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The Effect of GDP and Exchange Rate on Import of Photovoltaic Cells in Indonesia

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ABSTRACT

The use of renewable energy has increasingly become a great concern for many countries due to environmental issues. One of the widely used sources of renewable energy nowadays is solar energy. The conversion of solar energy into electrical occurs through three main types of technology, namely photovoltaic (PV), solar thermal, and concentrating solar power (CSP). PV is the fastest-growing and widely used technology. In Indonesia, the utilization of PV technology continues to rise especially in the use of rooftop PV. Indonesia currently imports PV components such as solar cells from abroad. Most of the PV cells are imported from high-income countries. This study analyzes the effect of differences in Gross Domestic Product (GDP) per capita between Indonesia and trading partner countries. It also analyzes the effect of the real exchange rate on imports of photovoltaic cells from 13 countries in 2004-2019. Meanwhile, analysis of the impulse response and panel variance decomposition obtained from the Panel Vector Error Correction Model (PVECM) was used to ascertain the import response to the independent shock variable. Therefore, it was concluded that the differences in GDP per capita of Indonesia together with trading partner countries significantly affect the importation of photovoltaic components in the long run. In contrast, Rupiah's real exchange rate against partner countries' currency has a significant effect on imports of photovoltaic cells in the short and long term.

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1. Introduction

The use of renewable energy has increasingly become a great concern for many countries due to climatic changes, reduced fossil fuels production, and greenhouse gas emissions (Algieri et al., 2011; Lee et al., 2016; Ogura, 2020; Spertino et al., 2013). One of the widely used sources of renewable energy nowadays is solar energy (Liu et al., 2019; Nguyen and Kinnucan, 2019; Zhao et al., 2017). This form of energy has unlimited characteristics, hence it is regarded as an alternative to minimize greenhouse gas emissions (Algieri et al., 2011).

The conversion of solar energy into electrical occurs through three main types of technology, namely photovoltaic (PV), solar thermal, and Concentrating Solar Power (CSP). PV is the fastest growing and widely used technology (Algieri et al., 2011; IEA, 2019; Lee et al., 2016). Meanwhile, PV has become a significant energy supplier due to the sharp decline in solar PV prices since 2010. Over the past ten years, global installed solar PV capacity has increased by 47% per annum (IEA, 2019). In addition, trade in the sector has also increased due to the low tariff rates imposed on the industry (Algieri et al., 2011).

According to the Energy and Mineral Resources Ministry of Indonesia (2019), available solar energy potential is significant, amounting to 207.8 GW meanwhile, the installed solar PV capacity was only 0.135 GWp up to 2019. Although, the utilization of this technology is not optimal, public interest continues to rise especially in the use of rooftop PV or power plants, which is now commonly used in households, businesses, government, and industries in electricity market (Kementerian ESDM, 2019).

Residential Rooftop PV installation increased continuously up to 2019 while a quite sharp increase, which occurred in April 2019, resulted in a rise from 681 consumers in March 2019 to 934. As of August 2019, the numbers of users reached 1,329 (Kementerian ESDM, 2019). This increasing trend is due to the decreasing price of solar module (IRENA, 2017). Moreover, the government also declared the National Movement for One Million Solar Roofs to achieve a renewable energy target in the primary energy mix of 23% by 2025, in which 6.4 GW comes from PV power plants (Kementerian ESDM, 2019).

Indonesia currently import PV components such as solar cells (PV cells) from abroad (Kementerian ESDM, 2019). This is because industries in the country carry out production at the downstream stage, producing Balance of Systems (BOS) components such as lamp, battery, control circuit, system integration, distribution, and installation (Kumara, 2010). Meanwhile, domestic companies that have entered the solar cell industry only carry out production at the last stage, which include cell printing with a capacity of 50 MWp (Kementerian ESDM, 2019).

