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Heliyon 6 (2020) e03141

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

The impact of exchange rate volatility on Indonesia's top exports to the five main export markets

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ARTICLE INFO

Keywords:
Volatility exchange rate
GARCH
Commodity trade
ARDL
NARDL
Indonesia
Econometrics
International finance
International trade
Macroeconomics
Money
Economics

ABSTRACT

This study examines the impact of exchange rate volatility on Indonesia's primary export commodities to the top five export destination countries, namely China, India, Japan, South Korea, and the United States. This study uses a GARCH model to obtain an estimated value of exchange rate volatility, using monthly data covering from 2006 to 2018. The ARDL method helps to measure the effect of exchange rate volatility on exports to destination countries in both the short and the long-term. Aggregate exports are compared employing a linear (ARDL) and a non-linear autoregressive distributed lag model (NARDL). The findings suggest that exchange rate volatility has a significant effect on exports of commodities under code 26 (ores), 38 (chemicals), 40 (rubber), and 47 (pulp paper) to India, Japan, South Korea, and the United States, either in the short or long-run. The exchange rate volatility of exports to China only affects plastics goods (code 39), although many goods experience negative effects due to exchange rate depreciation. In India, exchange rate volatility affects the largest number of export commodities. The Index of Industrial Production (IIP) has a strong long-term effect on exports to Asian countries. Impacts due to exchange rates offer both negative effects and positive effects (expected) in exports at commodity and trade partner case-to-case levels. Both aggregate ARDL and NARDL models suggest that Indonesian exports are negatively affected by exchange rate fluctuations.

1. Introduction

After the collapse of the Bretton Woods system, the impact of floating exchange rates on international trade has become an attractive object of research as the shift from fixed exchange rates exposed currencies to volatility, likely affecting trade flows. Although the exchange rate fluctuates typically beyond its fundamental condition, macroeconomic forces, market sentiment, global shocks, speculation, among others, could cause currency exchange rates to move beyond their underlying conditions. More recently, the interest has gained force as currency misalignments are seen as a source of global imbalances (Auboin and Ruta, 2013). Exchange rate volatility could potentially lead to market uncertainty, volatility in profits of traders, increase in risk, inflation uncertainty, unfavorable balance of trade, and impacts on production and transaction cost (Juhro and Phan, 2018).

Economic theory proposes that exchange rate volatility is negatively associated with trade flows as changes in currency rates are linked to uncertainty (Clark, 1973), leading to changes in price expectations, and to potential changes in demand for goods (Clark et al., 2004) as traders aim to reduce risk exposure (Obstfeld and Rogoff, 1998).

At the empirical level, a large body of research offers evidence on the discouragement of exports due to exchange rate fluctuations, supporting trade theory (Bahmani-Oskooee and Gelan, 2018; Chit et al., 2010; Hayakawa and Kimura, 2009). Nevertheless, some findings suggest positive or mixed effects of exchange rate volatility on exports (Chi and Cheng, 2016), while others find no evidence of impacts of volatility in exports (Nishimura and Hirayama, 2013). The literature suggests mixed effects of exchange rate volatility on exports at the short or long-run (Asteriou et al., 2016), depending on the industry (Bahmani-Oskooee and Aftab, 2017), the income of the import partner (Chi and Cheng, 2016), the level of financial development (Aghion et al., 2009), the risk behavior of the importer (De vita & Abbott, 2004), periods of special shocks (Fitrianti, 2017), among other factors. Besides, the different assumptions, methodological approaches, and data employed in models are likely to provide different outputs. Moreover, low availability of hedging tools (forward contracts) which are more evident in developing countries (Hall et al., 2010), the large fluctuations in commodity prices in the last decade (Hegerty, 2016), depreciation of currencies in the developing world, and changes in global demand open an empirical gap.

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https://doi.org/10.1016/j.heliyon.2019.e03141
Received 2 September 2019; Received in revised form 3 December 2019; Accepted 29 December 2019

The main objective of this study is to question the effects of real exchange rate volatility on exports from Indonesia to its top five largest export partners: Japan, South Korea, China, India, and the United States. While other studies on Indonesia include a large number of partner countries at an aggregated level (Asteriou et al., 2016; Clark et al., 2004; Hayakawa and Kimura, 2009), this paper focuses on the top eleven export goods from Indonesia and the top five destination countries, as combined they account for more than 30% of total exports, likely relevant for the balance of trade of Indonesia. Besides, exports of the top goods slowed down during the financial crisis and after the year 2012, tentatively because of sharp changes in prices and a slow-down in demand from top partners (see low CAGR in Table 1). The top eleven products included are mainly natural resource-related goods. Indonesia displays the characteristics of a "commodity economy" in which changes in commodity prices are linked to volatility in exchange rates (Hegerty, 2016).

The paper employs a GARCH model to estimate the real exchange rate (RER) volatility, using monthly data covering from 2006 to 2018. To examine the effects of RER volatility on the top eleven export products to main destination countries in both the short and the long-term, an Autoregressive Distributed Lag Model (ARDL) is employed. Besides the novelty of estimating the effects at specific product-partner level, the study examines both the symmetric and asymmetric effects at an aggregate level to test whether asymmetric effects exist, and the direction they take. Recent literature suggests that trade flows could respond asymmetrically to the volatility of the exchange rate (Bahmani-Oskooee and Aftab, 2017; Sharma and Pal, 2018). Asymmetric effects are carried out employing the Nonlinear Autoregressive Distributed Lag (NARDL) approach proposed by Shin et al. (2014).

It should be noted that the recent period of sharp movement has occurred in the exchange rate of Indonesia versus main partners (see Figure 1, Figure 2, Figure 3), also noted in (Juhro and Phan, 2018). Besides, Indonesia has rapidly expanded in trade with rapid income growth developing countries (India and China) where hedging tools may be less frequent while lowering dependency with Japan, South Korea, and the United States (developed ones). Exports of the top eleven goods to the top five destinations countries account for a large share of total exports (see Table 1), with a potentially broad impact on the balance of trade amid periods of high volatility of exchange rate, periods of low prices, and weak global demand. While countries less dependent on natural resources may recover more rapidly from global shocks, Indonesia may be more affected by exchange rate volatility versus neighboring countries (Fitrianti, 2017) (see Figure. 4 and Figure 5).

The reasons for choosing Indonesia and eleven commodities are thus not random. Indonesia experienced a substantial liberalization of markets in the last two decades and deep regional integration (Padilla et al., 2019). Since the year 2005, Indonesia has implemented free trade agreements with more than 25 countries. Besides, exports expanded from nearly US $ 100 billion in 2006 to more than US$ 200 billion in 2011, although on the year after, exports continually declined until reaching US$ 145 billion in 2014, unable to recover to pre-commodity crisis level (2012). The pattern of trade of Indonesia records more than 50% of total exports on raw materials and intermediate goods (mainly resource-based), more volatile in prices, and more sensitive to changes in prices and global demand. Trade as a percentage of GDP in Indonesia decreased from 55% in 2006 to nearly 40% in 2017, both as the role of local consumption increased but also due to lower exports. Besides, Indonesia's Real Effective Exchange Rate has been under pressure since 2012. From 2006 to 2018, the Indonesian Rupiah depreciated in real terms against the Renminbi (CNY, 34%), the Indian rupee (INR, 26%), and the USD (5%), while it appreciated slightly versus the South Korean Won (KRW, 5%) and the Japanese Yen (JPY, 10%). While theoretically it may be expected that exports increase with a weaker Indonesian Rupiah (Pino et al., 2016), exports have not recovered, likely as the currency is tight due to demand and prices of commodities (Hegerty, 2016), besides negative global macroeconomic factors (Juhro and Phan, 2018).

While country partners like the United States and Japan have broad access to heading tools and often display lower impacts due to volatile exchange rates, emerging country partners like India (Sharma and Pal, 2018), China (Nishimura and Hirayama, 2013), and to some degree South Korea (Baek, 2014) have less access and appear more exposure to volatility. Only recently (Nov 2018) the Indonesian government has promoted more actively the use of hedging tools to protect exporters, amid large fluctuations of the Indonesia Rupiah. Similarly the reason why the focus of this study is in exports alone arises as some evidence provides negative impacts on volatility of exchange rate on exports from developing countries, but with low impacts of exports from advanced countries (Baek, 2014; Nishimura and Hirayama, 2013; Sharma and Pal, 2018). Limited access to exporters from developing economies to hedging instruments may play a role, as it is theoretically proposed (Clark, 1973).

Shedding light on the impact of exchange rate volatility on product exports could lead to providing possible reasons for the sharp drop in exports in Indonesia starting in the year 2012. Besides comparing how volatility on the exchange rate influences the exports of top goods to developing countries (China, India, and South Korea to some extent) and those developed ones (Japan and USA), as well as explain how sensitive are the top exports of Indonesia to unstable exchange rate situations, it is timely as the trade balance is under pressure. It is worth noting that to our knowledge, there are few studies analyzing linkages between volatility exchange rate and exports in Indonesia at the commodity level, within a

Table 1. Trade Indicators (Total Exports, Share Exports, Growth per partner/Group).

