An Investigation of an Adaptive Neuro-Fuzzy Inference System to Predict the Relationship among Energy Intensity, Globalization, and Financial Development in Major ASEAN Economies

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Abstract: The enhancement of the financial sector significantly drives a nation's economy and thereby increase energy intensity. Considering this situation, the current study aims to examine the link between globalization and financial advancements with the energy intensity of the top 5 ASEAN (Association of Southeast Asian Nations) economies. The development structure of the ASEAN region is considered significant for having stable growth. The authors used the annual data from 1990 to 2018 for five of the largest ASEAN economies: Singapore, Malaysia, Thailand, Indonesia, and the Philippines. The present study used novel methodology, the Adaptive Neuro-Fuzzy Inference System (ANFIS), to examine the nonlinear behaviour among globalization, financial development, and energy intensity in the top 5 ASEAN countries. The study results using ANFIS confirm that globalization and financial development are positively correlated and have a significant impact on the energy intensity level in the top ASEAN countries. The results further suggest that globalization and financial development increase the level of energy intensity more in the countries that are developed relative to their peers in the top ASEAN countries. Moreover, the outcomes of ANFIS also suggest that those countries, which are more globalized and financially developed, have more potential to increase the level of energy intensity. Therefore, the government needs to focus more on projects that involve renewable energy and are environmentally friendly.

Keywords: globalization; energy intensity; financial development; Adaptive Neuro-Fuzzy Inference System

1. Introduction

In the modern era, the enthusiasm for being advanced has not merely unified the nations economically but has also resulted in escalating international competitiveness among industrialized and emerging economies. The potential of augmented competitiveness in industrialized and emerging economies is massively accomplished through increased output growth that often gives rise to higher

energy intensity [1]. The ecological concerns of augmented energy intensity have caused environmental degradation in terms of global warming. The augmented climate change is harmful to the ecological condition and natural habitat. In order to decrease the levels of global warming, the countries from all around the world are focused on articulating policies to curtail the energy footprint and explore the potential driver of energy intensity in the various economies [2].

In this regard, the role of globalization is considered significant in influencing the levels of energy intensity in an economy. The theoretical link between globalization and energy utilization asserts that the rise and decline in energy usage relies on the aggregated effect of numerous significant factors, including globalization [3]. Specifically, it is considered that the increases in global economic production and income levels are connected to globalization, while the elimination of trade barriers seems to expand the levels of energy utilization [3]. In this context, the rise of globalization is perceived to enhance the levels of energy intensity in the economies, generally providing the positive association in the prevailing literature [4–6]. On the other hand, numerous studies have recently highlighted the alternative connection among the variables and suggested that the link between globalization and energy usage varies from country to country. In this regard, a panel investigation of developed economies reported that globalization had a positive impact on energy utilization in twelve out of twenty-five studied economies [7]. The study found that the association between globalization and energy utilization in the United States and United Kingdom is negative, which means the increase in globalization actually decreases the power usage in the specified countries. For the rest of the eleven countries, the results of the study failed to find any empirical connection between globalization and power consumption. Similarly, based on another study, the increase in globalization would likely decrease the levels of energy demand for the developing country India [8]. Hence, the disparity in the specified link between globalization and energy, in the recent literature, has enhanced the need of examining the association of globalization with energy intensity, given its significant role in influencing economic advancement of both developed and developing economies.

Another critical motivator of energy intensity is the advancements in a country's financial sector [9]. Financial advancement regards the activities that can promote a country's efficiency in banking, investments, and financial markets [10]. The enhancement of the financial sector is significant in driving a nation's economy and thereby augmenting energy intensity. Several measures of financial development are found in the existing literature to influence the demand for energy. In this context, the literature reports that the rise in the financial advancements in the stock market is positively related to energy demand in developing economies [11]. On the other hand, utilizing the measure of banking development establishes a positive link between financial advancements and energy utilization in European economies [10].

Theoretically, the relationship between financial development and energy intensity is argued for having both negative and positive linkages. In this regard, the primary belief argues that the progress of financial collaborations in terms of institutions, financial markets, and foreign investments motivates extended lending to be domestic and motivates corporate purposes for financing energy-intensive products such as automobiles and machinery, thereby increasing energy utilization that has a negative impact on the environment through more significant air and water pollution [12]. Alternatively, the adherents of negative links insist that the advancements in the financial sector could offer a more significant opportunity to stimulate lending to green energy and deliver debts to finance renewable ventures [13]. In this way, the progress of financial intermediations can support ecologically supported projects at lower costs. Moreover, foreign investments can encourage technological advancements through domestic firms that can curtail power utilization and offer energy efficiency [14–16]. In this regard, the relationship between energy intensity and financial advancements is deemed critical for enduring the unclear association that varies from economic and environmental aspects.

Given the situation, the current study aims to examine the link between globalization (GLOB) and financial advancements (FAD) [17] with the energy intensity (ENIT) of ASEAN countries. The development structure of the ASEAN region is considered significant for having stable growth. In the

last ten years, the output development in the region displayed a growth of 5.66 percent and reflected a higher growth pattern relative to global growth of 2.76 percent during the period [18]. However, as the development is often accompanied by higher energy utilization, mostly at the cost of the environment, the dynamics of energy intensity need to be investigated in the region. More importantly, the significance of ASEAN countries is attributed to their varied income levels and has placed higher emphasis on persisting varied energy dependence. In the ASEAN region, Singapore is regarded as the highest income economy, Malaysia and Thailand are referred to as upper–middle-income economies, and Indonesia and the Philippines are regarded as lower–middle-income economies [18]. Being an economically diversified region, ASEAN practices hasty globalization and augmented financial advancements that expand energy demand in the region [19]. In this regard, the empirical examination of the variables would prove significant to capture the specific link of financial advancements and globalization in driving energy intensity in the top five ASEAN countries separately, to add a more accurate and cohesive view of the GLO-FAD-ENIT nexus.

To provide a better measurement of globalization, unlike prior studies that used the narrower measures of FDI or trade openness to indicate globalization, the current study utilizes the KOF globalization index that indicates the comprehensive reflection of country's globalization in exhibiting how socially, economically, and politically globalized an economy is. In addition to the above discussion, the novelty of the current study is also linked to the application of the advanced methodology in capturing the empirical link between GLOB, FIND, and ENIT of the ASEAN countries. From the studied literature, many studies have insisted on the utilization of advanced econometrics for lending support and authenticity of the derived outcomes [20,21]. In response, the current research has adopted the novel method of the Adaptive Neuro-Fuzzy Inference System (ANFIS) to examine the predictive capacity of financial advancements and globalization in influencing energy intensity. The significance of ANFIS lies in investigating the associations among the variables that are unexplored by traditional methodologies by amalgamating the benefits of fuzzy inference systems and artificial neural networks together to gain superior insights into the dependence structure [22]. Moreover, ANFIS is also vital to resolve the econometric limitations in non-linear associations, thereby being considered efficient for analysing non-linear behaviour [23].

The remaining part of the present research is structured into the following four sections. Section two reviews the existing energy-related literature to identify the expected link among the variables. Section three explains the utilized methodology of the study followed by section four that demonstrates empirical results and their interpretations. Finally, section five concludes the investigation by presenting a discussion of the findings, limitations, and policy implications.