Most of the PV cells import countries are have high income, such as Japan, Singapore, and the United States. These countries have quite large differences in income per capita compared to Indonesia. This difference is one factor that affects trade patterns of commodity (Athukorala and Yamashita, 2006; Mcpherson et al., 2001; Narayan and Nguyen, 2016; Rasoulinezhad and Wei, 2017). Furthermore, studies on the effect of differences in per capita income on trade raised debate on two different hypothetical views namely; the Heckscher-Ohlin (HO) model and Linder hypothesis. The HO model states that trade patterns are determined by differences in relative endowment factors between countries. Hence, large differences in per capita income usually increase trade (Kahouli, 2016; Narayan and Nguyen, 2016; Ogura, 2020; Rasoulinezhad and Wei, 2017). Meanwhile, Linder's hypothesis states that similar level of per capita income between countries tends to increase trade due to similarity in tastes (Akram and Mahmood, 2012; Athukorala and Yamashita, 2006; Mcpherson et al., 2001; Rauh, 2010).

Another factor that affects imports is exchange rate. Studies related to the impact of exchange rate on imports resulted in mixed findings. Several studies have found that increase in exchange rate often reduce imports (Huynh and Hoang, 2019; Rauh, 2010; Stender, 2018). However, this increase was discovered along with currency depreciation in other studies (Meniago and Eita, 2017; Sweidan, 2013). It was also indicated that exchange rate has no significant effect on imports (Wang, 2018; Zheng et al., 2017).

Many empirical studies have been conducted on the determinants of bilateral trade (Athukorala and Yamashita, 2006; Kahouli, 2016; Ogura, 2020; Rasoulinezhad and Wei, 2017; Rauh, 2010; Zheng et al., 2017), and most used static panel method. In addition, economic variables are usually dynamic; hence, the value is determined relatively to both present and past variables. This study aims to fill the gap through the application of panel vector error correction model to analyze factors influencing the import of photovoltaic cells. Studies have been conducted on the factors that influence photovoltaic cells trade (Groba, 2014; Kuik et al., 2019; Ogura, 2020). Groba (2014) examined the influence of renewable energy policies and trade barriers on exports of solar energy technology components (SETCs) from 21 OECD countries to 118 importing countries between 1999 and 2007 (Groba, 2014). Kuik et al. (2019) examined the factors influencing wind power generation exports in 49 developed and developing countries and solar PV exports in 40 developed and developing countries (Kuik et al., 2019). Ogura (2020) examines the impact of interactions between innovative capacity and feed-in tariff (FIT) policies and renewable portfolio standards

(RPS), on exports of photovoltaic (PV) and wind energy components in OECD and BRICS countries (Ogura, 2020). The limited number of studies regarding the influence of GDP and exchange rates on imports of rooftop PV products, especially in Indonesia, becomes the main reason why this study was conducted.

Therefore, this study analyzes the effect of differences in GDP per capita between Indonesia and trading partner countries. It also analyzed the effect of real exchange rate on PV cells imports from 13 countries. Analysis of the impulse response function and panel variance decomposition obtained from the Panel Vector Error Correction Model (PVECM) method was applied to examine the import response to the independent variable.

2. Literature Review

Studies have analyzed the relationship between differences in GDP per capita and bilateral trade (Kahouli, 2016; Kurihara, 2021; Mcpherson et al., 2001; Narayan and Nguyen, 2016; Ogura, 2020; Rasoulinezhad and Wei, 2017; Rauh, 2010; Singh et al., 2021; Toplu Yilmaz, 2022). They support Linder's hypothesis, which states that differences between countries have a negative effect on trade (Kurihara, 2021; Mcpherson et al., 2001; Narayan and Nguyen, 2016; Rauh, 2010; Toplu Yilmaz, 2022). Meanwhile, other studies support Heckscher-Ohlin theory, which states that the difference in GDP per capita has a positive effect on trade (Kahouli, 2016; Khan and Hossain, 2012; Narayan and Ngoc, 2019; Narayan and Nguyen, 2016; Ogura, 2020; Rasoulinezhad and Wei, 2017).

A study conducted by Kurihara (2021) analyzed whether Linder's hypothesis holds or not to trade that occurs in Japan. The research results show that the Linder effect as measured by the difference in per capita income between Japan and partner countries reduces trade volume. Thus, export patterns are determined by the structure of internal demand (Kurihara, 2021). Research conducted by Toplu Yilmaz (2022) also shows that differences in per capita income have a negative effect on intra-industry trade intensity. These results suggest that smaller per capita income differences will increase intra-industry trade (Toplu Yilmaz, 2022).

