Energy consumption, economic growth, foreign direct investment and globalization causality nexus in OECD countries: A symbolic transfer entropy analysis

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Abstract

In this paper, we investigate the validity and usefulness of the symbolic transfer entropy (STE) test for longitudinal data by examining causality relationships among foreign direct investment, energy consumption, globalization and economic growth respectively, between the periods 1970-2015 using Organization for Economic Co-operation and Development (OECD) countries as a case study. Our empirical results are in line with the existing literature and empirical outcomes generated using other forms of causality approaches. Thus, we are of the opinion that the STE causality approach is suitable approach for longitudinal panel data.

1. Introduction

To justify the strength and validity of the symbolic transfer entropy test for longitudinal data, and how the results can outperform, corroborate or contrast existing studies results (see Abdouli & Hammami, 2017; Akadiri, Bekun, Taheri & Akadiri, 2019; Balibey, 2015; Latif, Latif, Ximei, Pathan, Salam & Jianqiu, 2018; Leitao, 2015; Ozcan & Ozturk, 2019; Pao & Tsai, 2011; Salahuddin, Alam, Ozturk & Sohag, 2018; Shahbaz, Shahzad, Mahalik & Sadorsky, 2018; Sarkodie & Strezov, 2019) basically generated using other forms of causality test, we empirically examine panel-based causality relationships among foreign direct investment, energy consumption, globalization and economic growth respectively, between the periods 1970-2015 using Organization for Economic Co-operation and Development (OECD) countries as a case study. The main objective of this study is to test the significance of symbolic transfer entropy (STE) in practice, and to test whether the causality test results generated are in line with the existing literature and empirical outcomes (as robustness check) from other forms of causality approaches.

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Contemporary empirical study in the area of Granger causality examination have broaden the causality investigation among macroeconomic variables to the scope of testing longitudinal data via imposition of coefficient restrictions that can be examined using relatively conventional causality approaches most especially when linear relationship are present in panel data. Holtz-Eakin, Newey and Rosen (1988) that controls for individual fixed effects in panel data and Dumitrescu and Hurlin (2012) that control for heterogeneity in panel model are two major thoughts that adhere to this causality technique. Having consider the lucidity and intelligibility of these conventional causality techniques, the power and sample size problems of these causality tests can gravely worsen or degenerate when the following happen; the linearity proposition fail to hold, presence of regime switching or structural breaks are present in some of the cross-sectional units, or existence of heterogeneity in the data-generating process is across the cross-section units. Furthermore, most of the conventional causality techniques are not built to capture qualitative time-series data.

To overcome this drawback, Camacho et al. (2020) introduced a non-parametric Granger causality test procedure for panel data based on the concept of transfer entropy and a multiple-unit symbolic dynamics. In other words, the Camacho et al. (2020) test avoids the need to rely on a linear parametric representation of the data set. Consequently, the test displays correct size and higher power in those cases where causality tests based in linear panel data specifications fail. The symbolic transfer entropy is a non-parametric test, which by construction is built on sensitive propositions. The non-parametric behavior of the symbolic transfer entropy is captured in the Monte-Carlo estimations, proposing that the symbolic transfer entropy exhibit higher power and correct sample size in situations where causality estimations built on linear specifications fails. Thus, symbolic transfer entropy avoids depending on linear parametric representation of the panel dataset, in case the panel model is not consistently estimated or mis-specified, which might lead to spurious outcomes or invalidate such empirical results that are majorly built or relies on linear panel data representation[1]. Lastly, the symbolic transfer entropy is built for longitudinal data and it provides robust results even when the data-generating process varies significantly across the cross-section units (Camacho et al., 2020).

