World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:11, No:1, 2017

Granger Causal Nexus between Financial Development and Energy Consumption: Evidence from Cross Country Panel Data

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***Abstract*—**This paper examines the Granger causal nexus between financial development and energy consumption in the group of 35 Financial Action Task Force (FATF) Countries over the period 1988-2012. The study uses two financial development indicators such as private sector credit and stock market capitalization and seven energy consumption indicators such as coal, oil, gas, electricity, hydro-electrical, nuclear and biomass. Using panel cointegration tests, the study finds that financial development and energy consumption are cointegrated, indicating the presence of a long-run relationship between the two. Using a panel vector error correction model (VECM), the study detects both bidirectional and unidirectional causality between financial development and energy consumption. The variation of this causality is due to the use of different proxies for both financial development and energy consumption. The policy implication of this study is that economic policies should recognize the differences in the financial development-energy consumption nexus in order to maintain sustainable development in the selected 35 FATF countries.

***Keywords*—**Financial development, energy consumption, Panel VECM, FATF countries.

I. Introduction

THE role of financial development[1] [1] in enhancing energy consumption has accredited mounting attention recently from both academicians and policy makers [2], [3]. It has been argued that financial development is particularly well suited to examine the determinants of energy consumption. For this reason, many countries have been concerned to foster financial development as a means to increase energy consumption and hence, achieving economic growth [4]-[8]. The fact is that financial development[2], which refers to a country's decision to allow and promote activities like increased foreign direct investment, increase in banking activity, and increase in stock market activity, presents one possible avenue for which economic growth can be increased and this will affect the demand for energy [2], [9].

Financial development can affect the demand for energy in many different ways. For example, financial development can affect energy demand by making it easier for consumers to borrow money to buy big ticket items like automobiles, houses, refrigerators, washing machines, and so forth [5], [9]. In short, financial development makes it easier for consumers to satisfy their wants and needs. These big ticket consumer items typically consume a lot of energy which can affect a country's overall demand for energy. Likewise, there are many other different ways financial development can actually affect energy consumption in a country [10], [11]. In a similar line, energy consumption can also affect the financial development of a country; this means that there is the possibility of a feedback relationship between the two [12]. In brief, the relationship between financial development and energy consumption can be summarized into three main hypothesis, including the supply-leading hypothesis (SLH), demand-following hypothesis (DFH), and feedback hypothesis (FBH). SLH emphasizes the unidirectional causality from financial development to energy consumption, while DFH emphasizes the unidirectional causality from energy consumption to financial development. Additionally, FBH emphasizes the bidirectional causality between energy consumption and financial development. The aim of this study is to examine the long-run relationship between energy consumption and financial development, and the Granger causality thereof.

The remainder of this paper is organized as follows. Section II describes the methodology and data structure. Section III describes the empirical results, and the final section concludes with policy implications.

II. Methods of Study, Variables and Data

We deploy the panel Granger causality test [13] to learn the casual-nexus between financial development and energy consumption. The discussions of this technique are not available here due to space constraints. The following VECM is used to test the Granger causality between financial development and energy consumption:

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[1] Financial development is commonly defined in terms of aggregate size of the financial sector, its sectorial composition, and a range of attributes of its individual sub-sectors that determine their effectiveness in meeting the various economic agents' requirements to enhance their wealth.

[2] Financial development encourages a number of changes within a country including, i) supplying information about promising investments, so as to apportion capital efficiently; (ii) supervising firms and exerting corporate governance; (iii) risk diversification; (iv) mobilizing and pooling savings; (v) easing the exchange of goods and services; (vi) technology transfers, and so forth. All of the above can affect the demand for energy by increasing consumption and business fixed investment.

$$\begin{bmatrix} \Delta EnergyCons\ umtion_{it} \\ \Delta FinancialD\ evelopment_{it} \end{bmatrix} = \begin{bmatrix} \lambda_{1j} \\ \lambda_{2j} \end{bmatrix} + \sum_{k=1}^{p} \begin{bmatrix} d_{11ik}(L) d_{12ik}(L) \\ d_{21ik}(L) d_{22ik}(L) \end{bmatrix} \begin{bmatrix} \Delta EnergyCons\ umtion_{it-k} \\ \Delta FinancialD\ evelopment_{it-k} \end{bmatrix} + \begin{bmatrix} \delta_{1i} ECT_{it-1} \\ \delta_{2i} ECT_{it-1} \end{bmatrix} + \begin{bmatrix} \xi_{1it} \\ \xi_{2it} \end{bmatrix}$$