2. Literature Review

The roles of financial advancements and globalization are considered vital to drive development and structural changes in economic layouts [24]; however, their association with energy utilization is often debatable for enhancing environmental burdens. Nevertheless, with proper allocation of green investments in economic activities, the rise in globalization and the financial growth could improve energy efficiency and reduce a country's dependence on energy-intensive development [25]. For identifying the association between globalization and energy [26], i.e., the contribution of globalization in terms of trade liberalization in affecting environmental degradation and energy intensity, the authors examined 22 emerging nations between 1980 and 2010. The empirical examination was carried out by applying the methods of heterogeneous linear and nonlinear panel estimations. The outcome of empirical analysis suggested that globalization significantly influences energy intensity and environment. Specifically, the results showed that the rise in trade liberalization led to a decline in environmental degradation and energy intensity in the studied economies. Similarly, a different study investigated the drivers of energy intensity in the context of the Nigerian economy [27]. For this, the authors examined data from 1971 to 2011. The empirical examination was carried out by applying the methods of fully modified ordinary least square estimations. The outcome of empirical analysis

suggested that globalization, in terms of trade liberalization, significantly influenced energy utilization. In particular, the findings established that the increase in trade liberalization led to reduced energy intensity in Nigeria.

Moreover, a recent study examined the role of globalization using the KOF index in affecting energy utilization via a sample of 12 Latin American and Caribbean nations between 1991 and 2012 [4]. The empirical examination was carried out by applying the conventional method of autoregressive distributed lags. The outcome of empirical analysis suggested that globalization significantly influenced the demand for energy in both the long run and short run. Specifically, the outcomes stated that the rise in globalization resulted in increased energy utilization in the sampled economies. Similarly, time-series analysis showed the contribution of globalization in influencing energy utilization [7]. In this study, the authors investigated the economies of the Netherlands and Ireland separately between 1970 and 2015. The empirical examination was carried out by applying novel econometrics, quantile ARDL estimations. The outcome of empirical analysis revealed that globalization significantly influenced energy utilization in both economies. The findings indicated that the rise in globalization in both economies brought a positive change in energy utilization [4].

In a panel examination, [5] analysed the link between globalization and energy utilization. For this, the authors examined the BRIC nations between 2000 and 2012. The empirical examination was carried out by applying the methods of Pedroni and Kao cointegration along with panel Granger estimations. The outcome of empirical analysis pointed out that globalization was cointegrated with energy in the long run. Moreover, the causal investigation reported the neutrality hypothesis among the variables. The results imply that there is no causal link between globalization and energy utilization in BRIC nations. Similarly, another study also investigated the contribution of globalization, in terms of the KOF Index, in affecting energy utilization [28]. In that study, the authors examined the Bangladeshi economy from 1980 to 2015. The empirical examination was carried out by applying the methods of J-J cointegration and Granger estimation. The findings of empirical analysis revealed that globalization was significantly cointegrated with the demand for energy in the long run. On the other hand, the results of a causal investigation, similar to that conducted by Dogan and Deger [5], failed to find any causal link among the variables.

In another time-series examination, Shahbaz et al. [8] investigated the role of globalization in influencing the demand for energy. In doing so, the authors examined the Indian economy from 1971 to 2012. Similar to Koengkan [4], the empirical examination was carried out by applying the methods of ARDL analysis. The outcome of empirical analysis showed that globalization significantly influenced the demand for energy in India. Specifically, the results showed that the rise in globalization reduced the country's demand for energy in both the long run and short run. Likewise, Shahbaz et al. [29] also investigated the contribution of globalization, in terms of the KOF index, in affecting energy utilization. In that study, the authors examined BRICS nations between 1970 and 2015. The empirical examination was carried out by applying the novel method of non-linear ADRL estimations. The outcome of empirical analysis showed that globalization significantly influenced the demand for energy. Specifically, the results showed that the positive and negative shocks of globalization had a negative impact on energy utilization in BRICS economies. Similarly, Shahbaz et al. [7] also investigated the causal association between globalization and energy utilization. For this, the authors examined 25 industrialized nations between 1970 and 2014. The empirical examination was carried out by applying the method of Granger causal estimations. The outcome of empirical analysis pointed out that globalization significantly influenced the demand for energy. Specifically, the results showed that the rise in globalization led to enhanced energy utilization for most sampled nations. On the other hand, the results for the UK and USA indicated that the rise in globalization resulted in a decreased demand for energy, which could be utilized to fulfil the objective of sustainable development in both developed economies.

For ASEAN-5 nations, Phong [7] examined the link between globalization, financial development, energy usage, and the environment between 1971 and 2014. By applying the methodology of panel

regression (fixed effect), the study found that the rise in financial development and energy usage degraded the environment in the ASEAN-5 region. Moreover, the study also elaborated that the increase in globalization had a negative effect on environmental quality. Overall, the study revealed that expansions in financial advancements, globalization, and energy demand were detrimental for the ASEAN-5 environment [18,19,30]. On the other hand, highlighting the role of financial development and energy utilization in countries' sustainable growth prospect, Mahi et al. [30] also analysed ASEAN-5 economies and found that financial development and energy played a significant role in boosting sustainable growth in Malaysia, Thailand, Singapore, and the Philippines. The results failed to find the significance of both variables in the Indonesian economy [31,32].

While focusing on the role of financial development with globalization to alter the demand for energy, Saud, Danish, and Chen [33] analysed the Chinese economy from 1980 to 2016. The empirical examination in the study was centred on linear examinations and applied the methods of ARDL estimations. The outcome of empirical analysis showed that both variables significantly influenced the demand for energy in China. Notably, the findings suggested that the rise in financial development led to a further increase in energy intensity. On the other hand, the empirical results showed a negative association between globalization and energy demand, indicating that an increase in globalization can improve energy intensity in the Chinese economy. Similarly, Danish et al. [34] also investigated the contribution of globalization and financial advancements to energy utilization. For this, the authors examined the economies of the Next-11 nations between 1990 and 2014. While applying the empirical estimation for panel analysis, the authors found that both variables were crucial in influencing energy utilization. The findings revealed that the increases in globalization and financial development were the reasons for the enhanced energy utilization in the Next-11 economies.

In a time-series investigation, Rafindadi [17] also investigated the impact of trade liberalization and financial advancements on energy utilization. In that study, the authors examined the German economy from 1970 to 2013. The empirical examination was carried out by applying the methods of ARDL and VECM estimations. The outcome of empirical analysis showed that both variables were vital in influencing the energy utilization in Germany; however, unlike Danish et al. [34], the results showed that the rise in trade liberalization and financial advancements resulted in a reduced demand for energy. Emphasizing the contribution of financial advancements, Islam et al. [35] examined the impact of financial development, in terms of a domestic credit to the financial sector, in affecting energy utilization. For this, the authors examined the Malaysian economy between 1971 and 2009. The empirical examination was carried out by applying the methods of ARDL and VECM estimations. The outcome of empirical analysis showed that financial advancements significantly influenced the demand for energy. Specifically, the outcomes reported that the rise in financial development led to a decline in energy utilization and brought efficiency in energy utilization in Malaysia. Similarly, Sadorsky [11] also investigated the contribution of financial advancements to energy utilization. In that study, the authors examined nine European nations between 1996 and 2006. The outcome of empirical analysis suggested that financial advancements were vital in influencing energy utilization, indicating the presence of a positive relationship among the variables. In another examination, Chang [12] also analysed the role of financial advancements in altering the demand for energy in a panel examination. In that study, the authors investigated 53 nations between 1999 and 2008. The empirical results reported that financial advancements enhanced the demand for energy, especially in high-income economies.