Product	Total Export $ 000 USD			Share Total Exports 2018 (%)					Growth 2006–2018 (%)				
	2006	2018	CAGR Growth %	CHN	IDN	JPN	KOR	USA	CHN	IDN	JPN	KOR	USA
03	1.642.919	3.311.916	0,5	14,1	0,1	15,0	1,6	40,0	23%	20%	-1%	7%	9%
15	6.069.939	20.346.230	0,3	16,0	17,9	1,3	1,5	4,7	10%	11%	31%	33%	25%
26	4.994.074	5.254.702	1,0	37,5	8,2	23,6	11,7	0,0	17%	-4%	-4%	-1%	-2%
28	473.923	1.142.405	0,4	12,1	23,8	6,4	6,0	0,3	19%	19%	0%	0%	-2%
29	1.883.666	2.928.795	0,7	27,5	7,0	9,2	4,4	5,9	3%	8%	6%	1%	9%
38	706.579	4.926.359	0,2	24,7	8,4	2,3	3,7	5,1	22%	15%	7%	19%	16%
39	1.738.039	2.587.556	0,7	10,2	2,9	19,0	2,3	5,2	9%	5%	2%	8%	-5%
40	5.529.132	6.381.285	0,9	9,1	7,2	15,1	4,5	25,7	-1%	18%	0%	4%	2%
44	3.355.625	4.435.145	0,8	15,2	3,8	19,9	9,7	12,2	8%	27%	0%	8%	3%
47	1.126.425	2.649.365	0,5	71,3	4,7	1,7	6,8	0,0	11%	7%	-4%	-2%	-100%
48	2.805.339	4.483.133	0,7	13,5	4,3	8,0	3,1	6,0	10%	14%	1%	5%	1%

Note: Product Code. 03 Fish & crustaceans, molluscs; 15 Animal vegetable fats oils; 26 Ores, slag and ash; 28 Inorganic chemicals; 29 Organic chemicals; 38 Miscellaneous chemical; 39 Plastics and articles; 40 Rubber and articles; 44 Wood & articles, charcoal; 47 Pulp of wood; 48 Paper and paperboard.

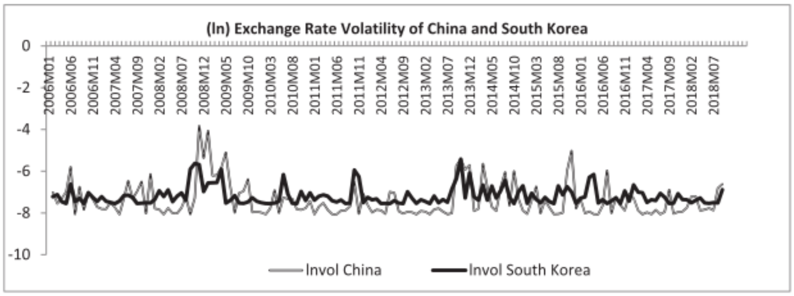

Figure 1. Exchange Rate volatility of Indonesian Rupiah (IDR) versus Chinese Renminbi (CNY) and South Korean Won (KRW).

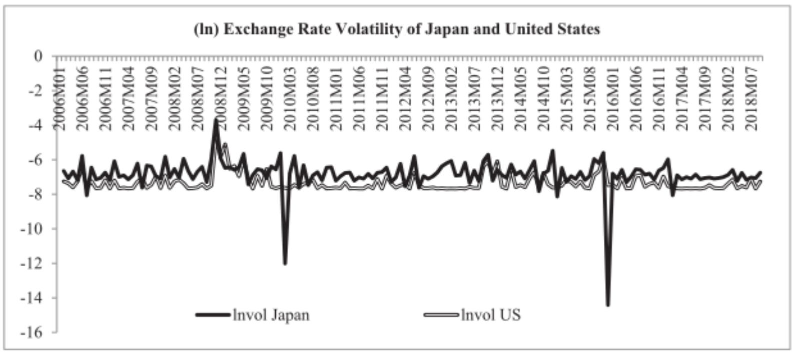

Figure 2. Exchange Rate volatility of Indonesian Rupiah (IDR) versus USA Dollar and Japanese Yen (JPY).

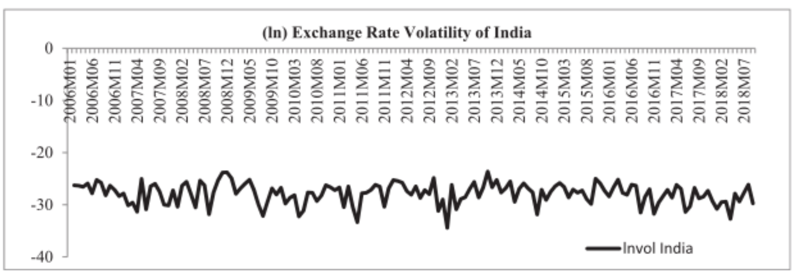

Figure 3. Exchange Rate volatility of Indonesian Rupiah (IDR) versus Indian Rupee (INR).

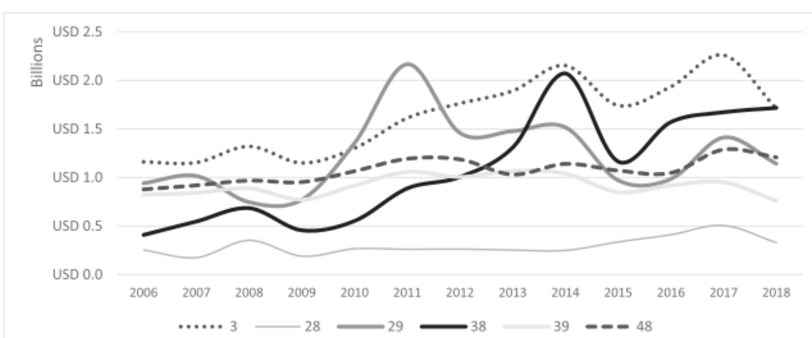

Figure 4. Export Performance goods HS code 03, 28, 29, 39, and 48 to five partners (USD Billions).

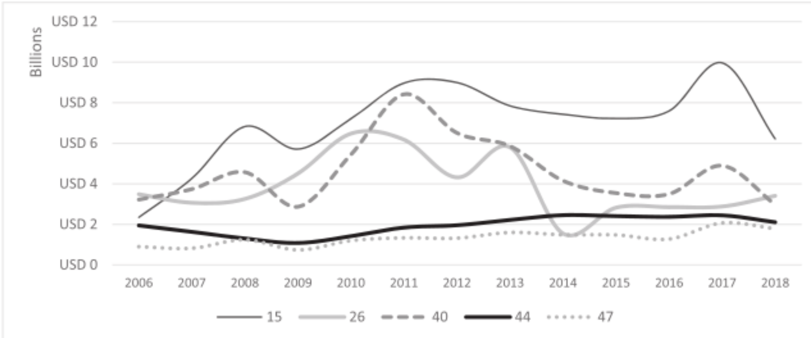

Figure 5. Export Performance goods HS Code 15, 26, 40, 44, and 47 to five partners (USD Billions).

period of high volatility in exchange rates and low commodity prices, and trade versus developing countries. The findings of Bahmani-Oskooee et al. (2015) on Indonesia – US trade suggest that the effects of volatility in exchange rates differ at the commodity level, opening a gap for further research. Besides, this paper applies the nonlinear autoregressive distributed lag (NARDL) of Shin et al. (2014) to compare volatility effects under symmetric and asymmetric assumptions.

Our unique contribution to the literature is first in the specific empirical case of exports from Indonesia to eleven sectors and five different trade partners, not previously studied. Besides, employing a disaggregated industry – country-specific data may draw more meaningful results (Aftab et al., 2017). The sectors are mainly natural resource-based, and the partners are both developing and developed countries. Second, the paper offers both symmetric and an asymmetric approach to highlight the existence of diverse effects arising from volatility in the exchange rate. As noted in previous studies, likely, the effects of exchange rate volatility are not symmetric (Bahmani-Oskooee and Aftab, 2017). Third, the period of study is of interest considering the change in global trade (slowdown), shocks in prices, and implementation of trade agreements, likely influencing the impact on exports.

2. Literature review

Several theoretical models attempt to explain the impacts of exchange rate volatility in trade flows. Proposing a model under perfect market competition, a single final traded good, for a single export market, and where payments are carried out in foreign currency, Clark (1973) predicted that in the absence of hedging instruments, exchange rate volatility is likely to have a negative impact on exports as firms need to anticipate output based on expectations on changes in currencies. The lack of alternative inputs (not considered in the model) to substitute higher cost inputs, and the absence of alternative markets, lead the firm to decide on output levels in anticipation of exchange volatility. As unfavorable movements in the exchange rates could lower profits, firms would tend to avoid exposure to risk. The simplifying assumptions of Clark (1973) were further relaxed, in scenarios where hedging is possible (Viaene and De Vries, 1992), where trade is carried out across different nations experiencing different exchange levels (Cushman, 1986), where goods traded allows for substitution of lower-cost inputs (Clark, 1973), where the existence of alternative markets allow export relocation (Broll and Eckwert, 1999), among other variations on assumptions. While those relaxations may support lower exposure to risk, the assumptions still entail additional cost and for instance, lower profits, meaning that the possibility of adverse effects on trade arising from exchange rate volatility may still prevail. As noted in Obstfeld and Rogoff (1998), hedging instruments lower uncertainty but increase the cost of trade, lowering expected profits. Besides, depending on the risk aversion behavior of firms, output and exports may change at different levels as firms lower exposure to risk (Clark et al., 2004).

Theoretically, large volatility in exchange rates leads to uncertainty portrayed as a risk and for instance, to adverse effects in exports depending on the behavior of traders. Under scenarios of high volatility, risk-averse traders may lower trade as they could incur unexpected costs linked with variations in exchange rates (Doğanlar, 2002). Differences in risk behavior and availability of instruments suggest that the effects of exchange rate volatility could be positive or negative, meaning that no conclusive evidence is supported by a superior model (McKenzie, 1999).

