Is Causality between Globalization and Energy Consumption Bidirectional or Unidirectional in Top and Bottom Globalized Economies?

Muhammad Shahbaz
Montpellier Business School
Email: muhdshahbaz77@gmail.com

Mehmet Balcilar
Department of Economics
Eastern Mediterranean University
Famagusta, North Cyprus, via Mersin 10, Turkey;
Montpellier Business School, Montpellier, France;
University of Pretoria, Pretoria, South Africa
Email: mehmet@mbalcilar.net

Mantu Kumar Mahalik
Department of Humanities and Social Sciences
National Institute of Technology (NIT), Rourkela, Odisha, India
Email: mahalikm@nitrkl.ac.in

Seyi Saint Akadiri
Department of Economics, Eastern Mediterranean University
seyi.saint@emu.edu.tr

Abstract: By using quarterly data over the period 1970Q1-2015Q4, this paper examines the dynamic causal relationship between globalisation and energy consumption by using rolling and recursive rolling Granger causality methods. This study is pioneering effort to examine the dynamic causal relationship between globalization and energy consumption using time-varying Granger causality tests for 20 top and bottom globalized economies. The empirical results reveal that, the dynamic causality relationship between globalisation and energy consumption is time-varying. Although, causal relationship could not be observed for some of the study periods, bidirectional causality is found in many sub-samples. From the empirical findings, we observe that unidirectional causality running from globalisation to energy consumption has grievous impact on trade and environmental quality. In general, our empirical results resonate with the previous findings of globalisation-energy driven hypothesis, with significant policy implications for top and bottom globalized countries.

Keywords: Globalization, Energy Consumption, Time-Varying Granger Causality
JEL Codes: C22, F49, Q43

1. Introduction

In the past, it was the case that most national economies were relatively self-contained but not even in the part of cross-border transaction of goods, services and energy which are required for their development (Shahbaz et al. 2017). With massive globalisation of the 21st century, most of the economies are interconnected socially, economically and politically (Shahbaz et al. 2015). Globalisation is understood as a worldwide phenomenon that affects socio-economic and political aspects of human life. It also enhances prosperity of a nation via trade, capital flows and diffusion of culture and public policies (Shahbaz et al. 2017). Given that there are notable reasons why one would be interested in studying the causal linkage between globalisation and energy consumption in developed countries. The globalisation has also been a steppingstone for the growing linkage between economic activity and energy consumption. On account of growing globalisation with scale effect, nations are highly interconnected and desperate to compete with each other by expanding their economic activity. The increased economic activity requires more usage of energy which has larger environmental consequences in terms of global warming and climate change. This concludes that energy consumption is the cause of increased economic activity via the stimulating role of globalization (Cole, 2006). In line with technique effect, globalization enables economies to reduce the usage of energy by importing advanced low-cost energy-saving technology into the consumption and production activities (Dollar and Kraay, 2004). In a similar vein, Antweiler et al. (2001) argued that the use of low-cost energy-saving technology will not only enhance economic growth but it also will create less carbon emissions for the atmosphere where the future generations usually live. Finally, the composite effect of globalisation helps countries to reduce energy consumption while expanding their economic activity (Stern, 2007). In addition, globalisation enables an economy in shifting the production process from agriculture to industry and eventually to service sectors and thereby it requires less usage of energy resulting in better environmental quality (Jena and Gote, 2008).

Dreher (2006) in his seminal work argued that countries with greater degree of globalisation are capable of enhancing their growth in the long run. This implies that globalisation plays a vital role in the promotion of economic growth besides shaping economies and societies (Dreher 2006, Hill 2006). Environmental degradation is also another important reason to study the effect of globalization on energy demand in developed countries. Recently, few studies for the case of developed and developing countries found that globalization is harmful for the environmental quality via increasing energy consumption (Shahbaz et al. 2015, 2017). The environmental impacts of trade liberalization have been recently studied in energy economics literature (Copeland and Taylor 1994, 2004, Copeland 2005, Baek et al. 2009). Moreover, the role of globalization on the evolution of energy demand has also been examined for the developed and developing countries (Shahbaz et al. 2016, 2017). The recent study by Shahbaz et al. (2016) argued that globalization helps the Indian economy in reducing energy demand. This is not consistent with the recent finding of Shahbaz et al. (2017) in which they also argued that globalization increases energy consumption for most of the developed countries. Though the findings are mixed, but the role of globalization on the dynamics of energy demand cannot be ignored because of the fact that it is considered as an important determinant in affecting energy consumption for developed and developing countries as well. Subsequently, the extent to which both globalisation and energy consumption are related that not only creates a trade and environmental policy implications but also raises a research question: what types of causal direction (bidirectional or unidirectional) between globalisation and energy consumption for developed countries? It is important for the researchers to find an answer to this research question because the nature of causal linkage between the series has the policy implications for trade and environment in developed countries of the world.

Subsequently, it is also important for the researchers and policymakers to understand the causal effect of energy demand on globalisation for developed and developing countries in an era of competitive and changing world. In this line, the recent study by Rehman and Miah (2017) argued that globalisation can also be driven by energy demand. Since developed countries are more regulated than that of developing countries in addressing the issues related to climate change and environmental degradation, the flow of goods produced from using low carbon emitting technologies is expected to be high between the countries. This shows the positive relationship between energy demand and globalization for developed countries, further indicating that energy consumption does not discourage greater trade policy among the countries. Increased energy demand also induces many developing countries to get more integrated into the global energy systems and, hence, promoting globalization. In contrast, the inverse relationship between energy demand and globalization which shows that if a country produces energy that has high emitting carbon emissions, and then it does not encourage flow of goods and services with other countries. This is because the commodity produced from high carbon emitting technologies will damage the environmental quality of commodity importing countries. In such situation, the commodity producing countries have to sacrifice the growth of globalization for the sake of environmental quality of own country along with imported countries. This broadly shows that developed countries are ready to sacrifice the usage of high carbon generating energy and growth of globalization in the question of sustainable and green environmental quality. Overall, if the developed countries are more concerned about globalization and economic development, then they are less compromising in the question of using high carbon emitting energy in production and consumption activities. This theoretical understanding provides a scope for our study is to examine the causal impact between globalization and energy demand in case of developed countries.

Besides, economic causalities are built on economic theory to deduce the direction of dynamic causality between variables and to execute empirical examination of causal hypotheses. However, there seems to be no appropriate theoretical basis in most of these studies in determining empirical causal relationship between variables that seems to be jointly determined overtime. Therefore, there are difficulties in test execution, empirical interpretation and policy implication formulations. This is also applicable in the case of globalization-energy consumption relationship. Since, there is no straightforward theoretical economic model that exist on the relationship between globalization and energy consumption, the few existing studies usually applied Granger causality analysis to examine the dynamic relationship between globalization and energy consumption. The Granger causality test has been frequently used in the previous studies relatively because the empirical analysis do not take into considerations impact of structural breaks in the model, they are rather focus on stochastic properties of the variables. According to Stock and Watson (1989), Thoma (1994), Swanson (1998), Stern (2000), Psaradakis et al. (2005), Balcilar et al. (2010), Balcilar and Ozdemir (2013a), Arora and Shi (2015), Shi et al. (2006) and Hurn et al. (2016) Granger causality test may be reactive to estimation time span, which also appears to be the case for existing studies that has investigated Granger causality between globalization and energy consumption.

In existing literature, several approaches have been employed to integrate time-varying feature of the Granger causality relationship between time series variables. First of its kind is forward expanding window form of causality test proposed by Thoma (1994), Swanson (1998). Second, the rolling causality test of Swanson (1998), Balcilar et al. (2010), Balcilar and Ozdemir (2013a) and Arora and Shi (2015). Third, the recursive rolling causality test as advanced by Shi et al. (2016) and Hurn et al. (2016) and lastly, Markov-switching causality test suggested by Psaradakis et al. (2005). However, no studies have put into consideration structural breaks inherent in globalization and energy consumption series when examining the causal relationship between these variables. As we all known that, energy and its related products are globally traded, while energy markets are prone to uncertainties, such as hikes, policy changes, economic crises, financial crises, political instability, wars and technological changes among others. Any of these phenomena could probably motivate shifts in the dynamic relationship between globalization and the amount of energy consumed. Meanwhile, existing studies on the dynamic causal relationship between globalization and energy consumption all propose constant parameters, thus, their empirical results may not be reliable. Granger (1996) posited that, regime shifts or structural breaks are one of the most difficult problems one can encounter applying time series econometric methods. Perron (2006) and Hansen (1996) are also of the opinion that, econometric analysis applying time series data, should as a matter of fact, put into consideration the impacts of regime shifts or structural breaks. When structural breaks are present in a series, the parameters estimators of such model would be time variant, and empirical tests conducted on constant parameter assumption, for instance, Granger causality link will be unreliable and produce misleading inferences. In our study, we examine time-varying Granger causality tests between globalization and energy consumption and its implications for trade and environmental policy insights.

This study contributes to the existing energy and trade literature in four novel ways. First, this is the first study in exploring the nature of bidirectional or unidirectional causal relationship between energy consumption and globalization for the case of 20 top and less globalized countries within a time series framework. Second, we employ time-varying rolling test as proposed by Balcilar et al. (2010) and, Balcilar and Ozdermir (2013a) the recursive rolling test as suggested by Shi et al. (2016) and Hurn et al. (2016) to investigate time-varying feature of the causal relationship between globalization and energy consumption for 20 top and less globalized countries. Third, we apply quarterly data of the globalization and energy consumption. Since the sampled countries attained globalization and energy markets started operations at varying periods, the data time span varies for each variable. The empirical findings obtained from these methodologies indicate that, the dynamic causality relationship between globalization and energy consumption within the sampled countries show significant time–varying links with various shifts from neutrality (non-causality) to unidirectional and bidirectional causality. Our results detect many periods of bidirectional causal relationship between globalization and energy consumption over the sampled periods 1970Q1-2015Q4 for 20 top and less globalized economies. We observe longer periods of neutrality hypothesis relationship over the sampled period. Although, neutrality hypotheses are more frequent. This empirical attempt is likely to add a new dimension to the field of energy economics literature. Fourth, an empirical exploration of bidirectional or unidirectional causal link between energy demand and globalization in 20 top and less globalized countries is also likely to assist policymakers' emphasis on energy demand as an additional economic dimension towards building trade and environmental policies.

The rest of the paper is scheduled as follows: Section 2 highlights the related literature on the linkage between globalization and energy consumption. Section 3 provide in details the methodology employed in the study analysis and discuss the data with description of variables. Section 4 reports the results and discuss empirical findings. Lastly, Section 5 concludes the key findings with added policy implications for viable trade and sustainable environmental quality.

2. Review of Existing Studies

Before, we begin the origins of energy economics literature, it is pertinent to discuss the role of energy consumption and globalization on economic growth and environmental degradation. Energy has been one of the important inputs in helping economic activity besides using the traditional inputs of land, labour and capital. When economies are highly integrated, their demand for production increases with the help of traditional inputs along with the role of energy usage. The way economies are growing with passing globalization, their demand for energy usage increases given the limited supply of energy. This eventually stimulates economic activity but at the cost of environmental quality by discharging more carbon emissions into the atmosphere (Shahbaz et al. 2015). This shows that the environmental consequences of massive energy consumption with the greater role of globalization are larger for developed and developing countries in terms of producing unbearable climate change and global warming (Shahbaz et al. 2015, 2017). This has initially created an empirical platform for the researchers in linking the causal linkage between environmental pollution and income without considering the role of energy demand and globalization. Given that several studies observed that income is found to be sufficient variable in the carbon emissions function as it decreases environmental pollution in the latter stage of economic development (Shafik and Bandhopadhaya 1992, Panayotou 1993, Seldon and Song 1994, 1995).

However, Baek et al. (2009) strongly argued that it is difficult to check the environmental consequences just by adding only the role of income level in carbon emissions function. In such circumstance, they have added trade liberalization (exports and imports) as one of the independent variables in carbon emissions function and found that trade liberalization plays a vital role in affecting environmental quality in 25 developed and developing countries. In this line, various studies have come up in using exports plus imports as an indicator of trade liberalization in the energy demand function for both developed and developing countries. For instance, Antweiler et al. (2001) used international trade as an indicator of globalization and found that trade openness reduces energy consumption. This is possible mainly due to the dominant role of technique effect over the scale and composite effects and thereby enabling economies to adopt energy saving and low-cost-driven less carbon emitting technologies in production and consumption activities. This results in saving of scarce energy resources and protects environmental quality without undermining the growth of domestic output. Copeland and Taylor (2004) also supported the beneficial role of international trade in saving energy and stimulating environmental quality via imported technology and environmental regulations. Cope (2006) using international trade as an indicator of globalization for 32 developed countries found that trade liberalization increases energy per capita.