Likewise, Shahbaz and Lean [36] also studied the association between financial advancements and energy utilization, and that study was conducted using time-series investigation for the Tunisian economy from 1971 to 2008. The empirical examination was carried out by applying the methods of ARDL bound estimations. The outcome of empirical analysis revealed that financial advancement, in terms of a domestic credit to the financial sector, was significantly cointegrated with energy utilization in the long run. Moreover, the results of causal analysis indicated the existence of a feedback effect between financial advancements and energy utilization in Tunisia. In addition, Destek [9] also investigated the contribution of financial advancements to energy utilization. Applying

a panel examination of 17 developing economies, the authors studied the data from 1991 to 2015. In order to measure financial advancements, the study adopted the proxies of the banking industry, equity market, and bond market indices. The empirical outcome of the study found that financial progress significantly influenced the demand for energy. Specifically, the results established that the rise in financial advancements could efficiently reduce energy utilization in the studied economies.

The review of recent literature has emphasized the utilization of advanced methodology to strengthen the validity of derived empirical findings. Hence, in order to predict the energy intensity in the top five ASEAN countries, the present study employed the ANFIS method, which is widely used for complex model problems [22,37,38]. Primarily, the utilization of a mere fuzzy logic system is criticized for having nonappearance of the amenities, which need to be attained from the sample information. Therefore, the combination of both a neural network and fuzzy logic provides the maximum advantage. The combination of these two methods is called neuro-fuzzy. Given the importance of environmental quality in current economies, Mardani et al. [22] utilized an ANFIS approach for predicting the impact of CO_2 emissions in G8+5 economies between 1990 and 2016. Moreover, Mardani et al. [38] used the same method for analysing the link between energy usage, the environment, and growth in G20 nations. However, there is no study that adopts the advanced ANFIS method in the ASEAN region. In response, the current research applies ANFIS and establishes an estimation framework utilizing the information collected from the prediction of the energy intensity of ASEAN-5 economies.

3. Methodology

The present study employs ANFIS methodology to predict the energy intensity in the ASEAN-5 region. ANFIS is a framework for prediction dependent on finding the fuzzy guidelines in the information and makes the connections among predictor and criterion variables. Three kinds of information are utilized to build the ANFIS framework: initially by preparing, secondly by checking, and finally by testing. In the first phase, ANFIS utilizes the preparation group to build the framework. In the second phase, it uses the test and confirming groups for the justification and simplification of the framework, and the third phase is testing. Mardani et al. [22] presented the ANFIS framework for establishing a prediction framework that depends on genuine information. There are five principal layers for creating the forecasting of the framework. The five fundamental layers are presented in Figure 1. ANFIS is similar to the Takagi–Sugeno–Kang fuzzy guideline constructed framework. This technique takes its parameters from the predictor and criterion information. The basic system of ANFIS is displayed in Figure 1 in which ANFIS employs a few layers to prepare the information to predict the dependent variable. A Takagi–Sugeno–Kang fuzzy induction framework with one dependent variable f, two independent variables "x" and "y", and two fuzzy logic "IF-THEN" guidelines appears in Equation (1). In this condition, the fuzzy groups for independent variables y and z are characterized, individually, by A1, A2 and by B1, B2. Likewise, the dependent factors are characterized by the p_1, q_1, r_1 and the p_2, q_2, r_2 constraints.

$$\text{Rule \#1 : if } (x \text{ is } A_1) \text{ and } (y \text{ is } B_1), \text{ then } f_1 = p_1 x + q_1 y + r_1$$
$$\text{Rule \#2 : if } (x \text{ is } A_2) \text{ and } (y \text{ is } B_2), \text{ then } f_2 = p_2 x + q_2 y + r_2 \tag{1}$$

The guideline-dependent framework determines the mapping from the predictor variable to the criterion variable of the fuzzy groups. The defuzzification and fuzzification techniques are utilized for presenting the likelihood of dealing with a framework focused on two sorts of new independent/dependent variables. In the fuzzification phase, MFs are connected to get the fuzzy independent and dependent variables from new independent/dependent variables. In the defuzzification, MFs are utilized for obtaining the new dependent variable from the fuzzy independent variable. For logical connections among the fuzzy independent variable and fuzzy dependent variable, this research utilized the guideline by translating the principles utilizing fuzzy logic and operators. In this research, the fuzzy principles-based framework additionally created four resulting phases: independent fuzzification, group of the MFs, extraction of the dependent defuzzification, and fuzzy

principles. In the fuzzification phase, Gaussian MFs were used to determine the level of independents in each appropriate fuzzy group. On the other hand, in the defuzzification phase, the current study used the centroid of area [39], which returns the focal point of the area under the curve. The engineering of ANFIS is exhibited in Figure 2.
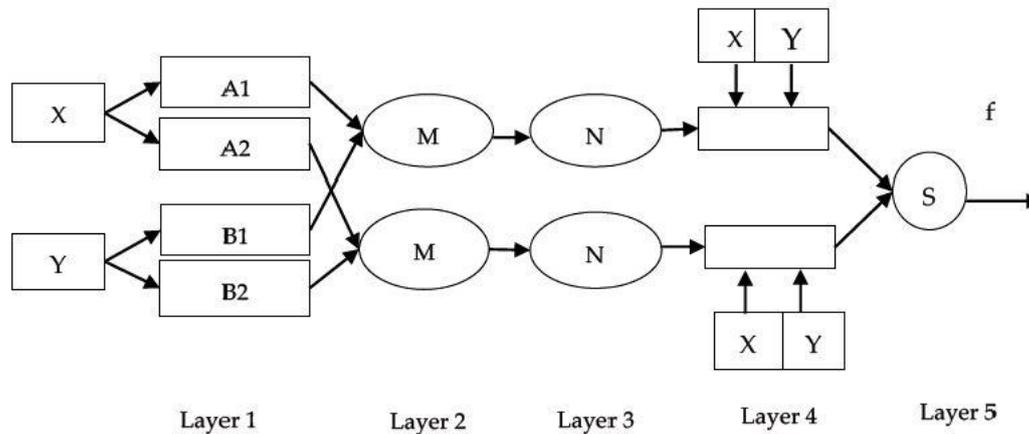
Figure 1. Fundamental Model of Adaptive Neuro-Fuzzy Inference System (ANFIS).
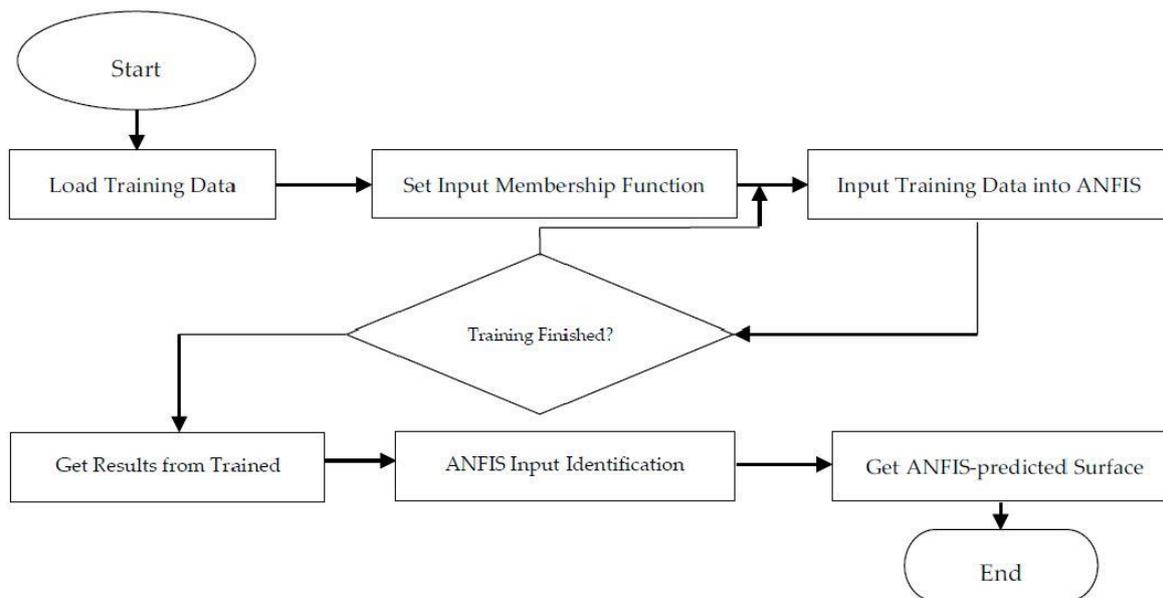
Figure 2. The ANFIS Engineering.

