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RESEARCH ARTICLE

Modeling the non-linear relationship between financial development and energy consumption: statistical experience from OECD countries

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Abstract

The linkage between financial development and energy consumption is widely investigated in the literature. However, the non-linear relationship between financial development and energy demand is still under debate. Therefore, this study aims to examine the non-linear relationship between financial development, economic growth, and energy consumption in OECD countries. The study uses the Driscoll–Kraay standard errors panel regression model for spanning from 1980 to 2016. The empirical findings indicate that an inverted U-shape relationship exists between financial development and energy consumption as well as between economic growth and energy consumption. Moreover, the feedback hypothesis is found between financial development and energy use. Additionally, income and energy use granger cause each other. The innovative findings contribute to extant literature, which is of special interest to the country's policymakers regarding energy efficiency.

Keywords Financial development · Energy consumption · Non-linear relationship · OECD countries

Introduction

Energy consumption is one of the dynamic factors to boost economic growth (Belke et al. 2011; Danish et al. 2017), sustainable development (Kahouli 2017), and a key element in the production of goods and services (Islam et al. 2013). Energy plays a crucial role in a country's financial systems. An adequate amount of energy, effective financial policy, and economic growth is required to achieve sustainable development (Kahouli 2017). Further, if financial development affects energy demand in an economy, it would also influence the policies related to energy (Sadorsky 2011). The adaptation of new technology, skills, and knowledge during financial development increases energy efficiency (Mahdi Ziaei 2015). Further, financial development encourages investment in energy efficient technologies that reduce energy consumptions (Chang 2014; Liu et al. 2017). Apart from it, financial development boosts economic activities and sequentially energy consumption increases (Baloch et al. 2018a).

The Organization for Economic Cooperation and Development (OECD) countries are the largest and fastest growing economies, which can highly influence the rest of the world. The OECD countries composed of the world most industrialized and developed countries which cover around 45% of the world's GDP. Also, OECD countries contained a huge amount of total primary energy supply (TPES). The TPES merely in 2013 was about 40% of the world's energy supply, and further, these countries show a decline in energy consumption (Ulusoy and Demiralay 2017). Moreover, OECD countries have brought major financial sector reforms by stimulating institutional investment such as investment and pension funds and insurance companies. The role of the financial sector and its impact on investment decisions has grown drastically over recent years along with deregulation and globalization of financial markets in OECD countries. The current development in the financial sector has brought rapid change and raised economic activities which may affect the energy consumption in OECD countries. In addition, the OECD countries also increase the reliance on small-medium

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enterprises (SMEs) and entrepreneurs on non-bank financing instruments. This development enables SMEs and entrepreneurs to fasten their roles in growth and employment, which thereby raises the level of energy consumption in OECD economies (Al Mamun et al. 2018).

A large number of studies in the literature are available on the nexus between financial development and energy use, including in Indonesia (Shahbaz et al. 2013a); in Malaysia (Islam et al. 2013); in Saudi Arabia (Xu et al. 2018); in Pakistan (Wang et al. 2018a); in European, East Asian, and Oceania countries (Mahdi Ziaei 2015); in Saudi Arabia (Baloch et al. 2018a); for emerging economies (Danish et al. 2018c); and Wang et al. (2018b) for BRICS economies. However, the findings of these studies show mixed results and no mutual consensus exists. Importantly, the majority of the studies took into account the linear effect of financial development on energy use. It is worthy to investigative how growth in financial development affects energy use. Therefore, this study takes a step forward and investigates the non-linear linkage between financial development and energy use in OECD countries. The ambiguous relationship between financial development and energy use indicates that perhaps after reaching a threshold level whether financial development helps to reduce energy consumption. With growing income, factors, such as awareness among people, structural changes, and efficient policy regulation, can be able to reduce energy demand. On the other hand, we cannot even ignore the potential use of technology in financial institutions; they may increase energy by adding new technology which may not be energy efficient. So the steps are taken by the financial institution and over time, whether financial development reduces energy demand. To determine the right direction of a financial institution in terms of energy consumption is the key focus of the study, and it would give new insights into the policymakers in OECD countries.

The contribution of this study is as follows. First, this study is the first attempt to examine the non-linear relation between financial development and energy consumption. To the best of authors' knowledge, none of the study so far has analyzed the non-linear linkage between financial sector development and energy use. Second, the study is the first attempt to examine the effect of financial development and energy use for OECD countries. Finally, we employ for longest available data from 1980 to 2016 and a family of econometric methods that produce more robust estimates.

