Is Globalization Detrimental to CO2 Emissions in Japan? New Threshold Analysis

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Abstract: Using annual data 1970-2014, this paper examines the effects of globalization on CO_2 emissions in Japan while accounting for economic growth and energy consumption as potential determinants of carbon emissions. The structural breaks and asymmetries arising due to policy shifts require attention and hence an asymmetric threshold version of the ARDL model is utilized. The results show the presence of threshold asymmetric cointegration between the variables. The threshold-based positive and negative shocks arising in globalization increase carbon emissions, while the impact of the latter is more profound. Energy consumption (economic growth) also has a significant positive effect on carbon emissions. Globalization, economic growth and energy consumption significantly increase carbon emissions in the short run. We suggest that policy makers in Japan should consider globalization and energy consumption as policy tools while formulating their policies towards protecting sustainable environmental quality in the long run. Otherwise, the Japanese economy may continue to face environmental consequences such as undesirable climate change and massive warming at the micro and macro levels as a result of potential shocks arising from globalization and energy consumption.

Keywords: Carbon emissions, energy consumption, globalization, threshold NARDL

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1. Introduction

Globalization is a worldwide phenomenon that affects human welfare through its effects on the socio-economic-political aspects of human life [41]. It enhances economic welfare through trade, capital flows and the diffusion of culture and public policies. Globalization stimulates economic growth through financial and trade openness, but it has considerable environmental consequences across economies [36]. The process of achieving economic growth, expanding industrialization and urbanization requires more energy, which in turn degrades environmental quality through the discharge of both carbon dioxide (CO_2) and sulfur dioxide (SO_2) emissions into the atmosphere. In turn, environmental quality affects sustainable growth and development through the welfare-retarding channel.

Japan is the third largest economy, after the United States and China, and it is the second largest partner of the European Union (EU), after China. Japan and China account for more than one-third of the world's GDP. The EU attempted to negotiate a Free Trade Agreement (FTA) with Japan to promote sustainable economic development in both regions. To achieve sustainable economic development, the Japanese economy also requires a greater degree of globalization in the long run. Globalization not only helps the Japanese economy by stimulating financial development but enables it to achieve sustainable economic development through improvements in the quality of institutions [26]. However, although the Japanese economy has been industrialized, its urban economy now faces declining population growth, which may slow the growth of industry. The lower rate of industrial growth will not only hamper the process of rural-urban migration but also decrease the long-run economic growth of Japan. Therefore, it is now time for Japan to strengthen economic cooperation with the rest of the world, particularly China, the US, Europe and other growing Asian economies, to maintain its global trade and financial competitiveness. Moreover, the Japanese economy had a beneficial position for many years due to its trade surplus, with revenue generated by exports of goods and services that exceeded the costs of imports of goods and services. Currently, Japanese corporations are increasing the volume of their business activities but at the same time maintaining profitable growth due to growing trade openness with rest of the world. This implies that the profitable growth of the Japanese corporate sector not only depends on other nations but also that corporate output relies on imported energy and technology as inputs into economic activity [20]. In this context, it can be further argued that importing energy and technology may be good for corporate production and the expansion of economic activity in Japan but detrimental to the natural environment of developed countries like Japan, if imported energy and technology are not carbon emissions-free [30].

In terms of emissions, the US and EU are the second and third largest polluters, although Japan is not exceptional in this regard [51]. It is the world's fifth largest emitter of greenhouse gases, and it is expected to reduce its greenhouse gas emissions by 26% between 2013 and 2030, compared with an 18-20% reduction by the United States and a 24% reduction by the European Union. Japan plans to have nuclear energy account for 20 to 22% of its electricity mix in 2030, compared with 30% before the Fukushima nuclear incident. It has established targets for renewable energy at 22-24% of this electricity mix, liquefied natural gas (LND) at 27% and coal at 26%.

It is therefore important to ask whether additional globalization is harmful to the environment in the globalized and developed country of Japan. This is important primarily because findings regarding the globalization-emissions nexus can assist policy makers in controlling carbon emissions, using globalization as a policy tool. To answer this question, we examine the asymmetric long-run relationship between globalization (using a comprehensive index of globalization that encompasses three different dimensions of globalization) and carbon emissions through a different version of the multivariate Non-linear Auto Regression Distributed Lag (NARDL) framework proposed by Shin et al. [42], which we call the threshold NARDL. Notably, the relevant literature either relies on the assumption of strict linearity or uses the zero value of a variable as a reference point to account for positive and negative asymmetric shocks. We posit that potential asymmetries in carbon emissions and globalization may arise because of the complexity of economic systems, especially in countries like Japan. More specifically, carbon emissions primarily depend on macroeconomic factors (e.g., the phase of the business cycle and product market regulations), while energy consumption depends on domestic as well as global energy market conditions, and globalization is related to trade policies. Moreover, globalization may not harm the natural environment, and hence, carbon emissions are less likely if imported clean and energy-saving technology is used in production and consumption [30].

Supporting our threshold asymmetry hypothesis, we find that globalization increases emissions after crossing the threshold level of ± one standard deviation from the average level. Interestingly, negative threshold globalization shocks have a more profound positive impact on carbon emissions than positive threshold globalization shocks. Furthermore, economic growth reduces carbon emissions, but energy consumption raises CO_2 emissions and thereby decreases environmental quality[1].

The remainder of the paper is structured as follows. Section 2 presents a brief overview of related literature. Section 3 describes the methodology employed, and Section 4 interprets and discusses the empirical results. Section 5 concludes with key findings and policy implications for the Japanese economy.

2. A brief overview of related literature

In this section, we begin with an overview of related literature to identify the sources of CO_2 emissions (environmental degradation), including globalization, energy consumption and economic growth.

