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The role of internet in efficiency of Indonesian primary energy export

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C H R O N I C L E

Article history:
Received August 24, 2024
Received in revised format October 25, 2024
Accepted January 21 2025
Available online January 21 2025

Keywords:
Business Analytics
Internet
International Trade
Stochastic Frontier Gravity Model

A B S T R A C T

The Internet is widely recognized as an important technology to accelerate export performance. In the case of energy trade, the issue of export efficiency must be achieved for every exporter country, including Indonesia. The essential input factor to achieve maximum efficiency of trade is to utilize the internet as a technological factor. Therefore, the objective of this study is to examine the impact of the internet on the efficiency of primary energy exports in Indonesia. The study employed the Stochastic Frontier Gravity Model (SFGM) to analyze data from 26 destination countries spanning the period from 2011 to 2020. The result reveals that the condition of internet technology from importers, proxied by fixed broadband subscriptions and secure internet servers has a significant effect on Indonesian export energy performance. Furthermore, the addition of internet technology enhances the Indonesian primary energy export efficiency by comparing the efficiency before and after involvement of the internet. Therefore, the condition of internet technology from importer countries must be considered to maintain the export performance of Indonesia's primary energy to the global market.

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1. Introduction

Indonesia is one of the biggest energy exporters in the global market. According to UN Comtrade (2023), In 2024, Indonesia's energy exports, which include oil and gas, were valued at $15.88 billion. This represented a slight decrease of 0.28% compared to 2023. The total export value for Indonesia in 2024 reached $264.7 billion, with non-oil and gas exports making up the majority. Fig. 1 shows the fluctuating performance of primary energy export in Indonesia from 2011 until 2020. One of the factors that could influence Indonesian primary energy export is the role of internet technology. Internet plays a crucial role in optimizing the data flow in the global network, identifying trade patterns, and facilitating real-time decision-making for global trade, particularly in supply chain issues and transportation network analysis (Harianto et al., 2024; Kanrak & Nonthapot, 2024; Pal, 2023; Liu et al., 2020). In the case of sectoral performance, Suroso et al. (2022) revealed that the Internet has a positive and significant effect on the agriculture sectoral performance in emerging and developing countries in three continents such as Africa, Asia, and Oceania. Moreover, the Internet has the potential to significantly enhance international trade for numerous countries worldwide (Meijers, 2014). However, Maurseth (2018) discovered an unexpected inverse effect of the Internet on economic growth when extending the analysis period. Similarly, mobile Internet was found to have no significant impact on productivity (Suroso et al., 2023a). Hence, the topic of the Internet is still interesting to discuss. In the case of energy, using the Internet is essential for industrial operations. With the development of an intelligent grid system, the renewable energy source enables connecting and exchanging energy-related data from renewable sources to a computer system and end-users in a communication network, increasing the monitoring quality (Long et al., 2022). The Internet of Things (IoT) application enabled smart grids and intelligent environments, such as smart cities, smart homes, smart metering, and energy management infrastructures, creating the energy internet concept (Kabalci et al., 2019). The Internet is also integrated into home energy management through IoT to enable more accessibility in anytime and anyplace connection (Guang et al., 2017).

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ISSN 2561-8156 (Online) - ISSN 2561-8148 (Print)
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doi: 10.5267/j.ijdns.2025.1.005