Research conducted by Singh et al. (2021) shows that the difference in GDP per capita between India and ASEAN countries has a significant positive effect on trade between India and ASEAN countries. These results indicate that countries that have different economic structures will trade more (Singh et al., 2021). Rasoulinezhad and Wei (2017) using the Fixed Effect (FE), Random Effect (RE), and Fully Modified Ordinary Least Square (FMOLS) methods showed the trade pattern between China and OPEC member countries was consistent with Heckscher-Ohlin (HO) theory. Therefore, the trade between these countries increases when GDP per capita gets bigger (Rasoulinezhad and Wei, 2017). Narayan and Nguyen (2016) also stated that the difference in Vietnam's per capita income with trading partner countries has a positive effect on trade when the partners are from high-income countries, while a negative effect is observed when the partners are low-income (Narayan and Nguyen, 2016).

Khan and Hossain (2012) studied the long and short-term relationship between bilateral trade and trade determinants in Bangladesh with 50 major trading partners using the Unrestricted Error Correction Model (UECM) method. It was shown that the GDP ratio of Bangladesh and its trading partners, as well as the real exchange rate negatively affected trade in the long run. In addition, the differences in GNI per capita between countries had a positive effect on trade, indicating that the Heckscher-Ohlin effect is more dominant compared to Linder effect (Khan and Hossain, 2012; Narayan and Ngoc, 2019). Narayan and Ngoc (2019) showed that the differences in GDP per capita, positively impacts trade in short term, while it negatively affects trade in the long run (Narayan and Ngoc, 2019).

The exchange rate is also an essential factor that affects trade (Huynh and Hoang, 2019; Stender, 2018; Zheng et al., 2017). Using the gravity model approach, Stender (2018) found that exchange rate has a negative effect on imports (Stender, 2018). This is consistent with Huynh and Hoang (2019), which stated that Vietnamese Dong depreciation, is capable of reducing imports (Huynh and Hoang, 2019).

Wang (2018) used the Autoregressive Distributed Lag (ARDL) method to analyze the effects of US dollar appreciation and Chinese Yuan depreciation on bilateral trade between both countries. The results showed that dollar appreciation against Yuan reduced export value but had no effect on imports in the long run (Wang, 2018). These results are in line with Zheng et al. (2017), which stated that the exchange rate has a positive effect on exports but has no effect on imports of Chinese non-ferrous metals (Zheng et al., 2017).

The study conducted by Iqbal et al. (2023) shows that the real exchange rate between the Indian rupee and the US dollar has a significant negative effect on imports of 6 industrial commodities and a significant positive effect on imports of 5 industrial commodities (Iqbal et al., 2023). The negative impact of the exchange rate shows that the appreciation of the Indian rupee against the dollar will reduce imports of these industrial commodities from the US. Meanwhile, the positive impact of the exchange rate shows that the appreciation of the Indian rupee will increase imports of these industrial commodities from the US (Iqbal et al., 2023).

Other studies also confirmed the positive effect of exchange rates on imports (Meniago and Eita, 2017; Sweidan, 2013). Furthermore, Sweidan (2013), using a bound testing approach reported that effective exchange rate has no long-term effect on imports, however, there is a positive effect in the short term (Sweidan, 2013). This was supported by Meniago and Eita (2017), which stated that the exchange rate depreciation increased imports in Sub-Saharan African countries (Meniago and Eita, 2017).

The Panel Vector Autoregressive (PVAR) and Panel Vector Error Correction Model (PVECM) methods have been applied in several bilateral trade studies (Chin et al., 2020; Srivastava, 2015). Chin et al. (2020) analyzed the dynamic relationship between Vertical Intra-Industry trading (VIIT) and the size of Malaysian economy together with the five major trading partners using the PVAR model. The results showed a two-way positive causality between Malaysian GDP and VIIT. It was also reported that the absolute difference in GDP per capita positively affected VIIT without any inverse causality between the two variables (Chin et al., 2020). These results are supported by Martín-Montaner and Ríos (2002) and Yong et al. (2016), which confirmed that the differences in GDP per capita significantly affect VIIT (Martín-Montaner and Ríos, 2002; Yong et al., 2016). In contrast, Srivastava (2015), using the VECM panel method, indicated that difference in GDP per capita has no significant effect on VIIT (Srivastava, 2015).