Drawing from empirical studies, the impact of exchange rate volatility on exports offers evidence of negative, positive, unidentified, or mixed effects, deriving into a field open to empirical findings. Umaru, Sa'idu, and Musa (2013) using three methods to examine the impact of volatility exchange rate on Nigerian exports such as OLS, Granger-Causality, and GARCH, find evidence of negative impact on exports due to volatility in the exchange rate. Serenis and Tsounis (2013), looking at the specific case of Cyprus and Croatia, conclude that the volatility of the exchange rate harms export flows (both directions). Studies involving emerging Asian countries seem to conclude similar adverse effects on exports as a result of a volatile performance of the exchange rate in cases such as Korea - US trade (Baek, 2014), East Asian emerging countries to advanced nations (Chit et al., 2010), ASEAN – US trade (except for Indonesia, Ramli & Podivinsky, 2011), East Asian countries (Pino et al., 2016), Pakistan exports (Aftab et al., 2012), and China-Japan exports (Nishimura and Hirayama, 2013).

Among developing countries in the world, empirical studies covering Latin America (Arize et al., 2008) and Africa (Bahmani-Oskooee and Gelan, 2018) often find negative impacts from exchange rate uncertainty on exports, although the impact is more predominant on the short term than in the long run in the latest case.

While the amount of empirical evidence supporting the adverse effects of volatile currencies on trade is abundant, some studies also support positive effects or mixed effects across different commodity groups. The impact of exchange rate volatility on trade is positive in the case of Germany and the US (McKenzie, 1999), or cases such as that of Chi and Cheng (2016) for exports from Australia to main Asian partners. Mordecki and Miranda (2018) find a negative effect from volatility to trade for Uruguay but do not find evidence on Chile and New Zealand from the 1990 to 2013 period. Mixed results are more often found in studies employing disaggregated data. In the bilateral trade between Brazil and the US (1971–2010), several industries were not affected by exchange rate volatility in the long run, while some among the affected ones respond positively to the uncertainty (Bahmani-Oskooee et al., 2013). Sharma and Pal (2018), using pooled mean group estimators and non-linear ARDL, conclude that in the long run, exports from India to the US, Germany, and China are harmed by nominal exchange rate volatility, although in the short run the effects are mixed. In the same line, Bahmani-Oskooee and Aftab (2017) find significant effects on exchange rate volatility for thirteen groups of products from Malaysia to the United

States, pointing out a stronger presence of short-run effects over long-run, but also a lower willingness to trade when exchange rate volatility is higher.

Drawing from theory, differences on impacts could arise due to availability of hedging instruments (Hall et al., 2010), by risk behavior of traders (McKenzie, 1999), by the structure of producer-importer (Bahmani-Oskooee et al., 2013), the level of international openness (Auboin and Ruta, 2013), among other theoretical assumptions. Hall et al. (2010) conclude that emerging countries (EMEs) with open capital markets experience fewer fluctuations on trade flows due to volatility in the exchange rate, while less open developing countries promptly face larger negative pressures on trade. As noted in Ćorić and Pugh (2010), while the volatility of the exchange rate imposes adverse effects in exports, the access to hedging tools helps to lower uncertainty and to lower the adverse effects on trade. Bahmani-Oskooee et al. (2015) find that smaller players in the US-Indonesia trade face stronger adverse effects due to exchange rate volatility versus larger companies which are more likely to employ hedging tools compared to smaller firms. Other cases, like that of China, show that impacts of exchange rates on exports are rather small as exports experience a pass-through into import prices (Li et al., 2015).

Studies on exchange rate volatility and trade in Indonesia also offer mixed results. Asteriou et al. (2016) find a significant short-run effect on exports and imports in Indonesia due to volatility, but no significant effects on trade in the long-run. Besides, the deviations from long-run equilibrium are estimated to be corrected within 3–4 months. Although Asteriou et al. (2016) find a demand for total exports of Indonesia to be income inelastic, other studies at a more disaggregated level suggest a positive effect of incomes on trade, suggesting using disaggregated data. Additional studies in Indonesia suggest a negative impact from volatility on the exchange rate to exports (Chit et al., 2010; Doğanlar, 2002; Fitrianti, 2017), although, at bilateral country-to-country case effects in the short and long run differ, in line with Tsen (2014).

At the commodity level, Bahmani-Oskooee et al. (2015) find that 66% of the goods traded between the US and Indonesia are significantly affected by exchange rate fluctuations in the short-run, while a third expanded the effects until the long run. Nevertheless, Indonesian importers are more often and more significantly affected than American ones. However, only a few Indonesian exported goods are included in the study (none among those included in this paper). In the study of Fitrianti (2017), total exports from Indonesia to Japan suffer amid exchange rate volatility in both the long and the short term, while exports to the US are positively influenced by exchange rate volatility in the short-run. The study of Ramli and Podivinsky (2011) also finds a positive effect of exchange rate volatility on exports from Indonesia to the United States, contrary to the effects experienced by the ASEAN neighbors. By contrast, Pino et al. (2016) find no conclusive evidence of the effects from exchange rate volatility to exports in Indonesia, while ASEAN neighbors experience adverse effects, similar to the results of Chit et al. (2010) where the results of Indonesia differ from the other sample countries.

In export demand functions, income and industrial activity are expected to be positively associated with trade flows. Empirically, studies such as those of Nishimura and Hirayama (2013), explain that the effect of income growth in China positively influences the exports from Japan to China, perhaps lowering effects due to volatility. Similar effects are also proposed in the S. Korea – United States (Baek, 2014), as well as in Chi and Cheng (2016) for Australia-Asia trade suggesting that income growth in Asian countries is an essential driver of exports for Australia in the long-term. Asteriou et al. (2016) supports that Indonesian exports are supported by income growth of partners, potentially absorbing adverse effects from exchange rate volatility.

The global financial crisis of 2008 affected the Indonesian economy and caused the Rupiah exchange rate to depreciate and to experience high volatility. Asteriou et al. (2016) estimate that the shock during the 2008–2009 period took nearly four months for Indonesia to return to long-run equilibrium, although shorter than other emerging countries like Mexico. Fitrianti (2017) also identifies a negative impact from external shocks to Indonesian exports, likely magnifying the negative effects on exports (besides exchange rate volatility).

A final note relates to the asymmetric effect of exchange rate volatility on trade. Applying an asymmetric approach on exchange rate volatility, Sharma and Pal (2018) illustrate that the effects of exchange rate volatility on Indian trade could influence volumes in either a positive and negative way. Some studies have employed asymmetric effects finding evidence of asymmetric movements in the effects of trade volumes due to exchange rate fluctuations (Bahmani-Oskooee and Aftab, 2017; Bahmani-Oskooee et al., 2017). Supported by a theoretical model on hysteretic behavior proposed by Baldwin and Krugman (1989), methodologies allowing for asymmetric effects are also employed to analyze the effects of currency appreciation or depreciation, leading to changes in trade flows (Arize et al., 2017).

Mirroring on the mixed findings of theoretical models and building on the mixed empirical results on exchange rate volatility, this study proposes an empirical exercise to analyze the effects of volatility of exchange rates on trade in Indonesia, focusing on top products and top country destinations where the size of exports could affect the overall export performance of Indonesia. A linear and non-linear ARDL model compare results at the aggregate level.

2.1. Exchange rate volatility

The literature on exchange rate volatility often employed three main approaches: the standard deviation approach (Chowdhury, 1993; Hayakawa and Kimura, 2009; Hooper and Kohlhagen, 1978; Nishimura and Hirayama, 2013), the moving average of the standard deviation (Arize et al., 2000; Hall et al., 2010), and the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) (Asteriou et al., 2016; Bahmani-Oskooee et al., 2015; Sharma and Pal, 2018). The first two approaches may face estimation bias and fail to observe information generated in the error terms, potentially failing to capture the effect of large variance experienced in previous (lagged) periods (Serenis and Tsounis, 2013), needed to estimate future volatility. By contrast, GARCH-type models have gained in popularity as they do much better in capturing the volatility by incorporating time-varying conditional variance (Sharma and Pal, 2018), capturing the effects of volatility clustering in time series. Studies such as that of Nishimura and Hirayama (2013) employed both standard deviation and an exponential GARCH approach capturing similar results, although they do not derive unique implications in using either approach. Other papers such as that of Hall et al. (2010) find that the GARCH method captures a smaller standard error of volatility versus that of moving standard deviation. A possible explanation is that moving the standard deviation approach may not completely capture the stochastic error term of the volatility exchange rate. After testing for fitness criteria, this paper employs a GARCH approach to observe exchange rate volatility as it is more accurate and efficient to capture risk and the combine conditional variances.

Another common debate in the literature of exchange rate volatility is whether to employ real exchange rate data or a nominal exchange one. A substantial number of papers employ real exchange measurements as it could capture the volatility arising from the nominal exchange rate and relative prices (Aftab et al., 2017; Baek, 2014; Chi and Cheng, 2016). Some studies successfully employed nominal exchange rates driving important considerations (Sharma and Pal, 2018). However, the effects of nominal and relative price changes are not easy to isolate when data on prices are not widely available. Besides, real exchange rates capture the relative prices of goods, which may play an active role in the decision of trade volumes as it reflects the relative competitiveness of products. This paper employs real exchange rates to estimate volatility as well as to measure the impact of the bilateral exchange rate between trade partners. Although, the study also compares the nominal exchange rate when employing the asymmetric approach, finding no differences in a sign for the case of Indonesia - S Korea and Indonesia – India.

