting. 2020. Vol. 39, Issue 7. Pp. 1081–1097. https://doi.org/10.1002/for.2677

28. *Polyzos E., Siriopoulos C.* Autoregressive Random Forests: Machine Learning and Lag Selection for Financial Research // Computational Economics. 2024. Vol. 64. Pp. 225–262. https://doi.org/10.1007/s10614-023-10429-9

29. *Ding J., Tarokh V., Yang Y.* Model Selection Technique // IEEE Signal Processing Magazine. 2018. Pp. 1–21. https://doi.org/10.48550/arXiv.1810.09583

30. *Nurjannah N., Masbar R., Majid M. S.A., Suriani S.* Inter-regional trade and economic growth of ASEAN low middle income: Are corruption control and HDI important? // Cogent Economics and Finance. 2023. Vol. 11, Issue 2. 2230733. https://doi.org/10.1080/23322039.2023.2230733

31. *Anwar A., Mifrahi M. N., Ahmad Kusairee M. A.B.Z.* International trade and economic growth in ASEAN // Jurnal Kebijakan Ekonomi Dan Keuangan. 2024. Vol. 3, Issue 1. Pp. 109–115. https://doi.org/10.20885/jkek.vol3.iss1.art14

32. *Matondang K. A., Silalahi H. H.B., Naibaho H. S.D., Safitri L., Siregar A. N.* The Role of International Trade in Increasing the Rate of Economic Growth in Indonesia: A Literature Review // International Journal of Education, Social Studies, And Management (IJESSM). 2024. Vol. 4, No. 2. Pp. 278–290. https://doi.org/10.52121/ijessm.v4i2.238

33. *Dieter H., Higgott R.* Exploring alternative theories of economic regionalism: From trade to finance in Asian co-operation // Review of International Political Economy. 2003. Vol. 10, Issue 3. Pp. 430–454. https://doi.org/10.1080/09692290308422

34. *Deardorff A. V.* Rich and Poor countries in Neoclassical Trade and Growth // The Economic Journal. 2001. Vol. 111, Issue 470. Pp. 277–294. https://doi.org/https://doi.org/10.1111/1468-0297.00608

35. *Ben-David D., Loewy M. B.* Trade and the Neoclassical Growth Model Trade and the Neoclassical Growth Model // Journal of Economic Integration. 2003 Vol. 18, Issue 1. Pp. 1–16. https://doi.org/10.11130/jei.2003.18.1.1

36. *Singh T.* Does international trade cause economic growth? A survey // World Economy. 2010. Vol. 33, Issue 11. Pp. 1517–1564. https://doi.org/10.1111/j.1467-9701.2010.01243.x

37. *Behrens K., Thisse J. F.* Regional economics: A new economic geography perspective // Regional Science and Urban Economics. 2007. Vol. 37, Issue 4. Pp. 457–465. https://doi.org/10.1016/j.regsciurbeco.2006.10.001

38. *Dzhurka N. G.* Interregional Economic Interactions in Light of the Central Place Theory // Regional Research of Russia. 2024. Vol. 14. Pp. 126–142. https://doi.org/10.1134/S2079970524600070

ИНФОРМАЦИЯ ОБ АВТОРАХ

Ризки Сетью Вира

Аспирант института промышленного менеджмента, экономики и торговли, Санкт-Петербургского политехнического университета Петра Великого, г. Санкт-Петербург, Россия (195251, г. Санкт-Петербург, ул. Политехническая, 29); ORCID https://orcid.org/0000-0003-0829-9767 e-mail: rizki.sv@edu.spbstu.ru

Диденко Николай Иванович

Доктор экономических наук, профессор, Институт промышленного менеджмента, экономики и торговли Санкт-Петербургского политехнического университета Петра Великого, г. Санкт-Петербург, Россия (195251, г. Санкт-Петербург, ул. Политехническая, 29); ORCID https://orcid.org/0000-0001-8540-7034 e-mail: didenko.nikolay@mail.ru

ДЛЯ ЦИТИРОВАНИЯ

Ризки С. В., Диденко Н. И. Анализ экономического развития и экономического взаимодействия в странах ASEAN на основе модели ARDL // Journal of Applied Economic Research. 2025. Т. 24, № 3. С. 754–785. https://doi.org/10.15826/vestnik.2025.24.3.025

ИНФОРМАЦИЯ О СТАТЬЕ

Дата поступления 24 марта 2025 г.; дата поступления после рецензирования 19 мая 2025 г.; дата принятия к печати 20 июня 2025 г.