This study aims to contribute to filling the research gap related to PV cell trade in Indonesia, considering that study regarding the influence of GDP and exchange rates on imports of rooftop PV products, especially in Indonesia, is still limited. Therefore, the following hypothesis were proposed:

> *H1*. Variable differences in GDP per capita and real exchange rate significantly affect imports of Indonesian PV cells in the *short term*.
>
> *H2*. Variable differences in GDP per capita and real exchange rate significantly affect imports of Indonesian PV cells in the *long run.*

3. Data and Research Methods

This study used a quantitative approach with Panel Vector Error Correction Model (PVECM) to examine the impact of differences in GDP per capita and real bilateral exchange rates on PV cells imports between 2004 and 2019. Panel data were used due to their several advantages over other types. This data is capable of producing more information, has a moderate degree of freedom and reduce multicollinearity problems (Gujarati & Porter, 2009). Meanwhile, the data used this study are secondary data obtained from various sources, such as World Bank, United Nations Commodity

Trade (UN Comtrade), and United Nations Conference on Trade and Development (UNCTAD). The variables are indicated as follows.

Table 1. Variable, Definition, Source

Variable	Definition	Source
Import (M)	The entry of goods from abroad into a country. Import data in this study used the 6-digit HS classification (HS 854140).	United Nations Commodity Trade (UN Comtrade)
The difference in GDP per capita (DGDPC)	The absolute difference between Indonesia real GDP per capita and the respective trading partner countries	World Bank
Real Exchange Rate (RER)	$\frac{Nominal\ Exchange\ Rate \times CPI_{Negara\ Asal}}{CPI_{Indonesia}}$ CPI: Consumer Price Index	United Nations Conference on Trade and Development (UNCTAD)

The next step is to determine the empirical model as follows:

$$\begin{bmatrix} \Delta lnM_{ijt} \\ \Delta lnDGDPC_{ijt} \\ \Delta lnRER_{ijt} \end{bmatrix} = \begin{bmatrix} \propto_{1\,ij} \\ \propto_{2\,ij} \\ \propto_{3\,ij} \end{bmatrix} + \sum_{k=1}^{q} \begin{bmatrix} \beta_{11\,ijk} & \beta_{12\,ijk} & \beta_{13\,ijk} \\ \beta_{21\,ijk} & \beta_{22\,ijk} & \beta_{23\,ijk} \\ \beta_{31\,ijk} & \beta_{32\,ijk} & \beta_{33\,ijk} \end{bmatrix} x \begin{bmatrix} \Delta lnM_{ijt-k} \\ \Delta lnDGDPC_{ijt-k} \\ \Delta lnRER_{ijt-k} \end{bmatrix} + \begin{bmatrix} \gamma_{1\,ij} & ECT_{ijt-1} \\ \gamma_{2\,ij} & ECT_{ijt-1} \\ \gamma_{3\,ij} & ECT_{ijt-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1\,ijt} \\ \varepsilon_{2\,ijt} \\ \varepsilon_{3\,ijt} \end{bmatrix} \quad (1)$$

where Δ denote first difference, LnM_{ij} as natural logarithm of Indonesian PV cells import from the country of origin (i), $LnDGDPC_{ij}$ as natural logarithm of difference in income per capita, $LnRER_{ij}$ denotes natural logarithm of Indonesia's real exchange rate against trading partner country i (IDR/trading partner currency), α is the constant, β is the coefficient, k is the amount of lag, γ is the ECT coefficient, ECT_{ijt-1} is the error correction term, and ε is the error term.

The steps taken in the PVECM estimations were similar with that of VECM for the time series data. Moreover, the first step was to test the panel data stationarity for all variables. The co-integration test and VECM estimations were susceptible to the lag length, hence, lag length criteria test is needed to obtain optimal length (Emerson, 2007; Hatemi-J, 2008; Kose and Ucar, 2006; Lütkepohl, 2006). Thereafter, the test was carried out to determine co-integration level between the model variables. This is followed by other several tests including Granger causality test, PVECM estimation, impulse response function, and variance decomposition.

4. Results

Two hundred thirty (230) observations were obtained for this study. Statistical descriptions of each variable are provided in Table 2. This consist of the mean, minimum, maximum, and standard deviation values.