Since volatility is not directly perceived, it is estimated from the log of real exchange rate employing the GARCH approach (Engle and Bollerslev, 1986). Following Gujarati and Porter (2009) the RER at time t depends on a constant value, a one-term lag (RER in the previous period, RER_{t-1}), and the error term in time t (u_t).

$$RER_t = \alpha_0 + \alpha_1 RER_{t-1} + u_t \quad (1)$$

$$h_t^2 = \sigma_0 + \sigma_1 u_{t-1}^2 + \sigma_2 u_{t-2}^2 + \ldots + \sigma_q u_{t-1}^2 + \theta_1 h_{t-1}^2 + \theta_2 h_{t-2}^2 + \ldots + \theta_p h_{t-p}^2 \quad (2)$$

where h_t^2 indicates the conditional variance of u at time t, influenced by the squared error term in the previous period (ARCH term), and a conditional variance in the previous period (GARCH term). The GARCH (p,q) model helps to estimate the value of exchange rate volatility in Eq. (2). Eq. (1) is further employed to obtain the conditional variance of the volatility exchange rate for Eq. (2).

Although it is not necessary to perform a unit root test since the ARDL bounds test allows explanatory variables to be I(0) or I(1), it is required that the explanatory variables do not have a higher order of integration as that of I(2). Table 2 shows the result of the unit root test of the bilateral exchange rate for the five destination countries using the Augmented Dickey-Fuller (ADF) test and the Phillips-Peron test. The result indicates that real exchange rates on the five bilateral cases are stationary in the first difference suggesting to use the real exchange rate in the first difference condition. All variables of exchange rate are transformed into logarithmic forms (*Ln*RER).

The next step is to determine the ARCH effect for each of the five countries. Table 3 shows the results of the ARCH effect test for China, India, Japan, South Korea, and the U.S. Each first-differenced variable of exchange rate allows using up to fourth lags. The Akaike's Information Criterion (AIC) and the Schwartz's Information Criterion (SIC) help to select the optimum models, based on the minimum value criteria. The results suggest that all the countries have an ARCH effect in their residuals. Subsequently, the ARCH-LM test describes that these models contain one of the classical assumption problems, i.e. heteroscedasticity, indicating the presence of volatility clustering in the data.

The presence of heteroscedasticity implies the autoregressive structure in the data, suggesting that the GARCH model can be used for modeling exchange rate volatility. The result for the fitted models of GARCH is presented in Table 3, applying the AIC and SIC to choose optimum lag lengths. If the coefficients on the GARCH model in the ARCH-LM test are significant, and the *p-value* of *chi*-2 is less than alpha, then the combination of GARCH/ARCH is ideal. For example, the best GARCH model for the bilateral exchange rate for China is ARCH(1). The probability X^2 of the ARCH-LM test is higher than alpha, meaning that it is possible to reject the null hypothesis (no homoscedasticity) suggesting to accept the alternative hypothesis.

Table 3 shows that all the variables are found stationary in level or first difference. The conditional bilateral real exchange rate volatility is depicted graphically in Figure 1, Figure 2, and Figure 3. After testing for stationarity, the ARDL method is employed to analyze the impact of exchange rate volatility on exports.

Table 2. Result of unit root test.

variables	Level		First Difference	
	ADF	PP	ADF	PP
LnRERChina	-1.317	-1.408	-11.486***	-11.475***
LnRERIndia	-1.847	-1.800	-11.144***	-13.663***
LnRERJapan	-2.343	-2.343	-10.813***	-10.787***
LnRERKor	-1.775	-1.726	-13.353***	-13.390***
LnRERUSA	-1.700	-1.732	-10.803***	-12.284***

Note. All variables are in log form, 2. *** Denotes significance at 1% level.

3. Models and methods

This study covers the period from 2006:01 to 2018:09, including exports of the eleven top products from Indonesia to the five largest export partners: China, India, Japan, S Korea, and the United States. The data consist of eleven Indonesia's primary export goods at the two-digit level of HS aggregation (Table 4), all of them within natural-resource sectors.

Following Bahmani-Oskooee and Aftab (2017), an export demand function is proposed as a function of income of trading partners, real bilateral exchange rates, and bilateral exchange rate volatility as:

$$LnEX_{I,t}^{IND} = \beta_0 + \beta_1 LnIIP_t^* + \beta_2 LnRER_t + \beta_3 LnVOL_t + \varepsilon_t \quad (3)$$

Where $EX_{I,t}^{IND}$ represents commodities exported from Indonesia to each of the five different partner countries. As commonly proposed in the literature (Sharma and Pal, 2018), to proxy the income of the destination country, the Index of Industrial Production is proposed (IIP_t^*). Meanwhile, RER_t is the bilateral real exchange rate between the Rupiah Indonesia (IDR) and the five different currencies of the partner countries; Renminbi (CNY), Indian rupee (INR), Japanese Yen (JPY), South Korean Won (KRW), and the United States Dollar (USD). The bilateral real exchange rate is chosen to capture the impact of the exchange rate on Indonesia's export to the five partner countries. Following Bahmani-Oskooee and Aftab (2017), the export demand function estimates the percentage change in exports when the rupiah depreciates or appreciates against other currencies. While some studies use relative prices to capture the ratio of prices goods or services against partners (Asteriou et al., 2016; Choudhry, 2005; Hall et al., 2010; Sharma and Pal, 2018), data of prices in Indonesia at commodity level is limited. VOL_t indicates the real exchange rate volatility, estimated via a GARCH approach. The IIP and the exchange rates data are available at the International Financial Statistics, while export flows are available in a monthly basis in the Trade Map dataset. We use the natural logarithm form (Ln) for all of variables.

In Eq. (3), the estimated value of β_1 is expected to be positive, as the coefficient of the Industrial Production Index suggests that a higher income level on the export destination country may encourage larger exports. On the other hand, β_2 could take a positive sign for the bilateral real exchange rate if the Indonesian Rupiah depreciates, leading to higher exports. Contrary, β_2 could be negative if the Rupiah depreciates, leading to a decrease in exports. Meanwhile, a negative estimated value of β_3 is expected to indicate that a higher fluctuation of the real exchange rate would decrease the volume of exports.

3.1. Autoregressive distributed lag (ARDL) model

Following Bahmani-Oskooee and Hegerty (2009), this study applies the ARDL approach to model export flows from Indonesia to the five main trade partners. A distributed model captures effects from the current

Table 3. Fitted GARCH (p,q) models for the bilateral real exchange rate for 2006:01–2019:09.

*Ln*RER	CHINA	INDIA	JAPAN	KOR	US
ARCH (1)	0.949*** (0.240)	12.715*** (0.671)	0.541*** (0.092)	0.388*** (0.152)	0.432*** (0.175)
GARCH (1)			-0.315*** (0.087)		
Constant	0.000 (0.0005)	0.009 (0.007)	0.001 (0.0002)	0.0005 (0.007)	0.000 (0.005)
ARCH-LM Test (p-value)	0.001	0.000	0.002	0.000	0.003

Note: (a) standard error in parentheses; (b) p-value X2 of ARCH-LM for heteroscedasticity test has null hypothesis: "no ARCH effect"; (c) df 1 for p-value of X^2; (d) ***significance at 1%.

Table 4. Indonesia's Top Commodities export to Five Countries.

HS-Code	Description
3	Fish and crustaceans, molluscs and other aquatic invertebrates
15	Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes
26	Ores, slag and ash
28	Inorganic chemicals; organic or inorganic compounds of precious metals, of rare-earth metals, of radioactive elements or of isotopes
29	Organic chemicals
38	Miscellaneous chemical products
39	Plastics and articles thereof
40	Rubber and articles thereof
44	Wood and articles of wood; wood charcoal
47	Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or
48	Paper and paperboard; articles of paper pulp, of paper or of paperboard

period (time *t*), but also it carries effects from the lagged independent variables (X variables). The lags introduce a dynamic effect incorporated in Eq. (3) to distinguish the short-run effect of exchange rate volatility on export from the long-run effect, as in Bahmani-Oskooee and Aftab (2017). Following Pesaran et al. (2001), the ARDL bound test is employed to specify Eq. (3) as an error correction model (ECM) in Eq. (4):

$$\Delta LnEX_{i,t}^{IND} = \beta_1 + \sum_{j=1}^{n1} \beta_2 \, \Delta LnEX_{t-j}^{IND} + \sum_{j=0}^{n2} \beta_3 \Delta LnIIP_{t-j}^{*} + \sum_{j=0}^{n3} \beta_4 \Delta LnRER_{t-j} + \sum_{j=0}^{n4} \beta_5 \Delta LnVOL_{t-j} + \delta_1 LnEX_{t-1}^{IND} + \delta_2 LnIIP_{t-1}^{*} + \delta_3 LnRER_{t-1} + \delta_4 LnVOL_{t-1} + \varepsilon_t \quad (4)$$

On Eq. (4) the first-differences represent the coefficient estimation in the short-term, while the long-run effects are represented by the $\delta_2 - \delta_4$ (lagged level) normalized on δ_1 in Eq. (4). A priori, we expect that β_2 and β_3 are positively associated with exports in period *t*. The ideal lag interval for the short term is taken based on the Akaike Information Criterion (AIC).