2.1. Environmental degradation-globalization

Globalization has helped both developed and developing economies grow faster and enhanced their foreign trade and investment [39]. In a globalized economic environment, developed countries can easily access labor at low wages from developing countries to enhance their production processes. Developing countries also receive environmental benefits from globalization via access to energy-saving advanced technology from developed nations. Moreover, globalization enables economies to achieve trade-related competitive advantages and higher growth [10, 30, 40]. In a study of the environmental impact of the North American Free Trade Agreement, Grossman and Krueger [11] report that the process of trade openness (globalization) may affect environmental quality through various channels. It may, for example, stimulate economic activity through trade, which induces CO_2 emissions globally and hence damages environmental quality. This channel is known as the *income effect* [5, 17]. Globalization also enables countries to access international markets for energy-efficient technologies, which can then be used to enhance domestic production without affecting energy use, reducing carbon emission levels [6, 7, 8]. This channel is called the *technique effect.* Werner et al. [50] and Liddle [23] recognized the potential role of the *technique effect*, through which trade openness (globalization) improves environmental quality. Finally, the structure of production can also change and thereby alter the capital-labor ratio, affecting environmental quality. This is called the *composition effect*. This effect impacts economic activity and carbon emissions due to the pollution intensity of the agricultural, industrial and services sectors. Carbon emissions start to rise as an economy moves from the

[1] The findings of this study are highlighted here. Interpretations of the findings are discussed in the results section.

agricultural to the industrial phase. As the economy then advances from an energy-extensive sector (i.e., the industrial sector) to a technology-intensive sector (i.e., the services sector), carbon emissions begin to decline [40]. Taken together, as Copeland and Taylor [6] noted, the environmental quality effect of globalization has not only varied across countries, depending upon their trade and environmental policies, but also emerged as a by-product of globalization.

Globalization tends to alter economic growth patterns, which in turn change the comparative advantages of trading partner countries. This change, called the *comparative advantage effect*, implies that globalization not only affects domestic production and energy use but also disturbs environmental quality through the *composition effect* and the *comparative advantage effect* [17, 48, 24]. Furthermore, globalization enables governments to change trade policies by reducing trade barriers to the import of energy-efficient technologies. Thus, globalization may indirectly affect environmental quality, ecological management practices, resource allocation and so on [37]. Cole [5] indicated that globalization assists economies, via institutional change, in acquiring energy-saving technologies, which not only improve energy efficiency but also lower carbon emissions.

Based on data from 98 countries, Lee et al. [22] recently investigated the relationship between trade openness and carbon emissions, with PM_{10} emissions used as a measure of environmental degradation. Their results reveal that trade openness decreases environmental quality. They find that high-income countries dump their pollution in low-income countries, due to strict environmental policies in developed countries, and that a feedback effect exists between trade openness and PM_{10} emissions. Dogan and Turkekul [9] investigate the validation of EKC by incorporating trade openness in carbon emissions for the US economy. They find that trade openness improves environmental quality by lowering CO_2 emissions in the presence of the EKC effect.

Few studies have used the globalization index, developed by Dreher [10], which combines economic, social and political globalization for reliable and consistent empirical findings. Shahbaz et al. [33] examine the relationship between globalization and carbon emissions for the global economy and find that globalization improves environmental quality by lowering CO_2 emissions. Shahbaz et al. [36] scrutinize the association between globalization (by separately considering the economic, social and political dimensions of globalization) and carbon emissions for the Indian economy. Their empirical findings reveal that globalization is detrimental to environmental quality. Using panel data for 255 countries, Lee and Min [21] examine the effect of globalization on carbon emissions, reporting that globalization benefits environmental quality. Shahbaz et al. [40] report that globalization is beneficial for environmental quality in the Chinese economy. Similarly, Shahbaz et al. [38] find that globalization is beneficial for environmental quality in the case of Australia. Recently, Shahbaz et al. [41] conclude that globalization deteriorates environmental quality via increasing carbon emissions and also supports globalization-driven carbon emissions hypothesis for the case of 25 developed economies.

Subsequently, Magani [25] utilized data of 63 developed and developing countries to empirically assess the impact of trade openness (globalization) on carbon emissions, finding that a 0.58% increase in carbon emissions is linked to a 1% increase in trade openness. Shahbaz et al. [34] found that trade openness (globalization) hampers environmental quality in the case of the Indonesian economy. In a similar vein, Shahbaz et al. [39], in a recent study, used data on 105 (high, middle and low income) countries to examine the impact of trade openness (globalization) on carbon emissions. They found that trade openness impedes environmental quality globally. They further report that trade openness does not benefit environmental quality among high-, middle- and low-income countries.

2.2. Environmental degradation-energy consumption-economic growth

Over the last four decades, the world economy has experienced substantial economic growth, with massive energy consumption. The impressive economic growth and increased energy demand, however, have come with environmental consequences [39]. The evidence of increasing carbon emissions linked to economic growth and energy consumption were first established in the seminal paper of Kraft and Kraft [19], in which they show that economic growth has been achieved with significant energy consumption, resulting in rising CO_2 emissions.[2] With respect to the environmental consequences of economic growth and energy consumption, Stern [44] intuitively argues that sustainable development is also hard to achieve without rising global warming and climate change. Therefore, the issue of economic growth and environmental degradation has attracted considerable attention among energy economists, environmentalists and policy makers in many countries, and the relationship between economic

[2] The existing literature on the nexus between energy consumption and economic growth is voluminous, with varying results across countries [1, 43].

growth and environmental quality has been studied extensively in the field of resource and energy economics under the umbrella of the Environmental Kuznets Curve (EKC) hypothesis. Grossman and Krueger [11], in their seminal paper, first examined the environmental implications of NAFTA within an economic growth framework. Grossman and Krueger postulated the '*EKC hypothesis*' of an inverted U-shaped relationship between economic growth and environmental quality. Selden and Song [31] proposed the inverted U-shaped EKC hypothesis that economic growth initially reduces environmental quality and then improves it, once the economy has achieved a threshold level of income.