Table 2. Variable Descriptive Statistics

Variable	Obs.	Mean	Min.	Max.	Std. Dev.
LnM	208	13.24464	5.308268	18.20344	2.853539
LnGDPC	208	9.898807	3.844508	10.91124	1.257517
LnRER	208	7.738109	2.055860	10.03085	2.209216

Source: Research finding.

The Fisher-ADF stationarity test was carried out at the first difference level. Meanwhile, based on the results in table 3, all variables were neither stationary nor contain unit roots as the chi-square, and z-statistic values were greater than alpha (α). Therefore, the stationarity test was continued at the first difference level while results showed positive stationarity for all variables. This is because the chi-square and z-statistic values were smaller than α (1%).

Table 3. Fisher-ADF Stationary Test

Variable	Level		First Difference		Stationary Level
	ADF-Fisher Chi-sq	ADF-Choi Z-stat	ADF-Fisher Chi-sq	ADF-Choi Z-stat	
LnM	1.0000	1.0000	0.0000***	0.0000***	I(1)
LnDGDPC	1.0000	1.0000	0.0000***	0.0000***	I(1)
LnRER	0.3864	0.3057	0.0000***	0.0000***	I(1)

Source: Research finding.

Note: *** significant at α = 0.01

The optimal lag selection aims to obtain the best amount for the co-integration, Granger causality test as well as PVECM estimation. Meanwhile, selection was performed by using the available information criteria on the VAR system. The lag with the most asterisks was then selected. Table 4 shows that the best lag is lag 3; hence, it was used in later stages.

Table 4. Optimal Lag Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1007.45	NA	31.32474	11.95804	12.01360	11.98059

1	178.9695	2316.685	2.78e-05	-1.975970	-1.753728	-1.885780
2	254.8336	145.4437	1.26e-05	-2.767262	-2.378339	-2.609430
3	293.2250	72.23944*	8.91e-06*	-3.11508*	-2.55948*	-2.88961*

Source: Research finding.

The co-integration test was carried out to identify any occurring long-term relationships between variables. The test type used in this study was Kao, meanwhile, the decision-making criteria in this test were based on ADF probability value. Hence, the existence of a long-term relationship was indicated when the value is smaller than α (5%). The results in table 5 show co-integration between variables as the probability value was smaller than 0.01.

Table 5. Kao's Cointegration Test

	t-statistic	Prob.
ADF	-3.467364	0.0003

Source: Research finding.

The PVECM estimation were used to observe the impact of differences in GDP per capita and real exchange rates on PV imports. This test was performed by comparing the t-statistic and t-table values at 1%, 5%, and 10% significance levels. In addition, the null hypothesis was rejected when the t-statistic value was greater than the t-table value. The PVECM estimation results are shown in Table 7.

In the short term, only the import variable (lag 1) and real exchange rate (lag 3) significantly affected PV cells import at 5% and 10% significance levels. In addition, the variable at lag 1 negatively affected imports, and the real exchange rate at lag 3 has a positive impact. The Error Correction Term (ECT) coefficient was negatively significant at 1% level. This indicates an adjustment process between the short and long term amounting to 27.4%. Furthermore, the long-term PVECM estimation results showed that the differences in GDP per capita and real exchange rate significantly affected import at the 5% and 1% significance levels. The differences in GDP per capita has a negative effect on Indonesian PV cells import while real exchange rate has positive effect.

Table 6. Long Term and Short Term PVECM Estimation Results

Long-term			
Variable	**Coefficient**	**Standard Error**	**t-Statistics**
LnM(-1)	1.000000		
LnDGDPC(-1)	-0.644362	0.29509	-2.18363**
LnRER(-)	0.591782	0.12780	4.63056***
C	-11.98755		

Short-term			
Variable	**Coefficient**	**Standard Error**	**t-Statistics**
CointEq1	-0.274198	0.05109	-5.36707***
D(LnM(-1))	-0.177113	0.07880	-2.24765
D(lnM(-2))	-0.004914	0.07688	-0.06391
D(LnM(-3))	0.112905	0.07368	1.53236
D(LnDGDPC(-1))	2.439643	3.44263	0.70866
D(LNDGDPC(-2))	4.517931	3.07096	1.47118
D(LnDGDPC(-3))	-1.533020	1.88243	-0.81439
D(LnRER(-1))	-0.259911	1.57917	-0.16459
D(LnRER(-2))	-1.574381	1.42855	-1.10208
D(LnRER(-3))	2.620689	1.42215	1.84276*
C	0.155262	0.12756	1.21719

Source: Research finding.

