Causal relationships between energy consumption, foreign direct investment and economic growth: Fresh evidence from dynamic simultaneous-equations models

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Causal Relationships between Energy Consumption, Foreign Direct Investment and Economic Growth: Fresh Evidence from Dynamic Simultaneous-Equations Models

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Abstract

This paper examines the interrelationships between energy consumption, foreign direct investment and economic growth using dynamic panel data models in simultaneous-equations for a global panel consisting of 65 countries. The time component of our dataset is 1990–2011 inclusive. To make the panel data analysis more homogenous, we also investigate this interrelationship for a number of sub-panels which are constructed based on the income level of countries. In this way, we end up with three income panels; namely, high income, middle income, and low income panels. In the empirical part, we draw on growth theory and augment the classical growth model, which consists of capital stock, labor force and inflation, with foreign direct investment and energy. Generally, we shows mixed results about the interrelationship between energy consumption, FDI and economic growth.
Keywords : Energy consumption, FDI inflows, Economic growth.

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1. Introduction

The nexus between energy consumption, foreign direct investment and economic growth has newly started to be discussed in energy economics literature. This literature can be divided into three lines. The first line of research focuses on the nexus between energy consumption and economic growth. This nexus suggests that economic growth and energy consumption may be jointly determined, because higher economic growth requires more energy consumption. Similarly, more efficient energy use needs a higher level of economic growth. Therefore, the direction of causality may not be determined prior. Since the pioneer work of Kraft and Kraft (1978), Granger causality test approach has become a popular tool for studying the relationship between economic growth and energy consumption in different countries (see, *inter alia*, Stern, 1993; Belloumi, 2009; Pao, 2009; and Ghosh, 2010; Ozturk and Acaravci, 2010) and this leads to four testable hypotheses; 1) a Granger causal relationship from energy to GDP, 2) a Granger causal relationship from GDP to energy, 3) a feedback relationship between energy and GDP, and 4) no Granger causal relationship between energy and GDP (neutrality). Ozturk and Acaravci (2010) have investigated the causal relationship between energy and economic growth and find a bi-directional Granger causality between energy variables and economic growth in Hungary. However, Belloumi (2009) has used a VECM Model and showed that, in Tunisia, there is a causal relationship between energy consumption and income over the period of 1971-2004.

The second line of researches has examined the relationship between foreign direct investment and economic growth. The role of foreign investment in economic growth has been considered one of the basic principles in economics. Many researchers conclude that the rate of capital formation determines the rate of economic growth (see, *inter alia*, Ekanayake and Vogel, 2003; Tsang and Yip, 2007; Omri and Kahouli, 2013). For example, De Long et al. (1992) found a strong causal relationship between equipment investment and economic growth. Blomstrom et al. (1996) also reported that the growth rate is more closely related to the capital formation rates in succeeding periods than to the contemporary or preceding rates. Alfaro et al. (2010) have shown that FDI leads to higher additional growth in developed economies. Lee and Chang (2009) reported that FDI has a large direct effect on economic growth and extends the potential gains associated with FDI. Aitken et al. (1997) have shown evidence of beneficial spillovers from multinational enterprises to the host economy, whereas Hsiao and Shen (2003) reported that economic growth is one of the important factors in attracting FDI, in particular in developing countries. Some studies indicate that the direction

of causality between economic growth and FDI is subject to country-specific factors (Zhang, 2001). Nguyen and Nguyen (2007) have identified the two-way linkage between FDI and economic growth in which FDI promotes economic growth and, in turn, economic growth is viewed as a tool to attract FDI. Moreover, Anwar and Nguyen (2010) study the two-way linkage between economic growth and FDI in 61 provinces of Vietnam over the period 1996–2005. They support the view that, in overall terms, reinforcing two-way linkage between FDI and economic growth exists in Vietnam and explored the link between FDI and economic growth across seven regions of Vietnam. The empirical analysis reveals that a two-way linkage between FDI and economic growth exists only in four regions.