The rest of the study is designed in a manner that the second section provides a "literature review." The next section is titled as "Data source, model construction, and econometric strategy." Results analysis and discussion are provided in "Empirical results and discussion." Finally, in "Conclusion," we conclude the study with policy suggestions.

Literature review

In the literature, the energy growth model has widely investigated. Apart from it, financial development influences energy demands both directly and indirectly. There is sufficient evidence found in the literature that confirms financial development stimulates economic growth which raises energy demand (Katircioglu et al. 2007; Soukhakian 2007a, b; Jenkins and Katircioglu 2010; Waheed and Younus 2010; Saqib and Waheed 2011; Katircioglu and Turan 2012).

There are different schools of thought exist regarding the financial development–energy use link. For instance, one school of thought suggests that financial development boosts energy consumption (Sadorsky 2010; Kakar et al. 2011; Chtioui 2012; Shahbaz and Lean 2012). Moreover, Abosedra et al. (2015) conclude that financial development encourages economic activities and thereby energy consumption in Lebanon. Further, Mahalik et al. (2017) found the existence of a non-linear inverted U-shaped link between financial development and energy consumption in the case of Saudi Arabia. Recently, Kahouli (2017) shows that financial development increases energy consumption which adversely stimulates the real output growth. Moreover, Heidari et al. (2013) reported that energy use does not affect the economic growth in the case of Iran.

The second school of thought maintains that financial development improves energy efficiency (Al-Mulali et al. 2013; Islam et al. 2013; Shahbaz et al. 2013b; Park et al. 2018). For instance, Farhani and Solarin (2017) confirm financial development causes financial sector progress which can cause a decrease in energy consumption and ensure energy efficiency. Similarly, in the case of China, Fan et al. (2017) measured financial development in term of ratio analysis and observed an increasing trend in energy consumption with respect to financial development. Moreover, energy efficiency is positively related to financial development that can minimize energy consumption.

There is another school of thought exists that supports the causal link between financial development and energy use. Moreover, Komal and Abbas (2015) indicate that an increase in financial development might cause an increase in energy consumption. Furthermore, Ahmed (2017) confirms that financial development improves energy efficiency that leads to reducing energy consumption in BRICS countries, whereas Katircioglu (2013) provides the evidence of unidirectional causality running from energy to income for Singapore. Similarly, Istaiteyeh (2016) found causal relationship between electricity consumption and real GDP.

On observing the prior literature, which mainly focused on the role financial development plays in energy consumption, adding various control variables in different cultural contexts produces inconclusive results and the panel of OECD countries is ignored in the literature. Furthermore, previous studies mainly focused on the linear relationship among economic growth, financial development, and energy consumption. However, this work considers specifically the OECD dataset along with a non-linear approach, which differentiates this study from other existing literature.

Data source, model construction, and econometric strategy

Model construction

Consistent with Mahalik et al. (2017) and Danish et al. (2018a), this study advances the financial development-energy use link. The key focus of the study is to analyze the non-linear relationship between financial development, economic growth, and energy consumption controlling the model for urbanization and foreign direct investment (FDI) which is expressed as followed:

$$\mathrm{LogEC}_{it} = \alpha_0 + \alpha_1 \mathrm{FD}_{it} + \alpha_2 {\mathrm{FD}_{it}}^2 + \alpha_3 \mathrm{GDP}_{it} + \alpha_4 {\mathrm{GDP}_{it}}^2 + \alpha_5 \mathrm{FDI}_{it} + \alpha_6 \mathrm{URB}_{it} + \mu_0 \quad (1)$$

In the above Eq. (1), EC shows energy consumption, FD indicates financial development, and FD^2 is the square of financial development implying that FD > 0 and $\mathrm{FD}^2 < 0$ directed U-shaped between financial development. Likewise, GDP is gross domestic product proxy for economic growth; GDP^2 is square of GDP shows a non-linear linkage between energy use and income. FDI is a foreign direct investment, and URB is urbanization. *i* and *t* show a number of countries and year selected for the study respectively.