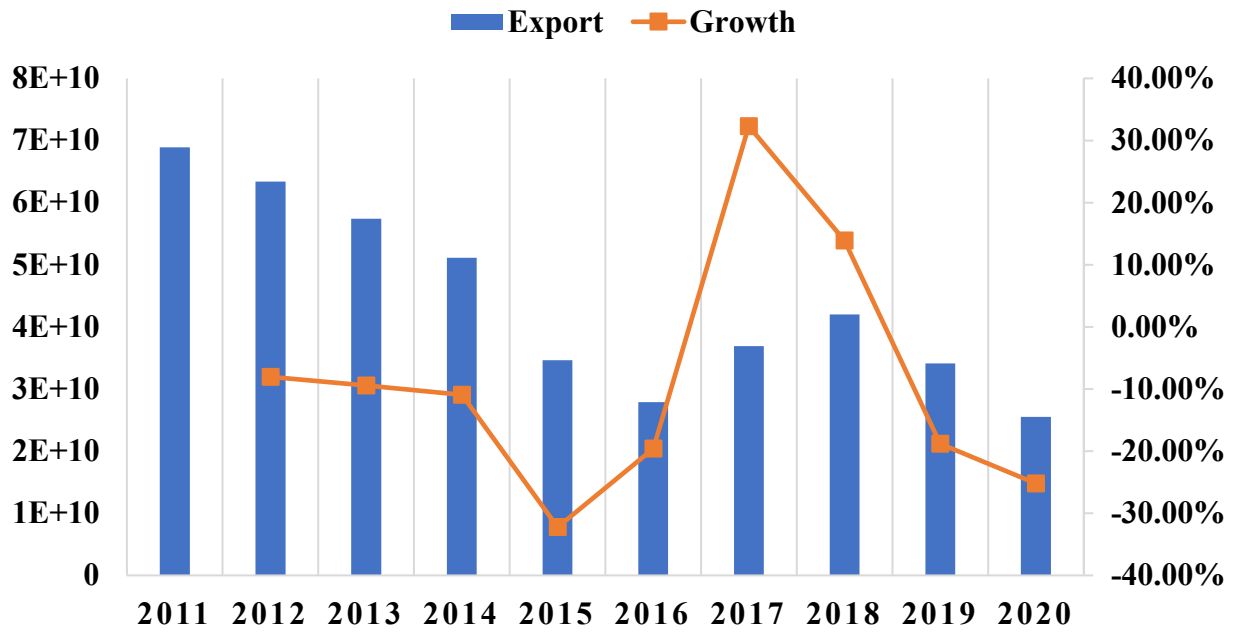

Fig. 1. The Trend of Indonesian Export Energy and Its Growth

Source: UN Comtrade (2023)

Therefore, the demand of energy also depends on the condition of internet quality. Fig. 2 reveals that the share of Indonesian primary energy exports to destination countries in the form of raw materials. The destination country with highest share of Indonesian energy export in the form of raw materials is Japan with 21%, followed by China (16%), Rep. of Korea (13%), India (11%), and Singapore (11%). There are various countries beside 10 countries with 6% share distributions. From the top five list of countries, there are three advanced economies categories (Japan, Rep. of Korea, and Singapore) with the higher need of energy, inline with the technological usage in these countries.

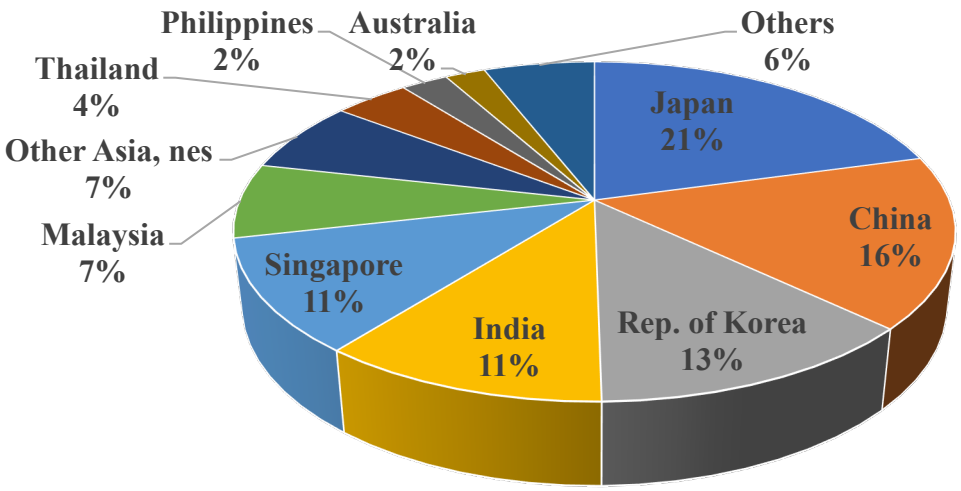

Fig. 2. Export Share of Energy

Source: UN Comtrade (2023)

Therefore, the research about the relationship between internet and energy trade must be explored from its impact and whether the internet can improve energy efficiency. Moreover, the previous study about the nexus between internet and energy trade is still rare. Hence, this study aims to examine the impact of the internet variables in energy export efficiency, particularly in Indonesia as one of the energy exporters. Based on the research problems, there are two main research questions in this study:

RQ1: How does the internet technology in importer countries in terms of users, infrastructure and security affect Indonesian primary energy exports?

RQ2: How does the efficiency of Indonesian primary energy exports compare before and after the presence of variables related to internet conditions in importing countries?