In ANFIS, for explaining the dependent variable, there is an important and essential measure that is named the mean absolute error (MAE) parameter. Equation (2) is utilized for estimation of MAE of the residual of the forecasting framework:

$$\text{MAE} = \frac{\sum_{0-1}^{n} \text{actual (o)} - \text{foresight(o)}}{n} \tag{2}$$

In the above equation, actual (o) is the actual dependent variable, foresight (o) is the foresighted dependent variable, and n denotes the number of total observations in the dataset. The current study is primarily designed for anticipating the energy intensity based on methods for two independent variables, i.e., globalization and financial development in the top 5 ASEAN nations based on the information available from 1990 to 2018. In doing so, the authors constructed the forecasting

framework through the fuzzy principles found by methods for the ANFIS model from the genuine dataset. Additionally, the authors established the connection among dependent and independent variables (Z = *f* (X1, X2)) in an approach to ensure forecasting with extreme correctness concerning the energy intensity. Here, X1, X2 imply the independent variable; more explicitly, (X1) indicates globalization, and (X2) is financial development, while Y speaks to the dependent variable, that is, energy intensity. Three arrangements of information (which are preparing, checking, and testing) were utilized in ANFIS to build the forecasting models.

4. Data Analysis and Interpretation

4.1. Data

In the current study, the authors consider the historical information from 1990 to 2018 to establish the prediction model of energy intensity for the top 5 ASEAN countries using two main variables, globalization and financial development. The information for energy intensity, globalization, and financial development was gathered from the World Development Indicator (WDI) database managed by the World Bank. The information on energy intensity was calculated by the ratio of energy supply and GDP (PPP—purchasing power parity). Moreover, energy intensity was measured in (megajoules/GDP = PPP). In addition, financial development was calculated by domestic credit to the private sector, measured as a percentage. The data for the globalization index were gathered from the website of the KOF Swiss Economic Institute (https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html) [40]. The importance of the KOF index is attributed to measuring globalization from multidimensional aspects. The current KOF index that is utilized in the present study measures a country's globalization in terms of three crucial prospects. These include the combination of indices reflecting social, economic, and political globalization of the country.

4.2. Results and Discussion

The results of descriptive statistics are reported in Table 1. There was a positive mean value for all variables in all top 5 ASEAN countries. Furthermore, the standard deviations of globalization, energy intensity, and financial development for all selected ASEAN countries were close to, 1 which means the data are close to the mean value. Also, the study used the Jarque-Bera (JB) test to check the normality of the data. The results of the JB test confirmed that energy intensity, globalization, and financial development in all top five ASEAN countries were non-normally distributed, indicating the existence of a nonlinear relationship among the variables in all selected ASEAN countries [41,42].

In this study, the authors further applied a unit root test to confirm the stationarity properties of the variables in all countries. In doing so, the present study used two novel unit root tests, the augmented Dickey Fuller and Phillip−Perron unit root tests and reported in Table 2 below. The results of the unit root tests confirmed the t-statistics, suggesting that energy intensity, globalization, and financial development showed non-stationary behaviour at level series (without differencing) in the top 5 ASEAN countries. However, the results further suggested that all variables showed stationary features in the first differential series. In summary, the outcomes confirmed a different order of integration, i.e., I (1) for energy intensity, globalization, and financial development in all selected ASEAN countries.

Next, to motivate the utilization of a novel nonlinear approach, the current study statistically examined the likelihood of a nonlinear relationship between energy intensity, globalization, and financial development for all selected ASEAN countries. In doing so, the authors adopted the Brock et al. [43] test on the residuals of the variable equation of the vector autoregressive model (VAR). The results of the BDS test are presented in Table 3; '*m*' in the first row refers to the embedded dimensions [44–46]. The outcomes confirmed the rejection of the null hypothesis of residuals at the 1% significance level across different dimensions. Technically speaking, the results confirmed the nonlinearities in energy intensity, globalization, and financial development for all selected ASEAN

countries. This was due to the extensive changes in economic and environmental conditions of the ASEAN nations in which globalization and financial growth behave irregularly.

Table 1. Results of Descriptive Statistics.

Country	N	Mean	SD	Min	Max	JB
Panel A: Energy Intensity						
Singapore	29	0.0045	0.1599	−0.1909	0.0478	18.173***
Malaysia	29	0.0054	0.1709	−0.1572	0.0484	12.863***
Thailand	29	0.0058	0.3486	−0.1526	0.0057	29.328***
Indonesia	29	0.0049	0.1305	−0.2674	0.0490	8.273**
Philippines	29	0.0051	0.1517	−0.1598	0.0461	8.382**
Panel B: Globalization						
Singapore	29	0.0037	0.1600	−0.1365	0.0461	21.393***
Malaysia	29	0.0043	0.1446	−0.6430	0.0448	19.384***
Thailand	29	0.0001	0.8025	−0.9119	0.0171	54.328***
Indonesia	29	0.0052	0.8400	−0.8380	0.0301	39.310***
Philippines	29	0.0028	1.2384	−0.8438	0.0365	22.938***
Panel C: Financial Development						
Singapore	29	0.0027	1.2310	−1.0837	0.0397	6.094**
Malaysia	29	0.0046	1.2970	−1.7900	0.0419	6.883**
Thailand	29	0.0038	1.8430	−0.8087	0.0575	47.382***
Indonesia	29	0.0019	1.0490	−0.9743	0.0304	83.981***
Philippines	29	0.0010	0.4730	−0.9112	0.0392	18.177***

*** and ** represent significance at 1% and 5%, respectively.

The results of Gaussian membership functions (MFs) are reported in Table 4. The outcomes of MFs for the ANIS model are the generated Gaussian MFs. The table shows that for the fuzzification phase, there were three etymological aspects as predictors, i.e., "lower", "middle", and "upper". The fuzzification was focused on creating Gaussian MFs of the ANFIS framework for "GLOB (globalization as a first predictor)" and "FIND (financial development as a second predictor)". For "lower", "middle", and "upper", the bands of predictor−1 were estimated as [1278, 2103], [2873, 5928], and [2273, 9846]. Furthermore, the bands of predictor−2 were estimated as [1093, 3348], [1442, 6983], and [1578, 10,836] for "lower", "middle", and "upper", respectively.