The remaining sections of the study are outlined as follow; section 2 discusses data and methodology adopted. Section 3 entails results and empirical findings, while section 4 conclude the study.
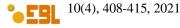
2. Data and methodology

2.1. Data

To conduct our empirical analysis and investigate the relationship between the energy consumption (EC), economic growth (GDP), foreign direct investment (FDI) and globalization (Gb) in OECD countries between the periods 1970-2015, we use the following proxies to measure the variables: energy consumption is measured by the energy use (kg of oil equivalent per capita); economic growth is measured as GDP per capita (constant 2010 US$); FDI as net inflows (% of GDP); and the globalization index which measures the economic, social and political dimensions of globalization. All variables are derived from the World Bank, excepting globalization index, which is sourced from the work of Dreher (2006).

2.2. Methodology

To investigate the relationship between the energy consumption, economic growth, foreign direct investment and globalization in OECD countries, we use the new non-parametric Granger causality test recently introduced by Camacho et al. (2020). In fact, testing if the values of x with r delays help to predict the actual values of y or testing if the values of y with r delays help to predict the actual values of x necessitates a using of stacked vectors such as:

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[1] For brevity and the research note word counts, we could not discuss each section in details. Interested reader should see Camacho et al. (2020).

$$\{y_t = y_{1,r}, \ldots, y_{1,T_i}, \ldots, y_{N,r}, \ldots, y_{N,T_i}\},$$
$$\{x_t = x_{1,r}, \ldots, x_{1,T_i}, \ldots, x_{N,r}, \ldots, x_{N,T_i}\},$$
$$\{y_{t-r} = y_{1,1}, \ldots, y_{1,T_i-r}, \ldots, y_{N,1}, \ldots, y_{N,T_i-r}\},$$
$$\{x_{t-r} = x_{1,1}, \ldots, x_{1,T_i-r}, \ldots, x_{N,1}, \ldots, x_{N,T_i-r}\}. \tag{1}$$

Indeed, Camacho et al. (2020) investigate the informational content of the pooled symbols of $\{x_{t-r}\}$ on the pooled conditional entropy $h_m(y_t|y_{t-r}, x_{t-r})$ which is defined as the sum of the conditional entropies of the N cross-sections:

$$h_m(y_t|y_{t-r}, x_{t-r}) = \sum_{i=1}^{N} h_m(y_{i,t}|y_{i,t-r}, x_{i,t-r}) \tag{2}$$

Following Schreiber (2000), Camacho et al. (2020) introduced the Symbolic Transfer Entropy (STE) to measure the information transfer from $\{x_{t-r}\}$ to $\{y_t\}$ given $\{y_{t-r}\}$

$$STE_{x \to y}(m, r) = h_m(y_t|y_{t-r}) - h_m(y_t|y_{t-r}, x_{t-r}) \tag{3}$$

If the $STE_{x \to y}(m, r)$ is large then the past values of x helps to predict current values of y. To derive the asymptotic distribution of the statistic $STE_{x \to y}(m, r)$, Camacho et al. (2020) propose a bootstrap test procedure which on replicating B times the following steps:

- *Step 1*: Based on the original pooled time series $\{x_t\}$ and $\{y_t\}$, we start by computing the value of $STE_{x \to y}(m, r)$.
- *Step 2*: Using the stationary bootstrap method of Politis and White (2004), we sample $\{x_{i,t}^b\}$ and $\{y_{i,t}^b\}$ for $i = 1, 2, \ldots, N$ to compute the relative frequencies of the symbols and obtain the entropy measures $h_m^b(y_t|y_{t-r})$ and $h_m^b(y_t|y_{t-r}, x_{t-r})$.
- *Step 3*: The bootstrapped realization of the symbolic transfer entropy is calculated as:
$$STE_{x \to y}^b(m, r) = h_m^b(y_t|y_{t-r}) - h_m^b(y_t|y_{t-r}, x_{t-r})$$
- *Step 4*: We obtain B bootstrap realizations of the statistic $\{STE_{x \to y}^b(m, r)\}_{b=1}^{B}$ by repeating $(B-1)$ times the steps 2 and 3.
- *Step 5*: The bootstrap p_b-value is calculated as:
$$p_b = \frac{1}{B} \sum_{b=1}^{B} I\left(STE_{x \to y}^b(m, r) > STE_{x \to y}(m, r)\right),$$
  where $I(.)$ is an indicator function which takes 1 for a true statement and 0 otherwise. If $p_b < \alpha$, we reject the null hypothesis that x does not cause y with α is the nominal level.