The other available studies also look at the impact of international trade on energy consumption. Narayan and Smyth (2009) used exports as an indicator of globalization and its causal linkage with energy consumption for MENA region and found the neutral hypothesis between the series. Sadorsky (2011), using the panel data for Middle East countries, found the unidirectional causality running from exports to energy consumption in the short run but also supported the bidirectional causality between imports and energy consumption in the long run. In case of South American economy, Sadorsky (2012) confirmed the unidirectional Granger causality from energy consumption to imports in the short run while supporting the bidirectional causality between energy consumption and trade in the long run. In a similar fashion, Ozturk and Acaravci (2013) found that trade increases energy consumption via increasing economic growth for Turkey. Lean and Smyth (2010a) found the unidirectional Granger causality running from exports to energy consumption for the Malaysian economy. Similarly, Lean and Smyth (2010b) found that exports Granger cause electricity generation for the Malaysian economy. Sami (2011) also found the unidirectional causality running from exports to energy consumption for the Japanese economy. Shahbaz et al. (2013a) found that international trade Granger causes energy consumption for the Chinese economy. Dedeoglu and Kaya (2013) found that there exists feedback effect between international trade and energy consumption for 25 OECD countries. Shahbaz et al. (2014) used heterogeneous Granger causality test to examine the causal linkage between trade openness and energy consumption for 91 low, middle and high income countries. They found U-shaped relationship between trade openness and energy consumption for low and middle income countries but also found an inverted U-shaped relationship between them for high income countries. Aissa et al. (2014) for the African countries found an evidence of neutral effect between trade openness and energy consumption. On the contrary, Erkan et al. (2010) found an evidence of unidirectional causality running from energy consumption to exports for the Turkish economy. Li (2010) for the Chinese economy also found an evidence of unidirectional causality running from energy consumption to exports. Shahbaz et al. (2013b) also observed that natural gas consumption causes exports in case of Pakistan.

It is interesting to note that results on the causal linkage between international trade and energy consumption are found to be mixed and conflicting. The use of narrowly defined globalization (e.g. trade liberalization) and different econometric techniques is the basis for emerging mixed findings. In this context, the recent study by Shahbaz et al. (2017) argued that the mixed findings are not beneficial for policymakers while designing their comprehensive trade and environmental policies toward efficient utilization of scarce energy resource for improved environmental quality and enhancing domestic output in the long run. This eventually warrants a study using comprehensive measure of globalization index (Dreher, 2006) in the energy demand function in order to help policymakers for constructing better trade and environmental policies for developed and developing countries. In this context, it is further important for the researchers to review the existing studies. Shahbaz et al. (2016) made an empirical attempt for the emerging countries like India by adding comprehensive KOF index of globalization (Dreher, 2006) in the energy demand function. Their results reported that globalization reduces energy consumption which is due to the fact that it brings win-win situation for the Indian economy in terms of higher economic growth and improved environmental quality through using energy efficiency and less carbon emitting technologies. Recently, Shahbaz et al. (2017) using time series and panel techniques for 25 developed countries found that globalization increases energy consumption for most of the countries. This is an indication of supporting globalization-driven energy consumption hypothesis for developed countries.

We arrive at conclusion that no study raises a research question: which nature of causal relationships (bidirectional, unidirectional, and neutral) between globalization and energy demand is good for the trade and natural environment of developed countries? What kind of trade and environmental policy implications we may expect from doing an empirical causal analysis between comprehensive globalization and energy demand for developed countries? These are the research questions and unaddressed gap that our study aims at examining for 20 top and bottom globalized economies within a time series framework.

3. Methodology

In order to evaluate Granger causality relationship when considering structural breaks in a series, one of the crucial techniques employed in the existing studies is regime switching models, which includes the Hamilton (1989) and Krolzig, (1999) Markov switching model and the threshold autoregression suggested by Granger and Teräsvirta (1994) and Teräsvirta (1998). In addition, Balcilar and Ozdemir (2013b,c) employed two-regime Markov switching VAR models to carry out causality evaluation with the existence of Markov switching. In spite of the fact that regime switching models can be employed for a regime switching causality analysis, sometimes, they are carried out by assuming that, there are commonly two or three regimes, and these models are not designed to incorporate multiple regime switches with different levels of regime time span.

Therefore, the recursive estimation method as proposed by Swanson (1998) and Thoma (1994), the rolling window estimation method as advanced by Swanson (1998), Balcilar et al. (2010) and, Balcilar and Ozdemir (2013a) the recursive rolling estimation method as suggested by Shi et al. (2016) and Hurn et al. (2016) as an alternative to regime switching models, can be employed to carry out time-varying causality analysis. These methods have their advantages and disadvantages, yet the methods takes into consideration multiple structural breaks with potential switches in parameters in each time span. According to Balcilar et al. (2010) and Hurn et al. (2016) the rolling, recursive or recursive rolling methods are appropriate and should be selected when dealing with time-varying Granger causality tests, where the methodical changes that link two or three regimes rely on the parameters that are subject to multiple shift and not the dominant attribute of the regimes.

In our current study, we opt for the rolling and recursive rolling methods based on their robustness with reference to true and false causality detection power. Shi et al. (2016) and Hurn et al. (2016) carry out Monte Carlo simulations to measure the difference between the true and false causality discovery rates of the rolling, recursive and recursive rolling techniques. Recursive method was found to have the least performance with reference to both false and true causality discovery rates. Meanwhile, using the application in Balcilar et al.

(2010) and Balcilar and Ozdemir (2013a) the rolling method has the highest true causality discovery rate, while the recursive rolling method has a moderately lower false discovery rate liken to the rolling method. Thus, Shi et al. (2016) conclude that, the rolling method demonstrate matchless all-inclusive performance for integrated time series data.

In order to explain the time-varying Granger causality tests carried out for the causality relationships running between globalization (z_{1t}) and energy consumption (z_{2t}) define the bivariate VAR(p) as follow:

$$z_{1t} = \alpha_{10} + \sum_{i=1}^{p} \alpha_{11,i} z_{1t-i} + \sum_{i=1}^{p} \alpha_{12,i} z_{2t-i} + \eta_{1t} \tag{1}$$

$$z_{2t} = \alpha_{20} + \sum_{i=1}^{p} \alpha_{21,i} z_{1t-i} + \sum_{i=1}^{p} \alpha_{22,i} z_{2t-i} + \eta_{2t} \tag{2}$$

where p represent the lag order and η_{it}, $i = 1, 2.....N$ are the white noise error terms. This VAR(p) can be written using the matrix notation a:

$$z_t = \varphi_0 + \varphi_1 z_{t-1} + \varphi_2 z_{t-2} + ... + \varphi_p z_{t-p} + \eta_t \tag{3}$$

with the associated multivariate form:

$$z_t = \pi y_t + \eta_t,\ t = 1, 2, ...T \tag{4}$$

where $z_t = (z_{it}, z_{2t})'$, $y_t = \left(1, z'_{t-1}, z'_{t-2}, ..., z'_{t-p}\right)'$, $\eta_t = \left(\eta_{1t}, \eta_{2t}\right)'$, and $\pi = \left[\varphi_0, \varphi_1, ...\varphi_p\right]$ which is $2 \times (2p+1)$ matrix.

Furthermore, the Granger non-causality running from energy consumption to globalization indicates that energy consumption does not have predictive power over globalization $(z_{2t} \neq> z_{1t})$ while the Granger non-causality running from globalization to energy consumption indicates that globalization does not have predictive power over energy consumption $(z_{1t} \neq> z_{2t})$. Therefore, the two Granger non-causality statements, subsequently, result in the succeeding joint restrictions to be tested under the null hypotheses given below:

$$H_0 : z_{2t} \neq> z_{1t} \Rightarrow \varphi_{12,1} = \varphi_{12,2} = ...\varphi_{12,p} = 0 \quad (5)$$

$$H_0 : z_{1t} \neq> z_{2t} \Rightarrow \varphi_{21,1} = \varphi_{21,2} = ...\varphi_{21,p} = 0 \quad (6)$$

We concisely write the Granger non-causality constraints in equation (5) and (6) as follow:

$$H_0 : C\pi = 0 \quad (7)$$

where, C depict the selection matrix of dimension $p \times 2(2p+1)$ and $\pi = vec\left(\prod\right)$ represent a vector of dimension $2(2p+1) \times 1$ employing row vectorization.

The rolling estimation method employs a fixed window size $\upsilon_w = \left[\upsilon_w T\right]$, where $[\cdot]$ depict the integer part with fraction υ_w of the number of observations. The starting point of the estimation is $\upsilon_1 = \left[\upsilon_1 T\right]$ with the fraction υ_1 while the end point is represented by $\upsilon_2 = \left[\upsilon_2 T\right]$ with the fraction υ_2, considering the sequence of Wald statistics for $t = \upsilon_1, \upsilon_1 + 1, ..., \upsilon_2$. The rolling method can be depicted with start point $\upsilon_1 = 1, \upsilon_2 - \upsilon_w + 1$ while the sequence of the end points can be represented with $\upsilon_2 = \left\{\upsilon_w, ..., T\right\}$. Using this approach, we derive the $T - \upsilon_w + 1$ sequence of Wald statistics. The study represents the sequence of the rolling Wald statistics with $\left\{W^{\upsilon_2}_{\upsilon_1 = \upsilon_2 - \upsilon_w + 1}\right\}_{\upsilon_2 \in \left[\upsilon_w, T\right]}$.

Meanwhile, the recursive rolling method is matching with the rolling method. It also uses fixed window evaluation technique with window size υ_w. Comparable to the rolling evaluation, the end point of the regression is the sequence $\upsilon_2 = \left\{\upsilon_w, ..., T\right\}$. Although, the start point of the evaluation takes into account each of the possibilities, that is, 1 to $\upsilon_2 - \upsilon_w + 1$. While the recursive rolling method incorporates the sequence of the end point $\upsilon_2 = \left\{\upsilon_w, ..., T\right\}$ with the start point order $\upsilon_1 = \left\{1, \upsilon_2 - \upsilon_w + 1\right\}$. In addition, the recursive rolling Wald statistics are the supremum of all feasible rolling Wald statistics of a given point, they are represented by $\left\{\sum W^{\upsilon_2}_{\upsilon_1 = \upsilon_2 - \upsilon_w + 1}\right\}_{\upsilon_2 \in \left[\upsilon_w, T\right]} = \sup_{\upsilon_1^s \in \left[1, \upsilon_2 - \upsilon_w + 1\right]}\left[\left\{W^{\upsilon_2}_{\upsilon_1^s}\right\}\right]$.

In order to implement the rolling and recursive rolling methods, there is a need to estimate the Wald test sequences for a subset of the sample with start and end point υ_1 and υ_2. We specify the ordinary least squares (OLS) estimate of the VAR(p) model in equation (4) estimated for the subsample as $\hat{\pi}_{\upsilon_1,\upsilon_2}$ while its row vector form as $\hat{\prod}_{\upsilon_1,\upsilon_2} = vec\left(\hat{\pi}_{\upsilon_1,\upsilon_2}\right)$. The Wald statistics sequences are derived by imposing restrictions in equation (7) on the subsample parameter estimates, that is, the study evaluates the null hypothesis with restrictions $H_0 : R\hat{\pi}_{\upsilon_1,\upsilon_2} = 0$. The ordinary least square (OLS) estimates $\hat{\pi}_{\upsilon_1,\upsilon_2}$ are considered for individual equations of the VAR, $i = 1, 2....N$ via $\hat{\pi}_{i,\upsilon_1,\upsilon_2} = \left[\sum_{t=\upsilon_1}^{\upsilon_2} z_{it} y_t'\right]\left[\sum_{t=\upsilon_1}^{\upsilon_2} y_t y_t'\right]^{-1}$. Meanwhile, the residuals for the individual equation in the subset estimate are derived as $\hat{\mu}_t' = \left[\hat{\mu}_{1t,}\hat{\mu}_{2t}\right]$ accompanied by $\hat{\eta}_{it} = z_{it} - \hat{\pi}_{i,\upsilon_1,\upsilon_2} y_t$. The study derived the estimate of the residual covariance matrix Φ as $\hat{\Phi}_{\upsilon_1,\upsilon_2} = \mathrm{T}_w^{-1} \sum_{t=\upsilon_1}^{\upsilon_2} \hat{\eta}_t \hat{\eta}_t'$ where $\mathrm{T}_w = \upsilon_2 - \upsilon_1 + 1$. Considering the above explanations, we derived Wald statistics for each subsample for the Granger non-causality restrictions from

$$W_{\upsilon_1}^{\upsilon_2} = \left(R\hat{\pi}_{\upsilon_1,\upsilon_2}\right)' \left\{R\left[\Phi_{\upsilon_1,\upsilon_2} \otimes \left(\sum_{t=\upsilon_1}^{\upsilon_2} y_t y_t'\right) R'\right]\right\}^{-1} \left(R\hat{\pi}_{\upsilon_1,\upsilon_2}\right) \qquad (8)$$