To determine the outcomes of ANFIS for the top 5 ASEAN countries, the interdependency of the globalization and financial development parameters and energy intensity was pictured and constructed on a surface design that is displayed in Figure 3. The figure explains the lingering functions for globalization and financial development against energy intensity. Moreover, the surface design displays the impact of globalization and financial development at the level of energy intensity. Figure 3 represents the dependence of the average energy intensity on globalization and financial development focused on the structure of the fuzzy guidelines for energy intensity forecasting. Furthermore, the colour in the graph describes the nature of the fuzzy inference system focusing on the globalization and financial development, the fuzzy guidelines, and energy intensity. In the case of Singapore, by increasing the globalization and financial development, energy intensity increased significantly, though this tendency was not similar for entire values of globalization and financial development. For instance, in the initial stage, when the globalization value (2.5–3.0) was small and the financial development value (4.6%–4.8%) was relatively high, the value of energy intensity was at its lowest. On the other hand, when the values of globalization (6.0) and financial development (6.2%) were

high, the value of energy intensity was also high, around (7.2 megajoules/GDP PPP). In conclusion, the results of ANFIS confirmed that the relationships between globalization, financial development, and energy intensity are strong and positive. The higher globalization and financial development reflect higher energy intensity in Singapore.

Table 2. Results of the Unit Root Test.

Countries	Variables	Augmented Dickey−Fuller Test				Phillip−Perron Test			
		I (0)		I (1)		I (0)		I (1)	
		C	C&T	C	C&T	C	C&T	C	C&T
Singapore	ENIT	−1.077	−1.204	−6.002	−6.988	−0.659	−0.954	−6.102	−6.171
	GLOB	−0.388	−0.456	−8.352	−8.359	−0.143	−2.266	−8.770	−8.918
	FIND	−1.423	−1.648	−11.721	−11.738	−2.041	−2.541	−11.201	−12.139
Malaysia	ENIT	−0.652	−1.545	−7.341	−7.303	−0.680	−1.608	−7.201	−7.139
	GLOB	−1.064	−1.874	−7.108	−7.106	−1.013	−1.838	−8.775	−8.299
	FIND	−0.238	−1.949	−8.996	−8.991	−0.293	−2.012	−9.044	−9.045
Thailand	ENIT	−0.155	−1.197	−5.252	−5.226	−1.349	−1.369	−5.322	−5.982
	GLOB	−0.170	−2.337	−14.456	−14.451	−0.039	−2.327	−11.239	−11.389
	FIND	−0.467	−2.162	−13.548	−13.623	−1.970	−2.062	−12.473	−12.583
Indonesia	ENIT	−0.238	−1.949	−8.996	−8.991	−0.293	−2.012	−8.044	−8.045
	GLOB	−1.192	−1.854	−8.806	−8.874	−1.035	−1.642	−7.211	−7.347
	FIND	−0.249	−2.009	−8.419	−8.444	−0.066	−1.875	−8.475	−8.347
Philippines	ENIT	0.100	−1.848	−7.838	−7.015	−0.999	−1.500	−7.759	−7.537
	GLOB	−0.590	−1.838	−9.208	−9.180	−0.614	−1.951	−9.387	−9.230
	FIND	−1.670	−1.121	−7.378	−7.350	−1.414	−1.522	−7.389	−7.111

In the case of Malaysia, by enhancing the globalization and financial development, energy intensity increased substantially; however, this propensity was not same for all parameters of globalization and financial development. For example, in the initial stage, when the globalization value (6.4–6.6) was small and the financial development value (7.9%–8.0%) was low, the value of energy intensity was also at its lowest (i.e., 3.5 megajoules/GDP PPP). The results at lower values confirmed that both factors are important and have equal importance in predicting energy intensity in Malaysia. Moreover, at higher values of globalization (financial development) and lower values of financial development (globalization), the colour bands confirmed that both variables increased the level of energy intensity in Malaysia. On the other hand, when the values of globalization (8.4) and financial development (8.7%) were high, the value of energy intensity was also high (4.1 megajoules/GDP PPP). In summary, the results of ANFIS showed that the associations between globalization, financial development, and energy intensity are strong and positive.

The results of Thailand are different in comparison to those of Malaysia. Overall, the globalization and financial development are increasing the level of energy intensity in Thailand; however, this portion was not equal for all values of globalization and financial development. For example, in the beginning phase, when the globalization value (1.6–1.8) was small and the financial development value (8.0%–8.1%) was low, the value of the energy intensity was also at its lowest (i.e., 2.6 megajoules/GDP PPP). However, at a higher value of globalization (i.e., 3.2–3.4) and lower value of financial development (i.e., 8.0%–8.1%), the value of the energy intensity was 2.6 megajoules/GDP PPP. The results confirmed that increasing globalization will have no significant impact on energy intensity if there is no change in the financial development of Thailand. On the other hand, when the value of globalization was 1.6–1.8 and the value of financial development was high (i.e., 8.6%–8.7%), the value of the energy intensity was 2.95 megajoules/GDP PPP. This finding indicates that financial development increases the level of energy intensity in Thailand. Generally speaking, the outcomes of ANFIS confirmed that globalization and

financial development both increased the level of energy intensity while the magnitude of financial development was higher compared to globalization in Thailand.

Table 3. Results of BDS test for nonlinearity.

Country	*m* = 2	*m* = 3	*m* = 4	*m* = 5	*m* = 6
Energy Intensity Equation Residual					
Singapore	27.978***	31.121***	33.921***	37.507***	41.680***
Malaysia	34.648***	37.185***	39.919***	43.344***	48.151***
Thailand	27.136***	31.334***	34.403***	38.892***	43.581***
Indonesia	42.643***	46.645***	50.765***	55.818***	62.354***
Philippines	59.698***	64.205***	69.575***	77.206***	87.592***
Globalization Equation Residual					
Singapore	11.820***	14.656***	15.531***	16.887***	18.622***
Malaysia	44.088***	47.856***	51.466***	56.478***	63.717***
Thailand	33.254***	36.615***	39.370***	42.723***	46.599***
Indonesia	19.772***	20.320***	20.834***	21.577***	22.686***
Philippines	12.703***	13.457***	13.589***	13.934***	14.599***
Financial Development Equation Residual					
Singapore	11.859***	31.121***	33.921***	37.507***	41.680***
Malaysia	15.776***	37.185***	39.919***	43.344***	48.151***
Thailand	17.505***	31.334***	34.403***	38.892***	43.581***
Indonesia	12.950***	46.645***	50.765***	55.818***	62.354***
Philippines	14.193***	64.205***	69.575***	77.206***	87.592***

*** represents significance at 1%.

Table 4. Generated Gaussian MFs of the ANFIS model.