Eventually, evidence of an inverted U-shaped relationship between economic growth and environmental degradation was found in various studies [32, 12, 46, 14, 49], although Kaufmann et al. [18] failed to find such a relationship. Recently, Shahbaz et al. [35] found evidence for the EKC hypothesis in the case of Romania, suggesting that economic growth plays a vital role in improving environmental quality in the latter stage of economic development. Additionally, energy consumption in their study was found to be a major contributor to environmental degradation. He [13] also found support for the EKC hypothesis in the Chinese economy. Jayanthakumaran et al. (2012) validated the EKC hypothesis in the case of China and India, with energy consumption found to positively impact the environment in both economies. Tiwari et al. [46] also validated the EKC hypothesis for the Indian economy. Although Shahbaz et al. [36] validated the EKC hypothesis in the long run, they also found a detrimental effect of economic growth and energy consumption on environmental quality in India. Finally, Yaguchi et al. [53] conducted a comparative analysis of China and Japan, finding evidence for the EKC hypothesis only for Japan.

3. Data and econometric framework

3.1. Data

Data on CO_2 emissions (in metric tons), energy use (in kg of oil equivalent), and real GDP (in local currency) are collected for the period between 1970 and 2014 from the World Development Indicators (CD-ROM, 2016). We use total population to transform CO_2 emissions, energy use and real GDP into per capita terms.[3] Data for the Konjunkturforschungsstelle (KOF) aggregate globalization index used in the literature on the economic, social and political dimensions of globalization were adopted from Dreher [10]. Following Dreher [10], economic globalization

[3] This study uses natural logarithms for all variables to reduce heteroscedasticity in the data series.

(EG) is understood through economic flows (i.e., trade flows, foreign direct investment and portfolio investment). Economic globalization (EG) can be further understood by examining the extent of restrictions on trade and capital flows. Dreher also defines social globalization (SG) in terms of the sharing of culture and language among countries. Finally, Dreher [10] uses the number of embassies in a country, a country's membership in international organizations, and its participation in UN Security Council membership and in international treaties to generate an index of political globalization (PG)[4].

The time trends of the variables are shown in Figure 1. CO_2 emissions show an abrupt increase beginning in 1988 and then a sudden drop in 2008; this motivates us to find possible determinants of variations in CO_2 emissions in the Japanese economy, using advanced econometric tools.

Figure 1. Trends in CO_2 Emissions, Real GDP, Energy Consumption and Globalization

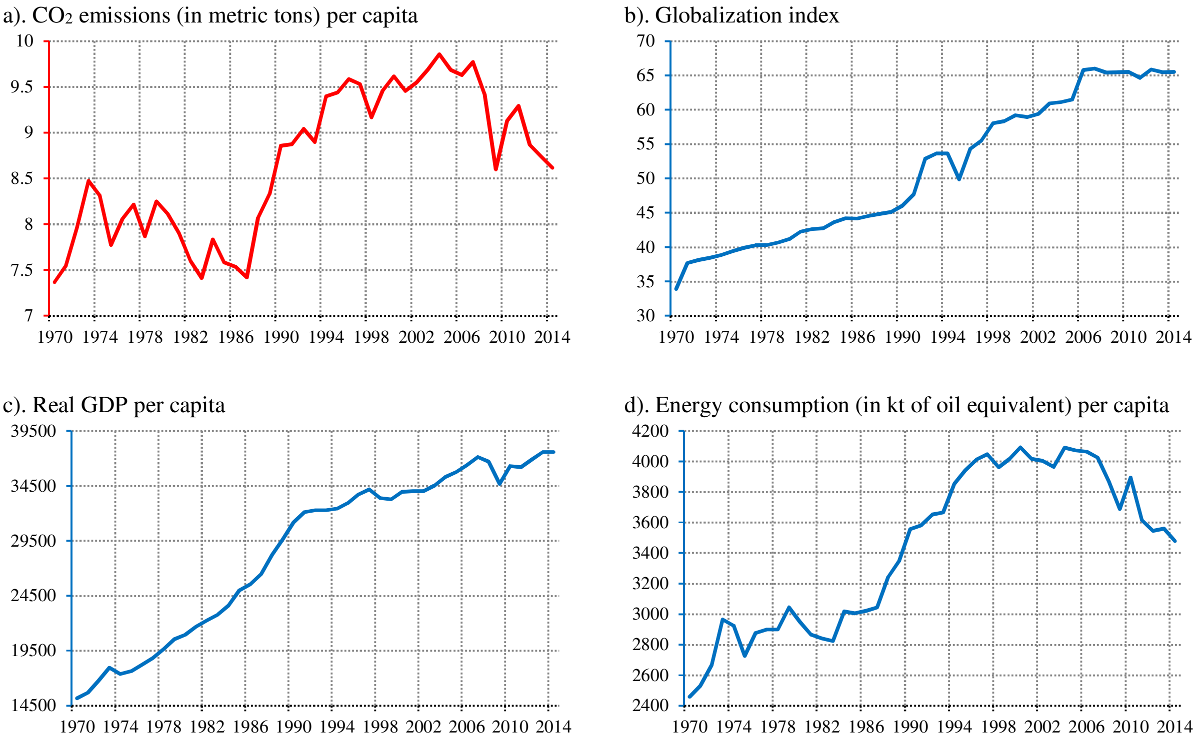


Table 1 presents descriptive statistics for the data. A distribution is termed symmetric if it is normally distributed, i.e., a bell-shaped curve, with the third and fourth moments (skewness and kurtosis) equal to zero and

[4] Please see: http://globalization.kof.ethz.ch/.

three, respectively. We find that variable distributions are asymmetric, i.e., skewed right or left and/or fat-tailed. The null hypotheses of the Jarque-Bera (J-B) test that time series are normally distributed is rejected for CO_2 emissions, globalization and energy consumption at the usual level of significance and are thus non-normal.