Note*:* *** significant at α 1%; ** significant at α 5%; * significant at α 10%

Critical score for Student's t 1% = 2.576; 5% = 1.960; 10% = 1.645.

Interpretation of the PVECM estimated coefficients is quite difficult. Thus, IRF analysis aims to see the impact of a shock to the standard deviation of one variable on other variables. Figure 1 shows impulse response to variable shock, differences in GDP per capita, and real exchange rate. The import variable always responds positively to shock and differences in GDP per capita with observable positive trends, which began in period 2. In period 4, the response decreased but remained on a positive trend. Furthermore, response increased again and became stabilized in period 5. Imports demonstrated a negative response to real exchange rate shocks from period 2 to period 3. Meanwhile, in periods 4 to 6, imports indicated a positive response, however, the response moved steadily and began to decline in period 7.

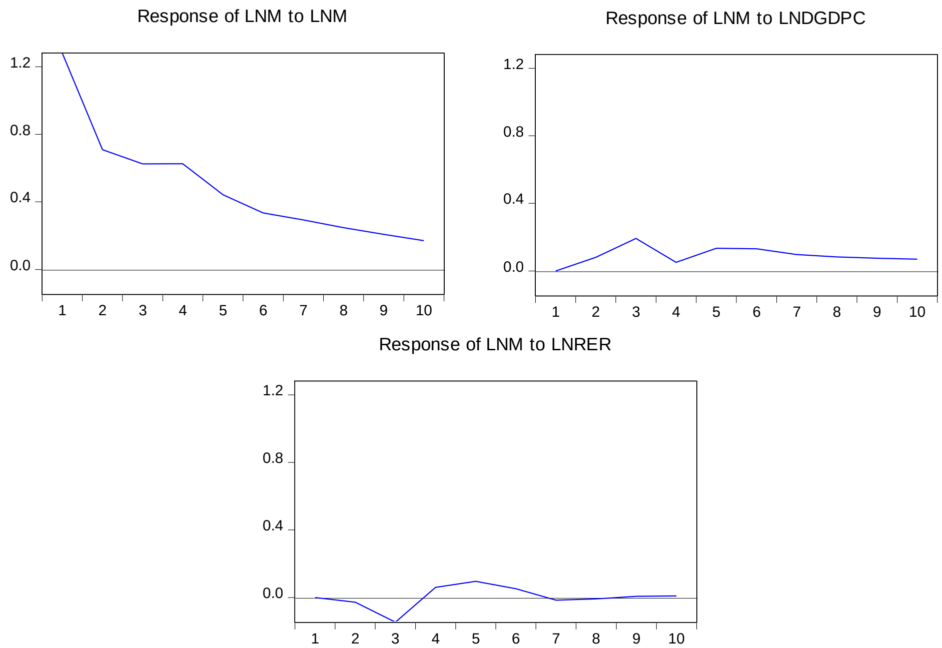

Figure 1. Impulse Response Function Analysis
Source: Research finding.

Variance decomposition is used to measure the magnitude of the shock contribution of each variable in influencing other variables. Table 8 shows the variance decomposition results of all import variables. Accordingly, the variable with the most significant effect was import, with 100% in period 1. The contributions of this variable continued to decline in subsequent periods but still dominated. Furthermore, the next variable that also influenced imports is differences in GDP per capita with considerable contributions of 0.03% beginning in period 2 and further increased by 1.67% in period 3. In period 4, the contribution decreased slightly and increased again in period 5 to subsequent period. However, real exchange rate contributed the least effect. The value was 0.03% in period 2 and increased to 1.11% in period 6. It gradually began to decline in period 7 and following periods.