The FDI refers to the transfer or diffusion of technology, management skills, knowledge, and practices from one country to another country (Doytch and Narayan 2016). It has proven that FDI is a reliable way to improve domestic production capacities of a country, to increase their investments through new finance, and to access new technologies (Sirin 2017; Danish et al. 2018d). The financial development and energy use can attract FDI, which stimulates economic growth and enhances research activities to increase economic efficiency (Mahdi Ziaei 2015). Urbanization is incorporated in the model due to the reason that at the initial stage of urbanization, the higher electronic goods use to boost energy demand (Danish et al. 2018e). The rapid growth in economy stimulates the process of urbanization that brings several structural transformations throughout the economy, which ultimately affect the energy consumption (Danish and Baloch 2018). According to Islam et al. (2013) and Danish et al. (2018a), urbanization encourages economic activities and populations; hence, both intensifies the energy use.

Econometric specification

Panel unit root tests

In the case of time series and panel data estimation, economic variables are often considered non-stationary that may lead to producing spurious results. To avoid spurious regression, this study checks the level of stationary for the variable of interest (Danish et al. 2018b; Danish and Wang 2019). Numerous penal root tests have been suggested in the recent studies which are categorized into two groups. One group of unit root tests knows the first generation such as LLC (Levin Lin Chu) test, Breitung test, and Hadri penal unit root test. These are based on different cross-sectional properties and rely on a common unit root process. Besides, another group of unit root tests is known as second-generation tests such as IPS (IM Pesaran Shin) test, Fisher ADF test, and Fisher PP unit root test. Application of these tests controls the problem of homogeneity. As OECD countries have varied economic structure and different level of emissions, therefore this study takes the second generation of unit root test into account. This study applies Fisher–ADF test, Fisher–PP test, and Shin W-stat (IPS) unit root test as well as Pesaran's (2007) CIPS and CADF unit root tests.

Panel cointegration test

This study employs "Westerlund panel cointegration test" to determine the cointegration among variables of interest (Westerlund 2007). Westerlund cointegration approach is preferred due to suitability for short time series component of each cross-section and gives reliable estimates. Latif et al. (2017) noted that only limited studies had taken cross-sectional dependence into account while testing the cointegration among variables. The Westerlund cointegration approach is based on two parts, group statistic (Gs, Ga) and panel statistic (Ps, Pa). Panel statistic (Ps, Pa) obtains the information from the error correction term, while group statistics do not collect information from the error correction model. The rejection of the null hypothesis for the group tests and penal test implies the existence of cointegration for at least one cross-sectional country and all cross-sectional countries, respectively.

Panel estimation model

This work endeavors to probe the non-linear linkage between financial development and energy use in OECD countries. The presence of cross-sectional dependence and possible heterogeneity in simultaneous equation models produce biased estimates. Moreover, ordinary least squares (OLS) regressions produce biased and inconsistent parameter estimates that go against the

Table 1 Descriptive statistic

	ln ENC	ln FDPS	ln FDBS	ln FDFS	ln FDI	ln GDP	ln URB
Mean	3.556	1.877	1.844	1.997	0.070	4.484	1.877
Median	3.567	1.920	1.884	2.009	0.137	4.531	1.885
Maximum	4.259	2.494	2.494	2.560	1.941	4.961	1.974
Minimum	2.848	1.045	1.045	1.289	− 3.141	3.568	1.631
Std. dev.	0.232	0.269	0.263	0.242	0.636	0.252	0.061
Correlation matrix							
ln ENC	1						
ln FDPS	0.494	1					
ln FDBS	0.406	0.933	1				
ln FDFS	0.357	0.920	0.842	1			
ln FDI	0.165	0.148	0.182	0.124	1		
ln GDP	0.720	0.668	0.638	0.592	0.263	1	
ln URB	0.574	0.254	0.210	0.218	0.101	0.387	1

assumptions of the classical linear regression model. Therefore, to produce unbiased and reliable results, this study utilizes Driscoll–Kraay (DK) standard errors (Driscoll and Kraay 1998) method to analyze the non-linear linkage of financial development and energy use for a panel of OECD countries. The study follows two steps procedure while applying DK approach. In the first step, the average values from the product of independent variables and residuals are obtained, whereas in the second step, these averaged values further were utilized in weighted HAC estimator to generate standard errors that own additional quality against cross-sectional dependence (Özokcu and Özdemir 2017; Baloch et al. 2018b). The real advantages of using DK standard error techniques owes to the following reasons: (i) DK standard error approach can handle the problem of heteroscedasticity and cross-sectional dependence in the panel data and (ii) DK standard error technique has the ability to counter missing values and suitable in case of balanced and unbalanced penal data. In addition, it counters the issue of serial dependency, heteroscedasticity, and spatial in the data (Heberle and Sattarhoff 2017; Pei et al. 2017). Therefore, this study prefers DK standard error approach.