Table 1. Descriptive statistics

Variables	C_t	G_t	Y_t	E_t
Mean	8.6615	51.179	28641.9	3431.5
Maximum	9.8569	66.014	37595.1	4091.7
Minimum	7.3681	33.888	15161.7	2458.3
Std. Dev.	0.7922	10.342	7404.4	517.33
Skewness	-2.1244	1.1299	-0.4684	-2.1919
Kurtosis	4.6177	7.5178	1.6770	9.5752
J-B Stats	16.6987*	19.2456**	2.9269	17.0825**

Note: C_t, G_t, Y_t and E_t represent CO_2 emissions, globalization, economic growth and energy consumption, respectively. J-B stands for Jarque-Bera test of normality. ** and * indicate rejection of the null hypothesis of normality at 5% and 1% level of significance, respectively.

3.2. The NARDL and TNARDL models

We use a multivariate model to examine the effects of globalization, economic growth and energy consumption on CO_2 emissions in Japan by adopting the following general form of the carbon emissions function:

$$C_t = f(Y_t, E_t, G_t) \tag{1}$$

where C_t, Y_t, E_t and G_t represent CO_2 emissions, income, energy consumption and globalization, respectively. The long-run relationship between the variables is established through an asymmetric version of the autoregressive distributed lag model (NARDL), developed by Shin et al. [42]. The NARDL is superior to existing cointegration approaches for four reasons: (i) it allows us to determine the cointegration between CO_2 emissions and its determinants in the presence of asymmetries; (ii) it allows us to examine the impact of positive and negative globalization shocks on CO_2 emissions; (iii) it differentiates between short-run and long-run asymmetric impacts of globalization on CO_2 emissions; and (iv) it can be applied even if time series have mixed orders of integration, i.e., I(0) or I(1), allowing for flexibility in addressing long-run relationships [15].

The empirical equation of the asymmetric cointegration model is expressed as follows:

$$C_t = \beta_0 + \beta_1 G_t^+ + \beta_2 G_t^- + \beta_3 Y_t + \beta_4 E_t + \mu_t \qquad (2)$$

where the majority of the definitions are the same as above; however, globalization (G_t) is transformed by decomposing it into positive and negative partial sums, as in following equations:

$$G_t = G_0 + G_t^+ + G_t^- \qquad (3)$$

$$G_t^+ = \sum_{i=1}^{t} \Delta G_i^+ = \sum_{i=1}^{t} \max(\Delta G_i, 0) \qquad (4)$$

$$G_t^+ = \sum_{i=1}^{t} \Delta G_i^+ = \sum_{i=1}^{t} \min(\Delta G_i, 0) \qquad (5)$$

where Δ is the difference operator, $\Delta G_i = G_t - G_{t-1}$, and the $^+$ and $^-$ show the partial sums of negative and positive changes in globalization (G_t). The NARDL model proposed by Shin et al. (2014) represents the asymmetric error correction model as follows:

$$\Delta C_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i} \Delta C_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta G_{t-i}^+ + \sum_{i=0}^{0} \alpha_{3i} \Delta G_{t-i}^- + \sum_{i=0}^{p} \alpha_{4i} \Delta Y_{t-i} + \sum_{i=0}^{q} \alpha_{5i} \Delta E_{t-i} + \emptyset_1 C_{t-1} + \emptyset_2 G_{t-1}^+ + \emptyset_3 G_{t-1}^- + \emptyset_4 Y_{t-1} + \emptyset_5 E_{t-1} + \varepsilon_t \qquad (6)$$

where *m*, *n*, *o*, *p* and *q* are the lag orders of the variables. The lag order is chosen by using the Akaike Information Criterion (AIC), due to its superior explanatory power and properties. The model in equation-6 is estimated using ordinary least squares, and the null hypothesis of no asymmetric long-run relationship between the variables, $H: \phi_1 = \phi_2 = \phi_3 = \phi_4 = \phi_5 = 0$, is tested against the alternate hypothesis,

$H: \phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4 \neq \phi_5 \neq 0$, using the F-test. The critical values generated by Pesaran et al. [29] are used, and a long-run association between the variables is confirmed when the F-statistic is above the upper critical bound value. Following Banerjee et al. [2], we also apply a statistical t-test to the null hypothesis, $\emptyset_1 = 0$, against the alternative hypothesis, $\emptyset_1 > 0$; rejection implies a long-run association between the variables.

The short-run estimates are shown by α_i, while the long-run coefficients are represented by ϕ_i, where $i = 1...4$. The short-run analysis shows the immediate effect of globalization, economic growth and energy consumption on CO_2 emissions, while the long-run counterpart measures the time reaction and the speed of adjustment towards the equilibrium level. The Wald test is applied to examine the long-run ($\emptyset_2 = \emptyset_3 = 0$) and short-run asymmetry ($\alpha_2 = \alpha_3 = 0$) of globalization. The long-run asymmetric coefficients of positive and negative globalization shocks to CO_2 emissions are obtained as $L_{mi^+} = \emptyset_2/\emptyset_1$ and $L_{mi^-} = \emptyset_3/\emptyset_1$, respectively.

It is highly likely that CO_2 emissions may not be impacted by an average change in globalization. The NARDL framework uses the zero value change as a reference point to generate positive and negative shocks (see equation 3-5); however, globalization may impact CO_2 emissions when a globalization shock is substantial, which we define as a threshold level, namely, the average value of globalization ± one standard deviation. Accordingly, we decompose globalization into partial *m* sums, i.e., G_t^0, G_t^+ and G_t^-, as follows:

$$G_t = G_t^+ + G_t^0 + G_t^- \tag{7}$$

$$G_t^+ = \sum_{t-1}^{t} G_t^+ = \sum_{i-1}^{t} G_i * D\{G_i > (\mu + \sigma\} \tag{8}$$

$$G_t^0 = \sum_{t-1}^{t} G_t^0 = \sum_{i-1}^{t} G_i * D\{G_i > \{(\mu + \sigma) > G_i(\mu - \sigma)\} \tag{9}$$

$$G_t^- = \sum_{t-1}^{t} G_t^- = \sum_{i-1}^{t} G_i * D\{G_i < (\mu - \sigma\} \tag{10}$$