In equation (8), the Wald test statistics assume that Granger causality tests are based on homoscedastic errors, formulated in such a manner tests may have unreasonable empirical slevel and possibly be followed by power loss, most especially when the errors variance are not constant. Thus, to refrain from problems as a result of conditional and unconditional heteroskedasticity, the current study employs a modified Wald test (MWald) that takes into consideration the impacts of heteroskedasticity in the residuals. The MWald test is specified as given below:

$$W_{\upsilon_1}^{*\upsilon_2} = \mathrm{T}_w \left(R\hat{\pi}_{\upsilon_1,\upsilon_2}\right)' \left[\left(R\hat{\mathrm{X}}_{\upsilon_1,\upsilon_2}^{-1} \hat{W}_{\upsilon_1,\upsilon_2} \hat{\mathrm{X}}_{\upsilon_1,\upsilon_2}^{-1}\right) R'\right]^{-1} \left(R\hat{\pi}_{\upsilon_1,\upsilon_2}\right) \qquad (9)$$

$$\hat{\mathrm{X}}_{\upsilon_1,\upsilon_2}^{-1} = S_2 \otimes \hat{D}_{\upsilon_1,\upsilon_2}, \quad \hat{D}_{\upsilon_1,\upsilon_2} = \mathrm{T}_w^{-1} \sum_{t=\upsilon_1}^{\upsilon_2} y_t y_t' \text{ and } \hat{W}_{\upsilon_1,\upsilon_2} = \mathrm{T}_w^{-1} \sum_{t=\upsilon_1}^{\upsilon_2} \Lambda_t \Lambda_t', \quad \Lambda_t = \hat{\eta}_t \otimes y_t$$

Furthermore, the asymptotic distribution of the rolling Wald statistic is a Chi-square, while that of recursive rolling is nonstandard as proposed in Hurn et al. (2016). Following the work of Guilkey and Salemi (1982), Toda and Phillips (1993, 1994) there is significant evidence that the Wald statistic tests together with the Granger causality test employed in our current study, may suffer from size distortions problem. Besides, the MWald test in equation (9) require the evaluation of the matrix $\hat{W}_{\upsilon_1,\upsilon_2}$, that is a matrix of the fourth (4^{th}) moment. Fourth moment estimator are highly sensitive to high fluctuations in small samples. Thus, this study employ the bootstrap method of Balcilar et al. (2010) to derive the empirical distributions of the Wald tests.[1,2] In addition, the bootstrap method is carried out by putting into consideration that fact that, under the null hypothesis restrictions of Granger non-causality $H_0 : R\hat{\pi}_{\upsilon_1,\upsilon_2} = 0$, and the VAR($p$) model exhibit constant coefficients $\Pi_{\upsilon_1,\upsilon_2} = \Pi$ for all subsamples $t = \upsilon_1, \upsilon_1 + 1, ..., \upsilon_2$. Using the residual-based bootstrap method of Balcilar et al. (2010), the probability values (or the critical values) for the Granger causality tests were derived under the restrictions of the null hypothesis using with 1,000 replications.

4. Data and description of variables

This paper aim to examine the causal relationship between globalization and energy consumption and its implication for trade and environmental policy insights, using 20 top and bottom globalized countries. The list of sampled countries includes top-10 globalized countries i.e. Netherlands, Ireland, Belgium, Austria, Switzerland, Singapore, Denmark, Sweden, Hungary and Canada while bottom-10 globalized economies are Kyrgyz Republic, Bolivia, Macedonia FYR, Kazakhstan, Ecuador, Bahamas, Nicaragua, Namibia, Senegal and Puerto Rico [3]. We have excluded Puerto Rico from sample due to unavailability of data for globalization and energy consumption. Our key measure of overall globalization index is the KOF index of globalization obtained from the database of the Swiss-Federal Institute of Technology, Zurich proposed by Dreher (2006) which is a composite of three rich sub-indexes: social, political and economic globalization.[4] Potrafke (2015) and Gozgor and Ranjan (2017) recently argued that the KOF index of globalization is not only superior to other quantitative measures of globalization but also it is a multi-faceted one capturing many dimensions of socio, economic and political globalization aspects that that go beyond

[1] The details of the bootstrap implementation can be found in Balcilar et al. (2010).

[2] For integrated time series data, rolling and recursive rolling Granger causality Wald tests can be performed using the lag-augmented VAR approach of Toda and Yamamoto (1995). Balcilar et al. (2010) and Shi et al. (2016) also adopt a lag-augmented VAR approach to perform rolling and recursive rolling Granger causality Wald tests.

[3] For more details, see http://globalization.kof.ethz.ch/

[4] The beginning date of KOF globalization data set is 1970 which is the basis for selecting starting period of our empirical analysis from 1970-2015.

quantitative indicators such as trade openness and capital movements. It also considers a large number of countries and the time coverage which is also updated annually. Broadly speaking, KOF indices of globalization are the most often used globalization measures in the international economic literature (Dreher, 2006, Dreher et al. 2008).[5] However, the largest component is the social globalization sub-index (37%), which includes telephonic contact, international letters, transfers and internet users along with reduced costs of transport and communication through technology). The political sub-index of KOF globalization (27%) considers embassies in a country, membership in international organization and participation in UN Security Council missions and International treaties. Finally, the economic sub-index of KOF globalization (26%) includes international trade and capital movements.[6] Energy use (kg of oil equivalent per capita) proxy for energy consumption is sourced from the World Development Indicators (WDI). The study covers the period of 1970-2015. We have transformed annual data into quarter frequency following Shahbaz et al. (2017). The match-sum quadratic method is used for converting annual data into quarter frequency. This method automatically adjusts seasonality variations in raw data while converting low frequency into high frequency data (Shahbaz et al. 2017). The data on globalization and energy consumption has been transformed into natural-log before empirical estimation for efficient empirical results. The plots of globalization and energy consumption are displayed in Figure 1.

<Insert Figure 1 here>

Table 1A and 1B reports the descriptive statistics of globalization and energy consumption, the mean, minimum, maximum, standard deviation, skewness, kurtosis, the Jarque-Bera (JB) normality test, the first and fourth order Ljung-Box [Q(1)] and [Q(4)] autocorrelation tests, the first and fourth order [ARCH(1)] and the [ARCH(4)] Lagrange multiplier (LM) tests for the autoregressive conditional heteroskedasticity (ARCH) for globalization and energy consumption in their natural logarithms forms. As reported in Table 1A, globalization has the lowest mean across countries especially for Senegal with 10.52, but rises slightly for Netherlands, having the highest average globalization of about 20.84. In addition, the mean of energy consumption is highest for Canada, followed by Sweden, Belgium and Netherlands with an average mean approximately 1894.52, 1326.31, 1246.39 and 1125.56 respectively. The average decreases for Ecuador, Namibia, Kyrgyz Republic, Nicaragua, Bolivia and

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[5] According to Google Scholar Records, there are 1799 citations to the seminal paper of Dreher (2006) up to 31st December, 2017.

[6] For more details estimations of KOF subindex of globalization, see the seminal papers of Dreher (2006) and Gozger (2017).

Senegal for energy consumption with an average of 167.22, 155.85, 153.71, 128.40, 118.78 and 63.87 million tons respectively. In addition, from the Table 1A and 1B, we observe that globalization and energy consumption series are highly volatile. The negative values (though with some positive values) of the skewness indicate a higher probability of lower decreases in energy consumption and globalization. However, from the kurtosis values of both series, we observed a long-tailed distribution. Interestingly, both variables of interest under observation are negatively skewed, with negative kurtosis, indicating a non-normal distribution, that is, the relationship between globalization and energy consumption is highly nonlinear. The nonlinearity of the variables are justified by the rejection of the null hypothesis of normal distribution as suggested by Jarque and Bera (1980) test at ($p < 0.01$) significant level. This outcome also justify the utilization of rolling and recursive rolling approach via the long-tailed distribution of the time series data. Furthermore, we also observed a significant serial correlation for globalization and energy consumption as advanced by Ljung-Box (1978). Lastly, the autoregressive conditional heteroskedasticity-Lagrange multiplier (ARCH-LM) statistics imply that ARCH effects exist in the variables of interest, which is statistically significant at 5% level.

<Insert Table 1A and 1B here>

5. Results and Empirical Findings

We discuss the results obtained from rolling and recursive-rolling empirical estimations conducted. Although, this study primarily intent to analyse the nonlinear characteristics via direction of causal relationship between globalization and energy consumption among countries that are highly globalized with higher level of energy consumption over the study time-span, however, we also carried out the linear Granger causality estimation based on a full sample vector autoregressive (VAR) model for comparability and completeness.[7] Table 2 shows the results of the linear Granger causality tests conducted. Column 2 of Table 2 presents the linear causality test results for examining the null hypothesis that energy consumption does not Granger cause globalization, while column 3 presents null hypothesis that globalization does not Granger cause energy consumption. The statistical insignificance of the causality estimates in column 2 of Table 2 provided an evidence that the null hypothesis that energy consumption does not Granger cause globalization, cannot be rejected

[7] In this study, all Granger causality tests are performed using the lag-augmented VAR approach of Toda and Yamamoto (1995), due to the nonstationarity of the series.

at 5% significance level. However, this is significant for Namibia at 5% level. In addition, the *F*-test results reported in column 3 for most of the sampled countries fail to reject the null hypothesis that globalization does not Granger cause energy consumption, except for Austria, Singapore and Kazakhstan at the 5% level of significance. Generally, from the results of the linear Granger causality test, we infer that there is no evidence of predictability running between energy consumption and globalization at the 5% level of significance.

<Insert Table 2 here>

Moreover, the results presented in Table 2 for testing the causal relationship between globalization and energy consumption for each of the sampled countries are based on restrictions imposed on a linear VAR model evaluated for the full sample time series analysis. Using the full sample time series VAR model, the study asssumes non-existence of structural breaks within the sample and that parameters are constant overtime. Although, structural switches may change the values of the parameter and alter directions of causality overtime, i.e. structural changes may impact on temporal causality relationships, since it is sensitive to the sample period opted for. In such a situation, according to Andrews and Ploberger (1994) there are various available test one can employ to examine stability of the vector autoregressive (VAR) models. However, when the estimated parameters emanate from undetected unstable relationships, problems are bound to surface. Hansen (1992) argued that, it is feasible for such parameter estimates emanating from undetected unstable relationship to have severe impacts, which Zeileis et al. (2005) reported to be as a result of biased inferences in addition to imprecise forecasts. This study examine the stability of the VAR model parameters in order to evaluate the temporal stability of the coefficient estimates of the VAR model comprises of globalization and energy consumption. We use three distinct statistics such as, *Sup-F, Mean-F and Exp.-F* as proposed by Andrews (1993) and, Andrews and Ploberger (1994). These tests necessitate trimming from the ends of the sample to examine stability of short-term parameter estimates. Table 3 presents the results of the parameter stability test conducted for globalization and energy consumption. As suggested by Andrews (1993) we obtain the *p*- and critical values applying the parametric bootstrap distribution derived using 2,000 replications produced from VAR model with constant parameters. For each of the sample, we used 15% trimming.

Although, the three (*Sup-F, Mean-F and Exp.-F)* tests suggested by Andrews and Ploberger (1994) examine similar null hypotheses, however, they vary in their selection of alternative hypotheses. The selection of suitable test to use rest on the aim of the test.[8] Table 3 presents the results of the *Sup-F*, *Mean-F*, and *Exp.-F* test. According to the results presented in Table 3, all the tests reject the null hypothesis of parameter constancy at 5% significance level, (except for some countries under *Exp.-F* test) for the globalization equation, energy consumption equation and the VAR system. Consequently, it may be concluded that Granger causality estimations built on the VAR model, conducted for globalization and energy consumption are not reliable, since the parameter estimates in the VAR model are not constant (stable) over the sample period.