Technically, there is no need to perform unit root test since the ARDL bounds test allows explanatory variables to be I(0) or I(1). Nevertheless, because it is crucial not only to ensure that these variables do not have a higher order of integration than I(2) but also that the regressand is I(1), there is a need for unit root test.

Following Pesaran et al. (2001), to validate the effect of long-run relation in the equation, we use the bound test and apply the F test to verify the presence of cointegration. A statistical value above the upper value I(1) of the bound test indicates that the null hypothesis "there is no cointegration" is rejected, leading to accepting the alternative hypothesis "there is cointegration" condition. To check for cointegration, the F test is applied to validate the joint significance of lagged variables. As noted in Pesaran et al. (2001), two asymptotic critical values are proposed, with a lower bound assuming that variables are below I(0) levels, and an upper bound assuming that values are I(1). An F statistic above the upper bound critical value I(1) means that there is cointegration effect. A probability of ECM_{t-1} below the alpha 5% means there is cointegration effect. Once testing for cointegration, the ARDL model could be implemented to estimate the short run and the long-run effects among the variables that present significant cointegration.

As an additional diagnostic check, the Lagrange Multiplier (LM) test of residual serial correlation is applied, indicating a null hypothesis of "no serial correlation." The LM follows a χ^2 distribution with one degree of freedom (first-order). Furthermore, Ramsey's RESET test for mis-specification model is proposed with the null hypothesis of "no mis-specification." The RESET is distributed as χ^2 with one degree of freedom. The Jarque-Bera (J-B) test for normality is also applied to test the distribution of residual with the null hypothesis of "residual has a normal distribution." Finally, the CU and CUQ test is applied for stabilization of the model using CUSUM and CUSUMQ. The result of S means "Stable," and U means "Unstable."

4. Empirical result

For a compact and more efficient way of reporting results, the short-run Table 5 estimates for volatility and the long-run Table 6 estimates for all commodities, and all countries are displayed in single tables. Only significant results are displayed. Complete estimates are available upon request. Cointegration results are presented in each sub-section when the bilateral trade is analyzed.

4.1. *Analysis of China*

Table 5 shows the impact of real exchange rate volatility of exports from Indonesia to China in the short run. The results indicate that only two commodities out of eleven have a short-run impact on exports from Indonesia to China due to RER volatility, organic chemicals (negative), and plastics (positive). A negative sign of RER volatility suggests that exports are affected by high exchange rate volatility. In the case of organic chemicals, the effects are estimated within three months ahead. The negative effect may help to explain the decline of exports of organic chemicals as China account for 27.5% of the total Indonesian exports of organic chemicals. During periods of high RER volatility (e.g., crises 2008–2009), exports under code 29 decreased by 80 percent versus the previous period. Once the exchange rates stabilized, exports returned to previous levels.

On the other hand, plastics and articles under code 39 have the opposite sign, leading to an increase of exports during periods of high volatility, contrary to what is expected, and suggesting that RER volatility offered room for additional profits. In the short run, traders within plastics are risk-takers as they continue to trade even though exchange rate volatility is high. The effect of RER volatility in plastics lasts in the long run. Plastics are the only commodity that displays significant positive RER volatility effects on exports to China (code 39, Table 6).

Regarding the other explanatory variables in the export demand function, in the long run, the impact of the Index of Industrial Production (IIP) has a significant positive effect on Indonesia's exports to China within six groups of products (fish, vegetable oils, ores, organic chemicals, inorganic chemicals, and paper). The combined value of exports of those five groups increased from US$ 1.06 billion in 2005 to more than US$ 6.25 billion in 2018. The positive effect of IIP to exports is as expected as it illustrates that improvements in the economic activity of China tend to increase exports from Indonesia to China. Growth in the economic activity of China appears as the primary driver of exports.

Meanwhile, in the long-run, the bilateral exchange rate has a significant negative impact on Indonesia's exports to China for seven out of the eleven product groups. A depreciation of the Rupiah against the Renminbi tends to weaken the exports from Indonesia, contrary to what is expected by theory. A possible explanation is that RER incorporates changes in relative prices, leading to a negative effect.

Table 7 displays the diagnostic test for the model for China. The result of cointegration uses F-test and ECM_{t-1}. The null hypothesis "there is no cointegration" is rejected as the critical value is above upper critical I(0) value. The result shows that most of the products have long-run cointegration (10 goods out of 11). Furthermore, the value of ECM_{t-1} also indicates the presence of cointegration among the other variables included in the model. The ECM_{t-1} explains the speed of adjustment in the long-run equilibrium. As an example, a value of ECM_{t-1} on fish (code 3) equal to 0.489 implies that any deviation from the long-run equilibrium is corrected within two months (1/0.489). The LM-test helps to validate the serial correlation of residuals, suggesting that no sign of serial correlation present between residuals. The RESET test applied for mis-specification

Table 5. Short-run coefficient estimates on Exchange Rate Volatility in the ARDL export model to China, India, Japan, South Korea, and the US.

Product code	Product label	China		India		Japan		South Korea		USA
		ΔVOL_t	ΔVOL_{t-3}	ΔVOL_t	ΔVOL_{t-1}	ΔVOL_t	ΔVOL_{t-3}	ΔVOL_{t-1}	ΔVOL_{t-2}	ΔVOL_{t-2}
3	Fish & crustaceans, molluscs									
15	Animal vegetable fats oils									
26	Ores, slag and ash				0.2620**	-0.2633**				
28	Inorganic chemicals									
29	Organic chemicals		-0.119**							
38	Miscellaneous chemical			-0.0304**				0.1759**		0.274**
39	Plastics and articles	0.074***								
40	Rubber and articles			-0.0394**				0.1287***		
44	Wood & articles; charcoal									
47	Pulp of wood			-0.0441**			-0.1166***		0.1996***	
48	Paper and paperboard									

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

suggests that two goods present misspecifications (40 and 44). The J-B test shows that the results have a normal distribution in the residuals, while the CU-test suggests that all models are stable.

4.2. Analysis of India

Exports to India are next examined. There are four products with significant short-run RER volatility effects on exports (codes 26, 38, 40, and 47). RER volatility has a significant positive impact on exports of code 26 (ores), contrary to what is expected, although a risk-taker behavior of importers may support this effect. Meanwhile, RER volatility has a significant negative impact on exports of chemicals, rubber, and paper (codes 38, 40, and 47), signaling lower exports amid high RER volatility as traders may be risk-averse. The results are in line with a priori expectations, as theory suggests that trade flows may be affected by significant volatility. On the other hand, in the long run, volatility in RER has a significant negative impact on goods 15 (vegetable fats, mainly Crude Palm Oil), 26 (Ores), 40 (Rubber), and 47 (Pulp), all natural-resource based. The only product with a significant positive impact due to RER volatility, in the long run, is chemicals (38). The effect of RER volatility is carried from the short to the long run on products 26 (ores), 38 (miscellaneous Chemicals), 40 (rubber), and 47 (pulp of wood).

In the long term, similar to the case of China, the impact of the Industrial Production Index (IIP) is positive for five goods, meaning that high industrial activity in India is positively associated with exports of goods under codes 29, 40, 44, 47, and 48. Interestingly rubber and paper affected negatively by RER volatility experience compensations through economic activity.

The bilateral exchange rate between the Rupiah and the Indian Rupee displays mixed impacts on exports. During the period of analysis, the Indonesian Rupiah depreciated 25% in real terms against the Indian Rupee. Goods under codes 3 (fish), 28 (inorganic chemicals), 38 (organic chemicals), and 48 (paper) have a positive impact, meaning that a depreciation of the Rupiah against the Indian Rupee tends to increase exports (as expected) as real prices fell. An interesting point is that none of these goods is significantly affected by volatility. Nevertheless, rubber (40) and pulp (47) have the opposite effects, meaning a negative impact due to the exchange rate, both negatively affected by the volatility of RER, displaying different behavior towards risk.

The diagnostic test for India is displayed in Table 8. The error correction term for pulp -0.792, implies that any deviation from the long-run equilibrium is compensated in 1.2 months (1/0.792). Most deviations are adjusted within a relatively short time, except for vegetable fats CPO (15), which take nearly four months to adjust. Considering that the largest export of Indonesia to India is CPO, a long period of adjustment may place pressure on the stability of exports. It is worth noting that India displays the largest exposure to volatility effects among all five partners. The remaining diagnostic tests suggest that most goods do not contain serial correlation, the models are stable and have no signs of misspecification.

4.3. Analysis of Japan

The results for Japan show that in the short term, the effect of exchange rate volatility only affects goods 26 (ores) and 47 (paper). Japan was the largest destination for Indonesian's ores. In the short term, exports of goods under codes 26 and 47 are highly responsive to exchange rate fluctuations in India and Japan. Meanwhile, in the long-term, exchange rate volatility only has an impact on exports of ores (code 26), indicating a strong relationship between short-term and long-term effects. RER volatility has large significant effects on exports of ores to Japan and India, on both short and long-term.

Furthermore, the effect of the index of industrial production in the long-run as a proxy for economic activity in Japan is significant only for exports of rubber (code 40) and paper (code 47). Overall, exports to Japan report a 35% growth during the period of study, a low level compared to other partners, likely as the Japanese economy slowed down. On the other hand, exports of ores (26) to Japan are not affected by the IIP, but they are influenced by the bilateral exchange rate between the Rupiah and the Yen. The RER coefficient shows a significant positive sign, which means that a depreciation of the Rupiah by 1 percent leads to an increase in exports of ores in 7.32 percent. Exports to Japan have low effects from RER volatility as Japanese importers may employ hedging to cover from risk, in line with other studies capturing Japan (Nishimura and Hirayama, 2013).