Dumitrescu–Hurlin panel causality test

Finally, to find the causal relationship among financial development, economic growth, FDI, urbanization, and energy consumption the study utilizes "Dumitrescu–Hurlin panel causality test." It is the latest version of the Granger non-causality test for panel data. Moreover, this approach comprises two different statistics, i.e., Wbar-statistics and Zbar statistics. Wbar-statistics takes average statistics of the test, while Zbar-statistics indicates a standard normal distribution (Dumitrescu and Hurlin 2012).

Data sources

In this study, we consider a panel data of OECD selected 25 countries.[1] The data for analysis have derived from the World Development Indicator (WDI-CD 2017), for spanning from 1980 to 2016. The measures used for energy use (EU) is kilograms of oil equivalent per capita. Financial development is measured through domestic credit provided by the private sector (% of GDP) (Kahouli 2017; Balsalobre-lorente et al. 2018); economic growth in constant 2010 US $; the urban population is used to measure urbanization and FDI is measured in term of net inflow of investment (% of GDP). The descriptive statistics of all the variables and correlation matrix are reported in Table 1. The correlation analysis reveals that financial development is positively linked with energy consumption, FDI, income, and urbanization. A positive correlation also exists between energy use, income, FDI, and urbanization. Moreover, FDI and urbanization are positively correlated with economic growth. FDI also has a positive correlation with urbanization.

Empirical results and discussion

In the energy economics literature, a cross-sectional dependence (CD) issue is emerged in panel data series and produces misleading results. So in the first test of analysis, we checked the CD by employing CD test such as Breusch-Pagan LM test by (Breusch and Pagan 1980), Pesaran scaled LM test, and the Pesaran CD recommended by (Pesaran 2004), and the result is

[1] The list of OECD countries used in the final analysis is namely Austria, Australia, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea Rep, Mexico, Netherland, New Zealand, Norway, Portugal, Sweden, Spain, Switzerland, Turkey, the UK, and the USA. We choose 25-OECD countries, and the rest of the countries are eliminated from the final analysis due to lack of sufficient data of those countries.

Table 2 Cross sectional dependence results

Variable	CD test	*P* value	Corr	Abs(corr)
LogEC	44.16*	0.000	0.419	0.539
LogFD	63.43*	0.000	0.602	0.610
LogGDP	98.93*	0.000	0.939	0.939
LogFDI	45.14*	0.000	0.428	0.501
LogURB	93.90*	0.000	0.891	0.891

*Significance at 1%

illustrated in Table 2. From the CD, it is revealed that the null hypothesis of no cross-sectional is rejected and a shock that arises in one of sample country may spill-over to the other countries.

After checking the CD now, it turns to see the level of integration of variables under consideration because any non-stationary variables would produce inconsistent and unreliable estimates. However, from the CD test, it can be seen that CD is present in the data. Therefore, unit root test is required that handle the issue of CD, for this purpose, we use second-generation panel unit root test series, and the outcome is reported in Table 3, which indicates that all indicators are significant at first difference. This allows us to go further and estimate the regression coefficients among variables of interest.

The unit root test recommends the series is integrated at first difference, i.e., I(1). So the next step is to find cointegration among variable of consideration. Therefore, we use Westerlund (2007) cointegration test, which can handle the problem of CD present in the data. The results of Westerlund cointegration test suggest the rejection of null hypothesis of no cointegration; in other words, cointegration presents among variables of consideration (Table 4). The existence of cointegration indicates towards the long run relationship between an underlying variable of the study.