<Insert Table 3 here>
<Insert Table 4 here>
<Insert Table 5 here>

The results reported in Table 3 provide an evidence for using rolling and recursive rolling Granger causality tests considering the fact that, all estimated parameters of the VAR models indicate significant instability. Figure 2 shows the Wald test results for Granger causality effects running from energy consumption to globalization, while Figure 3 displays the heteroskedasticity-consistent Wald test outcomes for Granger causality relationship running from energy consumption to globalization.[9] We report in Figure 4, the Wald test results for Granger causality relationship running from globalization to energy consumption, while, the heteroskedasticity-consistent Wald test results for Granger causality running from globalization to energy consumption are displayed in Figure 5. In Figures 2-5 the reported *p*-values are obtained using the bootstrap versions of the rolling and recursive rolling Wald statistics derived from the VAR model with a differing lag order with a window size of 40. We choose the optimal lag order applying the Bayesian Information Criterion (BIC). In addition, we obtained the *p*-values using 1,000 bootstrap replications for the individual subsample. In Figure 2 and Figure 4, the bootstrap *p*-values of the rolling and recursive rolling Wald statistics presented are derived under the assumption of homoskedastic residuals, while we assume heteroskedastic residuals in Figure 3 and 5, respectively. However, since in Table 1, the residuals of the estimated VAR models display heteroscedasticity, we suggest there might be dissimilarities between the standard Wald test results reported in Table 2 and 4, and between the heteroskedasticity-consistent Wald test results reported in Table 3 and 5.

[8] For details, see Andrews (1993) and Andrews and Ploberger (1994).
[9] All-time series data used in the analysis are integrated of order one. Thus, following Balcilar *et al*. (2010) and Shi *et al*. (2016), the rolling and recursive rolling Granger causality tests are conducted via the lag-augmented VAR method of Toda and Yamamoto (1995).

Furthermore, in this study, we will evaluate the non-causality tests at 5% significance level, yet, 10% significance level will also be used to apply caution against low power test, which is due to the sample size in the individual rolling and recursive rolling sub-sample estimate. In accordance with the results displayed in Figures 2-5, the estimated bootstrap *p*-values vary significantly over the sample period, implying frequent structural breaks. Confirmation from Figure 2 for 19 top and bottom globalized countries reveal that, the null hypothesis of which energy consumption does not exhibit predictive power over globalization cannot be rejected at 5% significance level for most of the sampled countries, however, there are sub-periods where the bootstrap *p*-values, especially those of the rolling tests, are below 5% and more regularly below 10%. The periods where there is causality from energy consumption to globalization mostly fall between the periods 1980-1995 and 2005-2015 sub-periods, respectively. The causality relationship running from energy consumption to globalization is roughly confirmed in the 1980-1990, 1997-1998, and 2012-2015 sub-periods. Meanwhile, in Figure 2, the recursive rolling statistics show more causal relationship than the rolling statistics. Closely to the results presented in Figure 2, the heteroskedastic versions of the results reported in Figure 3 show that the null hypothesis in which energy consumption does not Granger causes globalization cannot be rejected at 5% significance level for most of the sampled countries. Unlike the homoskedastic Wald tests, the heteroskedastic Wald tests show strong causality relationship running from energy consumption to globalization during the 1980-1985, 1986-1989, 1990-1995, 1997-1999, 2000-2006 and 2009-2015 sub-periods, respectively. Compared to the homoskedastic Wald test types of the rolling and recursive-rolling Granger causality analysis, the heteroskedastic types more frequently reject the non-Granger causality hypotheses in sub-periods. We deduce that the recursive rolling tests are more sensitive to heteroskedasticity, especially in terms of its lower success rate in discovering Granger causality relationship. This is due to the fact that, the homoskedastic form of the recursive rolling test varies substantially from its heteroskedastic form when compared with the rolling test.

Figure 4 show the bootstrap *p*-values of the rolling and recursive rolling Wald tests for the Granger causality relationship running from globalization to energy consumption. From the results, globalization appear to have predictive power over energy consumption during the periods of 1980-1990, 1992-1995, 1997-1998, 2007-2008 and 2009-2015. Corresponding to the results reported in Figure 3, the bootstrap *p*-values of the Granger causality rolling and recursive rolling heteroskedasticity-consistent Wald test in Figure 5 fail to reject the null hypothesis at 5% significance level for the sampled countries. Concerning the Wald tests of Granger causality running from energy consumption to globalization, heteroskedasticity-consistent rolling and recursive rolling tests are found to be more consistent for the sub-periods where the null hypotheses was rejected. Besides, the recursive rolling method seems to be more sensitive to heteroskedasticity compare to the rolling method.

However, the periods where there are causality relationship running from globalization to energy consumption are towards the early 1990s for Netherland, Ireland, Belgium, Singapore, Switzerland, Austria, Denmark, Hungary, Canada, Kyrgyz Republic, Bolivia, Namibia, Ecuador and the United States (US) subprime mortgage crisis between the periods 2007-2008 for Macedonia FYR, Nicaragua, Kazakhstan. Furthermore, in these sub-periods, heteroskedasticity consistent rolling tests in Figure 5 show two sub-periods during which globalization seem to have predictive power over energy consumption for the sampled countries. These consist of the 1980-2000 and 2009-2015 sub-periods. According to Shi et al. (2016) and Hurn et al. (2016) they are of the opinion that the rolling approach of Balcilar et al. (2010) and, Balcilar and Ozdemir (2013a) is more effective in identifying structural breaks than the recursive rolling of Shi et al. (2016) and Hurn et al. (2016). The United States subprime mortgage crisis period that occur at the same time with the formal NBER recession between the periods 2007-2008, spread across most if not all the sampled countries. In addition, results from Figure 2 to 5 reveal that the rolling approach of Balcilar et al. (2010) and, Balcilar and Ozdemir (2013a) identify structural breaks better compared to the recursive rolling of Shi et al. (2016) and Hurn et al. (2016).

Generally, the heteroskedasticity consistent form of the recursive rolling test seems to identify similar causality relationships relative to the rolling test, however, the recursive rolling test reveals considerable reactiveness to heteroskedasticity. Our sampled data indicate conditional and unconditional heteroskedasticity. Furthermore, it is better and more rational to evaluate the heteroskedasticity consistent forms of the rolling and recursive rolling approach in order to date-stamp the eras of dynamic causality relationships. The rolling and recursive rolling tests identify causal relationship running from energy consumption to globalization in the 1980-1985, 1986-1989, 1990-1995, 1997-1999, 2000-2006 and 2009-2015 sub-periods. The sub-periods above are related to notable oil prices fluctuations due to significant events that had global influences. Based on results, we can conclude that, Granger causality running between globalization and energy consumption for most of the sampled countries. Overall, both the rolling and recursive rolling tests find bidirectional causality between the globalization and energy consumption in various subsamples, particularly when the heteroskedasticity consistent versions of the tests are considered. The heteroskedasticity consistent versions of both tests are in better agreement than the homoskedastic versions about the subperiods where there is unidirectional or bidirectional causality. The causality links, however, are mostly bidirectional.

The empirical findings from the rolling approach of Balcilar et al. (2010) and, Balcilar and Ozdemir (2013a) and the recursive rolling approach of Shi et al. (2016) and Hurn et al. (2016) employed in our current study provide evidence in support of a bidirectional dynamic causality relationships between globalization and energy consumption for many sub-periods for the sampled countries. Our empirical results provide significant insight into globalization-energy relationship; by date-stamping the periods of causality. This indicate that energy consumption influences globalization during the periods of high oil price fluctuations and globalization influences energy consumption during the great economic/financial crises. Our empirical findings show that, the rolling and the recursive rolling approaches reveal better performance in periods where there are several paired changes in the causal nexus between globalization and energy consumption over the sample period.

6. Conclusion and Policy Implications

This study examines the dynamic causal relationship between globalization and energy consumption in case of top and bottom globalized economies, and its implications for trade and environmental policy using the rolling and recursive rolling estimation techniques via quarterly frequency data for the period of 1970Q1-2015Q4. The rolling and recursive rolling methods are appropriate for examining time-varying Granger causality relationship between time series variables. These methods enable us to model parameter time variation to mirror variations in causality relationship in the absence of assumptions of the change structure. Another novelty of this study lies in the application of both the rolling and the recursive rolling Granger causality test approaches. We also examine the full sample linear Granger causality relationship between globalization and energy consumption.

The empirical results obtained from the linear full sample tests show no evidence to reject the null hypothesis that, globalization and energy consumption have no predictive power over one another. Then, we employ series of parameter stability tests to the models, where we obtained the results of full sample Granger causality tests. The empirical findings from the parameter stability test reveal that the VAR models are show significant parameter instablity. Therefore, estimated causality test results from the full sample VAR model for globalization and energy consumption appears unreliable. Consequently, we examine the estimation of the dynamic causal relationship between globalization and energy consumption, using rolling and recursive rolling approaches over the sample period. Our empirical results from this study indicates two major findings. First, there exists a bidirectional dynamic causality relationship between the variables for most of the sampled countries in several subperiods. Second, the rolling approach advanced by Balcilar et al. (2010) and, Balcilar and Ozdemir (2013a) is more reliable in identifying the structural breaks in this situation than the results from recursive rolling approach of Shi et al. (2016) and Hurn et al. (2016). In general, the findings from this study indicate that the dynamic causality relationships between globalization and energy consumption will be reactive to the frequency of the globalization and energy consumption, time span and approach employed. Third, globalization and energy consumption drives each other, and this may lead to unwarranted trade and environment issues via high global energy usage.

Various findings and policy implications can be deduced here. First, a bidirectional relationship exists between globalization and energy consumption in most of the sampled developed countries. This results show that globalization and energy consumption reinforce one another, i.e. they have predictive power over each other. This findings is consistent and in line with the views of Copeland and Taylor (2004), Cope (2006), Shahbaz et al. (2015), Rehman and Miah (2017) and Shahbaz et al. (2017) that higher trade liberalization and capital flows as a results of globalization may stimulate increase in energy consumption through increase in economic activities, which will eventually lead to long-term environmental challenges, in terms of global warming and climate change. Second, the Granger causality running from globalization to energy consumption was found in most of the countries, the major policy implications of these results are that, globalization-driven energy consumption is affirm here. This indicate that, globalization and energy consumption play a dynamic relationship over one another. Thus, policymakers and governments in charge of designing and implementing trade and environmental policies in these countries must put into consideration the impact of globalization in the level of energy consumed and vice-versa, in order to prevent grievous trade and environmental consequences of globalization and higher energy consumption in the long-run. This resonate with the views of Baek et al. (2009) Shahbaz et al. (2015, 2016). Thus, the role of globalization and energy consumption while designing and executing trade and environmental policies should not be ignored in order to prevent global warming and climate change.

In conclusion, our empirical findings propose that developed countries that are engaged in more trade may find it difficult to exclude themselves from environmental consequences in terms of global warming and climate change, if they continue to demand and consume more energy in order to stimulate economic growth, particularly with the existence of globalization in the long-run. Following the view of Shahbaz et al. (2017) in order for globalization-energy consumption relationship to be favourable for trade and environment, an alternative energy source must be put in place. Reduction in fossil fuel trades which will reduce its quantity usage, energy efficiency policies and increase investment in research and development (R&D) to enhance technology innovations and help in examining other renewable energy sources to meet the increasing energy demand. We suggest that further studies should be carried out on the dynamic causal nexus between globalization and energy consumption, along with other variables, allowing policy variations and remarkable switches in globalization and energy consumption.

References

Aïssa, M. S. B., Jebli, M. B. and Youssef, S. B. (2014). Output, renewable energy consumption and trade in Africa. *Energy Policy*, *66*, 11-18.

Antweiler, W., Copeland, B. R. and Taylor, S. M. (2001). Agyeman, Julian, Environmental Justice and Sustainability, in Atkinson/Dietz/Neumayer (eds), Handbook of Sustainable Development, Cheltenham, UK/Northampton, MA, USA: Edward Elgar 2007, reprinted 2008, 171–188 Alam, Shawkat, Sustainable Development and Free Trade, Institutional Approaches, London/New York: Routledge 2008 (Alam, 2008). *Environment*, *91*, 877-908.

Baek, J., Cho, Y. and Koo, W. W. (2009). The environmental consequences of globalization: A country-specific time-series analysis. *Ecological economics*, *68*(8), 2255-2264.

Balcilar, M., Ozdemir, Z. A. and Arslanturk, Y. (2010). Economic growth and energy consumption causal nexus viewed through a bootstrap rolling window. Energy Economics, 32(6), 1398-1410.

Balcilar, M. and Ozdemir, Z.A. (2013a) “The export-output growth nexus in Japan: a bootstrap rolling window approach”, Empirical Economics, 44(2), 639-660.

Balcilar, M. and Ozdemir, Z.A. (2013b). Asymmetric and time-varying causality between inflation and inflation uncertainty in G-7 countries. Scottish Journal of Political Economy, 60, 1-41.

Balcilar, M. and Ozdemir, Z. A. (2013c). The causal nexus between oil prices and equity market in the U.S.: A Regime Switching Model. Energy Economics, 39, 271-282.