where σ and μ are the standard deviations and average values of globalization, respectively. D is a dummy variable that indicates whether the condition in {} is true or false. If the condition in {} is true, then D equals 1; otherwise, it equals 0. To present the decomposition of globalization into three splitting variables in the NARDL model, we employ the following empirical equation:

$$\Delta C_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i}\Delta C_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\Delta Y_{t-i} + \sum_{i=o}^{o} \alpha_{3i}\Delta E_{t-i} + \sum_{k=1}^{p}\sum_{i=0}^{q} \alpha_{ki}\Delta G_{t-i}(s_k) + \emptyset_1 C_{t-1} + \emptyset_2 Y_{t-1} + \emptyset_3 E_{t-1} + \sum_{k=1}^{r} \emptyset_k G_{t-1}(s_k) + \mu_t \tag{11}$$

where k represents the total number of partial sums. The model in equation-11 is estimated using OLS, and the null hypothesis, $H_0 : \phi_1 = \phi_2 = \phi_3 ..... = \phi_k = 0$, is tested against the alternate hypothesis, $H_0 : \phi_1 \neq \phi_2 \neq \phi_3 ..... \neq \phi_k \neq 0$, to ascertain long-run associations between the variables. The computed TNARDL F-statistic is compared to the critical bounds (lower and upper) developed by Pesaran et al. [29]. Long- and short-run asymmetries are examined using Wald tests.

Finally, the NARDL framework allows for estimation of asymmetric dynamic multiplier effects, with the short- and long-run response of CO_2 emissions to globalization shown as:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial C_{t+j}}{\partial G_t^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial C_{t+j}}{\partial G_t^-}, \text{ for } h = 0, 1, 2 .....$$

where $m_h^+ \rightarrow L_{mi^+}$ as $h \rightarrow \infty$, and $m_h^- \rightarrow L_{mi^-}$.

The estimation of multipliers helps us observe dynamic adjustments from the initial to the new equilibrium, given a unit shock to globalization in the carbon emissions function.

4. Empirical findings and discussion

The existing literature examines the relationship between CO_2 emissions and globalization in a linear framework. However, the linkages between the variables need not be linear but may exhibit a more complex nature, owing to potential asymmetries and regime shifts caused by unusual changes in economic market conditions. Hence, we first use the unit root test proposed by Narayan and Popp [28], which allows for two structural breaks at unknown locations in the deterministic components of a series to verify the order of integration of each series. Importantly, traditional unit root tests have low power when there are structural breaks in the data series. The results of the Narayan and Popp [28] unit root test with two structural breaks, reported in Table 2, reveal that all of the variables except globalization are non-stationary in the level, irrespective of whether one allows for breaks in the intercept only or breaks in the intercept and trend of each series. The null hypothesis of the unit root is rejected at the 5% level of significance for globalization, using the M1 model, which allows for two breaks in the intercept. The most important conclusion of the Narayan and Popp [28] unit root test is the confirmation of structural breaks in the time series data, which provides an early indication of the asymmetric behavior of time series. The outcomes of linear models may thus be biased.

Table 2. Results of the Narayan and Popp (2010) unit root test with two structural breaks

	Model M1				*Model M2*			
	Test Statistics	TB1	TB2	*k*	Test Statistics	TB1	TB2	*k*
Panel A: Level series								
C_t	-3.964	1987	1993	0	-4.182	1987	1997	0
G_t	-5.221^{**}	1991	1994	0	-2.295	1991	1995	1
Y_t	-1.769	1987	1997	0	-3.829	1987	1997	0
E_t	-1.618	1983	1987	2	-4.557	1983	1997	0
Panel B: First difference series								
C_t	-8.163^{***}	1987	1997	1	-7.457^{***}	1983	1987	1
G_t	-5.581^{***}	1991	1995	0	-10.84^{***}	1991	1994	0
Y_t	-6.608^{***}	1992	1997	0	-7.420^{***}	1991	1997	0
E_t	-8.016^{***}	1983	1987	1	-7.276^{***}	1983	1997	1

Note: This table displays the results of the Narayan-Popp unit root test for the model M1 and M2 as explained in Narayan and Popp (2010). The model M1 (M2) assumes two structural breaks at unknown dates in the level (level and slope) of each series. The test statistics for the null hypothesis of a unit root are presented for both the series in the level. The critical values for the model M1 are -5.259, -4.514 and -4.143 at the 1%, 5% and 10% significance levels, respectively. The critical values for the model M2 are -5.949, -5.181 and -4.789 at the 1%, 5% and 10% significance levels, respectively. These critical values have been collected from Narayan and Popp (2010) based on 50,000 replications for a sample size of 50 observations. TB1 and TB2 are the dates of the structural breaks selected according to the sequential procedure discussed in Narayan and Popp (2010) and *k* stands for the optimal lag length obtained by using the procedure suggested by Hall (1994) and Narayan and Popp (2010). Following Narayan and Popp (2010), a trimming percentage of 20 is used, that is, the breaks are only searched in the interval [0.2T, 0.8T]. As usual, the asterisks *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Due to the presence of structural breaks in the time series variables, we use the BDS test [3] to investigate possible nonlinearities in the residuals of the linear equation, equation-1, relating CO_2 emissions and globalization, while controlling for the effects of income and energy consumption. The results, reported in Table 3, reject the null hypothesis that the residuals are independently and identically distributed (*i.i.d*). This implies that there is remaining dependence and an omitted non-linear structure not captured by the linear specification and hence non-linearity in the data. Thus, a dynamic asymmetric framework that can capture the structural changes and non-linear relationship between CO_2 emissions and globalization is essential.

