Effect of Exchange Rates and Information and Communication Technology on Indonesia's Economic Growth

A Nonlinear Autoregressive Distributed Lag Approach

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Abstract: Foreign exchange rates as well as information and communication technology (ICT) are crucial in the global economy. Exchange rates affect trade balance, which influences gross domestic product (GDP) and economic growth. ICT also affects economic growth by reducing business transaction costs and increasing the income of investors and companies, stimulating national income and economic growth. This research examines the effect of exchange rate asymmetry and ICT on Indonesian economic growth, using annual time-series data on exchange rates, ICT usage (proxied by Internet, telephone, and mobile phone users), and economic growth (GDP from 1994 to 2018). The data were analyzed using a non-linear auto-regressive distributed lag model. The results show that the exchange rate exerts an asymmetric effect on long-term economic growth. ICT has short- and long-term positive effects on economic growth. According to the findings, the Indonesian government should stabilize the IDR/USD exchange rate through monetary policies to encourage economic growth. Monetary policy needs

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also to support IDR/USD exchange rate appreciation to enhance the trade balance, GDP, and economic growth. The economic growth of Indonesia, which is driven by ICT development, still needs to be sustained by the government initiating ICT development in cities and rural areas.

Keywords: Economic growth, exchange rate, exchange rate asymmetry, ICT, NARDL model.

Introduction

Foreign currency and information and communication technology (ICT) are vital in the world economy. By definition, foreign currency is an instrument of transactions in the real and financial trade sectors, meaning that the currency exchange rate is essential in trading transactions and activities (Sathiwitayakul & Prasongsukarn, 2011). In comparison, ICT is used for sending, storing, creating, sharing, or exchanging information by almost all companies to improve and promote product quality and sell goods and services. Also, consumers use ICT to find and purchase quality products and conduct transactions online (Farhadi *et al.*, 2012).

Economic growth could be significantly affected by ICT and exchange rates. The influence of exchange rates is reflected through the trade channel. According to the traditional theory, depreciation in a foreign currency exchange rate (appreciation in a domestic currency exchange rate) reduces the trade balance. Contrastingly, an increase in the trade balance increases economic growth (Kandil, 2004; Wang, 2009; Saidi *et al.*, 2020; Bao & Le, 2021). Furthermore, ICT affects economic growth through its application, facilitating investment by individuals and companies. It could reduce transaction and production costs, increasing the income earned by investors and companies (Ketteni *et al.*, 2014). Subsequently, such an increase ultimately boosts national income and economic growth (Nguyen *et al.*, 2020; Millia *et al.*, 2020; Rosnawintang *et al.*, 2021). In addition, ICT skills tend to positively affect entrepreneurial intentions (Sreejith & Sreejith, 2023). According to Virasa *et al.* (2022), the process of promoting entrepreneurial intentions leads to business activities, which contributes to job creation and economic development, such as growth (Virasa *et al.*, 2022).

Indonesia is a developing country that adheres to a floating exchange rate system. It adopts a monetary policy to develop the economy by stabilizing the domestic currency (IDR) exchange rate against foreign currencies, such as the US Dollar. This exchange rate stability is also intended to increase economic growth. However, the 1998 Asian financial crisis decreased the IDR/USD exchange rate to 10013.62 IDR per 1 USD from 2160.75 IDR per 1 USD in 1994. Similarly, economic growth declined to -13.6% from 7.3% in 1994 (Indonesia-Investments, 2021).

The development of modern technology and information in Indonesia began with the launch of the Palapa satellite on July 8, 1976, from Cape Kennedy, USA. This satellite technology was then used to exchange data and information using the Internet and telephone, starting in 1988 (Prabowo & Gischa, 2021). The government issued rules to ensure the sustainable development and use of ICT by companies and the community (Zakaria, 2021). Subsequently, companies-built e-commerce using ICT to launch their business and increase their revenue with lower operating costs (Setiawan, 2017). However, ICT infrastructure has not been developed evenly, especially in rural areas, making most communities unable to access the Internet and telephone. Therefore, this study aimed to evaluate the two government policies regarding exchange rate stabilization and ICT development.