3. Empirical results

To check the integration order of each variable, we implement three panel unit root tests namely the Im, Pesaran and Shin (IPS) test, the ADF - Fisher Chi-square test and the PP - Fisher Chi-square test. The results of panel unit root tests are reported in Table 1. The test statistics show that the economic growth and globalization variables are stationary in the countries but at different levels. However, the energy consumption and FDI are stationary in level. Consequently, the energy consumption and globalization are used in first difference to deal with unit root issues.

Now, we proceed to the next stage, which consists on testing the presence causality between variables based on the Symbolic Transfer Entropy (STE) causality test. Table 2 shows the results of STE causality test. Following Camacho et al. (2020), each panel corresponds to a different lag length specification running from one to three years. The entropy test results reported bidirectional causality between energy consumption and economic growth, between energy consumption and globalization, and between energy growth and FDI. Also, the p-values

Table 1. Panel unit root tests results.

Variables	Level			First difference	
		Intercept	Intercept and trend	Intercept	Intercept and trend
Im, Pesaran and Shin (IPS)					
EC		0.0012 [a]	0.9184	-	0.0000 [a]
GDP		0.9999	0.8657	0.0000 [a]	0.0000 [a]
FDI		0.0000 [a]	0.0000 [a]	-	-
GB		0.9500	0.9984	0.0000 [a]	0.0000 [a]
ADF - Fisher Chi-square					
EC		0.0000 [a]	0.0255 [b]	-	-
GDP		0.9999	0.6900	0.0000 [a]	0.0000 [a]
FDI		0.0000 [a]	0.0000 [a]	-	-
GB		0.4688	0.9985	0.0000 [a]	0.0000 [a]
PP - Fisher Chi-square					
EC		0.0117 [b]	0.0001 [a]	-	-
GDP		0.9999	0.9929	0.0000 [a]	0.0000 [a]
FDI		0.0000 [a]	0.0000 [a]	-	-
GB		0.0007 [a]	0.9854	-	0.0000 [a]

Note: Statistical significance at the 5% and 1% levels are denoted by the superscripts [b] and [a], respectively.

of STE show one-way causality running from energy consumption to FDI and from globalization to economic growth. Also, we accept the null hypothesis of non – causality between FDI and globalization who validated the absence globalization-led-FDI hypothesis.

In other word, the results identified that increase in energy consumption increases economic growth and globalization in OECD countries and vice versa. Also, an increase in FDI provides the increase of economic growth and vice versa. Likewise, the results identified that increase in globalization increases economic growth and that increase in energy consumption increases the FDI.

Also, we report in Table 2 the statistical significance of the Net Transfer Entropy (NTE), which is based on one and two tailed p-values. Looking to the p-values of the null symmetric information flow, we report that the net transfer is not significant for all pairwise causality, excepting the case between economic growth and globalization. In fact, the negative value of this net effect implies the prevalence of economic growth over globalization.

Table 2. The Symbolic Transfer Entropy (STE) causality test results.