Table 3. [Brock *et al.* (1996)] BDS Test

Variables	m=2	m=3	m=4	m=5	m=6
C_t	0.9925	2.1326**	2.8314***	2.3822**	1.6717
G_t	2.1097**	2.0570**	2.2221**	2.3119**	1.9870**
Y_t	1.1325	2.1411**	2.1128**	1.9609*	1.9679*
E_t	0.3923	1.2159	1.9778**	1.6613*	1.7420*

Note: The entries indicate the BDS test based on the residuals of a VAR for all selected variables. m denotes the embedding dimension of the BDS test. *** indicates rejection of the null of residuals being *iid* at 1% levels of significance.

The preliminary analysis shows that globalization is stationary at levels, with two structural breaks in the intercept, and that the relationship between the variables in equation-1 is asymmetric. Hence, we apply the NARDL and threshold NARDL models to ascertain an asymmetric long-run association between CO_2 emissions and globalization while using income and energy consumption as control variables in the carbon emissions function. The results of the NARDL model (as per the specification in equation-6), with the globalization variable split into positive and negative shocks, are reported in columns 1-3 of Table 4. The value of the F-statistic (3.3231) is lower than the upper critical bound (5.060) value, according to Narayan [27]. Furthermore, there is no significant difference between the coefficients associated with positive and negative globalization shocks, as the Wald test ($\emptyset_2 = \emptyset_3$) is statistically insignificant. Thus, the asymmetric effect of globalization on CO_2 emissions could not be established when globalization is split into positive and negative shocks, using zero as the reference point. The diagnostic tests (lower panel of Table 4) also indicate that the model residuals exhibit heteroskedasticity (χ^2_{HET}) and are not normally distributed (χ^2_{NORM}). Furthermore, the cumulative sum of recursive residuals (CUSUM) and the CUSUM of squared plots (Figure 2a) show that the NARDL model is not a good fit and hence unstable.[5]

Table 4. Dynamic nonlinear analysis for CO_2 emissions using different models

Model 1: NARDL			Model 2: Threshold NARDL		
Dependent Variable =ΔC_t					
Variable	Coeff.	S.E	Variable	Coeff.	S.E
Const.	-1.1487**	(0.4720)	Const.	-2.7965***	(0.7648)
C_{t-1}	-0.4984***	(0.1370)	C_{t-1}	-0.6194***	(0.1428)
Y_{t-1}	-0.1714***	(0.0590)	Y_{t-1}	-0.1671**	(0.0689)
E_{t-1}	0.4816***	(0.1312)	E_{t-1}	0.7095***	(0.1434)
G^+_{t-1}	0.1330*	(0.0775)	G^+_{t-1}	0.5501***	(0.1698)
G^-_{t-1}	0.1896	(0.2562)	G^-_{t-1}	1.0384***	(0.3560)
			G^0_{t-1}	-0.1267	(0.1714)
ΔE_{t-1}	0.8451***	(0.0929)	ΔE_{t-1}	0.7085***	(0.1057)
			ΔY_t	0.3511**	(0.1464)
ΔY_{t-1}	0.2942*	(0.1540)	ΔY_{t-1}	0.4335**	(0.1940)
			ΔG^+_t	0.3050*	(0.1661)
			ΔG^-_t	0.5713*	(0.3360)
Long-run estimates					
L^+_G	3.0749	[0.0883]	L^+_G	0.8881	[0.0018]
L^-_G	0.5805	[0.4673]	L^-_G	1.6765	[0.0087]
			L^0_G	-0.2047	[0.4654]
Model diagnostics					
Adj. R^2	0.7229		Adj. R^2	0.7591	
χ^2_{SC}	0.7343	[0.4001]	χ^2_{SC}	0.6161	[0.3998]
χ^2_{FF}	0.5761	[0.7493]	χ^2_{FF}	1.2027	[0.5480]
χ^2_{HET}	2.5923	[0.0403]	χ^2_{HET}	0.7855	[0.5894]
χ^2_{NORM}	2.6761	[0.0642]	χ^2_{NORM}	0.0108	[0.9178]
CUSUM	Unstable		CUSUM	Stable	
$CUSUM^2$	Unstable		$CUSUM^2$	Stable	
F-bounds and Wald tests					
Null: $\emptyset_1 + \emptyset_2 + \emptyset_3 + \emptyset_4 + \emptyset_5 = 0$			Null: $\emptyset_1 + \emptyset_2 + \emptyset_3 + \emptyset_4 + \emptyset_5 + \emptyset_6 = 0$		
3.323			6.008***		
Null: $\emptyset_2 = \emptyset_3$			Null: $\emptyset_4 = \emptyset_5 = \emptyset_6$		
0.083			3.763***		
			Null: $\emptyset_4 = \emptyset_5$		
			3.454***		

Note: The superscript "+" and "-" denote the positive and negative cumulative sums, respectively. L^+ and L^- are the estimated long-run coefficients associated with the positive and negative changes, respectively, defined by $L_{mi^+} = \emptyset_i/\emptyset_1$. χ^2_{SC}, χ^2_{FF}, χ^2_{HET}, and χ^2_{NORM} denote the LM tests for serial correlation, functional form, heteroscedasticity and normality, respectively. The values in [ ] are the p-values. S.E stands for the standard errors. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

[5] CUSUM and CUSUM squared tests of Brown et al. [4] were used to test the constancy of the estimated parameters in NARDL model.

As highlighted above, globalization may not impact CO_2 emissions when the variations in the time series are within an average range; therefore, we now use the threshold version of the NARDL model, as specified in equation-11. The results of the threshold NARDL model are reported in the last three columns (4-6) of Table 4. The presence of a long-run relationship is established using the F-test, which yields a value (6.008) that exceeds the upper critical bound test value of 5.060. The statistical significance of the threshold NARDL model, using a bound testing procedure, supports our argument that globalization impacts CO_2 emissions after crossing the threshold level of ± one standard deviation from the mean. The difference between the coefficients for average, positive and negative globalization shocks ($\emptyset_4 = \emptyset_5 = \emptyset_6$) is found to be statistically significant. Additionally, the magnitude of positive and negative globalization coefficients ($\emptyset_4 = \emptyset_5$) is significantly different, as the Wald test is significant at the 1% level.