Extensive research has examined the impact of rates on economic growth in various countries. Examples include Elbadawi *et al.* (2012) in Sub-Saharan Africa, Wong (2013) in Malaysia, Saidi *et al.* (2015) in Indonesia, Lee & Yue (2017) in the US, Ribeiro *et al.* (2020) in 54 nations worldwide. The results showed that exchange rates affect economic growth. This is a symmetric effect in the economic literature (Shin *et al.*, 2014; Meo *et al.*, 2018; Saidi *et al.*, 2021; Abbasi & Iqbal, 2021). Research has also shown that exchange rates asymmetrically impacted economic growth. For instance, Bahmani-Oskooee & Mohammadian (2016) and Farouq & Sambo (2022) found that the exchange rates asymmetrically influenced economic growth. However, no research has shown the asymmetrical effect of the exchange rates on economic growth in Indonesia. Previous studies only examined the linear or symmetric effect of the exchange rate on economic growth. Saidi *et al.* (2015) and Yuliadi (2020) analyzed the effect of the exchange rate and other macroeconomic variables on Indonesia’s economic growth using annual data from 2010 to 2016. A panel data model analysis showed that the exchange rate affects economic growth. In addition, Yussof & Febrina (2014) discussed the effect of the exchange rate on economic growth. The Vector Auto-Regression (VAR) analysis of the annual data for 1970–2009 showed that the exchange rate affects economic growth.

García-Muñiz & Vicente (2014) and Salahuddin & Alam (2016) showed that ICT affects economic growth. However, no previous research explored the asymmetric impact of exchange rates and ICT on Indonesia’s economic growth. Therefore, this research investigates whether the exchange rates have an asymmetric effect on economic growth. Moreover, it examines the influence of ICT on Indonesia's economic growth using a Non-Linear Autoregressive Distributed Lag (NARDL) model. Therefore, these results could contribute to the literature on the influence of exchange rate asymmetry and ICT on economic growth using the NARDL model.

The second part of this paper reviews several empirical and theoretical studies consistent with this research, while the third describes the data and analysis methodology. The fourth part

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presents findings and discusses their analysis, while conclusions and recommendations are made in the fifth part.

Literature Review

Theory review

Theories explaining the relationship between exchange rates and economic growth through trading channels were stated in the introduction. This subsection presents the theory about the asymmetric relationship between the exchange rate and output. It was developed by Kandil & Mirzaie (2002) using the theory of rational expectations, as stated by Kandil (2008). In this theory, the exchange rate is divided into anticipated and unanticipated exchange rate components. Changes in the unanticipated component determine the asymmetrical effect of exchange rate on output, divided into two types. These are the effects of positive and negative exchange rate shocks, representing the depreciation and appreciation impacts of the domestic exchange rate, respectively. The positive shock effect decreases output or economic growth through the supply-side impact.

Theories about the relationship between ICT use and economic growth could be explained through Solow's and endogenous growth theories. According to Solow's growth theory, ICT use is an external factor that encourages economic growth (Solow, 1957). In contrast, the endogenous growth theory states ICT use is an internal factor as a production input that encourages economic growth (Mankiw, 2007). When ICT is considered a capital factor for improving production quality, it generates added value in increasing economic growth (Aghaei & Rezagholizadeh, 2017; Bahrini & Qaffas, 2019).

Empirical review

The literature shows that the exchange rates' impact on economic growth is both symmetrical and asymmetrical (Shin *et al.*, 2014; Meo *et al.*, 2018). Using annual time series data for the 1986–2010 period, Basirat et al. (2014) analyzed the effect of fluctuating currencies on economic growth in Iran, the Philippines, Colombia, and The Gambia. The panel data model results showed that economic growth was affected negatively by the exchange rate fluctuations. Furthermore, Habib *et al.* (2017) examined the influence of exchange rate movements on 150 nations' economic growth after the Bretton Woods period. The research used a dynamic panel model test against annual time series data during 1970–2010. The results showed that exchange-rate appreciation decreased economic growth. Ha & Hoang (2020) tested the effect of exchange rates on economic growth in Asian countries using annual panel data from 1994 to 2016. The Generalized Method of Moments (GMM) test showed that exchange rates and economic growth moved in the same direction. Moreover, Selimi & Selimi

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(2017) empirically assessed the exchange-rate impact on Macedonia's economic growth through a VAR review of quarterly data. The findings showed that economic growth was positively impacted by the exchange rates between the first quarters of 1998 and 2015.

Studies have also examined the asymmetrical impact of exchange rates on economic growth. For instance, Kandil (2008) analyzed the exchange rate's asymmetric influence on the economic growth of developing nations. The results showed that a depreciating currency exchange rate reduced output and economic growth. Similarly, Hussain et al. (2019) found that the domestic currency depreciation in Pakistan reduced GDP and economic growth. Wesseh & Lin (2018) reviewed the impact of exchange rates on Liberia's economic growth. The VAR analysis of yearly time series data during the 1980–2015 period showed that the exchange rates affected economic growth. Specifically, the depreciation of the Liberian currency against the US dollar reduced economic growth. Therefore, the exchange rates of the Liberian currency asymmetrically affected economic growth.