The null hypotheses and alternative hypotheses are as:

H_0: $d_{12ik = 0}$; and $\delta_{1ik} = 0$ for $k = 1, 2, ..., p$
H_A: $d_{12ik \neq 0}$; and $\delta_{1ik} \neq 0$ for $k = 1, 2, ..., p$
H_0: $d_{21ik = 0}$; and $\delta_{2ik} = 0$ for $k = 1, 2, ..., p$
H_A: $d_{21ik \neq 0}$; and $\delta_{2ik} \neq 0$ for $k = 1, 2, ..., p$

The variables used in this analysis are private sector credit, (PRSC) and stock market capitalization (STMC) for financial development, and coal energy consumption (COEC), oil energy consumption (OIEC), gas energy consumption (GAEC), electricity energy consumption (ELEC), hydro-electrical energy consumption (HEEC), nuclear energy consumption (NUEC) and biomass energy consumption (BIEC) for energy consumption.

Our working hypothesis is that financial development has contributed significantly to energy consumption. Our alternative hypothesis for testing is that the expansion of energy consumption is simply a consequence of financial development. Fig. 1 depicts the possible causal relationships between financial development and energy consumption.

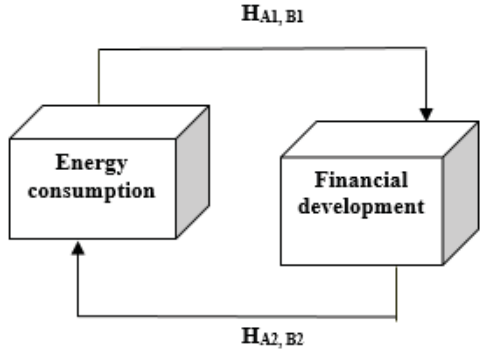

Fig. 1 A Conceptual Framework of Granger Causal Relations between Energy Consumption and Financial Development *Note*: $H_{A1, B1}$: Energy consumption Granger-causes financial development and vice versa, $H_{A2, B2}$: Financial development Granger-causes energy consumption and vice versa

The study uses a panel dataset covering the selected 35 FATF countries for the period 1988-2014. The countries included in the analysis are Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, India, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal, Russian Federation, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States. The countries in this group have been selected on the basis of purchasing power parity classification of the World Bank. The data have been collected from World Development Indicators, the World Bank, Washington DC.

III. Empirical Results

The discussion begins with the stationarity issue. Using panel unit root test (LLC: [14]); and (IPS: [15]), we find that both financial development indicators (PRSC and STMC) and energy consumption indicators (COEC, OIEC, GAEC, ELEC, HEEC, NUEC, and BIEC) are non-stationary at the level data but found stationary at the first difference. The results of this section are reported in Table I. This suggests that financial development and energy consumption are integrated of order one [i.e. I (I)] and proposes the possibility of cointegartion between them. In the subsequent stage, we array Pedroni panel cointegration test [16] to understand the existence of cointegration between financial development and energy consumption. The results indicate that the variables under study are cointegrated, indicating the existence of a long-run association between financial development[3] and energy consumption (see Tables II and III).