		EC vs. GDP				EC vs. FDI	
Direction	**Stat**	**1-tail pval**	**2-tail pval**	**Direction**	**Stat**	**1-tail pval**	**2-tail pval**
Panel A: r = 1							
$EC \rightarrow GDP$	0.026	0.150		$EC \rightarrow FDI$	0.029	0.135	
$GDP \rightarrow EC$	0.028*	0.085		$FDI \rightarrow EC$	0.026	0.300	
Net (EC-GDP)	-0.002	0.325	0.670	*Net (EC-FDI)*	0.003	0.325	0.655
Panel A: r = 2							
$EC \rightarrow GDP$	0.077**	0.015		$EC \rightarrow FDI$	0.068	0.215	
$GDP \rightarrow EC$	0.074**	0.040		$FDI \rightarrow EC$	0.066	0.345	
Net (EC-GDP)	0.003	0.410	0.820	*Net (EC-FDI)*	0.002	0.430	0.885
Panel A: r = 3							
$EC \rightarrow GDP$	0.064	0.295		$EC \rightarrow FDI$	0.074*	0.085	
$GDP \rightarrow EC$	0.066	0.315		$FDI \rightarrow EC$	0.064	0.490	
Net (EC-GDP)	-0.002	0.470	0.875	*Net (EC-FDI)*	0.010	0.160	0.385

Table 2. The Symbolic Transfer Entropy (STE) causality test results (cont'd).

Direction	EC vs. Gb			Direction	GDP vs. FDI		
	Stat	1-tail pval	2-tail pval		Stat	1-tail pval	2-tail pval
Panel A: r = 1							
$EC \rightarrow Gb$	0.022	0.390		$GDP \rightarrow FDI$	0.029*	0.065	
$Gb \rightarrow EC$	0.028*	0.070		$FDI \rightarrow GDP$	0.039*	0.075	
Net (EC-Gb)	-0.005	0.180	0.360	*Net (GDP-FDI)*	0.000	0.495	0.955
Panel A: r = 2							
$EC \rightarrow Gb$	0.065	0.190		$GDP \rightarrow FDI$	0.064	0.325	
$Gb \rightarrow EC$	0.074**	0.015		$FDI \rightarrow GDP$	0.065	0.265	
Net (EC-Gb)	-0.009	0.175	0.410	*Net (GDP-FDI)*	-0.000	0.450	0.945
Panel A: r = 3							
$EC \rightarrow Gb$	0.070*	0.050		$GDP \rightarrow FDI$	0.063	0.465	
$Gb \rightarrow EC$	0.074**	0.020		$FDI \rightarrow GDP$	0.073*	0.080	
Net (EC-Gb)	-0.004	0.440	0.720	*Net (GDP-FDI)*	-0.009	0.185	0.360

For robustness, we add the results of the Holtz-Eakin, Newey, and Rosen (1988, HNR) and the Dumitrescu and Hurlin (2012, DH) causality tests in Table 3. In addition, Table 4 reports a comparison between the causality results of the Symbolic Transfer Entropy causality test with the HNR and the DH causality tests. We show that the HNR provide one-way causality running FDI to energy consumption when the DH and STE causality tests confirm the existence of causality in the opposite direction. The roles of energy consumption in influencing the level of FDI inflows have been extensively discussed in literature. To some economists, FDI causes energy consumption, while to some; energy consumption causes FDI either in a negative or positive way. Increase in FDI would increase energy consumption and vice versa. This finding is in line with the study of (Omri & Kahouli, 2014; Kivyiro & Arminen, 2014) that increase in energy consumption would likely increases FDI, and vice versa, while we could not reject the null hypothesis of non-causal relationship between FDI and economic growth, and FDI and globalization respectively.

Table 2. The Symbolic Transfer Entropy (STE) causality test results (cont'd).