The effects of ICT on economic growth in several countries have been documented using panel data models. For instance, Amaghionyeodiwe & Annansingh-Jamieson (2017) analyzed the effect of ICT, particularly users of the Internet, mobile phones, and fixed subscriptions, on economic growth in the Caribbean nations. The research used a panel data model to analyze the yearly time series data from 1996 to 2013. The findings showed that ICT positively affected economic growth. Furthermore, Asongu & Odhiambo (2019) used panel data from 1980 to 2014 to examine the impact of ICT on economic growth in 25 of Africa's Sub-Saharan countries. The GMM method indicated that ICT positively impacted economic development. Similarly, Solomon & Klyton (2019) applied the GMM estimator to analyze the effect of digital technology use by individuals, businesses, and governments on economic growth in 39 African countries. The 2012–2016 panel data findings indicated that Internet use positively influenced economic growth. Habibi & Zahardast (2020) analyzed time-series data of 24 OECD and ten Middle-East nations from 2000 to 2017 to determine the contribution of ICT to economic growth. Data analysis using fixed-effect Ordinary Least Squares (OLS) and GMM methods indicated ICT positively affects economic growth. Therefore, the research recommended that the governments in OECD countries develop investment in ICT infrastructure to promote economic growth.

Arabi & Allah (2017) used an Auto-Regressive Distributed Lag (ARDL) model to investigate the impact of ICTs per 100 inhabitants, including fixed telephone lines, mobile phones, and Internet users, on Sudan's economic growth. The time-series data analysis between 1980 and 2024 indicated that ICT affected long- and short-term economic growth. In addition, García (2019) used 1990–2014 time-series data to analyze the effect of the Internet, mobile phone, computer, fibre optic, and Internet prices on Mexico's economic growth. Using a simultaneous

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equation model, the data analysis results showed that the Internet, cell phones, computers, and fibre optics positively impact economic growth. In contrast, Internet prices negatively influenced economic growth, meaning that the Mexican government should develop investment in ICT.

Data and Methodology

Data

This research employed annual time series data for Internet, telephone, and mobile users, as well as exchange rates and per capita GDP during the 1994–2018 period. IDR/USD exchange rates are a proxy for the exchange rates, while GDP per capita (measured in USD) is a proxy for economic growth (see Ramoni-Perazzi & Romero, 2022). The time-series data were obtained from the World Bank website. In the data analysis, the notations used are NET for Internet users, TEL for telephone users, MOB for mobile phone users, EXC for exchange rates, and GRO for economic growth. In this case, the EXC, NET, MOB, TEL, and GRO variables are in natural logarithmic forms.

Methodology

This research tested the long-term effect of positive shock (PEX) and negative shock (NEX) in exchange rates and ICT, comprising Internet, telephone, and mobile phone users, on economic growth in Indonesia. The test used the following co-integration regression model and the specifications of the long-term model used by Bahmani-Oskooee & Saha (2016) and Hussain *et al.* (2019).

$$GRO_t = C + \alpha PEX_t + \beta NEX_t + \gamma NET_t + \tau MOB_t + \delta TEL_t + \varepsilon_t \quad (1)$$

In equation (1), C, α, β, γ, τ and δ are the regression equation's parameters, assumed to be stable between 1994 and 2018. The parameters α, β, γ, τ and δ are also called long-run coefficients, while ε_t is an error or residual, identically distributed, independent and homoscedastic. Various empirical studies (Arfaoui, 2018; Jalil *et al.*, 2013) sometimes assume the error terms, ε_t, have equal, independent and normal distributions. Furthermore, PEX and NEX are partial-sum variables of positive and negative changes in the exchange rates, respectively. PEX and NEX state the IDR/USD exchange rate depreciation and appreciation variables, respectively (Bahmani-Oskooee & Saha, 2016). In line with this, Kandil (2008) named the term "the partial sum of positive and negative changes" with "positive and negative shocks in the exchange rate", respectively.

The next equation defines PEX as a positive shock or exchange rate depreciation variable. In comparison, NEX is interpreted as a negative shock or an exchange rate appreciation variable. They are described in the following.

$$PEX_t = \sum_{i=1}^{t} \max\,[\Delta EXC_i, 0] = \sum_{i=1}^{t} \max\,[D(EXC_i),0]$$

$$NEX_t = \sum_{i=1}^{t} \min\,[\Delta EXC_i, 0] = \sum_{i=1}^{t} \min\,[D(EXC_i),0]$$

where $D(EXC_i) = \Delta EC_i = EXC_i - EXC_{i-1} = EXC - EXC(-1),\ i = 1, 2, \dots, t$, is the change in the exchange rate.

All time-series data were transformed into a natural logarithmic form, and expressed with the notations NET, MOB, TEL, PEX, NEX, and GRO variables. This natural logarithm transformation is useful for eliminating multicollinearity between regressor variables (Nachrowi & Usman, 2006; Brooks, 2019).