The third line of researches has examined the relationship between foreign direct investment and energy consumption. In this issue, Tang (2009) opines that the influx of FDI is inducing energy consumption through the expansionary of industrialization, transportation and manufacturing sectors development while energy is required to support the manufacturing process. This area of research is relatively less researched and can be considered as nascent. Mielnik and Goldemberg (2002) found a positive relationship between FDI and energy intensity in a sample of 20 developing countries. Sadorsky (2010) also found a positive and statistically significant relationship between FDI and energy consumption in a sample of 22 developing economies. FDI allows businesses cheaper and/or easier access to financial capital, which can be used to expand their existing operations or construct new plants and factories, all of which increase the demand for energy. Consistent with this view that FDI leads to greater economic growth is the likelihood that energy demand should be positively affected by increases in FDI. Bekhet and Othman (2011) examine the causal relationship between electricity consumption and foreign direct investment in Malaysia, during a period of 1971–2009. The results were found to be cointegrated and indicated the existence of long run causal relationship among the variables. Bento (2011) showed that a modest and negative effect of FDI on energy consumption in the context of Portugal, during the period of 1980–2007.

Finally, most previous studies have shown that higher economic growth requires more energy consumption. It has also been found that FDI is often a key determinant of economic growth. It is therefore worthwhile to investigate the nexus between energy consumption, FDI and economic growth by considering them simultaneously in a modeling framework.

The present study is different from the three lines of the literature identified above in the following ways. Compared to previous studies, this paper used dynamic simultaneous equations based on structural modeling to study the nexus between energy consumption, FDI

inflows and economic growth for a global panel consisting of 65 countries. However, to the best of our knowledge, none of the empirical studies have focused to investigating the nexus between energy-FDI-growth via the simultaneous equations model. The model allows to examine at the sometime the interrelationship between energy consumption, FDI and economic growth estimated by the Generalized Method of Moments (GMM). We investigate the three-way linkage between energy–FDI–growth for 65 countries by using the GMM-estimator. Specifically, this study utilizes three structural equations models that allow one to simultaneously examine the impact of (i) FDI and energy consumption on economic growth, (ii) economic growth and energy consumption on FDI, and (iii) FDI and economic growth on energy consumption. In addition, in this study we do not use panel unit root and panel cointegration approaches, as has been the case in this literature to date. Rather, we use a dynamic simultaneous-equation model with panel data, which follows the spirit of the conventional 'growth model' framework. This approach ensures that there is a strong theoretical foundation for the empirical analysis (Sharma, 2010). Our approach in this study is to estimate the short-run elasticities and not to estimate the long-run elasticity given our growth form modeling approach. There is a strong motivation for us to apply a growth form approach to analyzing the interrelationship between energy, FDI and economic growth. We were motivated by the fact that there are no studies that model this interaction using growth form models. Finally, we use a dynamic simultaneous-equation model with panel data of 65 countries, which allows us to derive short-run elasticities.

The paper is organized as follows: after introduction which is provided in Section 1 above, brief literature review is carried out in Section 2. The methodological framework is explained in Section 3. Data and results are discussed in Section 4. Final section concludes the study and gives some policy implications.

2. Overview of related literature

This section will be devoted to review the findings of all those studies on energy, FDI and economic growth nexus that have used panel data modeling techniques. Therefore, it should be noted that the modeling techniques with panel data are relatively recent compared with modeling techniques based on time series data. In this context, Payne (2010) shows that most of the previous studies are based on time-series model and very few are based on panel data models. We focus on reviewing studies on panel data models since they are closest to our study and hence provide some insights of the relationship between energy-FDI-growth at least.

Apergis and Pyane (2009) examine the relationship between energy consumption and economic growth for a panel of 11 Commonwealth of Independent States using panel data for the period 1991-2005. By applying panel unit root, panel cointegration, and panel error correction models, their study shows that the presence of unidirectional causality from energy consumption to economic growth in the short-run while bi-directional causality between energy consumption and economic growth in the long-run. Thus, the results lend support for the feedback hypothesis associated with the relationship between energy consumption and economic growth. In addition, Chen et al. (2007), using the Pedroni (1999), Pedroni (2004) tests and panel data model for the time period 1971–2001, find evidence of bi-directional long-run causality between electricity and economic growth in 10 industrialized and developed Asian countries.