Therefore, this study tries to investigate the role of the Internet on Indonesian primary energy export by estimating it as a determinant of Indonesian primary energy export. This study also involves efficiency analysis using SFGM predicted by the internet, proxied by three indicators: internet users, fixed broadband subscriptions, and secure internet servers.

2. Literature Review

Numerous studies examined the relationship between the Internet and international trade. Freund and Weinhold (2004) identified a significant positive influence of the Internet on international trade. Their findings indicate that a 10% increase in web host growth within a country is linked to an approximately 0.2% increase in export growth. Similarly, Clarke and Wallsten (2006) found that enhanced Internet access improves export performance in developing countries, emphasizing the role of improved connectivity in fostering economic growth" through higher export levels. Bojnec and Ferto (2010) also showed the positive impact of the Internet on international food industry trade, which means that the Internet decreases market-specific entry costs in the export of the food industry. Otherwise, the significant positive effect of the Internet is found in the importing countries. Miraskari et al. (2011) showed that the increase in internet users had a positive and significant influence at the 5 percent level on the volume of exports and bilateral trade in exporting and importing countries in 2001-2008. Liu and Nath (2013) found the positive impact of subscriptions and hosts on exports and imports in the case of emerging market economies. Salmami et al. (2013) have already explored the positive and significant effect on the service trade of developing countries through the modified gravity model. Yadav (2014) revealed a positive impact of the Internet on the extensive margin of enterprise export and input import behavior. Specifically, both internet tools (e-mail and own website) affect manufacturing enterprises' export and input import possibilities. Riker (2014), in the case study on the nexus between Internet use and trade openness, revealed a positive impact of the Internet, proxied by broadband use, on trade openness and implicates economic growth.

Lin (2015) has already explored the positive nexus of internet users towards global trade due to this technology can reduce the information cost in trade. Osnago and Tan (2016) showed that the Internet positively affects international trade, which means that the improvement of bilateral exports with a 1.9 percent increase is explained by the adoption of the Internet with a 10 percent increase. Xing (2018) showed that the accessibility of ICT and the adoption of e-commerce are positive and significant on bilateral trade in various groups. Ismail (2020) also found that all digital facilitation indicators significantly impact bilateral trade, indicating the Internet's essential role in accelerating trade. Abendin et al. (2022) reported a positive and significant effect of digitalization on bilateral trade in the Economic Community of West African States (ECOWAS); internet usage is one of the digitalization components. Xu et al. (2023) also found that the issue of technology level in a country is one of the main determinants of potential exports in Vietnam's agriculture. It could be concluded that internet technology could influence trade performance. According to the reviewed studies above, there are many previous findings about the impact of the Internet on trade with positive signs. However, research about the nexus between the Internet and trade efficiency still needs to be done. Therefore, this study fills the gap by using three main indicators of the Internet (users, infrastructure, and security) that could influence export efficiency in the case of Indonesian primary energy.

3. Methodology

This study utilized the Stochastic Frontier Gravity Model (SFGM) to examine the impact of the Internet on the efficiency of Indonesian primary energy exports. This model combines the gravity model with the stochastic frontier production model. The gravity model idea was initially proposed by Jan Tinbergen in 1962 in his influential article “Shaping the World Economy: Propositions for an International Economic Policy”. This article revealed that the international trade was determined from economic size and distance between exporter and importer countries (Tinbergen, 1962). Gross Domestic Product (GDP) is often used to enhance trade between countries as a proxy for economic size. On the other hand, we employed geographical distance (DIST) as a proxy for transportation costs. Therefore, the equation of gravity model in case of Indonesian primary energy export could be written as follows:

$$XEN_{ijt} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP_{jt} + \beta_3 DIST_{ij} + \varepsilon_{ijt} \quad (1)$$

where XEN_{ijt} is the primary energy export between Indonesia (i) and importer country (j) at year t, GDP_{it} and GDP_{jt} are the Gross Domestic Product in Indonesia (i) and importer country (j) at year t, respectively, $DISTij$ is the geographical distance between Indonesia (i) and importer country (j), B_0 is constant of estimation, B_1, B_2 and B_3 is the coefficient of estimation, ε_{ijt} is the residual term. We extended the traditional gravity model by adding some variables, namely internet variables to answer our research objective (Maurseth 2018; Xu et al. 2023; Suroso et al. 2023; Suroso et al. 2024). Furthermore, there are several additional variables also be added to explain the actual condition of trade: contiguinity, ASEAN member, and OPEC member. Therefore, the extended gravity equation could be described as follows:

$$LnXEN_{ijt} = B_0 + B_1LnGDP_{it} + B_2LnGDPjt + B_3LnDIST_{ij} + B_4LnINT_{jt} + B_5LnFBS_{jt} + B_6LnSIS_{jt} + B_7CONT_{ij} + B_8ASEAN_j + B_9OPEC_j + \varepsilon_{ijt} \quad (2)$$

where *INTjt* is the internet users, proxied by percentage of individual used internet in importer country (*j*) at year *t*, *FBSjt* is the internet infrastructure, proxied by fixed broadband subscriptions in importer country (j) at year *t*, *SISjt* is the internet security, proxied by secure internet server in importer country (*j*) at year *t*, *CONTij* is the contiguinity border between Indonesia (*i*) and importer country (*j*) at year *t*, *ASEANj* is the ASEAN membership by importer country (j), OPECj is the OPEC membership by importer country (j). B_4, B_5, B_6, B_7, B_8, and B_9 is the coefficient of estimation, respectively. Ln is the natural logarithm. The stochastic frontier analysis (SFA) methodology was established by Aigner et al. (1977) and Meeusen & van Den Broeck (1977) in the context of production. This methodology can be utilized to quantify trade flows, as demonstrated by Kalirajan (1999) in the context of exports.This can be seen from the gravity model equation, which can be viewed as a bilateral trade production function based on maximizing economic size, distance, and other factors. When the trade gravity equation is viewed as the result of cost minimization, SFA is justified to estimate trade potential, where trade performance refers to the extent to which the actual level is lower than the maximum level of trade (Kang & Fratianni, 2006). In our case, the extended gravity model equation with the stochastic frontier approach is as follows:

$$LnXEN_{ijt} = B_0 + B_1LnGDP_{it} + B_2LnGDP_{jt} + B_3LnDIST_{ij} + B_4LnINT_{jt} + B_5LnFBS_{jt} + B_6LnSIS_{jt} + B_7CONT_{ij} + B_8ASEAN_j + B_9OPEC_j + \varepsilon_{ijt} - V_{ijt} \quad (3)$$

There is a similarity between equations (2) and (3), excluding the error term ($\varepsilon_{ijt} - V_{ijt}$), ε_{ijt} can be defined as a double-sided error term, meaning there is a statistic that is noisy by the residual estimate, N (O ~ σ2e). On the other hand, V_{ijt} is a one-sided error term that is estimated to be normally distributed. N (μ ~ σ2u), meaning the measurement of technical inefficiency. The calculation of technical efficiency by Battese & Coelli (1995) is shown by the following equation:

$$E\left[EXP\left(-V_{ijt}\right)\middle|e_{ijt} + V_{ijt}\right] = \frac{1 - \phi[\sigma_* + \gamma(e_{ijt} + V_{ijt})/\sigma_*]}{1 - \phi\gamma(e_{ijt} + V_{ijt})/\sigma_*} . \exp\left[\gamma\left(e_{ijt} + V_{ijt}\right) + \frac{\sigma_*^2}{2}\right. \quad (4)$$

where ϕ(.) is the density function, γ is an estimate of efficiency with a value between 0–1. If the efficiency value is 0, then it indicates inefficiency. If the efficiency value is 1, then there is evidence of maximum efficiency. Through this analysis, we can predict the export destination countries with high and stable export efficiency.

The data type is panel data, containing 26 countries from 2011 until 2020. Furthermore, the data in this study is secondary data gathered from various sources. We collected the Indonesian primary energy bilateral export (in value of USD) from UN Comtrade by using some Harmonized System (HS) Code in raw materials form with four digits of three energy types (Solid: 2701, 2702, 2703, 2704, 2705, 2708, 2714, 2715, Liquid: 2706, 2707, 2709, 2710, 2711, 2712, 2713, and Gas: 2705), according to previous literature by Gorecka et al. (2021). All primary energy based on HS Code "27", refers to "Mineral fuels, mineral oils, and products of their distillation: bituminous substances and mineral waxes". GDP (in current USD), The percentage of individuals who used the internet in importer countries (INT), fixed broadband subscriptions (FBS), and secure internet servers (SIS) were gathered from the World Development Indicator (WDI). The geographical distance was collected from the time and date of the distance calculator (https://www.timeanddate.com/worldclock/distance.html). In this study, we use three dummy variables, such as contiguous border (https://www.worldatlas.com/maps/indonesia) – 1 means that there are contiguous border between Indonesia and importer, and 0 is otherwise; ASEAN (https://asean.org/member-states/) – 1 means that importer countries is ASEAN membership, and 0 is otherwise; and OPEC https://www.opec.org/opec_web/en/about_us/25.htm) – 1 means that importer countries is OPEC membership, and 0 is otherwise.