The process of checking the multicollinearity assumption, according to the econometric literature, can be carried out by two methods, including (1) checking the correlation matrix among independent variables. When all correlations between two independent variables are less than or equal to 0.8, then there is no multicollinearity in the multiple regression (Gujarati & Porter, 2010). The other method (2) is checking the variance inflation factor (VIF) for each independent variable. When the VIF value for each independent variable is less than or equal to 10, there is no multicollinearity in the multiple regression (Cortinhas & Black, 2012). In this research, multicollinearity checking was conducted using the VIF values.

Equation (1) is a long-run model derived from the NARDL model when PEX, NEX, NET, MOB, TEL, and GRO are in equilibrium for the variable positive shock in exchange rates $PEX_t = PEX_{t-1} = \cdots = PEX_{t-q_1}$. The NARDL model with lag lengths $p,\ q_1,\ q_2,\ q_3$ and q_4, abbreviated as NARDL(p, q_1, q_2, q_3, q_4), are as follows (Shin *et al.*, 2014; Pesaran & Shin, 1999):

$$GRO_t = C_0 + \sum_{i=1}^{p} \theta_i GRO_{(t-i)} + \sum_{j=0}^{q_1} \left(\alpha_j PEX_{(t-j)} + \beta_j NEX_{(t-k)}\right) + \sum_{k=0}^{q_2} \gamma_k\, NET_{(t-k)} + \sum_{l=0}^{q_3} \tau_l\, MOB_{(t-l)} + \sum_{m=0}^{q_4} \delta_m\, TEL_{(t-m)} + \varepsilon_{1t} \quad (2)$$

where $C_0,\ \theta_i\ (i = 1, 2, \dots, p),\ \alpha_j\ (j = 0, 1, \dots, q_1),\ \beta_j\ (j = 0, 1, \dots, q_1),\ \gamma_k\ (k = 0, 1, \dots, q_2),\ \tau_l\ (l = 0, 1, \dots, q_3)$ and $\delta_m\ (m = 0, 1, \dots, q_4)$ are the parameters of the NARDL model.

In equilibrium, these parameters with those in equation (1) have a relationship:

$$C = \frac{C_0}{1-\sum_{i=1}^{p}\theta_i},\ \alpha = \frac{\sum_{j=0}^{q_1}\alpha_j}{1-\sum_{i=1}^{p}\theta_i},\ \beta = \frac{\sum_{j=0}^{q_1}\beta_j}{1-\sum_{i=1}^{p}\theta_i},\ \gamma = \frac{\sum_{k=0}^{q_2}\gamma_k}{1-\sum_{i=1}^{p}\theta_i},\ \tau = \frac{\sum_{l=0}^{q_3}\tau_l}{1-\sum_{i=1}^{p}\theta_i}, \text{ and } \delta = \frac{\sum_{m=0}^{q_4}\delta_m}{1-\sum_{i=1}^{p}\theta_i}.$$

Therefore, the model in equation (2) is also referred to as the long-term NARDL model (Ozturk & Acaravci, 2010). The residuals ε_{1t} are independent, identically distributed, and homoscedastic.

Several steps were taken to test the long- and short-term impacts of positive and negative shocks in exchange rates, the Internet, mobile, and telephone users on economic growth. The steps comprised testing variable stationarity, co-integration between variables, estimating model parameters, and the residual, and parameter stability requirements. It also examines the assumption of multicollinearity among independent variables.

The first step involved a stationarity test employing the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test adopted from Kwiatkowski *et al.* (1992). The hypothesis formula used is H_0: time series is stationary, as opposed to H_1: time series is not stationary. The test criterion used was to accept hypothesis H_0 when the test statistic value is lower than its critical value at 1%, 5%, or 10% significance levels. The KPSS test developed by Kwiatkowski *et al.* (1992) tests the stationarity of a time series for a sample of 30 to 500 observations. The KPSS test is stronger than the Augmented Dickey-Fuller (ADF) test for a sample with 25 to 100 observations (Shin & Schmidt, 1992). Furthermore, Hornok & Larsson (2000) tested the strength of the KPSS test for a sample with 10 to 20 observations. The KPSS strength to test the stationarity of a time series with a small sample is in line with Kwiatkowski *et al.* (1992).