The regression estimate from DK regression model is shown in Table 5. The series is converted into a logarithmic form, financial development, and income growth; FDI and urbanization are explained as elasticities of energy demand. According to the results, the coefficient of financial development (FDPS) is positive and statistically significant, implying that financial development causes to increase energy demand in the OECD countries. On the other hand, the square of financial development ($FDPS^2$) is negative and statistically significant (− 0.177, $P < 0.09$), which suggests the existence of a non-linear relationship between financial development and energy use. It confirms that there exists a U-shaped relation between financial development and energy use. More precisely, the rise in financial development after the threshold level leads to boost energy efficiency. The possibility may be that the private sector may provide more loan or debts for the establishment of new businesses and other investment

Table 3 Panel unit root test

Variables	Level					First difference					Decision
	IPS	ADF	PP	CIPS	CADF	IPS	ADF	PP	CIPS	CADF	
ln ENC	1.83906 (0.9670)	1.84859 (0.9677)	2.59777 (0.9953)	− 2.023	− 1.966	− 7.404* (0.000)	− 7.235* (0.000)	− 12.958* (0.000)	− 4.149*	− 3.186*	I (1)
ln FDPS	− 0.57073 (0.2841)	− 0.53305 (0.2970)	0.54849 (0.7083)	− 1.682	− 2.020	− 9.322* (0.000)	− 9.277* (0.000)	− 14.392* (0.000)	− 4.833*	− 3.528*	I (1)
ln $FDPS^2$	− 0.09255 (0.4631)	− 0.06389 (0.4745)	1.12624 (0.8700)	− 1.729	− 2.053	− 9.319* (0.000)	− 9.272* (0.000)	− 14.305* (0.000)	− 4.807*	− 3.550*	I (1)
ln FDBS	− 0.65825 (0.2552)	− 0.62579 (0.2657)	0.3681 (0.6436)	− 1.551	− 1.950	− 9.123* (0.000)	− 9.061* (0.000)	− 13.695* (0.000)	− 4.668*	− 3.439*	I (1)
ln $FDBS^2$	− 0.22607 (0.4106)	− 0.20163 (0.4201)	0.93341 (0.8247)	− 1.583	− 1.949	− 9.130* (0.000)	− 9.069* (0.000)	− 13.654* (0.000)	− 4.703*	− 3.461*	I (1)
ln FDFS	1.09846 (0.8640)	1.28595 (0.9008)	1.61645 (0.9470)	− 1.979	− 2.390	− 12.251* (0.000)	− 11.665* (0.000)	− 17.018* (0.000)	− 4.933*	− 3.913*	I (1)
ln $FDFS^2$	1.51232 (0.9348)	1.67601 (0.9531)	2.02502 (0.9786)	− 2.025	− 2.449	− 12.211* (0.000)	− 11.567* (0.000)	− 16.866* (0.000)	− 4.864*	− 3.901*	I (1)
ln FDI	− 3.48846 (0.0002)	− 3.60639 (0.0002)	− 7.2174 (0.000)	− 4.428	− 3.259	− 24.000* (0.000)	− 19.759* (0.000)	− 25.303* (0.000)	− 6.301*	− 5.595*	I (1)
ln GDP	0.21899 (0.5867)	0.26498 (0.6045)	− 0.06289 (0.4749)	− 1.789	− 2.425	− 11.921* (0.000)	− 11.555* (0.000)	− 13.170* (0.000)	− 4.302*	− 3.830*	I (1)
ln GDP^2	0.57622 (0.7178)	0.59877 (0.7253)	0.39774 (0.6546)	− 1.730	2.383	− 12.074 (0.000)	− 11.692* (0.000)	− 13.348* (0.000)	− 4.272*	− 3.805*	I (1)
ln Urb	4.93251 (1.0000)	4.52260 (1.0000)	2.31810 (0.9898)	− 2.385	− 0.485	− 2.940* (0.002)	− 2.827* (0.002)	− 3.584* (0.000)	− 3.168*	− 12.121*	I (1)

*One percent level of significance

Table 4 Results for Westerlund cointegration test

Statistic	FDPS			FDBS			FDFS		
	Value	*Z* value	*P* value	Value	*Z* value	*P* value	Value	*Z* value	*P* value
G^t	− 2.993*	− 2.870	0.002	− 2.968*	2.739	0.003	− 2.986*	− 2.832	0.002
G^a	− 7.351	3.658	1.000	− 7.455	3.590	1.000	− 7.334	3.669	1.000
P^t	− 7.783	2.732	0.997	− 8.349	2.209	0.986	− 7.280	3.196	0.999
P^a	− 9.260	0.030	0.512	− 9.833	− 0.348	0.364	− 8.382	0.609	0.729

*Significance at 1%

activities. Further, after the threshold level, financial sector allocates more resources and motivates the firms to utilize energy-efficient technology that may reduce energy consumption. Thus, it is suggested that the OECD countries should allocate more finance for energy efficiency projects.