Factor		Type	Generated Gaussian MFs of ANFIS for "Lower", "Middle" and "Upper"		
			Lower	Middle	Upper
Inputs (Predictors)	GLOB	Gaussian	"[1278, 2103]"	"[2873, 5928]"	"[2273, 9846]"
	FIND	Gaussian	"[1093, 3348]"	"[1442, 6983]"	"[1578, 10,836]"

The outcomes of Indonesia and the Philippines are quite similar and comparable to each other. The results of both countries suggest that globalization and financial development increase the level of energy intensity; however, the magnitude was not equal for all values of globalization and financial development. For instance, in the starting period, when the globalization value was 2.0–2.5 (1.6–1.8) and the financial development value was 5.5%–6.0% (5.4%–5.65%), the value of the energy intensity was also at its lowest, 0.8 (0.6) megajoules/GDP PPP for Indonesia (the Philippines). However, at the upper coefficient of globalization (i.e., 3.0–3.5) for Indonesia and (3.2–3.4) for the Philippines and at a low value of financial development (i.e., 8.0%–8.1%), the value of the energy intensity was 1 megajoule/GDP PPP for both countries. In addition, the same level of energy intensity was predicted by financial development in both countries. On the other hand, at upper values of globalization and financial development, the energy intensity value was 1.0 and 1.2 megajoules/GDP PPP for Indonesia and the Philippines, respectively. In summary, the results confirmed that globalization and financial development enhanced the level of energy intensity in both countries.
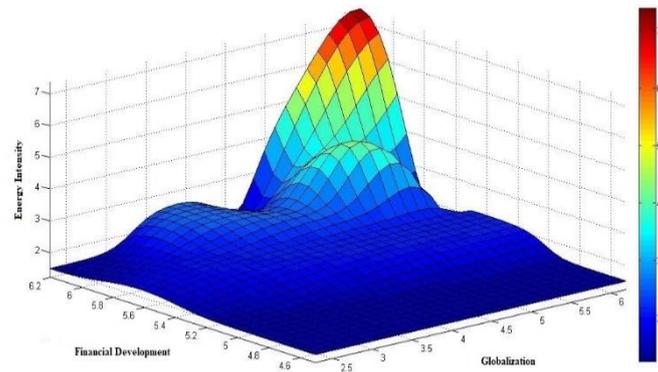
(i) Singapore
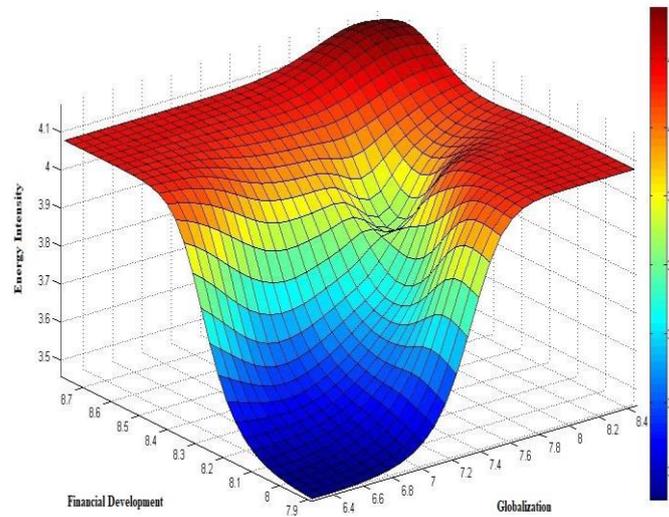
(ii) Malaysia
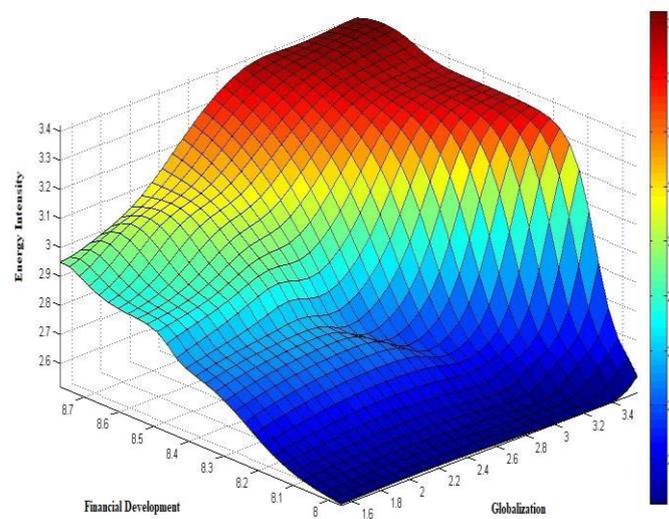
(iii) Thailand

Figure 3. *Cont.*
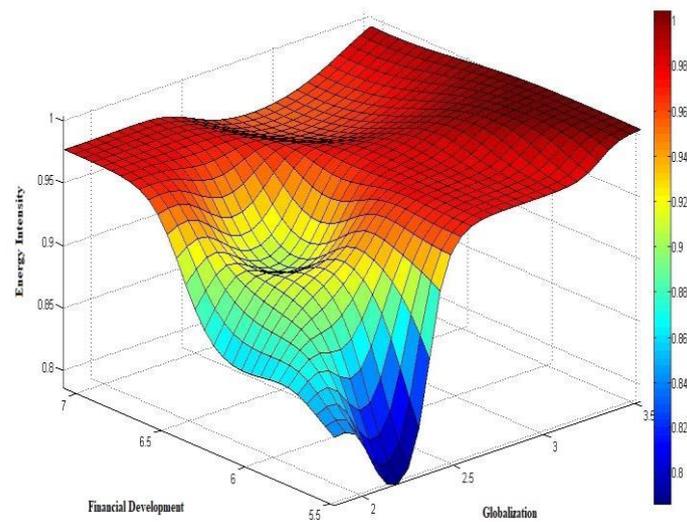
(iv) Indonesia
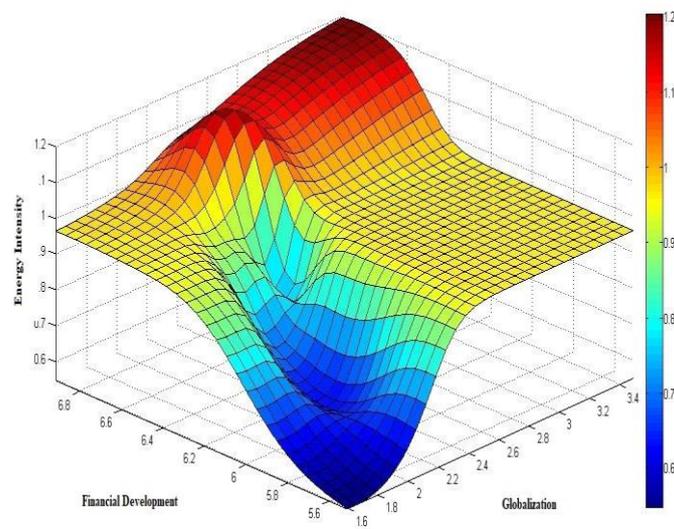
(v) Philippines

Figure 3. Energy Intensity prediction based on Globalization and Financial Development of Top 5 ASEAN Countries. Note: The X−axis represents the globalization index, the Y−axis shows financial development, and the Z−axis specifies energy intensity. Moreover, the blue colour shows the low magnitude, and the red colour describes the high magnitude of the relationship between the variables.