3. Result

Table 1 explains the descriptive statistics, containing mean, median, standard deviation (Std. Dev), maximum, and minimum. The descriptive statistics result reveals a normal distribution between variables due to mean value higher than Std. Dev value.

Table 1
Descriptive Statistics

Statistic	Mean	Median	Std.Dev.	Maximum	Minimum
$LnXEN_{ijt}$	18.54	19.01	3.56	23.68	2.30
$LnGDP_{it}$	27.59	27.55	0.08	27.74	27.48
$LnGDP_{jt}$	27.19	26.93	1.80	30.70	20.76
$LnDIST_{ij}$	8.64	8.65	0.76	9.73	6.79
$LnINT_{jt}$	4.01	4.31	0.67	4.61	1.39
$LnFBS_{jt}$	15.44	15.72	2.38	20.00	4.25
$LnSIS_{jt}$	10.38	10.28	2.94	17.66	0.00
$CONT_{ij}$	0.08	0.00	0.27	1.00	0.00
$ASEAN_j$	0.19	0.00	0.39	1.00	0.00
$OPEC_j$	0.04	0.00	0.19	1.00	0.00

Table 2 shows Indonesia's energy export determinant, explaining the two regression models. In the traditional gravity model, Indonesian GDP and geographical distance are negatively significant toward Indonesian primary energy export (Model 1). However, importer GDP has a positive effect. Furthermore, we also find a similar GDP and geographical distance result on Indonesian primary energy export in the extended gravity model (Model 2). This result is similar to previous research with the positive and negative effects of GDP and geographical distance, respectively (Irshad et al., 2018; Rosyadi et al., 2020; Tandra & Suroso, 2023). A country's economic growth can increase exports and economic stability through domestic consumption and investment. On the other hand, the long geographical distance proxied as transportation costs could implicate the lower export of Indonesian primary energy. Therefore, the exporter country must consider this variable affecting bilateral trade performance. In the internet variable, the fixed broadband subscription of importer countries positively affects Indonesian primary energy export. The increase in internet infrastructure also leads to the energy export in Indonesia, which means that the enhancement of internet infrastructure in importers could implicate the increase in trade for some exporter countries (Abeliansky & Hilbert, 2017; Luong & Nguyen, 2021). However, the secure internet server of importer countries has a negative impact.

Table 2
Regression Estimation

Variable	Model 1		Model 2	
	Coefficient	Std. Error	Coefficient	Std. Error
Constant	114.81***	6.44	35.52***	1.80
$lnGDP_{it}$	-3.67***	0.30	-0.51**	0.25
$lnGDPj_{t}$	1.03***	0.10	0.80***	0.30
$lnDIST_{ii}$	-2.41***	0.48	-3.18***	0.50
$lnINT_{jt}$			0.47	0.40
$lnFBS_{it}$			0.52**	0.25
$lnSIS_{jt}$			-0.44***	0.10
$CONT_{ii}$			-0.81	1.01
$ASEAN_{j}$			-1.88***	0.84
$OPEC_{j}$			-2.92***	1.07
sigma-squared	30.16***	11.62	16.24***	5.24
gamma	0.90***	0.05	0.82***	0.07
mu	-10.39***	4.00	-7.29**	3.43
eta	0.03***	0.01	0.08***	0.02
Log-Likelihood Function	-548.85		-541.18	
LR-Test of The One-Sided Error	157.72		161.45	