Table 6. Import Variance Decomposition

Period	SE	LNM	LNDGDPC	LNRER
1	1.280388	100.0000	0.000000	0.000000
2	1.466250	99.65851	0.305071	0.036422
3	1.612224	97.47628	1.678843	0.844880
4	1.731319	97.60406	1.543927	0.852010
5	1.794417	96.92696	1.993522	1.079521
6	1.830798	96.45454	2.428734	1.116728

7	1.856752	96.27003	2.637347	1.092628
8	1.875024	96.14593	2.780626	1.073448
9	1.888003	96.03962	2.900229	1.060152
10	1.896948	96.93966	3.007729	1.052616
Cholesky Ordering: LNM LNDGDPC LNRER				

Source: Research finding.

5. Conclusion

Based on the PVECM estimation, differences in GDP per capita have no significant effect on imports in the short term; however, it has a significant effect in the long run. In addition, the real exchange rate variable (lag 3) significantly affects imports in both the short and long term.

According to the impulse response function, photovoltaic cells import showed a positive response to the shock of per capita GDP differences between Indonesia and trading partner countries. Meanwhile, based on variance decomposition, the difference in GDP per capita contributed the second largest effect on imports. This positive impact is consistent with Heckscher-Ohlin theory. These findings are also in line with several previous studies which reported that the more significant the differences in GDP per capita, the higher the trade between the countries, (Kahouli, 2016; Khan and Hossain, 2012; Ogura, 2020; Rasoulinezhad and Wei, 2017; Satrio and Jamli, 2013).

The highest import value of Indonesian PV cells comes from relatively high-income partners such as Japan, Singapore, United States, Germany, Hong Kong, and South Korea. Indonesia's trade intensity tends to increase when the GDP per capita of its trading partner countries increases. This happens due to a large labor force; hence, there are more incentives to trade with countries that have abundant capital (Satrio and Jamli, 2013).

Based on the impulse response analysis, the real exchange rate shock have a negative impact on PV imports beginning from period 2. This condition showed that increase in the rupiah's exchange rate against the currencies of trading partner countries tends to cause a decrease in imports. These results are in accordance with previous studies (Huynh and Hoang, 2019; Stender, 2018). Furthermore, exchange rate describes the relative price of goods in the two countries. The rupiah's exchange rate depreciation against foreign currencies tends to increase the price of foreign goods in order to reduce import (Huynh and Hoang, 2019). However, this negative response only lasted up to period 3.

In period 4 to 7, imports responded positively to the real exchange rate shock. Hence, rupiah depreciation against trading partner currencies increases the import value of Indonesian PV cells. This result is in line with several previous studies, which stated that exchange rate positively, affect imports (Meniago and Eita, 2017; Sweidan, 2013). In contrast, the variance decomposition results showed that the real exchange rate contributed the least effect on the import.

This situation occurs because Indonesia depends largely on other countries to import the main components of PV Rooftop. According to the Energy and Mineral Resources Ministry, the industry has not produced PV or solar cells, which are the basic materials for constructing solar modules (Kementerian ESDM, 2019), which is the main component of Rooftop PV. Therefore, increase in exchange rate was not sufficient to affect imports.

Summarily, differences in GDP per capita between Indonesia and partner countries only significantly affected PV imports in the long run. Meanwhile, based on the impulse response function, import responded positively to GDP shock between countries. In contrast, the variance decomposition showed that the GDP differences contribute the most significant effect on import.

In addition, rupiah's exchange rate against the currencies of trading partner has a significant effect on imports in the short and long term. According to the impulse response function, the real exchange rate shock negatively affects imports from period 2 to 3. However, in period 4 to 7, it had a positive effect. The variance decomposition also showed that the real exchange rate contributes the least effect on imports.

Import increase and real exchange rate occur due to the large dependence on imports by the PV sector. Therefore, the Indonesian government needs to develop technology in the domestic industry to reduce dependency, given that the country has a natural wealth of silica sand, which is the raw material for solar cell plates. Moreover, this is necessary to enhance the industry to produce quality Rooftop PV components and compete globally. In addition, the government need to maintain exchange rate stability to avoid trade balance deficit.

Future studies are expected to use time series data to obtain analysis that is more specific. In addition, regulatory indicators related to solar PV, such as the Feed-In Tariff (FIT) policy are also recommended to be included in further studies together with other independent variables such as investment and Research and Development (R&D).

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