Lee (2013) examines the contributions of foreign direct investment (FDI) net inflows to energy use and economic growth using panel data of 19 nations of G20 countries from 1991 to 2009. The empirical results indicate that FDI has played an important role in economic growth for the G20 and finds no compelling evidence of FDI link with clean energy use. However, Mielnik and Goldemberg (2002) found a positive relationship between FDI and energy intensity in a sample of 20 developing countries. Sadorsky (2010) also found a positive and statistically significant relationship between FDI and energy consumption in a sample of 22 developing economies. By making use of a panel dataset that covers 61 provinces of Vietnam from 1996–2005, Anwar and Nguyen (2010) examine the link between FDI and economic growth. They showed that in overall terms a mutually reinforcing two-way linkage between FDI and economic growth exists in Vietnam.

The main difference between the above-mentioned panel data based analysis of energy, FDI and economic growth nexus and our work is that: (i) we examine at the sometime the interrelationship between energy-FDI- growth for a panel of 65 countries by using the GMM-estimator over the period 1990-2011. Specifically, this study utilizes three equations structural modeling that allows one to simultaneously examine the interrelationship between energy consumption, FDI and economic growth; (ii) we do not use panel unit root and panel cointegration approaches. Rather, we use a dynamic simultaneous-equation model for a panel of 65 countries, which follows the 'growth model' framework, ensuring that there is a strong theoretical foundation for our empirical analysis. The growth model is theoretically augmented with the traditional determinants of growth, such as labor force, capital stock, inflation and trade. Our study adds to this literature, in that we estimate growth models by augmenting the model with energy and FDI variables. We examine the proposed relationship for a global panel of countries and for

three different types of countries based on income level: High-, Middle-, and low income countries. Our classification of countries into sub-panels based on income level is crucial in terms of homogenizing countries into similar characteristics. This disaggregated panel data analysis allows results to be compared and contrasted by income levels.

3. Empirical Methodology

3.1. Econometric modeling

The objective of the paper is to use production function approach to explain the interrelationship between energy consumption, FDI and economic growth where GDP depends on energy consumption, FDI and others inputs. The extended Cobb-Douglas production framework helps us to explore the three-way linkage between the three variables: FDI, energy consumption and economic growth. These variables are in fact endogenous. It is therefore worth investigating the interrelationships between the three variables by considering them simultaneously in a modeling framework. Based on this interaction, this modeling can help policymakers to build sound economic policies to sustain economic development.

For this purpose, we employ the Cobb–Douglas production function including capital and labor as additional factors of production. Ang (2008), Anwar and Nguyen (2010), Sharma (2010), Menyah and Wolde-Rufael (2010), and Shahbaz et al. (2012), among others, include the energy and FDI variables in their empirical model to examine the impact of these two variables on economic growth. While they find generally that FDI and energy stimulates economic growth.

Furthermore, Bruno and Easterly (1998), Anwar and Sun (2011), among others, empirically test the impact of inflation on economic growth and these studies show that inflation has a statistical significant influence on economic growth. Thus, our proposed model, consistent with the broader literature on the determinants of economic growth cited above, takes the following form:

$$GDP = f\left(FDI, Energy, GFCF, LF, INF \right) \quad (1)$$

This essentially states that GDP is a function of gross fixed capital formation (GFCF or capital stock), labor force (LF), inflation (INF), foreign direct investment (FDI) and energy consumption (ENRGC).

We write Eq. 1 in growth form with time series specification as follows:

$$gY_t = \alpha_0 + \alpha_1 gFDI_t + \alpha_2 gENRGC_t + \alpha_3 gGFCF_t + \alpha_4 LF_t + \alpha_5 INF_t + \varepsilon_t \quad (2)$$

Since our study is a panel data study, Eq. (2) can be written in panel data form as follows:

$$gY_{it} = \alpha_0 + \alpha_1 gFDI_{it} + \alpha_2 gENRGC_{it} + \alpha_3 gGFCF_{it} + \alpha_4 \mathrm{LF}_{it} + \alpha_5 INF_{it} + \varepsilon_{\mathrm{it}} \quad (3)$$

Where the subscript i=1, ….., N denotes the country (in our study, we have 65 countries) and t=1, …...., T denotes the time period (our time frame is 1990–2011); gY represents growth rate of per capita GDP; gGFCF represents the growth rate of gross fixed capital formation (capital stock); LF represents the total labor force; INF represents the inflation rate; gFDI indicates the growth rate of foreign direct investment and gENRGC represents the growth rate of energy consumption (kg of oil equivalent per capita).