The next stage involved testing for co-integration between the Internet, telephone, mobile, positive and negative shock in exchange rates, and economic growth. The time-series data comprises three methods for testing cointegration, namely the Engle-Granger two-step, the ARDL Bound, and the Johansen tests. The Engle-Granger two-step test is applied to econometric models with a single equation, with all variables stationary at first differences and integrated with order 1, I(1). The co-integration test is accomplished by evaluating equation (1) and constructing (generating) its time-series residuals. When these time-series residuals are stationary at the level (a "level" in a time series refers to the overall value of a given variable over a period of time) or integrated of order 0, I(0), then all independent variables (PEX, NEX, NET, MOB, TEL) are co-integrated and have a long-term relationship with the dependent variable (Brook, 2019; Hill *et al.*, 2011). ARDL Bound cointegration test is also applied to a single equation, namely the ARDL equation. In this co-integration test, the stationarity of the variables involved in the model vary (Pesaran *et al.*, 2001). The Johansen co-integration test, which is applied to a system of equations, is generally used in Vector Autoregressive (VAR) models (Brook, 2019). This research used the NARDL co-integration test to determine the integration order of each variable and the number of equations in the model.

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The NARDL co-integration test follows the same procedures as the ARDL-bound co-integration test (Pesaran *et al.*, 2001). All the regressors of the NARDL model must be processed I(0) or I(1) to test the co-integration, meaning they must be stationary at the level of first difference. A dependent variable could be processed I(0) (Sam *et al.*, 2019). The NARDL model for testing cointegration could be:

$$D(GRO_t) = C_0 + \sum_{i=1}^{p-1} \theta_i D(GRO_{(t-i)}) + \sum_{j=0}^{q_1-1} \left(\alpha_j D(PEX_{(t-j)}) + \beta_j D(NEX_{(t-k)})\right) + \sum_{k=0}^{q_2-1} \gamma_k\, D(NET_{(t-k)}) + \sum_{l=0}^{q_3-1} \tau_l\, D(MOB_{(t-l)}) + \sum_{m=0}^{q_4-1} \delta_m\, D(TEL_{(t-m)}) + \theta_1 GRO_{t-1} + \theta_2 PEX_{t-1} + \theta_3 NEX_{t-1} + \theta_4 NET_{t-1} + \theta_5 MOB_{t-1} + \theta_6 TEL_{(t-1)} + \varepsilon_{2t} \quad (3)$$

where θ_i $(i = 1, 2, 3, 4, 5, 6)$ is the regression parameter and ε_{2t} is the residual. Testing was performed on the co-integration between a positive and negative shock in the exchange rate, the Internet, mobile, telephone, and economic growth in equation (3). The formulated hypothesis used is $H_0: \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \theta_6 = 0$, where all time-series are not co-integrated, versus $H_1: \theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 \neq \theta_6 \neq 0$, with all time-series co-integrated. Hypothesis testing used the F-statistic or Wald-statistic, where the criterion rejected the H_0 hypothesis when the statistic test of upper bound I(1) exceeded the critical value at the 1%, 5%, or 10% significance levels.

The next stage involved estimating the equation (1) long- and short-term coefficients of the error correction model (ECM-ARDL) in equation (4). The ECM-ARDL model modifies equation (2) (Heij *et al.*, 2004):

$$D(GRO_t) = \alpha_0 D(PEX_t) + \beta_0 D(NEX_t) + \gamma_0 D(NET_t) + \tau_0 D(MOB_t) + \delta_0 D(TEL_t) + \pi EC_{t-1} + \sum_{i=1}^{p-1} \theta_i{}^* D(GRO_{(t-i)}) + \sum_{j=1}^{q_1-1} \left(\alpha_j{}^* D(PEX_{(t-j)}) + \beta_j{}^* D(NEX_{(t-j)})\right) + \sum_{k=1}^{q_2-1} \gamma_k{}^*\, D\left(NET_{(t-k)}\right) + \sum_{l=1}^{q_3-1} \tau_l{}^*\, D(MOB_{(t-l)}) + \sum_{m=1}^{q_4-1} \delta_m{}^*\, D(TEL_{(t-l)}) + \varepsilon_{2t} \quad (4)$$

where $\theta_i{}^*$ $(i = 1, 2, \dots, p-1)$, $\alpha_j{}^*$ $(j = 1, 2, \dots, q_1 - 1)$, $\beta_j{}^*$ $(k = 1, 2, \dots, q_1 - 1)$, $\gamma_k{}^*(k = 1, 2, \dots, q_2 - 1)$, $\tau_l{}^*$ $(l = 1, 2, \dots, q_3 - 1)$ and $\delta_m{}^*$ $(m = 1, 2, \dots, q_4 - 1)$ are the parameters. EC_{t-1} is an error correction variable at time (t-1) that satisfies equation (5):

$$EC_{t-1} = GRO_{t-1} - C - \alpha PEX_{t-1} - \beta NEX_{t-1} - \gamma NET_{t-1} - \tau MOB_{t-1} - \delta TEL_{t-1} \quad (5)$$

When, in equation (1), $\alpha \neq \beta$, the test decision is a long-term asymmetric effect of exchange rates on economic growth. Conversely, when, in equation (4), $\alpha_0 \neq \beta_0$ and $\alpha_j^* \neq \beta_j^*$ $(j = 1, 2, \ldots, q_1 - 1)$, the exchange rates asymmetrically affect economic growth in the short term. Equation (4) involves D(PEX), D(NEX), D(NET), D(MOB), and D(TEL) as the regressor or the first difference between PEX, NEX, NET, MOB, and TEL variables. This transformation is useful for eliminating multicollinearity between regressor variables (Koop, 2006; Gujarati & Porter, 2009; Shin *et al.*, 2014).