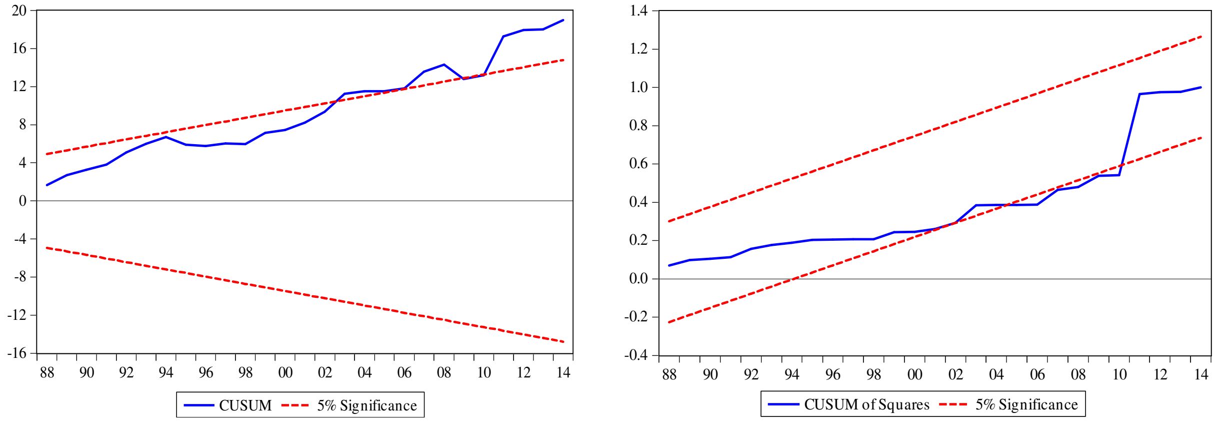
The long-run impact of negative globalization shocks (1.6765) is higher than that of positive globalizations shocks (0.8881), while average changes do not impact carbon emissions in Japan. Overall, globalization decreases environmental quality in Japan. Globalization increases foreign investment in the host economy, and foreign investors may exploit natural resources through low-cost production techniques in the interest of higher profits. The practice of exploiting natural resources not only limits their availability but also impacts the quality of the environment in the host economy [36]. In this case, it can be argued that the deterioration in environmental quality may be due to weak implementation of environmental regulations in Japan. Similar findings are reported by Shahbaz et al. (2015) for the Indian economy, although the impact of globalization is not threshold specific in their case. Furthermore, a 1% increase in income reduces CO_2 emissions by 0.1671%, with other factors remaining constant, indicating that a higher income level improves environmental quality in Japan via reductions in carbon emissions. This finding is not consistent with the result of Shahbaz et al. [36], who find that a higher income level decreases environmental quality for the Indian economy via an increase in carbon emissions. The finding that income boosts environmental quality also indicates that Japanese residents with high education levels have greater respect for environmental quality. Better environmental quality results in sustainable livelihoods for the people of Japan in the long run. In other words, a high education level—a product of human capital formation—results in a high income level, which provides an opportunity for people in Japan to improve the quality of the environment, which is key to survival. As Japan is a developed economy, it is also possible for the Japanese government to raise people's awareness of the need to care for and improve environmental quality for the sustainability of livelihoods. The consequence of environmental degradation is expected to be greater for the Japanese people if healthy environmental quality is not maintained over the long run. However, energy consumption has a positive and statistically significant effect on CO_2 emissions. When all other factors remain the same, a 1% increase in energy consumption is associated with a 0.7095% increase in CO_2 emissions in Japan.

In the short run, both positive (0.305) and negative (0.571) globalization shocks positively impact carbon emissions. Higher income also increases CO_2 emissions in the short run (by 0.3511 and 0.4335 for the first and second year lags, respectively). Energy consumption is also positively (0.708) linked with CO_2 emissions. Energy consumption, as an indicator of national income and growth, is more detrimental to long-run environmental quality in Japan because it releases CO_2 emissions into the atmosphere. Moreover, the Japanese energy consumption mix is changing as the country imports less oil and Liquefied Natural Gas (LNG) and more coal. Its utilities continue to increase the use of the cheapest but dirtiest fossil fuel, increasing coal imports to record levels. From a policy perspective, the Japanese government must be cautious regarding the use of massive amounts of energy or seek to foster competition to improve economic development. Otherwise, the Japanese economy will face the environmental consequences of massive energy consumption, harming current and future generations. The diagnostic tests indicate that there are no issues of serial correlation or heteroskedasticity. The functional form is well specified, and model errors are normally distributed. The model is also stable, as shown by the CUSUM and CUSUM of squared plots in Figure 2 (b).