5. Conclusions and Implications

In the modern period, increased energy intensity has caused environmental degradation in terms of global warming. The augmented climate change is harmful to ecological conditions and natural habitats. In order to decrease the levels of global warming, all countries around the world are focusing on policies to curtail the energy footprint and explore the potential driver of energy intensity in the various economies. In this regard, the role of globalization significantly influences the levels of energy intensity in an economy. Another critical motivator of energy intensity is the advancements in a country's financial sector. Financial advancement regards the activities that can promote a

country's efficiency in banking, investments, and financial markets. The enhancement of the financial sector significantly drives a nation's economy and thereby augments energy intensity. Theoretically, the relationship between financial development and energy intensity is argued for having both negative and positive linkages. In this regard, the primary belief argues that the progress of financial collaborations in terms of institutions, financial markets, and foreign investments motivates extended lending to be domestic and motivates corporate purposes for financing energy-intensive products such as automobiles and machinery, thereby increasing energy utilization that negatively impacts the environment through more significant air and water pollution. Alternatively, the adherents of negative links insist that the advancements in the financial sector could offer a more significant opportunity to stimulate lending to green energy and deliver much needed funding to finance renewable ventures. In this way, the progress of financial intermediations can encourage ecologically supported projects at lower costs.

Given the situation, the current study aims to examine the link between globalization and financial advancements with the energy intensity of the top 5 ASEAN countries. The development structure of the ASEAN region is considered significant for having stable growth. In the last ten years, the developmental output in the region displayed a growth of 5.66 percent and reflected a higher growth pattern relative to the global growth of 2.76 percent during the period. In this study, the authors applied two traditional unit root tests, namely, ADF and PP. The results of the unit root tests confirmed that variables in all countries were stationary in the first differential series. In addition, the study also applied the BDS test to check the nonlinearity among the variables. The outcomes of the BDS test also confirmed that globalization, financial development, and energy intensity had a nonlinear feature for all countries, and this nonlinearity has proposed the application of ANFIS because it is also vital to resolve the econometric limitations in non-linear associations, considered efficient for analyzing non-linear behaviour. The results of ANFIS confirmed that globalization and financial development had a positive and significant impact on the energy intensity level in the top ASEAN countries. The results further revealed that globalization and financial development increased the level of energy intensity more in developed countries. For instance, the coefficient parameters for Singapore and Malaysia were 7.0 and 4.1 megajoules/GDP PPP, respectively. However, the value of the energy intensity in Indonesia and the Philippines was 1.0 and 1.2 megajoules/GDP PPP, respectively. The results of ANFIS emphasised that those countries that are more globalized and financially developed have more potential to increase the level of energy intensity. Therefore, the government needs to focus more renewable energy and environmentally friendly projects.

Considering the outcomes displayed above, the investigation of this study focused on the requirement for genuine collaboration among ASEAN countries in sharing technologies that diminish energy inefficiency in the future years. As financial growth and globalization keep on growing, the world's interest in reducing energy use will increase. This tendency should enhance the scope of genuine ecological worries if not tended to soon.

Moreover, government intercessions urge neighbourhood firms to make new position openings and to compete internationally and domestically, prompting an enhancement in the capital arrangement. It is currently acknowledged that investment increases financial development. To be sure, the effective utilization of investment builds growth that upgrades financial development, which thus prompts higher power utilization. Government and think-tankers ought to focus on the past communication networks and connections to screen energy utilization by utilizing accessible instruments, for example, taxes and endowments. The last option may likewise be utilized to facilitate investment in the economy. Governments should then utilize this investment in suitable ranges to advance financial development while checking energy utilization to control or reduce energy intensity in ASEAN countries.

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References

1. Shahbaz, M.; Solarin, S.A.; Sbia, R.; Bibi, S. Does energy intensity contribute to CO_2 emissions? A trivariate analysis in selected African countries. *Ecol. Indic.* **2015**, *50*, 215–224. [CrossRef]
2. Shahbaz, M.; Zakaria, M.; Shahzad, S.J.H.; Mahalik, M.K. The energy consumption and economic growth nexus in top ten energy-consuming countries: Fresh evidence from using the quantile-on-quantile approach. *Energy Econ.* **2018**, *71*, 282–301. [CrossRef]
3. Shahbaz, M.; Lahiani, A.; Abosedra, S.; Hammoudeh, S. The role of globalization in energy consumption: A quantile cointegrating regression approach. *Energy Econ.* **2018**, *71*, 161–170. [CrossRef]
4. Koengkan, M. Is the globalization influencing the primary energy consumption? The case of Latin America and Caribbean countries. *Cad. Unifoa* **2017**, *12*, 57–67.
5. Dogan, B.; Deger, O. How Globalization and Economic Growth Affect Energy Consumption: Panel Data Analysis in the Sample of BRIC Countries. *Int. J. Energy Econ. Policy* **2016**, *6*, 806–813.
6. Nasreen, S.; Anwar, S. Causal relationship between trade openness, economic growth and energy consumption: A panel data analysis of Asian countries. *Energy Policy* **2014**, *69*, 82–91. [CrossRef]
7. Shahbaz, M.; Shahzad, S.J.H.; Mahalik, M.K.; Sadorsky, P. How strong is the causal relationship between globalization and energy consumption in developed economies? A country−specific time−series and panel analysis. *Appl. Econ.* **2018**, *50*, 1479–1494. [CrossRef]
8. Shahbaz, M.; Mallick, H.; Mahalik, M.K.; Sadorsky, P. The role of globalization on the recent evolution of energy demand in India: Implications for sustainable development. *Energy Econ.* **2016**, *55*, 52–68. [CrossRef]
9. Destek, M.A. Financial development and energy consumption nexus in emerging economies. *Energy Sources Part B Econ. Plan. Policy* **2018**, *13*, 76–81. [CrossRef]
10. Sadorsky, P. Financial development and energy consumption in Central and Eastern European frontier economies. *Energy Policy* **2011**, *39*, 999–1006. [CrossRef]
11. Sadorsky, P. The impact of financial development on energy consumption in emerging economies. *Energy Policy* **2010**, *38*, 2528–2535. [CrossRef]
12. Chang, S.-C. Effects of financial developments and income on energy consumption. *Int. Rev. Econ. Financ.* **2015**, *35*, 28–44. [CrossRef]
13. Dasgupta, S.; Hong, J.H.; Laplante, B.; Mamingi, N. Disclosure of environmental violations and stock market in the Republic of Korea. *Ecol. Econ.* **2006**, *58*, 759–777. [CrossRef]
14. Alfaro, L.; Chanda, A.; Kalemli-Ozcan, S.; Sayek, S. FDI and economic growth: The role of local financial markets. *J. Int. Econ.* **2004**, *64*, 89–112. [CrossRef]
15. Hermes, N.; Lensink, R. Foreign direct investment, financial development and economic growth. *J. Dev. Stud.* **2003**, *40*, 142–163. [CrossRef]
16. Bailliu, J.N. *Private Capital Flows, Financial Development, and Economic Growth in Developing Countries*; Bank of Canada Ottawa: Ottawa, ON, Canada, 2000.
17. Rafindadi, A.A. Econometric prediction on the effects of financial development and trade openness on the German energy consumption: A startling revelation from the data set. *Int. J. Energy Econ. Policy* **2015**, *5*, 182–196.
18. Nuryartono, N.; Rifai, M.A. Analysis of causality between economic growth, energy consumption and carbon dioxide emissions in 4 ASEAN countries. *Int. J. Energy Econ. Policy* **2017**, *7*, 141–152.
19. Phong, L.H. Globalization, Financial Development, and Environmental Degradation in the Presence of Environmental Kuznets Curve: Evidence from ASEAN−5 Countries. *Int. J. Energy Econ. Policy* **2019**, *9*, 40–50.
20. Katircioglu, S.T. Revisiting the tourism-led-growth hypothesis for Turkey using the bounds test and Johansen approach for cointegration. *Tour. Manag.* **2009**, *30*, 17–20. [CrossRef]
21. Sharif, A.; Afshan, S.; Qureshi, M.A. Idolization and ramification between globalization and ecological footprints: Evidence from quantile-on-quantile approach. *Environ. Sci. Pollut. Res.* **2019**, *26*, 11191–11211. [CrossRef]