The validity of the parameter estimation results in equations (1) and (2) was determined by testing the normality, independence, and residual homoscedasticity. The tests used are Breusch-Pagan-Godfrey (BPG), Breusch-Godfrey Serial Correlation LM (BGSCLM), and Jarque Berra (JB). Furthermore, the stability of equations (1) and (2) regression parameters was tested using the CUSUM and CUSUM Square tests (Brown *et al.*, 1975). This research also determined the assumption of multicollinearity in equation (1).

To determine whether the variables PEX, NEX, NET, MOB, and TEL are exogenous (not endogenous) variables, the endogeneity test was conducted using the J-statistic test, also called the Durbin-Wu-Hausman test. The J-statistic has a Chi-squared distribution with degrees of freedom equal to the number of regressors in the regression equation. The regression parameter estimation method relating to the endogeneity test is the two-stage least square (TSLS) or generalized method of moments (GMM). The hypothesis formulation in the J-statistic test is H_o: $\mathrm{PEX, NEX, NET, MOB, and\ TEL}$ are exogenous to GRO; the alternative hypothesis is H_1: $\mathrm{PEX, NEX, NET, MOB, and\ TEL}$ are endogenous (See Davidson & Mackinnon, 1993; IHS-Markit, 2017).

Results and Discussion

Results

Table 1. Results of the KPSS Test

Variable	Level		First Difference		Result of stationary test
	Intercept	Intercept and trend	Intercept	Intercept and trend	
NET	0.690411**	0.177996**	0.552795	0.173604**	I(0)
TEL	0.414131	0.153211**	0.479141**	0.123060***	I(1)
MOB	0.693124**	0.201750**	0.731584**	0.155055	I(0)
PEX	0.610564**	0.150519**	0.284331	0.125285***	I(0)
NEX	0.659491**	0.167369**	0.311768	0.500000*	I(0)
GRO	0.695133**	0.158790**	0.261538	0.066552	I(0)

Source: Research finding.
Note: *, **, *** significant at 1%, 5%, 10%.

In the ARDL bound cointegration test, one variable must be non-stationary at the second difference or process I(2). To ensure this, every variable's stationarity was first tested using the tests of KPSS, as shown in Table 1. The Internet, mobile, positive and negative shock in the exchange rate, and economic growth variables are stationary or integrated of order 0, I(0). In contrast, the telephone variable is stationary at the first difference or integrated of order 1, I(1).

This research used the NARDL model with a single equation comprising an integrated variable of order 1, I(1), and order 0, I(0). Therefore, the co-integration test between the independent and the dependent variables was carried out using the ARDL Bound co-integration test. The co-integration test determined the Internet, telephone, mobile, positive and negative shock in exchange rates, economic growth, and the NARDL model's lag length. From the Akaike information criterion (AIC), the lag lengths p=3 and $q_1 = q_2 = q_3 = q_4 = 2$ were obtained. Furthermore, the NARDL(3,2,2,2,2) bound model was used to test for co-integration. The calculation of the F-test statistic obtained the F-statistic value of 33.07, compared with the critical statistical value of upper bound I(1) of 5.76 at a significance level of 5%. That is, the F-statistic value is more than the F-critical value. Therefore, there is a long-term relationship between a positive and negative shock in exchange rates, the Internet, cell phones, and growth. The long- and short-term coefficients in equations (1) and (4) were estimated. Table 2 displays the estimates of these coefficients.