Beck, U. (2000). The cosmopolitan perspective: sociology of the second age of modernity. *The British Journal of Sociology*, *51*(1), 79-105.

Berger, P. L. (2002). The cultural dynamics of globalization. *Many globalizations: Cultural diversity in the contemporary world*, *116*.

Chen, Z. M. and Chen, G. Q. (2011). An overview of energy consumption of the globalized world economy. *Energy Policy*, *39*(10), 5920-5928.

Cole, M. A. (2006). Does trade liberalization increase national energy use? *Economics Letters*, *92*(1), 108-112.

Copeland, B. R. and Taylor, M. S. (1994). North-South trade and the environment. *The quarterly journal of Economics*, *109*(3), 755-787.

Copeland, B. R. (2005). Policy endogeneity and the effects of trade on the environment. *Agricultural and Resource Economics Review*, *34*(1), 1-15.

Dedeoğlu, D. and Kaya, H. (2013). Energy use, exports, imports and GDP: New evidence from the OECD countries. *Energy Policy*, *57*, 469-476.

Dicken, P. (1992). *Global shift: The internationalization of economic activity*. SAGE Publications Inc.

Dollar, D. and Kraay, A. (2004). Trade, growth, and poverty. *The Economic Journal*, *114*(493).

Dreher, A. (2006). Does globalization affect growth? Evidence from a new index of globalization. *Applied Economics*, *38*(10), 1091-1110.

Dreher, A., Gaston, N., & Martens, P. (2008). *Measuring globalisation: Gauging its consequences*. Springer Science & Business Media.

Dunne, T., Schmidt, B. C., Baylis, J. and Smith, S. (2001). The globalization of world politics. *The Globalization of World Politics.*

Erkan, C., Mucuk, M. and Uysal, D. (2010). The impact of energy consumption on exports: The Turkish case. *Asian Journal of Business Management*, *2*(1), 17-23.

Featherstone, M. (1995). *Undoing culture: Globalization, postmodernism and identity* (Vol. 39). Sage.

Friedman, T. (1999). The Lexus and the olive tree: Understanding globalization. *New York: Straus and Giroux*.

Gaburro, G. and O'Boyle, E. J. (2003). Norms for evaluating economic globalization. *International Journal of Social Economics*, *30*(1/2), 95-118.

Granger, C. W. (1996). Can we improve the perceived quality of economic forecasts? *Journal of Applied Econometrics*, *11*(5), 455-473.

Granger, C. W. J., and Teräsvirta, T. (1993) *Modelling Nonlinear Economic Relationships*, Oxford University Press.

Gilpin, R. (2001). Global political economy. Princeton University.

Gozgor, G. (2017). Robustness of the KOF index of economic globalisation. *The World Economy*, 1-7.

Gozgor, G., & Ranjan, P. (2017). Globalisation, inequality and redistribution: Theory and evidence. *The World Economy*, *40*(12), 2704-2751.

Guilkey, D. K. and Salemi, M. K. (1982). Small sample properties of three tests for Granger-causal ordering in a bivariate stochastic system. Review of Economics and Statistics, 64, 668–680.

Hamilton, J. D. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. Econometrica, 57, 357-384.

Hansen, B. E. (2001). The new econometrics of structural change: Dating breaks in US labor productivity. *The Journal of Economic Perspectives*, *15*(4), 117-128.

Harris, M. C. (2001). The globalization of energy markets. *Challenges of the Global Century, Washington, DC: National Defense University*.

Hill Charles, W. L. (2006). Global business today. New York. McGraw-Hill Irwin.

Hurn, S., Phillips, P. C. B. and Shi, S. (2016). Change detection and the causal impact of the yield curve. Cowles Foundation Discussion Paper No. 2059.

International Energy Agency, (2007) World Energy Outlook, with projection to 2030.

Jarque, C. M. Bera, A. K. 1980. Efficient tests for normality, homoscedasticity and serial independence of regression residuals. *Economics letters*, *6*(3), 255-259.

Jena, P. R. and Grote, U. (2008). Growth-trade-environment nexus in India.

Keohane, R. O. (2002). *Power and governance in a partially globalized world*. Psychology Press.

Krolzig, H. M. (1999) Statistical analysis of cointegrated VAR processes with Markovian regime shifts, University of Oxford.

Laidi, Z. and Costopoulos, P. J. (2002). Democracy in real time. *Journal of Democracy*, *13*(3), 68-79.

Langhorne, R. (2001). *The coming of globalization: Its evolution and contemporary consequences*. Springer.

Lean, H. H. and Smyth, R. (2010a). Multivariate Granger causality between electricity generation, exports, prices and GDP in Malaysia. *Energy*, *35*(9), 3640-3648.

Lean, H. H. and Smyth, R. (2010b). On the dynamics of aggregate output, electricity consumption and exports in Malaysia: evidence from multivariate Granger causality tests. *Applied Energy*, *87*(6), 1963-1971.

Leit, N. C. (2014). Economic growth, carbon dioxide emissions, renewable energy and globalization. *International Journal of Energy Economics and Policy*, *4*(3), 391.

Li, L. (2010). An empirical analysis of relationship between export and energy consumption in shandong province. *International Journal of Business and Management*, *5*(3), 214.

Ljung, G. M. and Box, G. E. (1978). On a measure of lack of fit in time series models. *Biometrika*, 297-303.

Naimi, A. (2005). Globalization and the Future of the Oil Market. *Middle East Economic Survey*, *48*(22).

Narayan, P. K. and Smyth, R. (2009). Multivariate Granger causality between electricity consumption, exports and GDP: evidence from a panel of Middle Eastern countries. *Energy Policy*, *37*(1), 229-236.

Overland, I. (2016). Energy: The missing link in globalization. *Energy Research & Social Science*, *14*, 122-130.

Panayotou, T. (1993). *Empirical tests and policy analysis of environmental degradation at different stages of economic development* (No. 992927783402676). International Labour Organization.

Perron, P. (2006). Dealing with structural breaks. *Palgrave handbook of econometrics*, *1*(2), 278-352.

Potrafke, N. (2015). The evidence on globalisation. *The World Economy*, 38(3), 509-552.

Psaradakis, Z., Ravn, M. O. and Sola, M. (2005). Markov switching causality and the money–output relationship. *Journal of Applied Econometrics*, *20*(5), 665-683.

Rahman, S. M. and Miah, M. D. (2017). The impact of sources of energy production on globalization: Evidence from panel data analysis. *Renewable and Sustainable Energy Reviews*, *74*, 110-115.

Robertson, R. (1992). *Globalization: Social theory and global culture* (Vol. 16). Sage.

Ozturk, I. and Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics*, *36*, 262-267.

Sadorsky, P. (2011). Trade and energy consumption in the Middle East. *Energy Economics*, *33*(5), 739-749.

Sadorsky, P. (2012). Energy consumption, output and trade in South America. *Energy Economics*, *34*(2), 476-488.

Sami, J. (2011). Multivariate cointegration and causality between exports, electricity consumption and real income per capita: recent evidence from Japan. *International Journal of Energy Economics and Policy*, *1*(3), 59.

Selden, T. M. and Song, D. (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and management*, *27*(2), 147-162.

Selden, T. M. and Song, D. (1995). Neoclassical growth, the J curve for abatement, and the inverted U curve for pollution. *Journal of Environmental Economics and management*, *29*(2), 162-168.

Shafik, N. and Bandyopadhyay, S. (1992). *Economic growth and environmental quality: time-series and cross-country evidence* (Vol. 904). World Bank Publications.

Shahbaz, M., Lean, H. H. and Farooq, A. (2013a). Natural gas consumption and economic growth in Pakistan. *Renewable and Sustainable Energy Reviews*, *18*, 87-94.

Shahbaz, M., Khan, S. and Tahir, M. I. (2013b). The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate framework analysis. *Energy economics*, *40*, 8-21.

Shahbaz, M., Nasreen, S., Ling, C. H. and Sbia, R. (2014). Causality between trade openness and energy consumption: What causes what in high, middle and low income countries? *Energy Policy*, *70*, 126-143.

Shahbaz, M., Loganathan, N., Zeshan, M. and Zaman, K. (2015). Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. *Renewable and Sustainable Energy Reviews*, *44*, 576-585.

Shahbaz, M., Mallick, H., Mahalik, M. K. and Loganathan, N. (2015). Does globalization impede environmental quality in India? *Ecological Indicators*, *52*, 379-393.

Shahbaz, M., Mallick, H., Mahalik, M. K. and Sadorsky, P. (2016). The role of globalization on the recent evolution of energy demand in India: Implications for sustainable development. *Energy Economics*, *55*, 52-68.

Shahbaz, M., Shahzad, S. J. H., Mahalik, M. K. and Sadorsky, P. (2017). How strong is the causal relationship between globalization and energy consumption in developed economies? A country-specific time-series and panel analysis. *Applied Economics*, 1-16.

Shi, S., Hurn, S. and Phillips, P. C. B. (2016). Causal change detection in possibly integrated systems: revisiting the money-income relationship. Cowles Foundation Discussion Paper No. 2058.

Stern, D. I. (2000). A multivariate cointegration analysis of the role of energy in the US macroeconomy. *Energy Economics*, *22*(2), 267-283.

Stern, D. I. (2007). The effect of NAFTA on energy and environmental efficiency in Mexico. *Policy Studies Journal*, *35*(2), 291-322.

Stock, J. H. and Watson, M. W. (1989). Interpreting the evidence on money-income causality. *Journal of Econometrics*, *40*(1), 161-181.

Swanson, N. R. (1998). Money and output viewed through a rolling window. Journal of Monetary Economics, 41, 455–474.

Szeman, I. (2003). Culture and Globalization, or, the Humanities in Ruins. *CR: The New Centennial Review*, *3*(2), 91-115.

Teräsvirta, T. (1998) “Modelling economic relationships with smooth transition regressions”, in A. Ullah and D. E. Giles (eds.), *Handbook of Applied Economic Statistics*, Dekker, New York, pp. 507–552.

Thoma, M. A. (1994). Subsample instability and asymmetries in money-income causality. Journal of Econometrics, 64, 279–306.

Toda, H.Y. and Phillips, P. C. B. (1993). Vector autoregressions and causality. Econometrica, 61, 1367–1393.

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Toda, H. Y. and Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. Journal of Econometrics, 66, 225-250.

Table 1A. Descriptive statistics for the globalization index

	N	Mean	S.D.	Min	Max	Skewness	Kurtosis	JB	Q(1)	Q(4)	ARCH(1)	ARCH(4)	Starting Period
Netherlands	184	20.84	2.09	16.07	23.03	-0.74	-0.73	20.86***	180.28***	682.46***	181.89***	179.13***	1970Q1
Ireland	184	19.80	2.21	15.79	23.31	-0.22	-1.08	10.02***	181.57***	695.45***	180.79***	178.46***	1970Q1
Belgium	184	20.77	2.20	17.06	23.11	-0.52	-1.31	21.35***	183.23***	712.64***	181.82***	179.16***	1970Q1
Austria	184	19.90	2.87	14.14	23.01	-0.69	-0.76	19.02***	181.74***	697.48***	181.19***	178.60***	1970Q1
Switzerland	184	20.28	2.00	15.54	22.86	-0.74	-0.37	17.81***	180.85***	686.12***	180.32***	177.69***	1970Q1
Singapore	184	19.54	2.44	14.53	22.21	-0.76	-0.72	21.79***	181.43***	692.82***	181.80***	179.19***	1970Q1
Denmark	184	19.94	2.02	16.51	22.47	-0.37	-1.32	17.26***	183.20***	711.84***	181.76***	179.22***	1970Q1
Sweden	184	20.09	2.05	15.53	22.36	-0.59	-0.94	17.20***	181.39***	696.66***	181.38***	178.56***	1970Q1
Hungary	184	16.44	4.29	10.75	21.71	-0.03	-1.79	24.35***	183.88***	720.48***	180.71***	178.28***	1970Q1
Canada	184	20.42	1.31	17.21	22.21	-0.68	-0.38	15.49***	180.08***	682.37***	180.97***	178.29***	1970Q1
Kyrgyz Republic	100	12.20	1.92	7.49	14.41	-0.90	-0.60	15.29***	95.53***	343.45***	97.65***	94.85***	1991Q1
Bolivia	184	11.00	2.00	8.00	13.72	0.17	-1.66	21.68***	182.60***	700.43***	179.11***	177.85***	1970Q1
Macedonia FYR	100	11.92	2.77	7.23	15.57	-0.17	-1.51	9.55***	97.80***	364.26***	95.27***	92.97***	1991Q1
Kazakhstan	100	12.38	2.44	7.74	15.19	-0.53	-1.17	10.14***	97.67***	364.36***	97.88***	95.30***	1991Q1
Ecuador	184	10.77	2.42	7.36	14.39	0.16	-1.65	21.23***	182.76***	704.80***	179.20***	177.43***	1970Q1
Bahamas	184	12.12	1.05	9.64	14.25	-0.45	0.06	6.31**	176.65***	635.38***	178.48***	176.70***	1970Q1
Nicaragua	184	10.65	2.11	8.29	13.56	0.35	-1.72	26.03***	183.43***	714.53***	179.69***	177.81***	1970Q1
Namibia	104	12.96	1.58	10.05	15.51	-0.46	-0.82	6.46**	100.05***	352.93***	96.20***	95.11***	1990Q1
Senegal	184	10.52	1.96	6.98	13.54	0.10	-1.18	10.61***	179.64***	669.14***	176.73***	174.90***	1970Q1

Note: Table reports the descriptive statistics for the globalization index series. Sample period starts at the period given in the last column of the table and ends at 2015:4 at quarterly frequency with *n* observations for each series. In addition to the mean, the standard deviation (S.D.), minimum (min), maximum (max), skewness, and kurtosis statistics, the table reports the Jarque-Bera normality test (JB), the Ljung-Box first [*Q*(1)] and the fourth [*Q*(4)] autocorrelation tests, and the first [ARCH(1)] and the fourth [ARCH(4)] order Lagrange multiplier (LM) tests for the autoregressive conditional heteroskedasticity (ARCH). The asterisks ***, ** and * represent significance at the 1%, 5%, and 10% levels, respectively.