The error correction term for Japan indicates longer periods of adjustment versus the average time of partners. Deviations from the long-run equilibrium of commodity 26 (ores) are back in place in 2.7 months (1/0.371). Adjustments for exports due to the RER volatility of chemicals, rubber, wood, and paper take five to ten months to return to equilibrium (see Table 9).

4.4. Analysis of Korea

The impact of short-term exchange volatility on Indonesia's exports to South Korea only affects commodities coded 38, 40, 47. Chemicals (38) and Rubber (40) have a lagged positive effect of one period (t-1), while paper experienced the effects after three terms (t-3).

In the long-run, RER volatility has a significant negative impact on exports of goods 26, 40, and 47. The effect of RER volatility for rubber (40) and paper (47) changed from positive in the short-run to negative in the long-run. The change in the direction of the effects may be associated with the ability of traders to adjust volumes or to shift to alternative sources in the long run, while it shows the inability to do so in the short

Table 6. Long-run coefficient estimates of ARDL export model to China, India, Japan, South Korea, and the US.

Product code	Product label	LnIIP					LnRER					LnVol				
		China	India	Japan	S Korea	USA	China	India	Japan	S Korea	USA	China	India	Japan	S Korea	USA
3	Fish & crustaceans, molluscs	2.448**						13.065***	0.647**							
15	Animal vegetable fats oils	1.140**			3.961***		-1.778**		-8.000**	4.265***			-0.176*		0.563*	
26	Ores, slag and ash	4.049**					-11.989**		7.322**				-0.473*	-1.309**	-1.228*	
28	Inorganic chemicals	3.854**						3.876*	-1.509**		-5.229***					
29	Organic chemicals	1.521*	2.069***		1.708**		-5.802**		1.520**							
38	Misc chemical				1.821**			4.604***	-3.164**				0.122**			
39	Plastics and articles				2.244**		-1.469***		-0.573**			0.231***				
40	Rubber and articles		4.303***	3.345*	1.222**		-4.718***	-1.851*		-1.152**	-2.912***		-0.079**		-0.583**	-0.390**
44	Wood & articles; charcoal		5.582***		1.817***	3.492***	1.772**			3.012***	0.961***					-0.184***
47	Pulp of wood	2.464***	2.121***	2.136***	1.180***		-1.757*	-2.641***	0.962**				-0.055***		-0.786**	
48	Paper and paperboard		1.090***		0.817***			3.133***		0.808***					-0.246***	0.484***

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

run. In the case of rubber, with a 1 percent increase in RER volatility, it is expected to lead to a decline of 0.5 percent of exports in the long run. Furthermore, in the long run, exports of rubber to South Korea are negatively influenced by the bilateral exchange rate, meaning that a depreciation of the Rupia/Won exchange rate leads to a decrease in the export of rubber. On the contrary, oils (15), wood (44), and paper (48) are positively influenced by RER benefiting from a depreciated Rupiah, in line with theory.

On the other hand, eight out of the eleven product groups have significant positive effects due to IIP in South Korea. As an example, an increase in the IIP index in 1 percent increases the demand for rubber goods at 1.2 percent.

Table 10 displays the diagnostic case for the Korea model. All products have a significant coefficient in the error correction term, suggesting that deviations from long-run equilibrium levels are adequately corrected. Plastics, rubber, and wood present relatively more prolonged periods of adjustment (four to five months) versus the other goods.

4.5. United States

The results of exchange rate volatility on Indonesian exports to the United States in the short-term show that volatility only affects chemicals (38). The sign of the coefficient is positive indicating that a 1 percent increase in volatility will lead to an increase in exports of chemicals to the US by 0.27 percent. A possible reason why few goods are affected by short-term RER volatility arises as US importers may have access to risk hedging instruments as they enjoy a broader and deeper capital market (Bahmani-Oskooee et al., 2015).

The results of the impact of RER volatility, in the long run, indicate that goods under codes 40, 44, and 48 experience a long-run significant effect. Exports of wood and charcoal have a negative effect due to RER volatility. However, the same products experienced a larger positive effect due to IIP and the real bilateral exchange rate. In the long run, a 1 percent increase in US IIP leads to an increase of 3.5 percent in exports of plywood and charcoal to the US (Table 11). Plywood and charcoal are highly elastic to industrial activity as they are related to construction (plywood) and energy. For group 44 (wood), a 1 percent depreciation of the Rupiah will lead to an increase by 0.9 percent, in line with the exchange rate theory as it lowers the prices abroad, driving buyers to increase orders.

Out of 11 groups of products, only wood (44) is positively associated with IIP in the United States (similar to Japan). Contrary to China, India, and South Korea, cases where larger economic activity of Asian countries (proxied by IIP) is the primary driver of exports. Slow IIP of American, South Korean, and Japanese economies is reflected in lower export growth of Indonesia to those economies. From 2006 to 2018, exports to China of the 11 goods increased by more than 300%, exports to India 215%, versus growth of 35% to Japan, 121% to America, and 88% to Korea.

5. Discussion

The pressure in the trade balance in Indonesia seems to be affected by a decline in exports of the eleven goods in this study. In 2009, 2012, 2014, and 2015, exports of the top 11 goods to top five partners fell versus the previous year. In eight out of eleven sectors, exports to Japan ended at lower levels than those of the year 2006. Korea shows similar results, although with slightly better performance. By contrast, exports to China and India recorded growth versus 2006, while the US offered mixed results. More importantly, all goods experienced a period of large fluctuation in exports, with at least four years of negative growth. Products within rubber, wood, pulp, and paper recorded more than half of the years (6–8 years) of negative export growth to top partners (Figures 4 and 5). From 2016 to 2017, exports of top products recovered, although, in 2018, there was an overall slowdown.

Table 7. Diagnostic statistics for China.

Product code	Product label	F	ECM_{t-1}	Adj. R^2	LM	RESET	J-B test	CU	CUQ
3	Fish & crustaceans, molluscs	10.39*	-0.489*	0.732	0.205	0.037	55.23*	S	S
15	Animal vegetable fats oils	10.79*	-0.581*	0.250	0.08	0.502		S	S
26	Ores, slag and ash	7.909*	-0.482*	0.579	0.010	2.190	91.258*	S	U
28	Inorganic chemicals	4.032*	-0.438*	0.438	0.601	0.543	0.249	S	S
29	Organic chemicals	2.620	-0.288*	0.683	0.991	0.759	2.425	S	U
38	Miscellaneous chemical	2.515	-0.207*	0.795	0.898	0.000	3.281	S	S
39	Plastics and articles	4.414*	-0.323*	0.478	0.832	0.046	2.582	S	S
40	Rubber and articles	6.420*	-0.303*	0.869	0.474	3.581***	0.007	S	S
44	Wood & articles; charcoal	3.380	0.307*	0.813	0.606	4.100*	2.197	S	S
47	Pulp of wood	4.668*	-0.464*	0.677	0.148	0.122	1.118	S	S
48	Paper and paperboard	0.566	-0.063	0.808	0.001	0.185	0.238	S	S

Notes: * significance level at 10%, ** significance level at 5%, and *** significance level at 1%.

Table 8. Diagnostic statistics for India.

Product code	Product label	F	ECMt-1	Adj. R2	LM	RESET	J-B test	CU	CUQ
3	Fish & crustaceans, molluscs	25.0723**	-0.9690**	0.1958	0.18716	2.8675***	9.6486**	S	S
15	Animal vegetable fats oils	4.6827**	-0.2631**	0.4579	6.2269**	4.2277**	0.4605	S	U
26	Ores, slag and ash	34.0764**	-0.9629**	0.1	0.2267	0.1159	9.4906**	S	S
28	Inorganic chemicals	8.7537**	-0.6388**	0.1773	0.1291	5.0232**	5.1749***	U	S
29	Organic chemicals	2.9849	-0.3365**	0.5241	0.1476	0.2651	9.4867**	S	U
38	Miscellaneous chemical	7.802**	-0.4296**	0.5863	0.0392	0.0004	0.2801	S	S
39	Plastics and articles	17.42266**	-0.6769**	0.254	0.0291	0.1677	5.0487***	S	U
40	Rubber and articles	16.7704**	-0.4961**	0.823	1.0108	0.0481	26.1442**	S	U
44	Wood & articles; charcoal	10.0413**	-0.4104**	0.9022	0.2209	0.0326	158.202**	U	U
47	Pulp of wood	22.5607**	-0.7920**	0.3295	1.423	2.3848	18.9502	S	U
48	Paper and paperboard	4.1851	-0.3244**	0.8181	0.0063	0.9397	3.4255	S	S

Notes * significance level at 5%, ** significance level at 1%, and ** significance level at 10%.

Table 9. Diagnostic statistics for Japan.