Direction	GDP vs. Gb			Direction	FDI vs. Gb		
	Stat	1-tail pval	2-tail pval		Stat	1-tail pval	2-tail pval
Panel A: r = 1							
$GDP \rightarrow Gb$	0.023	0.480		$FDI \rightarrow Gb$	0.018	0.905	
$Gb \rightarrow GDP$	0.035***	0.000		$Gb \rightarrow FDI$	0.020	0.810	
Net (GDP-Gb)	-0.013	0.015	0.055	*Net (FDI-Gb)*	-0.002	0.445	0.775
Panel A: r = 2							
$GDP \rightarrow Gb$	0.058	0.610		$FDI \rightarrow Gb$	0.067	0.190	
$Gb \rightarrow GDP$	0.080***	0.005		$Gb \rightarrow FDI$	0.056	0.700	
Net (GDP-Gb)	-0.022	0.025	0.050	*Net (FDI-Gb)*	0.011	0.150	0.285
Panel A: r = 3							
$GDP \rightarrow Gb$	0.069	0.145		$FDI \rightarrow Gb$	0.073	0.110	
$Gb \rightarrow GDP$	0.082***	0.005		$Gb \rightarrow FDI$	0.066	0.300	
Net (GDP-Gb)	-0.013	0.135	*0.260*	*Net (FDI-Gb)*	0.007	0.240	0.505

Note: ***, ** and * represent significance level at 0.0, 0.051 and 0.10 per cents.

Table 3. HNR and DH causality tests results.

	EC vs. GDP				EC vs. FDI			
	HNR		DH			HNR		DH	
Direction	**Stat**	**p-value**	**Stat**	**p-value**	**Direction**	**Stat**	**p-value**	**Stat**	**p-value**
Panel A: r = 1									
$EC \rightarrow GDP$	-9.643***	0.000	1.795	0.135	$EC \rightarrow FDI$	0.440	0.660	13.115***	0.000
$GDP \rightarrow EC$	-1.773*	0.076	6.630***	0.000	$FDI \rightarrow EC$	-2.663***	0.008	2.542	0.105
Panel A: r = 2									
$EC \rightarrow GDP$	-5.995***	0.000	6.161***	0.005	$EC \rightarrow FDI$	-0.868	0.386	21.395***	0.000
$GDP \rightarrow EC$	-1.198	0.231	9.037	0.000	$FDI \rightarrow EC$	2.945***	0.003	5.000	0.110
Panel A: r = 3									
$EC \rightarrow GDP$	0.147	0.883	4.263*	0.065	$EC \rightarrow FDI$	0.220	0.826	29.694***	0.000
$GDP \rightarrow EC$	0.957	0.338	8.379***	0.000	$FDI \rightarrow EC$	-1.691*	0.091	6.393	0.115

Note: HNR and DH represent the Holtz-Eakin, Newey, and Rosen (1988) and the Dumitrescu and Hurlin (2012) causality tests, respectively. ***, ** and * represent significance level at 0.0, 0.051 and 0.10 per cents.

Table 3. HNR and DH causality tests results (cont'd).

	EC vs. Gb				GDP vs. FDI			
	HNR		DH			HNR		DH	
Direction	**Stat**	**p-value**	**Stat**	**p-value**	**Direction**	**Stat**	**p-value**	**Stat**	**p-value**
Panel A: r = 1									
$EC \rightarrow Gb$	-0.475	0.635	0.684	0.575	$GDP \rightarrow FDI$	-1.817*	0.069	3.558**	0.020
$Gb \rightarrow EC$	0.770	0.441	0.925	0.350	$FDI \rightarrow GDP$	8.106***	0.000	3.513***	0.020
Panel A: r = 2									
$EC \rightarrow Gb$	-0.909	0.364	1.717	0.305	$GDP \rightarrow FDI$	1.590	0.112	1.189	0.505
$Gb \rightarrow EC$	-0.996	0.319	-1.590	0.225	$FDI \rightarrow GDP$	-4.687***	0.000	7.846***	0.000
Panel A: r = 3									
$EC \rightarrow Gb$	-1.127	0.260	0.102	0.940	$GDP \rightarrow FDI$	1.141	0.254	1.762	0.280
$Gb \rightarrow EC$	0.771	0.441	-0.432	0.765	$FDI \rightarrow GDP$	-7.998***	0.000	6.675***	0.005

Note: HNR and DH represent the Holtz-Eakin, Newey, and Rosen (1988) and the Dumitrescu and Hurlin (2012) causality tests, respectively. ***, ** and * represent significance level at 0.0, 0.051 and 0.10 per cents.