Table 2. Long-Run and Short-Run Coefficients Estimation

Independent variable	Coefficient	t-Statistic	P-value
A. Long-run coefficients, dependent variable: GRO			
PEX	-0.876911	-4.972667	0.0156
NEX	0.858269	1.645616	0.1984
NET	0.327650	2.602713	0.0802
MOB	0.416925	4.767840	0.0175
TEL	0.093102	3.365624	0.0436
Constant	27.21383	80.76889	0.0000
B. Short-run coefficients, dependent variable: D(GRO)			
D(GRO(-1))	-0.579886	-8.641749	0.0033
D(GRO(-2))	-0.037280	-3.645185	0.0356
D(PEX)	-0.773370	-85.39890	0.0000
D(PEX(-1))	-0.307685	-7.327401	0.0053
D(NEX)	-0.640108	-14.25579	0.0007
D(NEX(-1))	-1.083090	-10.14017	0.0020
D(NET)	0.247196	26.01943	0.0001
D(NET(-1))	0.083681	8.389286	0.0036
D(MOB)	-0.020380	-1.972867	0.1430
D(MOB(-1))	-0.043380	-4.463320	0.0209
D(TEL)	0.067156	13.46396	0.0009
D(TEL(-1))	0.024617	4.631077	0.0190
EC(-1)	-0.328114	-26.35249	0.0001

Source: Research finding.
Note: P-values of test statistics: BPG, BGSCLM, and JB are 0.38, 0.39, and 0.97, respectively

Table 2 shows a column containing the variable coefficients and their probability values. These coefficients show the multiplier of the independent variables, including positive and negative exchange rate shocks, Internet, mobile, and telephone, to the dependent variable, economic growth. Some coefficient signs are positive, while others are negative. If the probability value is less than 1%, 5%, or 10% significance level, the positive coefficient indicates the positive influence of the independent variable on the dependent variables. In this case, an increase in the value of the independent variable increases the dependent variable. In contrast, the negative coefficient indicates the negative effect of the independent variable on the dependent variables. This means that an increase in the independent variable reduces the value of the dependent variable.

Panel A shows that the PEX coefficient is negative and significant at the 5% significance level because p-value=0.0156<5%, while the NEX coefficient is positive and insignificant, because p-value=0.1984>5%. The significance of the PEX coefficient economically shows the long-term effect of a negative exchange rate shock on economic growth. Furthermore, the different signs and values of the two coefficients imply the long-term asymmetric effect of the exchange rate on economic growth. Therefore, an increase of positive shock in the IDR/USD exchange rate reduces economic growth in the long term. The domestic exchange rate depreciation lowers economic growth in the long run. In contrast, the coefficients for the Internet (NET), mobile (MOB), and telephone (TEL) variables are positive and significant at 10%, 5%, and 5%, respectively, implying the long-term impact of ICT on economic growth. Therefore, increased ICT use boosts economic growth in the long run. Panel B shows that positive (PEX) and negative (NEX) shocks in exchange rate coefficients at time lag 0 and 1, respectively, are different and significant at 1% in the short term. Therefore, economic growth was asymmetrically impacted by IDR/USD exchange rate in the short term. The coefficients for the NET, MOB, and TEL variables at time lag 0 and 1 are significant, except for the D(MOB) variable, indicating ICT's short-term impact on economic growth. Therefore, the exchange-rate asymmetry affects economic growth in the short and long term. Furthermore, ICT affects economic growth in the short and long term.

A model requirement test was conducted regarding the completeness of testing the effect of positive and negative exchange rate shocks, Internet, mobile, and telephone on economic growth. The NARDL(3, 2, 2, 2, 2) model residuals are homoscedastic, independent, and normally distributed. The CUSUM and CUSUM Square test trends are shown on the left and the right side of Figure 1, respectively. This trend curve is between the two 5% significance limit lines, implying the stability of the NARDL(3,2,2,2,2) model parameters. Therefore, the stability assumption of the NARDL(3,2,2,2,2) model parameters is fulfilled.

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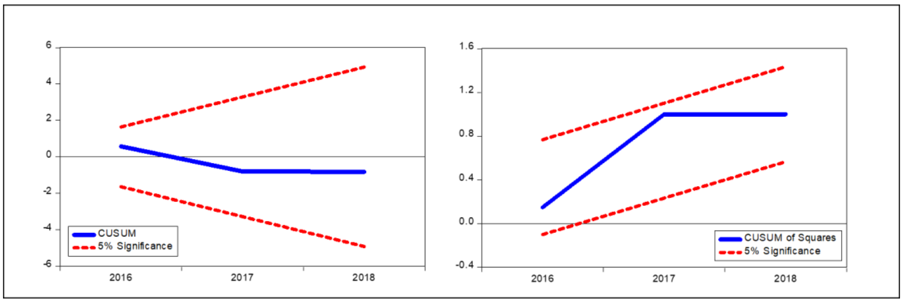

Figure 1. The CUSUM and CUSUM Square tests for NARDL(3,2,2,2,2) model parameters

The VIF for all independent variables (PEX, NEX, ITU, MOB, and TEL) is less than 10, as shown in Table 3. This indicates that there is no multicollinearity in model (1).