This result is different with the previous findings that found a positive influence of the Internet towards trade (Xing, 2018; Ismail, 2021). Surprisingly, there is no significant effect from internet users on trade. In the case of infrastructure, improving internet infrastructure could lead to the energy demand of importer countries caused by the enlargement of capacity. Therefore, it will implicate the energy exporter to increase the trade performance. Improving internet security could decrease the energy trade caused by stricter border control and decrease international trade (Carballo et al., 2016). The enhancement of ICT also leads to the efficiency of energy usage, which means that the highest number of internet users not affected by the highest demand for energy could be fulfilled by energy exporter countries. Other variables, such as the organization membership by importer countries in the case of international organizations, namely ASEAN and OPEC, negatively and significantly affect primary energy bilateral export in Indonesia to importer countries. It is due to compliance with new and restricted regulations of energy trade, which implicates the highest price of energy and decreases the energy trade performance for some countries, especially in ASEAN. The issue about the application of renewable energy for industrial activities is the new concern for energy due to the negative impact on environmental quality in the global world (Fahim et al., 2023). On the other hand, importers who are members of OPEC controlling prices and reducing competition in the global market can have a negative impact on energy trade by several exporters in the world, including Indonesia. After the estimation calculation, there is an efficiency result through SFGM regression. Table 3 describes the efficiency analysis before and after internet involvement.

In all destination countries for Indonesian primary energy exports, we found that six countries had a negative change from the comparison between before and after included internet variables. Otherwise, there are 20 countries with positive change. The highest change from comparison before and after including the internet variables is the United Arab Emirates (615.67%), Germany (382.35%), South Africa (235.40%), United States of America (USA) (193.04%), and Belgium (175%). The trend of Indonesian primary energy exports, including the internet variable, is relatively higher than in Figure 3. This shows a positive trend in export efficiency between before and after, including the internet variable since 2011. The highest export efficiency by excluding and including the internet variable was found in 2020, reaching 46% and 35.4%, respectively. To achieve a broader result about export efficiency, we classify the export efficiency result into advanced emerging and developing countries. Figure 4 reveals an improvement in export efficiency after including internet variables in both cases. Therefore, including internet variables from importer countries' perspectives could improve efficient export to many destination countries, considered one of Indonesia's critical determinants of energy export.

Table 3
Efficiency Analysis, Before and After Included Internet Variables

Country	Before	After	Change (%)
Australia	38.68%	50.92%	31.64%
Bangladesh	4.65%	1.55%	-66.67%
Belgium	0.08%	0.22%	175.00%
China	40.78%	10.95%	-73.15%
China, Hong Kong SAR	42.10%	24.48%	-41.85%
France	0.10%	0.23%	130.00%
Germany	0.17%	0.82%	382.35%
India	70.64%	68.86%	-2.52%
Italy	7.88%	15.69%	99.11%
Japan	70.30%	71.64%	1.91%
Malaysia	20.19%	45.46%	125.16%
Mexico	31.71%	24.35%	-23.21%
Netherlands	44.23%	68.97%	55.93%
New Zealand	41.38%	43.35%	4.76%
Pakistan	37.35%	24.73%	-33.79%
Philippines	49.29%	57.88%	17.43%
Rep. of Korea	78.94%	64.09%	-18.81%
Singapore	15.32%	30.61%	99.80%
Slovenia	76.71%	77.96%	1.63%
South Africa	1.13%	3.79%	235.40%
Spain	33.24%	46.46%	39.77%
Thailand	39.92%	49.64%	24.35%
Timor-Leste	45.77%	54.91%	19.97%
United Arab Emirates	7.85%	56.18%	615.67%
USA	24.57%	72.00%	193.04%
Viet Nam	17.82%	20.79%	16.67%