Product code	Product label	F	ECMt-1	Adj. R2	LM	RESET	J-B test	CU	CUQ
3	Fish & crustaceans, molluscs	9.8585**	-0.4006**	0.4006	0.0076	4.8327**	31.512**	S	U
15	Animal vegetable fats oils	2.609	-0.2209**	0.6907	0.1608	0.3661	141.5073**	S	U
26	Ores, slag and ash	9.7122**	-0.371**	0.4319	0.2337	16.9453**	390.19**	S	U
28	Inorganic chemicals	16.3844**	-0.9967**	0.0481	1.2896	0.7072	37.1136**	S	U
29	Organic chemicals	4.7757**	-0.2777**	0.566	0.2652	2.1979	3.1779	U	U
38	Miscellaneous chemical	2.5564	-0.1656**	0.7156	0.0823	0.4459	3.558	S	S
39	Plastics and articles	4.9965**	-0.3596**	0.3895	0.0001	6.8985**	3.9868	S	S
40	Rubber and articles	2.0965	-0.1008**	0.798	0.4189	1.2608	2.6318	S	S
44	Wood & articles; charcoal	2.581	-0.1921**	0.5887	1.8505	0.0007	17.8105**	S	S
47	Pulp of wood	16.1843**	-0.9162**	0.127	0.7603	1.2143	9.1288**	S	S
48	Paper and paperboard	2.4376	-0.1832**	0.5974	0.4227	0.3597	13.7352**	S	S

Notes: * significance level at 10%, ** significance level at 5%, and *** significance level at 1%.

The volatility of the exchange rate in both the short and long-term has stronger effects on products 26 (ores), 38 (chemicals), 40 (rubber), 47 (pulp), and organic chemicals (29) in the four Asian countries. In the short-run, exports to India are the most sensitive to volatility, reporting significant effects (mostly negative) in four out of eleven goods. Mining products fell notably, e.g., ores -30% (2012) and -73% (2014). In an analysis of impacts of exchange rate volatility on exports to Japan and the USA, Fitrianti (2017) finds that the introduction of an export regulation of 65 minerals in Indonesia was detrimental for exports to Japan both in short and the long run.

Exports of vegetable oils experienced large negative RER effects in the long run, particularly for India (largest destination of CPO) and China, causing a substantial drop in exports. Inorganic chemicals, plastics, rubber, and paper also experience adverse effects in the long-run associated with real exchange rates (depreciation). The negative effect is opposite to the expected outcome, as a depreciation of the rupiah is expected to lead to more exports, not to less. On the other hand, the exchange rate (RER) affected consistently and positively the exports of Indonesia of fish (to India and Japan), paper (India and Korea), and wood-charcoal (India and Korea). The positive effect is in line with the exchange rate theory.

The long-run effects of volatility of RER in exports are greater to India and South Korea than to the other countries. For China and Japan, only one group of products experienced long-run effects due to volatility

Table 10. Diagnostic statistics for South Korea.

Product code	Product label	F	ECMt-1	Adj. R2	LM	RESET	J-B test	CU	CUQ
3	Fish & crustaceans, molluscs	15.028**	-0.616**	0.156	5.967**	6.560**	36.85**	U	S
15	Animal vegetable fats oils	21.184**	-0.720**	0.357	1.542	1.671	78.93**	S	U
26	Ores, slag and ash	14.548**	-1.000**	0.053	0.010	0.497	41.73**	S	S
28	Inorganic chemicals	9.217**	-0.642**	0.088	0.055	0.012	33.04**	S	S
29	Organic chemicals	3.931	-0.374**	0.404	0.283	0.359	0.368	S	S
38	Miscellaneous chemical	4.164	-0.348**	0.411	0.390	5.459**	140.9**	U	U
39	Plastics and articles	2.169	-0.118**	0.783	1.920	1.787	225.8**	S	U
40	Rubber and articles	6.204**	-0.254**	0.719	0.001	0.138	5.107	S	S
44	Wood & articles; charcoal	1.967	-0.219**	0.767	0.572	3.090**	48.57**	S	S
47	Pulp of wood	7.800**	-0.388**	0.348	0.636	0.196	2.883	S	S
48	Paper and paperboard	9.780**	-0.544**	0.360	0.278	1.983	22.45**	S	U

Notes: * significance level at 10%, ** significance level at 5%, and *** significance level at 1%.

Table 11. Diagnostic Statistics based for the United States.

Product code	Product label	F	ECMt-1	Adj. R2	LM	RESET	J-B test	CU	CUQ
3	Fish & crustaceans, molluscs	1.136	-0.082**	0.847	0.000	0.555	24.19**	U	S
15	Animal vegetable fats oils	2.038	-0.209**	0.449	2.041	3.520	347.0**	S	U
26	Ores, slag and ash	-							
28	Inorganic chemicals	8.625**	-0.865**	0.204	6.329**	1.687	41.70**	U	U
29	Organic chemicals	1.766	-0.086*	0.789	0.766	0.634	0.098	U	S
38	Miscellaneous chemical	3.490	-0.256**	0.451	1.370	0.171	11.15**	U	S
39	Plastics and articles	1.952	-0.114**	0.702	0.127	7.704**	9.495**	S	S
40	Rubber and articles	9.321**	-0.410	0.759	2.822	1.569	11.35**	S	U
44	Wood & articles; charcoal	6.564**	-0.656**	0.544	1.228	1.059	2.159	S	S
47	Pulp of wood	-							
48	Paper and paperboard	8.340**	-0.337**	0.516	0.406	1.452	0.294	S	S

Notes * significance level at 10%, ** significance level at 5%, and *** significance level at 1%.

(plastics), while the USA reported three groups (rubber, wood, and paper). Three products did not report any impact on exports due to RER volatility: fish, inorganic chemicals, and organic chemicals. Those goods are more differentiated and are less exposed to price volatility, possibly in line with the findings of Fitrianti (2017), where manufactured goods to the US were less exposed to volatility. Plastics (China), chemicals (India), and wood (US) only reported one country case with significant effects due to volatility. Ores reported the largest effects due to volatility with three countries: India, Japan, and Korea, perhaps explaining the high fluctuations in exports during the entire period of study. Additional pressures due to the rise/fall in prices of commodities under ores (Hegerty, 2016), slow demand in Asian markets, and restrictive trade policy from Indonesia (Fitrianti, 2017) may have contributed to the poor performance of ores.

5.1. Aggregate data analysis and robustness test: symmetric and asymmetric effects on exports

The effects at the commodity level are compared versus the effects at the aggregate level employing both symmetric and asymmetric approaches. The comparison helps to observe if effects follow a similar direction at the aggregate level and test whether the aggregate effects are asymmetric, following Bahmani-Oskooee and Aftab (2017). Besides, the exercise helps as a robustness test, highlighting the behavior of traders towards risk. The concept of asymmetric impacts considers that under the presence of volatility of exchange rate, traders could react positively or negatively to fluctuations, not necessarily following the same direction of effects and not always being a proportionate reaction to changes in the volatility of RER.

To model the asymmetric effects on Indonesian exports, the volatility of the exchange rate ($\Delta LnVol_t$) in Eq. (4) is decomposed into positive volatility ($\Delta LnVOL_t^{POS}$) and negative volatility ($\Delta LnVOL_t^{NEG}$), following the NARDL proposed in Shin et al. (2014). Increasing volatility (positive) is measured based on a partial sum of positive change denoted by $Ln\mathrm{VOL}_{\mathrm{pos}}$, while the decreasing volatility (negative) is based on the partial sum of negative change denoted by $Ln\mathrm{VOL}_{\mathrm{neg}}$.

$$\begin{aligned} &\mathrm{VOL_{POS}}: \sum_{j=1}^{t} \Delta LnVOL_j^{pos} = \sum_{j=1}^{t} \max\left(\Delta LnVOL_j,\ 0\right) \\ &\mathrm{VOL_{neg}}: \sum_{j=1}^{t} \Delta LnVOL_j^{neg} = \sum_{j=1}^{t} \min\left(\Delta LnVOL_j,\ 0\right) \end{aligned} \tag{5}$$

Volatility in Eq. (4) is replaced by the positive and negative partial sums (Eq. 5) and expressed on a non-linear ARDL approach as below:

$$\begin{aligned} \Delta LnEX_{i,t}^{IND} = {} & \beta_1 + \sum_{j=1}^{n1} \beta_2 \Delta LnEX_{t-j}^{IND} + \sum_{j=0}^{n2} \beta_3 \Delta LnIIP_{t-j}^{*} + \sum_{j=0}^{n3} \beta_4 \Delta LnRER_{t-j} \\ & + \sum_{j=0}^{n4} \beta_5 \Delta LnVOLpos_{t-j} + \sum_{j=0}^{n5} \beta_6 \Delta LnVOLneg_{t-j} + \delta_1 LnEX_{t-1}^{IND} \\ & + \delta_2 LnIIP_{t-1}^{*} + \delta_3 LnRER_{t-1} + \delta_4 LnVOLpos_{t-1} \\ & + \delta_5 LnVOLneg_{t-1} + \varepsilon_t \end{aligned} \tag{6}$$

Following Sharma and Pal, 2018 the presence of long-run cointegration in Eq. (6) is tested $H_0: \ \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$ and compare to the upper and lower bound values provided in Shin et al. (2014). The Wald test helps to test for the presence of long-run asymmetric effects against: $\delta_4 = \delta_5 = 0$.

Table 12 illustrates the long-run estimates for export demand function for real exchange rate volatility employing a symmetric

Table 12. Long-run estimates for export demand function for real exchange rate volatility ARDL.