Table 3. VIF Estimation Results

Variable	VIF
PEX	9.00194
NEX	6.45138
ITU	7.38713
MOB	8.00801
TEL	3.431352

Discussion

This research revealed that the exchange rates asymmetrically affected long-term and short-term economic growth. A positive long-term increase in the IDR/USD rate negatively influences economic growth, characterized by a negative and significant positive shock coefficient value. Therefore, IDR depreciation reduced Indonesia's economic growth. A 1% increase in the IDR/USD exchange rate causes an 87.69% decrease in economic growth. This result is consistent with Kandil (2008), Bahmani-Oskooee & Mohammadian (2016), Wesseh & Lin (2018), and Hussain *et al.* (2019). This contradicts Yussof & Febrina (2014), Saidi *et al.* (2015) and Yuliardi (2020), which showed that the exchange rate affects Indonesia's economic growth symmetrically. Furthermore, these results support the theory on the effect of exchange rate asymmetry proposed by Kandil & Mirzaie (2002) and Kandil (2008). The theory states that unanticipated domestic exchange rate depreciation reduces economic growth.

This research found that ICT affected economic growth in the short and long run. The coefficients of the Internet, telephone, and mobile phone variables are significantly positive in the long term. The results imply that ICT positively influences economic growth. This confirms Amagiomyediwe & Annansingh-Jamieson (2017), Asongu & Odhiambo (2019), Solomon & Klyton (2019), Habibi & Zahardast (2020), Arabi & Allah (2017) and García (2019). The findings on the positive long-term influence of ICT on economic growth support Solow's and endogenous growth theories (Mankiw, 2007). This positive influence is an implication of the ICT development policy launched by the Indonesian government.

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Implications for practice and research

The findings showed that the Indonesian government should stabilize the IDR/USD exchange rate through monetary and fiscal policies to promote economic growth. The monetary and fiscal policies should support IDR/USD exchange rate appreciation to increase the trade balance, GDP, and economic growth. Monetary policy involves the process of decreasing the interest rates to a certain level without causing inflation to exceed the expected rate set by the Central Bank. Fiscal policy is the process of increasing exports and decreasing imports of goods. Indonesia's economic growth driven by ICT development still needs sustainability. Furthermore, the government should initiate ICT development in cities and rural areas. This development also involves the establishment of data and information-access speed.

The results are expected to contribute to empirical knowledge related to the asymmetric effect of exchange rates. It also shows an effect of ICT on economic growth and serves as a reference for future research.

Limitations and avenues for future research

This research was only conducted in Indonesia using IDR/USD as the currency exchange rate proxy. In the foreign exchange market in Indonesia, various currencies are traded in addition to the US dollar. Similarly, in international trade activities, currencies from other countries are often used instead of the US dollar, which have varying impacts on economic growth. Therefore, future investigation could be conducted in Indonesia and other countries on the use of different currency exchange rates or indices. Additionally, this research utilized telephone, Internet, and mobile phone users as proxies for ICT, which were examined using the analysis model. For future research, it is recommended to use an ICT index to avoid multicollinearity.

Conclusion and Recommendations

Foreign exchange rates and ICT play a vital role in the national economy. A currency forms a transaction instrument in international trade's real, service, and finance sectors. Furthermore, ICT is a means of communication between sellers and buyers in economic and business activities. This research aimed to determine the asymmetric effect of exchange rates and ICT on Indonesia's economic growth.

This research used yearly time-series data during the 1994–2018 period to test the asymmetric exchange rate and ICT's impacts on economic growth with the NARDL model. Furthermore, the ARDL bound co-integration test determined the long-term impact of positive and negative shocks in exchange rates and ICT on economic growth.

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The co-integration test showed that economic growth, positive and negative shocks in the exchange rate, and ICT were co-integrated. The long-term exchange rate positive shocks, Internet, mobile, and telephone coefficients are positive and significant. Therefore, the co-integration test shows a long-term effect of these variables on economic growth. The NARDL estimates showed that the exchange rates asymmetrically impact economic growth in the long term. Similarly, ICT affects economic growth. The ECM-NARDL estimates showed that exchange rates asymmetrically influenced short-term economic growth. ICT also affects economic growth in the short term, meaning that the exchange rate affects economic growth asymmetrically in the long and short term. Also, ICT affects economic growth in the long and short term. These findings could contribute to the economic literature and serve as input for the Indonesian government in monetary policy implementation and ICT development.

The findings imply that the Indonesian government must implement its monetary policy to stabilize the IDR exchange rate. Furthermore, ICT should be developed to respond to global advances and the increasing demand for its services.

The proxy for the exchange rate in this research was IDR/USD exchange rates. Therefore, future research could use a country's currency exchange rates against another foreign currency. Similarly, the ICT index could be used as a proxy for ICT, and there is a scope to research a wider area, such as ASEAN and Asia, by adding the government spending and inflation variables.

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