Table 1B. Descriptive statistics for the energy consumption series

	N	Mean	S.D.	Min	Max	Skewness	Kurtosis	JB	Q(1)	Q(5)	ARCH(1)	ARCH(4)	Starting Period
Netherlands	184	1125.56	71.93	932.76	1261.95	-0.87	0.46	25.32***	171.33***	523.43***	163.33***	164.79***	1970Q1
Ireland	184	702.88	124.66	470.22	930.00	0.23	-1.17	11.88***	182.36***	704.71***	177.73***	177.18***	1970Q1
Belgium	184	1246.39	123.28	1012.31	1430.85	-0.06	-1.19	10.53***	181.10***	663.83***	169.98***	171.27***	1970Q1
Austria	184	838.10	121.86	597.64	1029.47	-0.02	-1.22	11.04***	180.95***	685.17***	176.30***	174.20***	1970Q1
Switzerland	184	820.09	75.53	632.06	921.77	-0.77	-0.53	20.21***	176.91***	630.25***	174.93***	172.26***	1970Q1
Singapore	184	946.40	410.57	227.76	1887.83	0.00	-1.21	10.84***	180.59***	669.34***	158.56***	161.59***	1970Q1
Denmark	184	895.93	69.26	709.85	1050.92	-0.57	0.36	11.48***	165.03***	485.13***	166.24***	168.78***	1970Q1
Sweden	184	1326.31	103.50	1107.78	1474.01	-0.41	-1.01	12.85***	176.54***	595.09***	162.87***	166.32***	1970Q1
Hungary	184	622.90	66.06	419.20	726.21	-1.04	0.86	39.92***	173.01***	608.19***	181.04***	178.18***	1970Q1
Canada	184	1894.52	111.02	1610.51	2097.75	-0.28	-0.28	2.96	176.46***	612.68***	176.65***	176.17***	1970Q1
Kyrgyz Republic	100	153.71	39.72	108.10	299.16	1.46	1.87	52.82***	84.24***	240.42***	96.68***	93.32***	1991Q1
Bolivia	184	118.78	40.15	51.77	227.83	0.60	-0.02	11.21***	174.74***	624.47***	179.97***	177.75***	1970Q1
Macedonia FYR	100	343.08	19.86	286.08	381.42	-0.16	-0.28	0.62	77.76***	151.24***	66.89***	73.36***	1991Q1
Kazakhstan	100	924.68	222.90	571.45	1267.82	-0.15	-1.44	8.66**	98.46***	354.89***	91.83***	91.87***	1991Q1
Ecuador	184	167.22	42.14	86.71	254.90	0.12	-0.33	1.11	178.12***	659.50***	181.86***	179.37***	1970Q1
Bahamas	184	581.81	76.44	493.63	747.30	0.73	-0.96	23.48***	179.88***	673.22***	181.92***	178.92***	1970Q1
Nicaragua	184	128.40	9.46	109.61	163.38	1.42	2.51	113.80***	166.51***	512.95***	177.02***	175.76***	1970Q1
Namibia	104	155.85	21.03	115.46	191.58	-0.10	-1.01	4.25	98.70***	345.70***	101.04***	98.52***	1990Q1
Senegal	184	63.87	6.59	51.82	76.19	-0.02	-1.08	8.53**	181.04***	665.88***	170.97***	171.40***	1970Q1

Note: Table reports the descriptive statistics for the energy consumption series. Sample period starts at the period given in the last column of the table and ends at 2015:4 at quarterly frequency with *n* observations for each series. In addition to the mean, the standard deviation (S.D.), minimum (min), maximum (max), skewness, and kurtosis statistics, the table reports the Jarque-Bera normality test (JB), the Ljung-Box first [*Q*(1)] and the fourth [*Q*(4)] autocorrelation tests, and the first [ARCH(1)] and the fourth [ARCH(4)] order Lagrange multiplier (LM) tests for the autoregressive conditional heteroskedasticity (ARCH). The asterisks ***, ** and * represent significance at the 1%, 5%, and 10% levels, respectively.

Table 2. Linear Granger causality tests

	H_0: Energy consumption does not Granger cause globalization	H_0: Globalization dos not Granger cause energy consumption	Order of the VAR (p)
Netherlands	0.1576	0.5662	2
Ireland	0.5545	0.2168	2
Belgium	0.0612	1.2589	2
Austria	1.5480	3.5256**	2
Switzerland	2.2724	2.0586	2
Singapore	1.8392	3.4333**	2
Denmark	0.3060	0.7394	2
Sweden	0.4086	0.5515	2
Hungary	1.6182	1.8527	2
Canada	0.2025	0.7203	2
Kyrgyz Republic	0.8695	1.8833	2
Bolivia	1.2472	0.3814	2
Macedonia FYR	0.3372	0.6670	2
Kazakhstan	0.8737	4.1553**	2
Ecuador	0.7301	1.5402	2
Bahamas	1.1040	0.6690	2
Nicaragua	0.2735	1.7771	2
Namibia	3.7189**	1.3386	2
Senegal	0.0255	0.0947	2

Note: The table reports the F-statistic for the no Granger causality restrictions imposed on a linear vector autoregressive (VAR) model under the null hypotheses H_0. The VAR model is fitted to the level of the series. The order (p) of the VAR is selected by the Bayesian Information Criterion (BIC). ***, **, and * indicates rejection of the null of no Granger causality at 1%, 5%, and 10% level of significance respectively.

Table 3. Parameter stability tests

	Globalization Equation			Energy Consumption Equation			VAR System		
	Sup-F	***Mean-F***	***Exp-F***	***Sup-F***	***Mean-F***	***Exp-F***	***Sup-F***	***Mean-F***	***Exp-F***
Netherlands	52.319***	7.733**	21.344***	43.988***	3.241	17.131***	63.586***	9.049*	27.132***
Ireland	367.913***	14.890***	179.089	48.721***	18.176***	19.600***	168.370***	26.837***	79.318***
Belgium	144.052***	17.814***	67.172	149.212***	16.428***	69.877	50.002***	22.590***	20.574***
Austria	45.834***	14.412***	19.059***	74.681***	9.897***	32.474	60.541***	22.104***	26.114***
Switzerland	16.710**	4.631	4.499**	20.516***	3.401	5.482**	20.983**	8.820	6.912*
Singapore	37.282***	9.363***	13.792***	30.946***	7.618**	10.956***	92.131***	20.562***	41.198***
Denmark	272.361***	18.949***	131.313	32.500***	6.991**	11.963***	45.364***	19.819***	18.572***
Sweden	38.005***	14.068***	16.000***	20.290***	6.568**	6.447***	28.182***	17.236***	11.422***
Hungary	137.704***	39.398***	64.082	83.653***	11.542***	37.266	89.574***	39.966***	41.097***
Canada	26.251***	6.252**	9.451***	145.007***	13.167***	67.636	38.611***	14.501***	15.389***
Kyrgyz Republic	281.182***	21.992***	136.314	878.053***	61.874***	434.750	48.305***	30.964***	21.204***
Bolivia	38.014***	6.945**	14.484***	11.656	6.182**	3.827*	40.965***	14.602***	16.841***
Macedonia FYR	147.162***	17.273***	69.321	125.226***	12.637***	58.336	33.273***	9.926*	12.760***
Kazakhstan	331.242***	41.058***	161.344	108.690***	11.346***	50.068	54.422***	24.099***	23.007***
Ecuador	148.952***	10.291***	69.608	34.670***	6.614**	12.778***	36.026***	12.426**	13.772***
Bahamas	34.451***	19.473***	13.788***	52.096***	16.909***	21.785***	46.255***	23.533***	19.538***
Nicaragua	177.610***	23.555***	84.082	110.238***	8.232**	50.252	58.382***	24.485***	25.348***
Namibia	48.344***	5.984*	19.868***	66.526***	13.996***	29.670**	24.496**	9.293*	8.950***
Senegal	30.635***	4.476	10.464***	136.262***	9.120***	63.264	49.697***	12.494**	20.700***

Note: The parameter stability tests exhibit non-standard asymptotic distributions. By means of the parametric bootstrap procedure, Andrews (1993) and Andrews and Ploberger (1994) report the critical values and *p*-values for the non-standard asymptotic distributions of these tests. Besides, according to Andrews (1993), 15-percent trimming from both ends of the sample is required for the *Sup-F*, *Mean-F* and *Exp-F*. Hence, the tests are applied to the fraction of the sample in (0.15, 0.85). We calculate critical values of the tests using 2,000 bootstrap repetitions.

Figure 1. Time series plots of the globalization and energy consumption series

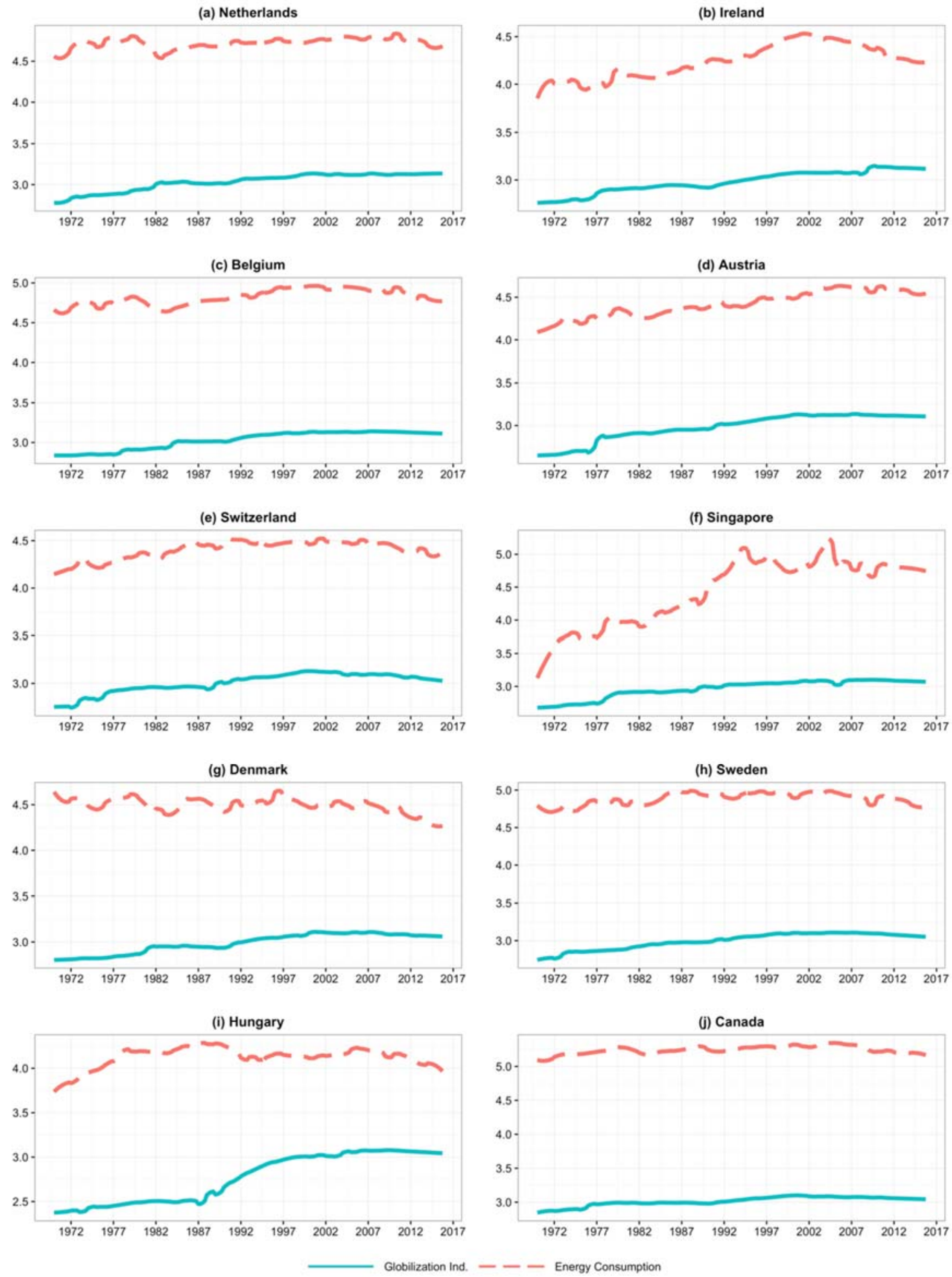


Figure 1. (continued)

Note: Figure plots the natural logarithms of the series. Level of the energy consumption series are scaled by 10 for easy presentation.