TABLE I
Results of Panel Unit Roots Test

Variables	Level	LLC	IPS	ADF	PP
PRSC	0	-0.30	1.72	10.27	7.99
	1	-9.30*	-12.6*	277.3*	544.5*
STMC	0	-0.44	-0.30	9.06	12.4
	1	-17.4*	-17.8*	404.0*	140.5*
COEC	0	-0.10	0.23	61.12	66.0
	1	-7.41*	-11.1*	222.2*	487.5*
OIEC	0	-0.95	3.00	46.62	79.1
	1	-7.89*	-8.24*	182.3*	420.2*
GAEC	0	1.91	4.40	48.59	58.2
	1	-2.74*	-8.08*	205.9*	454.2*
ELEC	0	-0.71	3.95	45.54	65.1
	1	-7.46*	-10.1*	239.2*	479.6*
HEEC	0	-0.20	-0.19	63.10	75.4
	1	-8.73*	-11.1*	190.8*	414.8*
NUEC	0	-0.02	-1.23	10.52	11.7
	1	-10.6*	-14.8*	331.8*	779.3*
BIEC	0	1.02	-0.44	67.4	89.6
	1	-4.48*	-3.65*	118.3*	244.8*

Note 1: PRSC is private sector credit, STMC is stock market capitalization, COEC is coal energy consumption, PIEC is oil energy consumption, GAEC is gas energy consumption, ELEC is electricity energy consumption, HEEC is hydro-electrical energy consumption, NUEC is nuclear energy consumption, and BIEC is biomass energy consumption.

Note 2: 0: Stands for the use of level data; and 1: stands for the use of first difference data.

Note 3: LLC stands Levine-Lin-Chu test (Levine *et al.* 2002), IPS stands Im-Pesaran-Shin test [17], ADF stands ADF- Fischer Chi-square test (Maddala and Wu, 1999), PP stands PP-Fischer Chi-square test [18].

Note 4: * indicates statistical significance at the 1% level; I [1] indicates the integration of order one.

[3] This is considerably true for both PRSC and STMC.

TABLE II
PANEL COINTEGRATION AND PANEL GRANGER CAUSALITY TEST RESULTS

Empirical Models							
Test Statistics	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
Case 1: Energy consumption with domestic credit to private sector							
Part A: Cointegration inference							
Panel v	-1.3	-1.2	1.51	4.8*	-2.0	-3.3	1.4
Panel ρ	-1.4*	-2.3*	-2.2*	-3.4*	-2.0*	-2.6*	-2.3*
Panel PP	-2.6*	-2.8*	-2.3*	-3.4*	-2.8*	-2.5*	-8.7*
Panel ADF	-2.6*	-9.3*	-2.3*	-2.6*	-2.9*	-2.2*	-6.8*
Group ρ	-0.23	-0.1	-2.0*	-1.6*	-2.0*	-1.9*	-2.2*
Group PP	-2.7*	-2.4*	-4.1*	-3.4*	-2.7*	-2.9*	-8.3*
Group ADF	-2.9*	-1.8*	-2.2*	-1.8*	-2.2*	-2.0*	-5.7*
Part B: Granger causality inference							
GC Inference	**DFH**	**DFH**	**SLH**	**DFH**	**FBH**	**FBH**	**DFH**

Note 1: S1 is specification 1, indicating the causal nexus between PRSC and COEC; S2 is specification 2, indicating the causal nexus between PRSC and PIEC; S3 is specification 3, indicating the causal nexus between PRSC and ELEC; S4 is specification 4, indicating the causal nexus between PRSC and COPEC; S5 is specification 5, indicating the causal nexus between PRSC and HEEC; S6 is specification 6, indicating the causal nexus between PRSC and NUEC; and S7 is specification 7, indicating the causal nexus between PRSC and BIEC.

Note 2: GC is Granger causality, PRSC is private sector credit, COEC is coal energy consumption, PIEC is oil energy consumption, GAEC is gas energy consumption, ELEC is electricity energy consumption, HEEC is hydro-electrical energy consumption, NUEC is nuclear energy consumption, and BIEC is biomass energy consumption.

Note 3: SLH indicates the Granger causality from financial development to economic growth, DFH indicates the Granger causality form energy consumption to financial development, and FBH indicates the bidirectional causality between financial development and energy consumption.

Note 4: * indicates statistical significance at the 5% level.