Countries	IIP	RER	VOL
China	1.150361***	-2.752335***	0.17781*
(2,1,2,1)	(0.011)	(0.0021)	(0.0931)
India	1.416793***	-1,189774	-0.092374***
(2,0,1,1)	(0.0003)	(0.1405)	(0.0107)
Japan	0,527447	1.253681***	-0.235236**
(3,4,4,2)	(0.2916)	(0.0037)	(0.017)
S. Korea	0.415624**	-0.54983***	-0.415492***
(2,0,0,4)	(0.0315)	(0.0101)	(0.0000)
US	1,997806	-1.393515*	-0.398597*
(3,0,0,1)	(-0.1787)	(0.0941)	(0.0924)

Notes: p-value in parentheses. * significance level at 10%, ** significance level at 5%, and *** significance level at 1%.

approach, and Table 13 illustrates the long-run estimates using asymmetric approach.

5.2. Symmetric effect of exchange rate volatility

The long-run estimates for aggregate top exports suggest that volatility in exchange rates harms exports from Indonesia to India, Japan, South Korea, and the US, while it supports exports to China. The negative long-run RER volatility effects suggest the need for policymakers to look closely at volatility as it can hurt exports, considering instruments (e.g., hedging) to manage uncertainty. At the product level, several goods exported to India, Japan, and South Korea also report negative effects. RER volatility has a consistent negative effect in exports of ores, rubber, and pulp to at least two countries (the largest destination markets). Exports of ores to India, Japan, and Korea fell considerably during the period of study, likely affected by volatility.

Furthermore, aggregate exports are positively associated with industrial production for China, India, and Korea, while Japan and the US are not significant. An improvement in the IIP may be the largest driver of exports from Indonesia, signaling that prospects of weak economic activity in foreign markets can suggest low demand for Indonesia exports. The results are in line with those at the commodity level in which Japan and the US have only a few goods significantly affected by IIP. On the other hand, exports are negatively related to the real bilateral exchange rates to China, South Korea, and the US, suggesting that a weak Rupiah has not supported exports, although theoretically, the contrary is expected. Only exports to Japan are positively associated with a depreciation of the Rupiah. At the product level, most goods reporting significant effects exported to China, and the US displayed negative effects (same sign as in the aggregate level). Japan, South Korea, and India offered mixed results. At the product level, the exchange rate has a positive effect on exports in fish, wood, and paper, suggesting that a weakening of the Rupiah can help to increase exports within those groups. Nevertheless, there is a negative impact in exports of plastics and mixed results in all other goods, suggesting that the effect of RER volatility is product specific.

In previous studies, the depreciation of the Rupiah displays a negative impact on exports (Pino et al., 2016). A possible reason why a depreciated Rupiah does not lead to higher exports is related to changes in prices and slow global demand, potentially linked to the exchange rate of Indonesia (Pino et al., 2016). The period of analysis covers a period where commodities as crude palm oil (CPO) and ores experience sharp fluctuations, and global demand slowed down (Hegerty, 2016).

5.3. Asymmetric effect of exchange rate volatility

Employing the demand function (Eq. 6), this section tests whether there are signs of asymmetric effects of RER volatility on exports from Indonesia. To illustrate, the cases of India and South Korea are presented as they show the largest number of goods with significant effects of symmetric volatility in the long run (Table 6). The NARLD results are presented in Table 13.

As for exports to India, the asymmetric effects of both positive and negative volatility harm Indonesia's exports to India. The symmetric results indicate that exports to India have a significant negative effect in both the long and the short run, in line with asymmetric results. Nevertheless, the asymmetric effects are higher under the presence of negative volatility, while the positive volatility has a slightly lower impact on exports. This condition is similar to those at the product level where four goods (code 15, 26, 40, 47) report negative impact on RER volatility on Indonesia's exports to India in the long term (Table 6). The asymmetric effects imply that under the presence of either positive or negative RER volatility, exports to India will decline as traders are risk-averse, adjusting the demand for goods amid uncertainty in the currency level.

For South Korea, RER volatility in the symmetric model has a negative significant effect on the long run and a positive effect in the short run. Nevertheless, when the asymmetric analysis is employed, the effects in both the short and the long run become significantly negative for both positive and negative RER volatility. The coefficient for positive volatility is larger than the negative one. At the product level, there are four goods (codes 26, 40, 47, 48) that experience a negative impact due to RER volatility in the long term, somehow in line with asymmetric results. The results highlight that exchange rate volatility has an asymmetric impact on exports from Indonesia to South Korea, with cross-border trade being more vulnerable to positive volatility.

As for the United States, asymmetric effects due to volatility are negatively significant for both positive and negative RER volatility. The striking point is that asymmetric effects in exports from Indonesia to India, South Korea and the US exist, signaling adverse effects in all. The implication is that stability in the Indonesia Rupiah is crucial for exports as volatility below or beyond long term level tends to depress exports.

Finally, we test whether using nominal instead of real exchange rate can affect the signs on the coefficients when employing asymmetric analysis. However, both real and nominal exchange rate volatility offers the same signs in the short run and long-run effects (results available upon request).

Table 13. Long-Run Coefficient Estimates of Nonlinear NARDL approach.

Country	Long-Run Coefficient Estimates				
	Constant	LnIIP	LnRER	LnVOLpos	LnVOLneg
China	26.352** (4.091)	2.654** (0.756)	-3.333** (0.661)	0.055 (0.083)	0.071 (0.081)
India	9.972 (6.056)	2.285** (0.696)	-1.324 (0.853)	-0.0496* (0.0246)	-0.0493* (0.0244)
Japan	-6.785 (13.987)	2.258 (1.673)	2.381 (1.559)	-0.276 (0.208)	-0.277 (0.206)
South Korea	2.900 (4.206)	2.732** (0.801)	-0.611 (0.530)	-0.320* (0.144)	-0.280* (0.143)
United States	15.204** (1.508)	0.788** (0.307)	-0.555** (0.183)	-0.154** (0.062)	-0.171** (0.062)

Note. standard error in parentheses, * significance level at 10%, ** significance level at 5%, and *** significance level at 1%.

6. Conclusion

This study analyzes the impact of exchange rate volatility on Indonesia's main export products to the five largest trade partner countries, namely China, India, Japan, South Korea and the United States, covering the period of 2006–2018. This study uses the GARCH model to estimate the value of exchange rate volatility. Meanwhile, the ARDL approach is employed to measure the effect of exchange rate volatility on exports to main destination countries, both in short and the long-term. Besides, the study estimates the effects of exchange rate volatility at the aggregate level, comparing linear ARDL and nonlinear autoregressive distributed lag NARDL models.

At the aggregate level, exports are positively associated with industrial production for China, India, and Korea, while Japan and the US are not significant. Exports are negatively related to the Real Bilateral Exchange rate in exports to China, South Korea, and the US, suggesting that a weak Rupiah has not supported exports, contrary to what is expected by theory. Only exports to Japan are positively associated with a depreciation of the Rupiah. The long-run estimates for overall top exports suggest that volatility in exchange rates harms exports to India, Japan, South Korea, and the US, but supports exports to China.

At the commodity level, the results of the exchange rate volatility are mixed. Exchange rate volatility has a significant effect on exports of commodities under codes 26 (ores), 38 (chemicals), 40 (rubber), and 47 (pulp paper) to India, Japan, South Korea, and the United States, either in the short or long-run. In the meantime, the exchange rate volatility in China only affected plastics goods (code 39). In India, exchange rate volatility affects the largest export commodity groups under codes 26 (ores), 38 (chemicals), 40 (rubber), and 47 (pulp of wood) in both the short and long-term and vegetable oils (15) on the short run. Meanwhile, exports of ores to Japan face negative short and long-term exchange rate volatility. Exchange rate volatility has an influence on commodity exports of codes 40 (rubber) and 47 (pulp of wood) both in the short and long term to South Korea, although in the opposite direction. Exports to the United States face volatility effects on chemical goods (code 38), rubber (40), wood-charcoal (44), and paper (48). Nevertheless, none of the largest export groups to the countries included face effects due to volatility for China.

In the model, the Index of Industrial Production (IIP) has a strong long-term effect in exports in several products for China, India, Japan, and South Korea, while not for the United States (US), suggesting a drive-in export due to Asian demand for goods. Exports of oils (HS 15) experienced large adverse effects in the long-run due to RER, particularly for India (largest destination of CPO) and China, causing a significant drop in exports. Inorganic chemicals, plastics, rubber, and paper also experience negative effects in the long-run due to real exchange rates, the opposite to the expected one. The exchange rate effects are consistent (positive) in exports of Indonesia of fish (to India and Japan), paper (India and South Korea), and wood-charcoal (India and South Korea).

It is worth noting that top exports are all natural-resource based and for instance, may be exposed to global prices. The negative balance of trade faced by Indonesia is often associated with the drop-in exports in the eleven goods included in this paper, some possibly affected by volatility and real exchange rate. Trade with the top fastest export markets, India and China, is more sensitive to volatility and exchange rates (India) and negatively related to the real exchange rate (China).

Finally, the NARDL approach indicates that exchange rate volatility has a negative asymmetric effect on exports from Indonesia to India, South Korea, and the United States. The results suggest that monetary policy supporting a stable Rupiah is essential in order to maintain exports of top Indonesian goods to top partners, while uncertainty tends the depress demand for exports.

Declarations

Author contribution statement

Lilik Sugiharti: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Miguel Angel Esquivias: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed Reagents, materials, analysis tools or data; Wrote the paper.

Bekti Setyorani: Performed the experiments; Analyzed and interpreted the data; Contributed Reagents, materials, analysis tools or data.

Funding statement

This research receive grant from funding under the Penelitian Terapan Unggulan Perguruan Tinggi Kemenristek Dikti (PTUPT), Ministry of Research and Technology of the Republic of Indonesia.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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