We later transform the production function into regression equations to treat simultaneously energy consumption, FDI and economic growth as endogenous. On this basis, we use the following simultaneous equations model to investigate the interrelationship between energy consumption, FDI and economic growth. The three-way linkages between these variables are empirically examined by making use of the following three equations:

$$gY_{it} = \alpha_0 + \alpha_1 gFDI_{it} + \alpha_2 gENRGC_{it} + \alpha_3 gGFCF_{it} + \alpha_4 \mathrm{LF}_{it} + \alpha_5 INF_{it} + \varepsilon_{\mathrm{it}} \quad (4)$$

$$gFDI_{it} = \varphi_0 + \varphi_1 gY_{it} + \varphi_2 gENRGC_{it} + \varphi_3 gGFCF_{it} + \varphi_4 \mathrm{LF}_{it} + \varphi_5 TOP_{it} + \varphi_6 RER + \pi_{\mathrm{it}} \quad (5)$$

$$gENRGC_{it} = \xi_0 + \xi_1 gY_{it} + \xi_2 gFDI_{it} + \xi_3 gGFCF_{it} + \xi_4 \mathrm{LF}_{it} + \xi_5 gPOP_{it} + \xi_6 FD + \pi_{\mathrm{it}} \quad (6)$$

Eq. (4) states that foreign direct investment (FDI), energy consumption (ENRGC) and other variables, namely, gross fixed capital formation (GFCF), labor force (LF), and inflation (INF) can potentially determine economic growth (see, *inter alia*, Bruno and Easterly, 1998; Ang, 2008; Menyah and Wolde-Rufael, 2010; Sharma, 2010; Anwar and Sun, 2011).

Eq. (5) states that economic growth (Y), energy consumption (ENRGC) and other variables, namely, gross fixed capital formation (GFCF), labor force (LF), Trade openness, measured as exports plus imports as a percentage of GDP (TOP), and real exchange rate (RER) can potentially affect FDI inflows (see, inter alia, Anwar and Nguyen, 2010; Anwar and Sun, 2011; Lee, 2013; Lucas 1993).

Eq. (6) suggests that economic growth (Y), foreign direct investment (FDI) and other variables, namely, gross fixed capital formation (GFCF), labor force (LF), total population (POP), and financial development, measured as total credit of the private sector as a percentage of GDP (FD) can potentially affect energy consumption (see, inter alia, De Mello, 1997; Lorde et al., 2010; Lotfalipour et al., 2010; Islam et al., 2013; Lee 2013).

3.2. Hypotheses

3.2.1. Hypothesis 1: FDI is in positive relation to economic growth

A fairly large amount of literature finds a causal relationship between foreign direct investment and economic growth. In addition, Nguyen and Nguyen (2007) have identified the two-way linkages between FDI and economic growth in which FDI promotes economic growth and, in turn, economic growth is viewed as a tool to attract FDI. Aitken et al. (1997) have shown evidence of beneficial spillovers from multinational enterprises to the host economy, whereas Hsiao and Shen (2003) reported that economic growth is one of the important factors in attracting FDI, in particular in developing countries.

Tsai (1994) tested the two-way linkages between FDI and economic growth for 62 countries between 1975–1978 and 51 countries for the period 1983–1986. His work supports the view that two-way linkages exist between FDI and growth. Moreover, Anwar and Nguyen (2010) study the two-way linkages between economic growth and FDI in 61 provinces of Vietnam over the period 1996–2005. They support the view that, in overall terms, reinforcing two-way linkages between FDI and economic growth exists in Vietnam and explored the link between FDI and economic growth across seven regions of Vietnam.

Though the general consensus of these studies is that there is a positive correlation between foreign direct investment and economic growth, some results contradict. For example, Zhang (2001) argued that the causal relationship between FDI and economic growth is mixed depending on the country-specific factors. Kim and Seo (2003) reported that FDI has a positive but insignificant effect on GDP growth, while GDP growth has a significant and highly persistent effect on the future level of foreign direct investment in South Korea.