TABLE III
PANEL COINTEGRATION AND PANEL GRANGER CAUSALITY TEST RESULTS

Empirical Models							
Test Statistics	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
Case 2: Energy consumption with stock market capitalizat							
Part A: Cointegration inference							
Panel v	0.87	3.4*	4.7*	4.4*	-0.1	2.05	1.35
Panel ρ	-2.8*	-7.4*	-8.9*	-9.0*	-2.3*	-5.6*	-2.4*
Panel PP	-3.2*	-8.6*	-9.9*	-10*	-3.1*	-7.0*	-4.2*
Panel ADF	-3.1*	-4.0*	-5.6*	-5.2*	-2.2*	-3.1*	-2.7*
Group ρ	-2.5*	-4.3*	-5.0*	-5.9*	-2.5*	-2.1*	-2.4*
Group PP	-5.1*	-7.1*	-7.9*	-9.1*	-3.4*	-5.1*	-7.7*
Group ADF	-3.8*	-4.0*	-5.0*	-5.7*	-2.7*	-3.0*	-5.4*
Part B: Granger causality inference							
GC Inference	**SLH**	**SLH**	**SLH**	**SLH**	**FBH**	**DFH**	**DFH**

Note 1: S1 is specification 1, indicating the causal nexus between STMC and COEC; S2 is specification 2, indicating the causal nexus between STMC and PIEC; S3 is specification 3, indicating the causal nexus between STMC and ELEC; S4 is specification 4, indicating the causal nexus between STMC and COPEC; S5 is specification 5, indicating the causal nexus between STMC and HEEC; S6 is specification 6, indicating the causal nexus between STMC and NUEC; and S7 is specification 7, indicating the causal nexus between STMC and BIEC.

Note 2: GC is Granger causality, STMC is stock market capitalization, COEC is coal energy consumption, PIEC is oil energy consumption, GAEC is gas energy consumption, ELEC is electricity energy consumption, HEEC is hydro-electrical energy consumption, NUEC is nuclear energy consumption, and BIEC is biomass energy consumption.

***Note 3*:** SLH indicates the Granger causality from financial development to economic growth, DFH indicates the Granger causality form energy consumption to financial development, and FBH indicates the bidirectional causality between financial development and energy consumption.

Note 4: * indicates statistical significance at the 5% level.

Having confirmation about the cointegration, the next step is to check the direction of causality between financial development and energy consumption. Using panel Granger causality, the results find that financial development (PRSC/STMC) Granger causes energy consumption (COEC/OIEC/GAEC/ELEC/HEEC/NUEC/BIEC), both in the long- run and short-run (see Tables II and III). Moreover, the short-run Granger causality results reveal both unidirectional[4] and bidirectional causal[5] relationship between financial development indicators (PRSC/STMC) and energy consumption indicators (COEC/OIEC/GAEC/ELEC/HEEC/NUEC/BIEC). That means they are reinforcing each other and having a dual impact on the economy.

IV. CONCLUSION AND POLICY IMPLICATIONS

This study has produced strong evidence on the relationship between financial development and energy consumption in the selected 35 FATF countries for the period 1988-2014. The major finding is that financial development and energy consumption are cointegrated, indicating the presence of long-run relationship between the two. The Panel Granger causality test further confirms the presence of both unidirectional and bidirectional Granger causality between the financial development and energy consumption. The variation of these findings is mostly due to the use of different financial development indicators (PRSC/STMC) and the energy consumption indicators (COEC/OIEC/GAEC/ELEC/HEEC/ NUEC/BIEC).

These results demonstrate that studies on energy consumption that do not consider financial development (and vice versa), will offer potentially biased results. On the policy front, close linkages between financial development and energy consumption show that the selected 35 FATF countries wishing to sustain energy consumption in the long run should focus attention in developing their financial markets, both banking sector development and stock market development. On the contrary, the stress on achieving high energy consumption can also bring sustainable financial development in these selected countries.

Therefore, the policy implication of this study is that the economic policies should recognize the differences in the financial development-energy consumption nexus in order to maintain sustainable economic growth in these economies, as both are very instrumental to high economic growth [4]-[9].

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[4] Unidirectional causality indicates the presence of either supply-leading or demand-following hypotheses. SLH indicates the Granger causality from financial development to energy consumption, while demand-following hypothesis indicates the presence of Granger causality from energy consumption to financial development.

[5] Bidirectional causality indicates the presence of FBH, representing the interdependence relationship between financial development and energy consumption.

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