Figure 2. Wald tests for Granger causality running from energy consumption to globalization

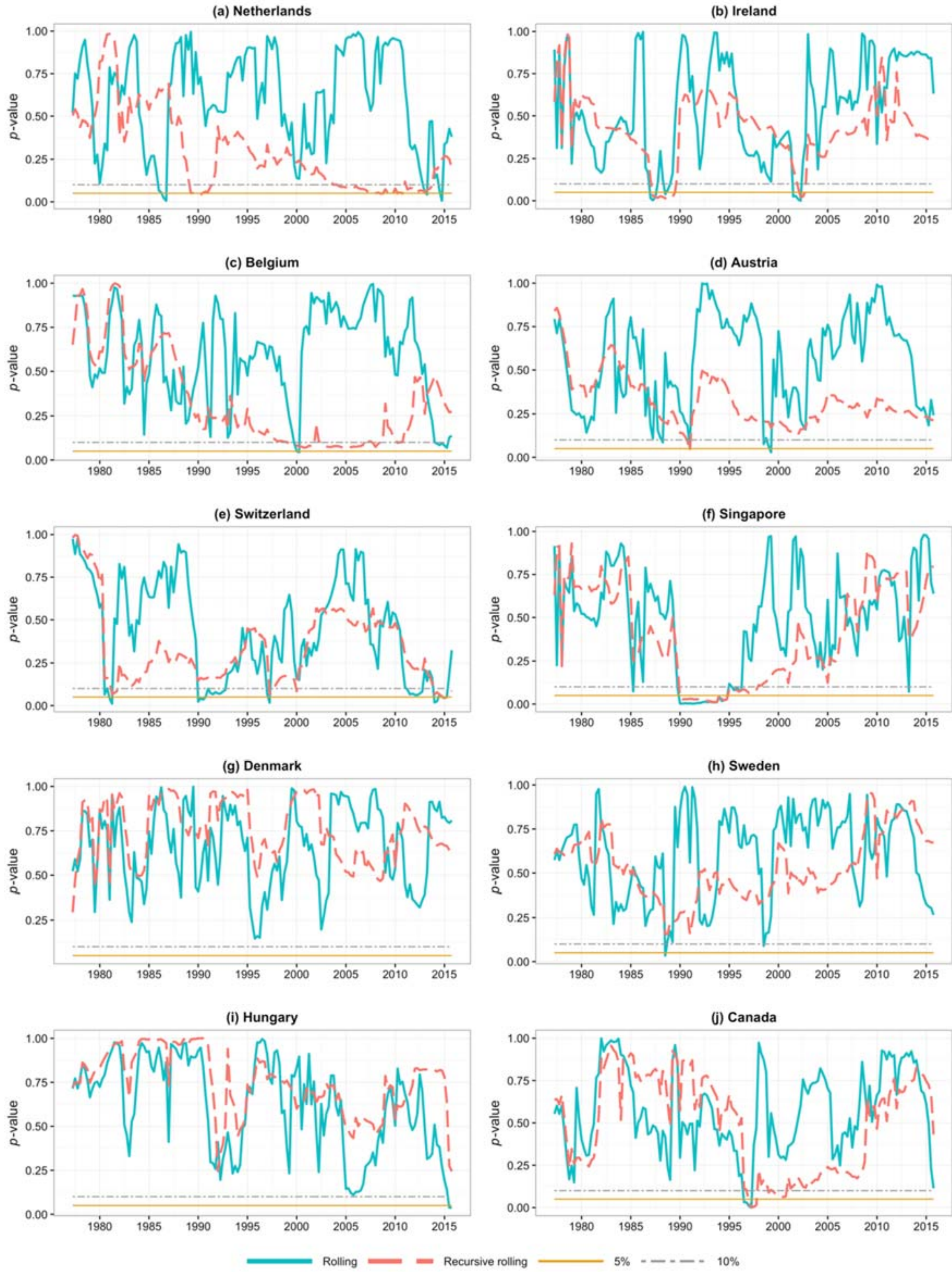
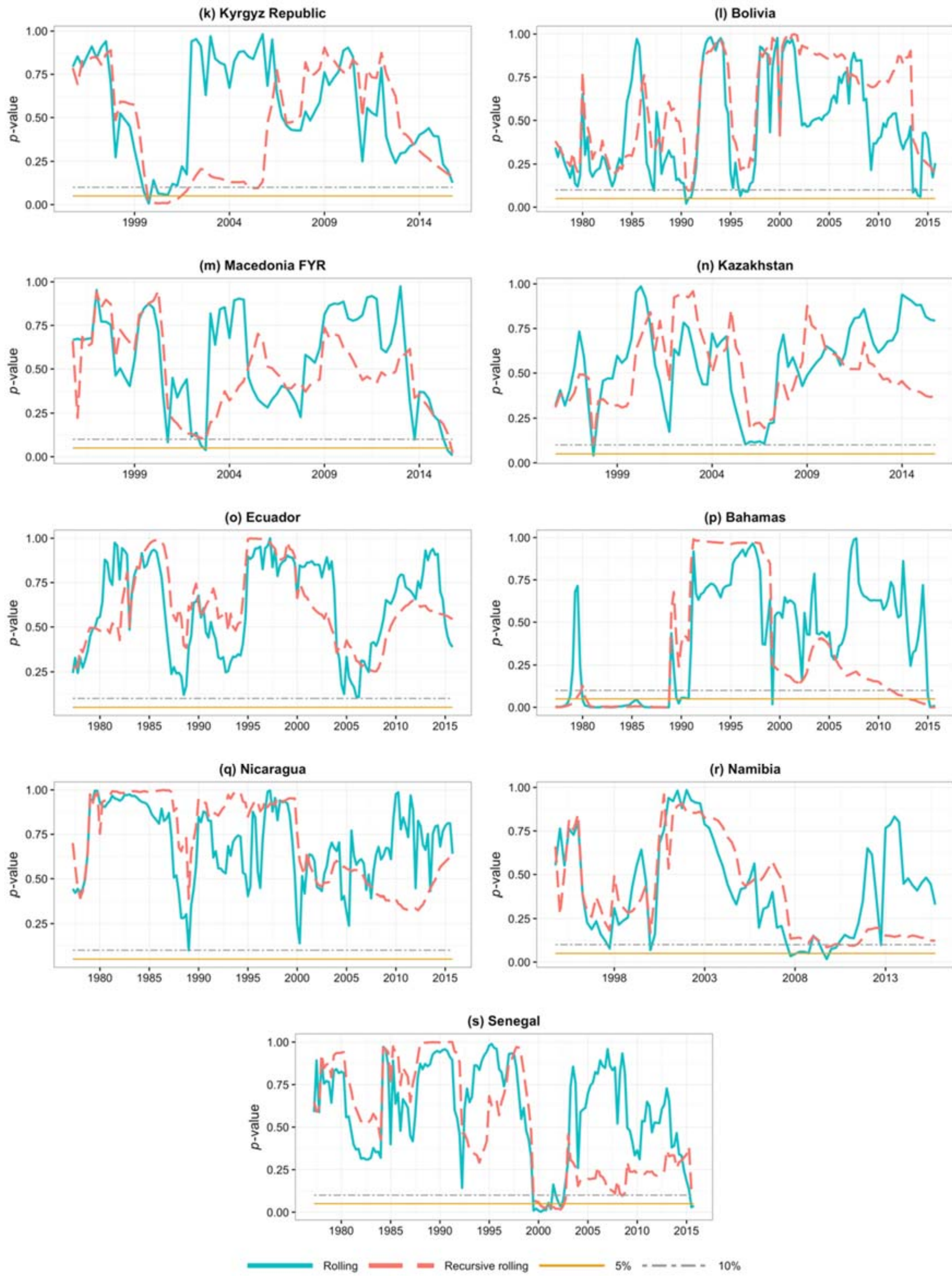


Figure 2. (continued)



Note: The bootstrap *p*-values of the rolling and recursive-rolling Wald tests are obtained from a VAR model with a varying lag order and a minimum window size that is equal to the integer part of 20% of the number of observations. For each sub-sample, the BIC is used to select the optimal lag orders with a maximum lag order of 12. The *p*-values of the tests are obtained using 1,000 bootstrap repetitions.

Figure 3. Heteroskedasticity consistent Wald tests for Granger causality running from energy consumption to globalization