Table 3. HNR and DH causality tests results (cont'd).

	GDP vs. Gb				FDI vs. Gb			
	HNR		DH			HNR		DH	
Direction	**Stat**	**p-value**	**Stat**	**p-value**	**Direction**	**Stat**	**p-value**	**Stat**	**p-value**
Panel A: r = 1									
$GDP \rightarrow Gb$	0.397	0.691	1.935	0.135	$FDI \rightarrow Gb$	-0.424	0.672	-1.288	0.310
$Gb \rightarrow GDP$	1.692*	0.091	-0.406	0.710	$Gb \rightarrow FDI$	-0.736	0.462	1.284	0.270
Panel A: r = 2									
$GDP \rightarrow Gb$	-0.634	0.526	2.876*	0.050	$FDI \rightarrow Gb$	0.720	0.472	1.292	0.295
$Gb \rightarrow GDP$	-5.380***	0.000	-0.299	0.820	$Gb \rightarrow FDI$	0.543	0.587	0.283	0.810
Panel A: r = 3									
$GDP \rightarrow Gb$	0.370	0.711	-0.970	0.425	$FDI \rightarrow Gb$	-0.311	0.756	0.918	0.445
$Gb \rightarrow GDP$	1.010	0.312	-0.645	0.560	$Gb \rightarrow FDI$	-0.445	0.656	0.099	0.940

Note: HNR and DH represent the Holtz-Eakin, Newey, and Rosen (1988) and the Dumitrescu and Hurlin (2012) causality tests, respectively. ***, * represent significance level at 0.01 and 0.10 per cents.

Also, HNR and DH report the absence of causality between energy consumption and globalization when STE show bidirectional causality. The roles of globalization in influencing energy consumption have been reported in literature. Globalization, either politically, economically or socially causes energy consumption in a negative or positive way and vice versa. This finding is in line with the study of (Saint Akadiri et al, 2019, 2020; Shahbaz et al,

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2018) that increase/decrease in globalization would likely increases energy consumption, and vice versa. The bidirectional causality relationship reported by STE tests lends support from the study of Saint Akadiri et al (2019; 2020). Thus we are of the opinion that STE causality test results resonate existing findings (Saint Akadiri & Ajmi, 2020). Finally, DH reports unidirectional causality running from economic growth to globalization. However, STE and HNR causality tests show unidirectional causality running from globalization to economic growth. This result resonate the study of Shahbaz et al (2018) and Saint Akadiri et al (2019; 2020) respectively.

Table 4. Summary of causality results.

Direction	HNR	DH	STE
EC vs. GDP	B	B	B
EC vs. FDI	FDI → EC	EC → FDI	EC → FDI
EC vs. Gb	NC	NC	B
GDP vs. FDI	B	B	B
GDP vs. Gb	Gb → GDP	GDP → Gb	Gb → GDP
FDI vs. Gb	NC	NC	NC

Note: B, X → Y and NC denote bidirectional causality, causality running from X to Y and no causality between variables, respectively.

4. Concluding remarks

To substantiate the validity and usefulness of the symbolic transfer entropy test for longitudinal data, and whether the results outperform, validate or contrast other existing studies results, this study investigate the relationship between energy consumption, economic growth, FDI and globalization for OECD countries we used annual data covering the period 1972 – 2015. For comparison, we employ also two conventional causality approaches: the Holtz-Eakin, Newey and Rosen (1988) that controls for individual fixed effects in panel data and the Dumitrescu and Hurlin (2012) that control for heterogeneity in panel model.

Based on empirical results, it would be right to conclude that STE tests for longitudinal data conforms with the existing results using conventional causality techniques, thus we are of the opinion that STE causality test results resonate existing findings, and it is suitable causality approach for longitudinal data (see Saint Akadiri & Ajmi, 2020) and causality tests for OECD countries.

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