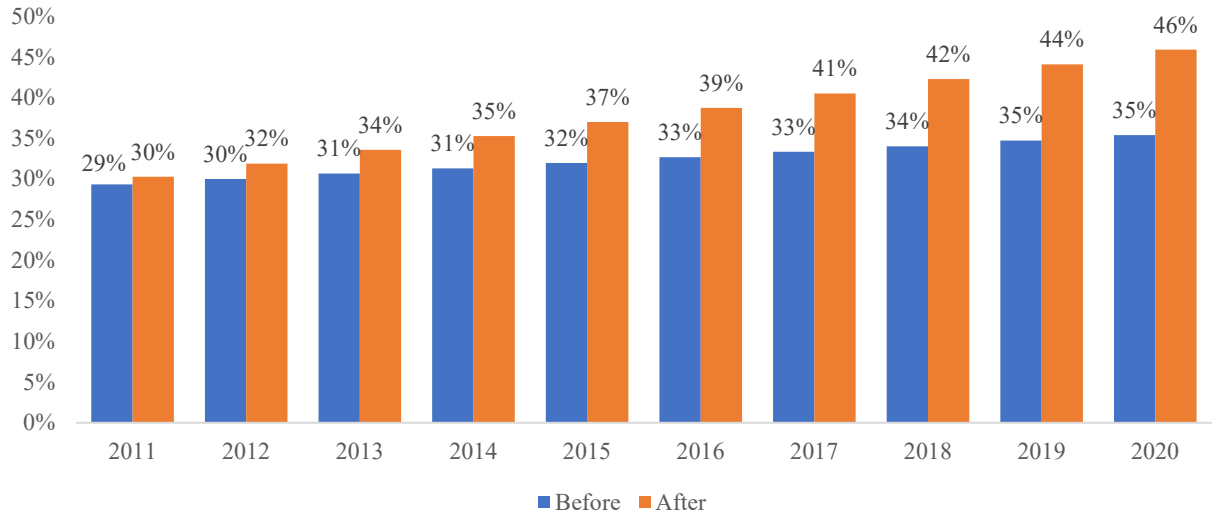

Fig. 3. Efficiency Comparison From 2011-2020

Before and After Internet Variable

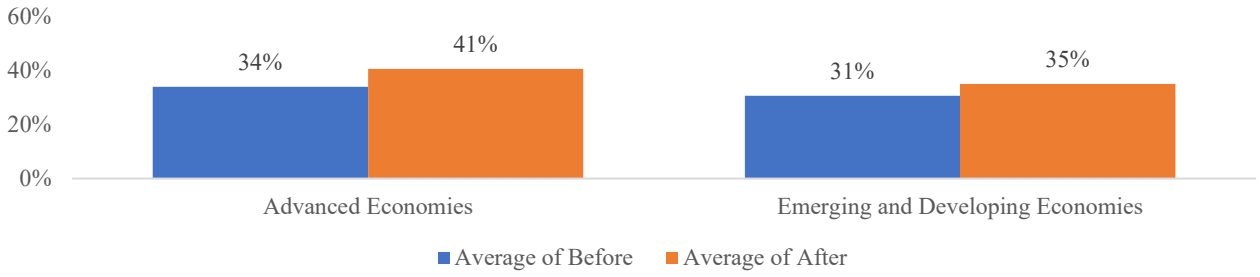

Fig. 4. Efficiency Comparison Between Developed and Developing Countries

Before and After Internet Variable

4. Conclusion

The Internet has currently become the central importance of international trade. Hence, the research about the nexus between the Internet and trade is interesting to discuss. This study explores the role of the Internet on trade efficiency, mainly the bilateral export of energy in Indonesia. The stochastic frontier gravity model (SFGM) was implemented in 26 Indonesian primary energy export destination countries from 2011 until 2020. The result revealed a positive impact from some variables on Indonesian primary energy export: importer GDP and fixed broadband subscriptions. Conversely, Indonesian GDP, geographical distance, secure internet server, ASEAN, and OPEC memberships by importers have a negative influence on Indonesian primary energy export. Furthermore, we found the enhancement of export efficiency after estimating the regression model using internet variables. By classifying the category of country economic and trendline analysis, there is a positive growth from before to after in the involvement of internet variables. Based on these results, we found some managerial implications, namely the involvement of technology (in the case of the study is the Internet) would lead to the energy demand from importers. The enhancement of the Internet from importer countries can signal the exporters to increase energy trade, increasing the overall trade performance. Therefore, the market intelligence for some importers with high technology performance must be implemented by energy exporters to gain a positive trade performance. Furthermore, the issue of internet security could be the main concern for energy exporters due to the negative impact on trade. Strengthening trade cooperation is needed to support the flow of energy exports to continue running smoothly and increase digital security. Last but not least, there a limitations in this study, such as 1) the exploration of new proxy in internet variables and its impact on trade efficiency due to rapid improvement in this technology, 2) the further need for research about the export strategy for Indonesian primary energy by investigating the internet variable in importers, 3) the focus of research only limited on mineral energy sources, means that the further research consider the renewable energy trade influenced by internet technology, and 4) the future research could replicate or extend our regression framework in another case of study to gain a new perspective for internet-energy trade nexus.

Funding

This research was funded by the Ministry of Education and Culture, Directorate General of Higher Education of the Republic of Indonesia based on contract number: 22003/IT3.D10/PT.01.03/P/B/2024.

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