Regarding GDP per capita, it is found that the coefficient of GDP is elastic to energy consumption. The coefficient of GDP is positive and statistically significant. On the other hand, the squared (GDP^2) is negative and statistically significant. First, an increase in GDP per capita (without squaring) causes to increase energy consumption, and after taking a square of GDP (GDP^2), the energy consumption becomes decrease implying that income reaches to a threshold level would lead to a decline in energy consumption. This confirms the existence of a U-shaped relationship. This suggests a U-shaped relationship exists between income and energy use. As in the banks and other financial institution, they invest more in the energy efficiency project and consumer goods those are more energy efficient. The possible reason could be that the increase in income brings people to an environment due to which they use energy more efficiently. In the same at the domestic level, people consume higher energy efficient home appliances that could reduce energy consumption.

Regarding the impact of urbanization on energy use, the result reveals a positive and significant relationship between urbanization and energy consumption. The adverse impact of urbanization could be attributed with that at an initial stage of urbanization people spend more on electronic goods, the transport activities expanded in the cities and developed more financial institution. These activities raised demand and consumption of energy. Finally, the relation between FDI and energy consumption is insignificant.

Table 5 Driscoll Kraay standard errors estimates

Variables	Dependent variable = energy consumption					
	FDPS		FDBS		FDFS	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
Constant	− 5.875	0.000	− 5.693*	0.001	− 7.301*	0.000
Log GDP	2.413*	0.000	2.102*	0.008	3.190*	0.000
Log GDP^2	− 0.218*	0.004	− 0.179**	0.042	− 0.297*	0.000
Log URB	1.289*	0.000	1.307*	0.000	1.258*	0.000
Log FDI	− 0.005	0.540	− 0.0006	0.950	− 0.008	0.172
Log FDPS	0.658**	0.037	–	–	–	–
Log $FDPS^2$	− 0.177***	0.053	–	–	–	–
Log FDBS	–	–	1.202*	0.003	–	–
Log $FDBS^2$	–	–	− 0.356*	0.003	–	–
Log FDFS	–	–	–	–	0.313	0.154
Log $FDFS^2$	–	–	–	–	− 0.106***	0.075
F-statistic	700.81		730.85		917.31	
Prob. F-statistic	0.0000		0.0000		0.0000	
R^2	0.6385		0.6538		0.6445	
RMSE	0.1403		0.1373		0.1391	
N	925		925		925	
Groups	25		25		25	