22. Mardani, A.; Van Fan, Y.; Nilashi, M.; Hooker, R.E.; Ozkul, S.; Streimikiene, D.; Loganathan, N. A two-stage methodology based on ensemble Adaptive Neuro-Fuzzy Inference System to predict carbon dioxide emissions. *J. Clean. Prod.* **2019**, *231*, 446–461. [CrossRef]

23. Buragohain, M.; Mahanta, C. A novel approach for ANFIS modelling based on full factorial design. *Appl. Soft Comput.* **2008**, *8*, 609–625. [CrossRef]

24. Putra, B.; Darwis, D.; Burhanuddin, B. ASEAN Political-Security Community: Challenges of establishing regional security in the Southeast Asia. *J. Int. Stud.* **2019**, *12*, 33–49. [CrossRef] [PubMed]

25. Mihaela, S. Competitiveness and economic growth in Romanian regions. *J. Compet.* **2016**, *8*, 46–60.

26. Rafiq, S.; Salim, R.; Nielsen, I. Urbanization, openness, emissions, and energy intensity: A study of increasingly urbanized emerging economies. *Energy Econ.* **2016**, *56*, 20–28. [CrossRef]

27. Adom, P.K. Asymmetric impacts of the determinants of energy intensity in Nigeria. *Energy Econ.* **2015**, *49*, 570–580. [CrossRef]

28. Murshed, M.; Jannat, F.T.; Amin, S. An Empirical Investigation of Globalization and Energy Consumption: Evidence from Bangladesh. *World J. Soc. Sci.* **2018**, *8*, 54–68.

29. Shahbaz, M.; Shahzad, S.J.H.; Alam, S.; Apergis, N. Globalisation, economic growth and energy consumption in the BRICS region: The importance of asymmetries. *J. Int. Trade Econ. Dev.* **2018**, *27*, 985–1009. [CrossRef]

30. Mahi, M.; Phoong, S.W.; Ismail, I.; Isa, C.R. Energy–Finance–Growth Nexus in ASEAN−5 Countries: An ARDL Bounds Test Approach. *Sustainability* **2020**, *12*, 5. [CrossRef]

31. Mahrinasari, M.S.; Haseeb, M.; Ammar, J. Is trade liberalization a hazard to sustainable environment? Fresh insight from ASEAN countries. *Pol. J. Manag. Stud.* **2019**, *19*, 249–259.

32. Rajiani, I.; Pypłacz, P. National culture as modality in managing the carbon economy in Southeast Asia. *Pol. J. Manag. Stud.* **2018**, *18*, 296–310. [CrossRef]

33. Saud, S.; Danish; Chen, S. An empirical analysis of financial development and energy demand: Establishing the role of globalization. *Environ. Sci. Pollut. Res.* **2018**, *25*, 24326–24337. [CrossRef] [PubMed]

34. Danish; Saud, S.; Baloch, M.A.; Lodhi, R.N. The nexus between energy consumption and financial development: Estimating the role of globalization in Next-11 countries. *Environ. Sci. Pollut. Res.* **2018**, *25*, 18651–18661. [CrossRef] [PubMed]

35. Islam, F.; Shahbaz, M.; Ahmed, A.U.; Alam, M. Financial development and energy consumption nexus in Malaysia: A multivariate time series analysis. *Econ. Model.* **2013**, *30*, 435–441. [CrossRef]

36. Shahbaz, M.; Lean, H.H. Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. *Energy Policy* **2012**, *40*, 473–479. [CrossRef]

37. Chong, S.S.; Aziz, A.A.; Harun, S.W.; Arof, H.; Shamshirband, S. Application of multiple linear regression, central composite design, and ANFIS models in dye concentration measurement and prediction using plastic optical fiber sensor. *Measurement* **2015**, *74*, 78–86. [CrossRef]

38. Mardani, A.; Streimikiene, D.; Nilashi, M.; Aranda, D.A.; Loganathan, N.; Jusoh, A. Energy Consumption, Economic Growth, and CO_2 Emissions in G20 Countries: Application of Adaptive Neuro-Fuzzy Inference System. *Energies* **2018**, *11*, 2771. [CrossRef]

39. Hellendoorn, H.; Thomas, C. Defuzzification in Fuzzy Controllers. *J. Intell. Fuzzy Syst.* **1993**, *1*, 109–123. [CrossRef]

40. Gygli, S.; Haelg, F.; Potrafke, N.; Sturm, J.E. The KOF Globalization Index−revisited. *Rev. Int. Organiizations* **2019**, *14*, 543–574. [CrossRef]

41. Mishra, S.; Sharif, A.; Khuntia, S.; Meo, M.S.; Khan, S.A.R.; Meo, S.A. Does oil prices impede Islamic stock indices? Fresh insights from wavelet-based quantile-on-quantile approach. *Resour. Policy* **2019**, *62*, 292–304. [CrossRef]

42. Sharif, A.; Shahbaz, M.; Hille, E. The Transportation-growth nexus in USA: Fresh insights from pre-post global crisis period. *Transp. Res. Part A Policy Pr.* **2019**, *121*, 108–121. [CrossRef]

43. Broock, W.A.; Scheinkman, J.A.; Dechert, W.D.; LeBaron, B. A test for independence based on the correlation dimension. *Econ. Rev.* **1996**, *15*, 197–235. [CrossRef]

44. Balcilar, M.; Bekiros, S.; Gupta, R. The role of news−based uncertainty indices in predicting oil markets: A hybrid nonparametric quantile causality method. *Empir. Econ.* **2017**, *53*, 879–889. [CrossRef]

45.　Jena, S.K.; Tiwari, A.K.; Hammoudeh, S.; Roubaud, D. Distributional predictability between commodity spot and futures: Evidence from nonparametric causality-in-quantiles tests. *Energy Econ.* **2019**, *78*, 615–628. [CrossRef]

46.　Rehman, M.U.; Apergis, N. Determining the predictive power between cryptocurrencies and real time commodity futures: Evidence from quantile causality tests. *Resour. Policy* **2019**, *61*, 603–616. [CrossRef]