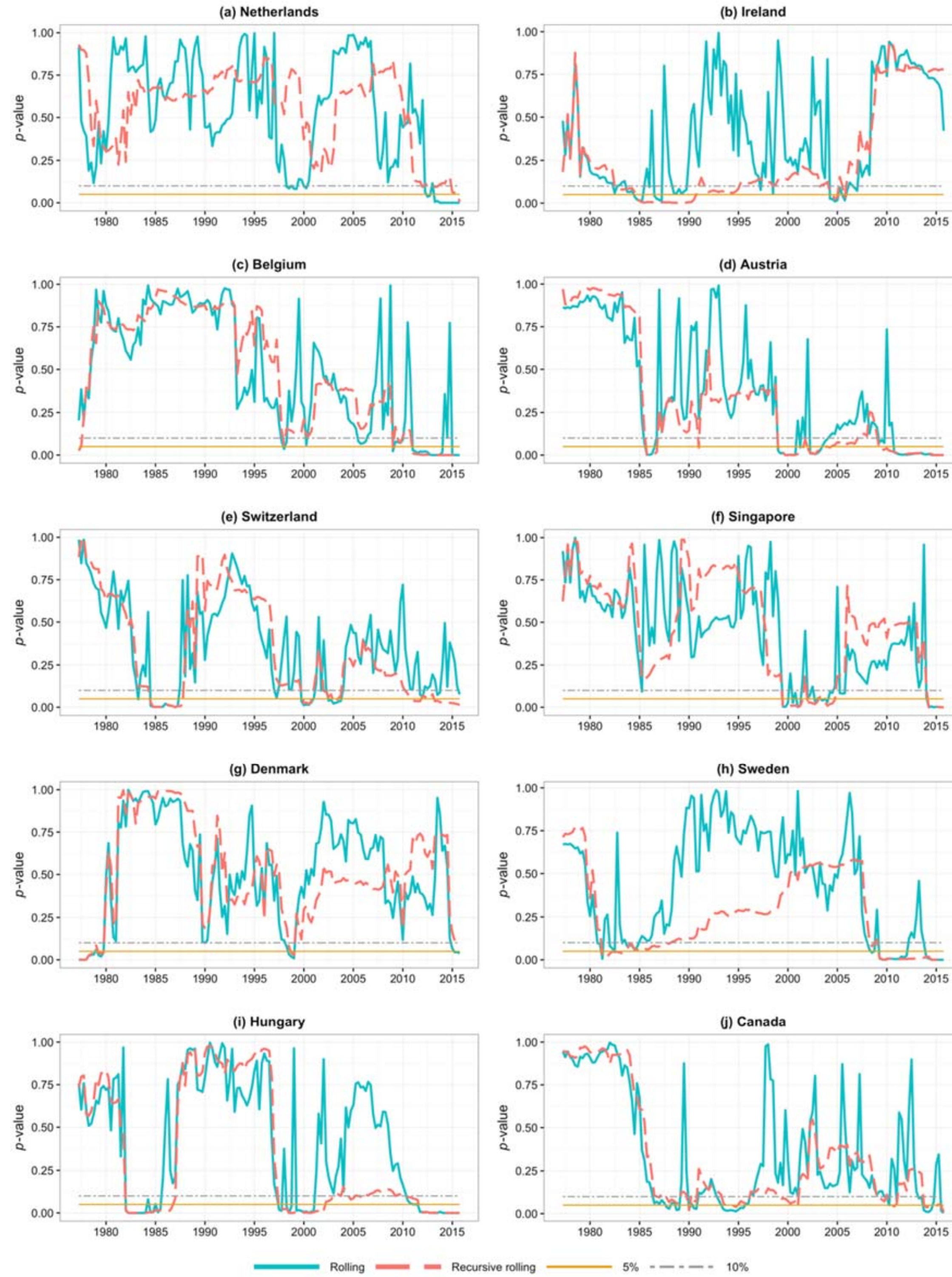
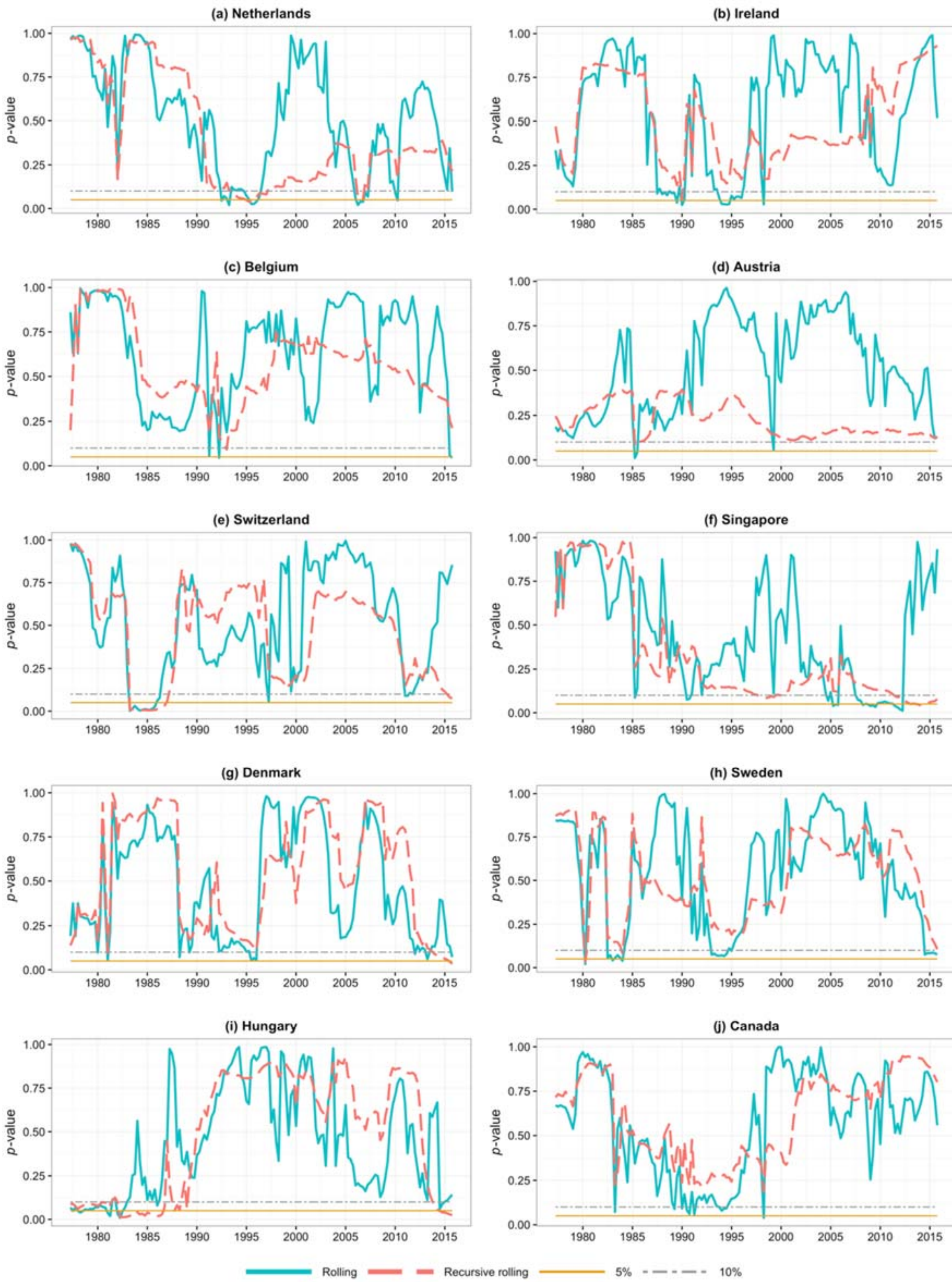


Figure 3. (continued)

Note: See note to Figure 2.

Figure 4. Wald tests for Granger causality running from globalization to energy consumption



Note: See note to Figure 2.

Figure 4. (continued)

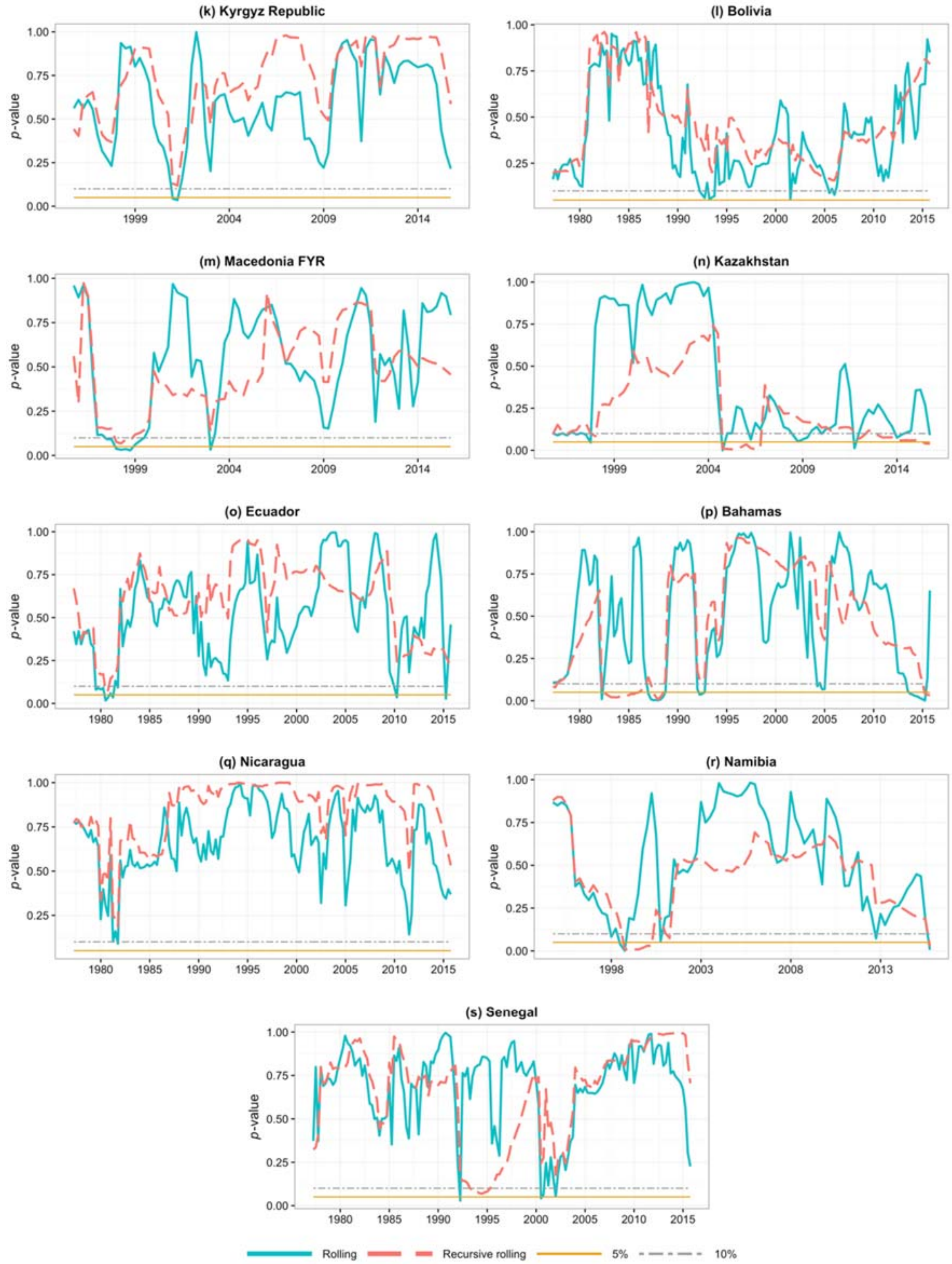
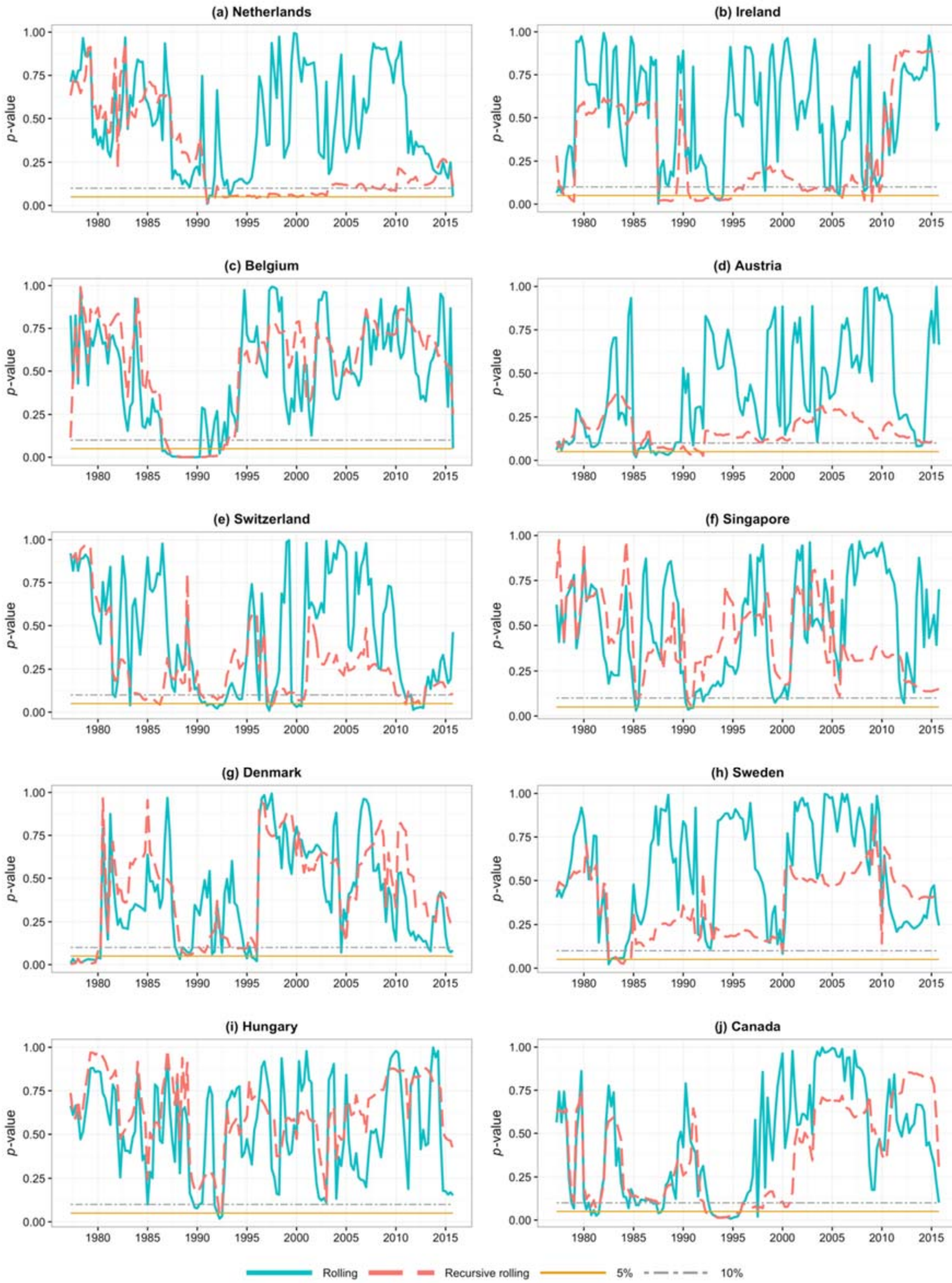


Figure 5. Heteroskedasticity consistent Wald tests for Granger causality running from globalization to energy consumption



Note: See note to Figure 2.

Figure 5. (continued)