Level of significance at the *1%, **5%, and ***10%

Table 6 Pairwise Dumitrescu–Hurlin panel causality tests

Null hypothesis:	Financial development from private sector			Financial development from banking sector			Financial development from financial sector		
	W-Stat.	Zbar-Stat.	Prob.	W-Stat.	Zbar-Stat.	Prob.	W-Stat.	Zbar-Stat.	Prob.
LOGFDI does not homogeneously cause LOGEC	2.424	0.611	0.541	2.424	0.611	0.541	2.424	0.611	0.541
LOGEC does not homogeneously cause LOGFDI	4.148	4.356*	0.000	4.148	4.356*	0.000	4.148	4.356*	0.000
LOGGDP does not homogeneously cause LOGEC	4.796	5.764*	0.000	4.796	5.764	0.000	4.796	5.764	0.000
LOGEC does not homogeneously cause LOGGDP	1.215	− 2.015	0.043	1.215	− 2.015**	0.043	1.215	− 2.015**	0.043
LOGURB does not homogeneously cause LOGEC	5.136	6.502*	0.000	5.136	6.502*	0.000	5.136	6.502*	0.000
LOGEC does not homogeneously cause LOGURB	6.173	8.755*	0.000	6.173	8.755*	0.000	6.173	8.755*	0.000
LOGGDP does not homogeneously cause LOGFDI	6.963	10.47*	0.000	6.963	10.470*	0.000	6.963	10.470*	0.000
LOGFDI does not homogeneously cause LOGGDP	2.795	1.418	0.156	2.795	1.418	0.156	2.795	1.418	0.156
LOGURB does not homogeneously cause LOGFDI	5.639	7.595*	0.000	5.639	7.595*	0.000	5.639	7.595*	0.000
LOGFDI does not homogeneously cause LOGURB	4.564	5.259*	0.000	4.564	5.259*	0.000	4.564	5.259*	0.000
LOGURB does not homogeneously cause LOGGDP	4.378	4.855*	0.000	4.378	4.855*	0.000	4.378	4.855*	0.000
LOGGDP does not homogeneously cause LOGURB	11.69	20.751*	0.000	11.696	20.751*	0.000	11.69	20.751*	0.000
LOGFD does not homogeneously cause LOGEC	4.905	6.000*	0.000	4.201	4.472*	0.000	8.207	0.000	8.207
LOGEC does not homogeneously cause LOGFD	3.961	3.949*	0.000	4.151	4.363*	0.000	4.470	0.000	4.470
LOGFDI does not homogeneously cause LOGFD	2.788	1.401	0.161	4.201	4.472*	0.000	1.790	0.073	1.790
LOGFD does not homogeneously cause LOGFDI	3.829	3.664*	0.000	4.151	4.363*	0.000	3.208	0.001	3.208
LOGGDP does not homogeneously cause LOGFD	5.182	6.603*	0.000	4.201	4.472*	0.000	7.520	0.000	7.520
LOGFD does not homogeneously cause LOGGDP	3.512	2.975*	0.002	4.151	4.363*	0.000	5.148	0.000	5.148
LOGURB does not homogeneously cause LOGFD	4.337	4.767*	0.000	4.201	4.472*	0.000	10.119	0.000	10.119
LOGFD does not homogeneously cause LOGURB	6.136	8.674*	0.000	4.151	4.363*	0.000	8.446	0.000	8.446

Level of significance at the *1% and *5% respectively

It is worth mentioning that we use two more proxies for financial development, such as financial development with the banking sector and financial development with the financial sector. The purpose of using these proxies is to check the robustness of financial development. The results of alternate proxies are illustrated in Table 5. According to the results, the alternate proxies used to validate the findings of financial development.

The regression model does not estimate causal relationship among underlying variable, because causality analysis provides direction about relationship which helps in policy direction. For the purpose, we uses DH causality approach robust to issue of CD in the data. The result of DH causality analysis is shown in Table 6. According to the results, bidirectional causal relationship exists between energy demand and financial development, between economic growth and energy consumption, and between urbanization and energy demand. The key findings suggest that financial development is not the only factor influencing energy demand but economic growth and urbanization. Besides, bidirectional causality exists between financial development and economic growth and between urbanization and financial developments. It recommends that financial development influence energy consumption, economic growth and urbanization.

Conclusion

This study examines the non-linear effect of financial development, on energy consumption by incorporating panel data of OECD countries from 1980 to 2016. The study uses Driscoll–Kraay standard errors technique which provides the most reliable and accurate results. The key findings from the empirical estimation are as follows: The estimation result reveals an inverted U-shaped relationship between energy consumption and financial development. Furthermore, an inverted U-shaped relationship was observed between economic growth and energy consumption. FDI causes to increase in energy consumption in OECD countries. Moreover, results suggest neutral hypothesis between financial development and energy use. Additionally, bidirectional causality is observed between income and energy use.

The OECD countries are not specialized in the production of non-energy consumption commodities (i.e., goods and services), neither taking advantages of technology spillover and financial development. Thus, it suggests that OECD countries should allocate more budgets to technology inflow, more attention to the energy efficient technology and innovative methods of production to use energy efficiently. Further, the results of the study recommend inverted U-shaped for the linkage of financial development-energy use and income-energy use nexus. With economic development, the structural changes occur in the economy which changes the energy mix towards renewable energy technologies from conventional energy sources. This paradigm shifts from energy-intensive industries towards to less intensive service sector ultimately reduces energy demand. Further, the technology and knowledge in the financial development will bring decline the energy use; we urge the government in OECD countries should continue with current status and policies in financial development to enjoy the fruit of sustainable development.

Finally, this study also suggests directions for future research. First, it would be interesting to employ the same model for a time series framework or other penal data to explore the non-linear linkage between financial development and energy use. In the same way, in the future, the non-linear linkage between financial sector growth and energy use can be further explored by including potential variables like institutional quality, oil price fluctuations, and globalization.

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