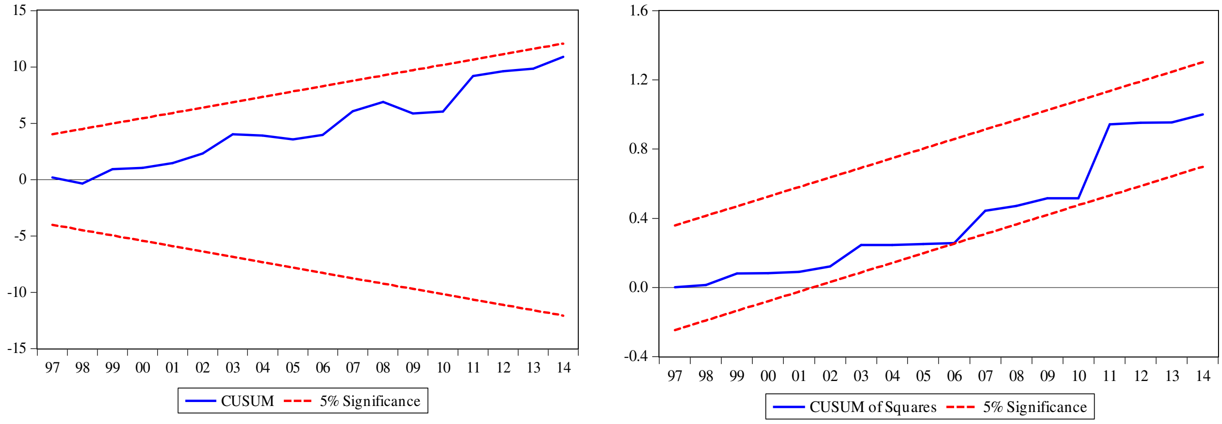
<< Insert Table 4 here please>>

Figure 2 (a, b). CUSUM and CUSUM Squared plots

a). NARDL specifications

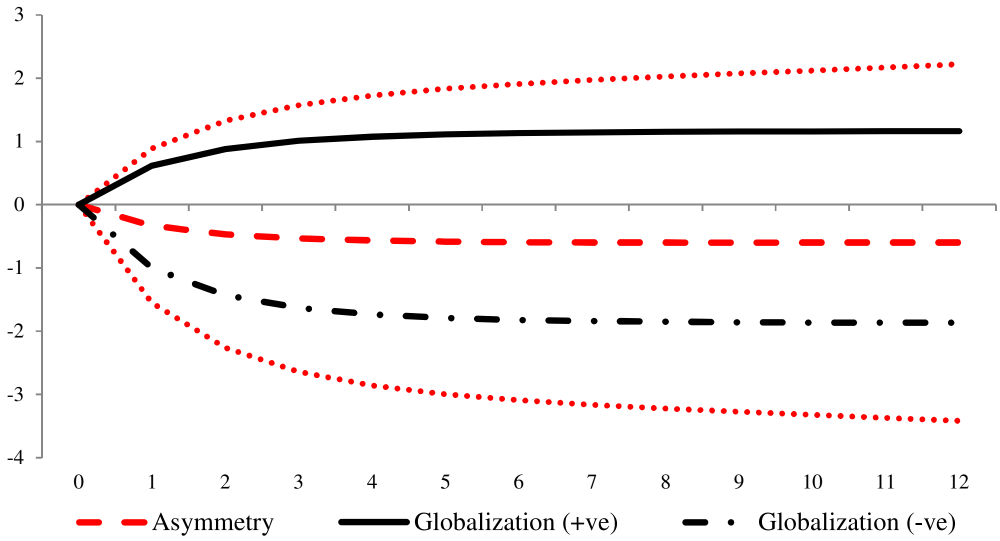


b). Threshold NARDL specifications



Finally, to understand the asymmetric adjustments from an initial long-run equilibrium to a new long-run equilibrium after a negative or positive unit shock, we plot the dynamic multipliers for the threshold NARDL model in Figure 3. The asymmetry curves depict the linear combination of the dynamic multipliers associated with positive and negative globalization shocks. The positive and negative change curves provide information about the asymmetric adjustment of CO_2 emissions to positive and negative globalization shocks, respectively, at a given forecasting horizon. The lower band and upper band (the dotted red lines) for asymmetry identify the 95% confidence interval. The overall impression is that negative globalization shocks have a more profound impact on CO_2 emissions in the long run than positive globalization shocks, i.e., there is a negative long-run threshold asymmetry. The long-run equilibrium is achieved in a two-year time period.

Figure 3. CO_2 – Globalization Dynamic Multiplier (LR and SR asymmetry)



Note: This figure plots the multiplier's effect of globalization on carbon emissions. The vertical axis shows the magnitude of the effect and on the horizontal axis are the years to achieve the long-run equilibrium relationship.

5. Conclusion and Policy Implications

We explore the determinants of CO_2 emissions for an advanced globalized economy such as Japan, focusing on both trade and financial competitiveness over a given time period. The Japanese economy has been in a phase of unstable macroeconomic conditions, with low and negative economic growth, very high external debt (as a percentage of GDP), rising energy imports (particularly coal), and massive deflation. Given the instability of this economy in terms of macroeconomic variables, it is of interest to evaluate the dynamic evolution of environmental quality in Japan. We believe our study is the first to explore the asymmetric association between globalization and CO_2 emissions while incorporating energy consumption and economic growth as additional factors in the carbon emissions function. We use a threshold NARDL (TNARDL) cointegration model to examine the effects of positive and negative shocks of globalization on CO_2 emissions.

We note that both positive and negative shocks arising from globalization increase CO_2 emissions in the long run, while the latter have a more profound impact on carbon emissions. Economic growth increases CO_2 emissions. Energy consumption is also positively linked to carbon emissions. All three selected variables positively impact carbon emissions in the short run. Both globalization and energy consumption play vital roles in driving the dynamics of CO_2 emissions in the Japanese economy. The Japanese economy uses increased energy to bolster economic growth, but this growth is achieved at the expense of environmental quality. Furthermore, higher income improves environmental quality via better education and improved skills, and increases in income may enable people to spend more money on energy-saving technologies. We suggest that policy makers in Japan consider both globalization and energy consumption as ''policy tools'' while formulating policy geared towards sustaining environmental quality in the long run. Without it, it is believed that the Japanese economy may continue to face the long-run consequences of undesirable climate change and massive warming, with negative effects on animals and human beings throughout the planet.

On a final note, this study also suggests that future research on the energy sector should focus on income inequality, financial development and urbanization in explaining energy emissions at the national and state levels, focusing on various sectors/industries in Japan. Micro-level emissions data are needed to fulfil this purpose. However, both national and micro-level studies would be of interest for energy policy design geared towards achieving '*sustainable development'* and averting rising temperatures and climate change disasters in Japan. Because the Japanese economy is one of the most advanced and globalized economies, it is also essential that future researchers need to examine the effects of carbon emissions and specific energy sources (e.g., renewable energy and non-renewable energy) on globalization, both in the short run and long run [30]. Although we have empirically studied the impact of globalization on CO_2 emissions, linking globalization to renewable energy and non-renewable energy along with the level of economic development is a newly emerging research gap and is likely to add a new trade policy perspective to the environmental and energy economics literature.

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