3.2.2. Hypothesis 2: Economic growth is in positive relation to energy consumption

A large number of studies find a causal relationship between energy consumption and economic growth, especially in OCDE countries (Chang et al., 2009; Apergis and Payne,

2010a), in Eurasia countries (Apergis and Payne, 2010b), in Central American countries (Apergis and Payne, 2012), in South Africa (Ziramba, 2009), in developed countries and developing countries (Sharma, 2010), and in European countries (Ciarreta and Zarraga, 2010). They show that, in the long-run, economic growth exerts a Granger causal influence on energy consumption, and in the short run, energy consumption points to output growth.

Though the general consensus of these researches is that there is a positive correlation between energy consumption and economic growth, some results contradict. For example, Costantini and Martini (2009) argued that the direction causality between energy consumption and economic growth is mixed depending on the functional form adopted and the sample of countries analyzed. More recently, some researchers have examined the time series dynamics between energy economics and economic growth to infer the direction of causality, for example, for a panel of 66 countries (Sharma, 2010), for the BRIC countries (Pao and Tsai, 2010), and for EU (Keppler and Mansanet-Bataller, 2010). They find that economic growth is in positive relation to energy consumption. In sum, this study assumes that higher economic growth may require greater energy consumption and vice versa.

3.2.3. Hypothesis 3: Energy consumption is in positive relation to FDI

While there is a considerable attention in the literature about the link between economic growth and energy demand, the nexus between FDI and energy demand is a topic that has received little attention. Based on a sample of 20 developing countries, Mielnik and Goldemberg (2002) found a positive relationship between energy intensity and FDI. Sadorsky (2010) also found a positive and statistically significant relationship between energy consumption and FDI in a sample of 22 developing economies. Consistent with these findings that FDI leads to greater economic growth is the likelihood that energy consumption should be positively affected by increases in FDI.

3.3. Estimation technique

In this study, we have a dynamic panel data models in a simultaneous-equations where lagged levels of economic growth, FDI and energy consumption are taken into account by using the Arellano and Bond (1991) GMM estimator. GMM (Generalized Method of Moments) is the estimation method most commonly used in dynamic models with panel data and a lagged dependent variable. This method uses a set of instrumental variables to solve the endogeneity problem of the regressors. Our proposed modeling is as follows:

$$gY_{i,t} = \alpha_0 gY_{i,t-1} + \varphi gFDI_{i,t} + \varphi gENRGC_{i,t} + \beta X'_{i,t} + \mu_{i,t} + \varepsilon_{i,t} \quad (7)$$

$$gFDI_{i,t} = \varphi_0 gFDI_{i,t-1} + \psi gY_{i,t} + \psi gENRGC_{i,t} + \beta X'_{i,t} + \mu_{i,t} + \varepsilon_{i,t} \quad (8)$$

$$gENRGC_{i,t} = \xi_0 gENRGC_{i,t-1} + \xi gY_{i,t} + \xi gFDI_{i,t} + \beta X'_{i,t} + \mu_{i,t} + \varepsilon_{i,t} \quad (9)$$

i = 1,……., N ; t = 1,……,T.

Where $gY_{i,t}$, $gFDI_{i,t}$, and $gENRGC_{i,t}$ represent, respectively, the growth rate of GDP, foreign direct investment and energy consumption of country i at time t. α_0 is the parameter to be estimated; X is a vector of core explanatory variables used to model economic growth (GFCF, labor force and inflation), to model foreign direct investment (GFCF, labor force, trade openness and real exchange rate), and to model energy consumption (GFCF, labor force, total population, and financial development); φ captures the effect of FDI and ENRGC on economic growth; ψ captures the effects of economic growth and energy consumption on FDI inflows; ξ captures the effects of economic growth and FDI on energy consumption; μ is country-specific effects; and ε is the error term.

Since the lagged dependant variables ($gY_{i,t-1}$, $gFDI_{i,t-1}$, and $gENRGC_{i,t-1}$) are correlated with the error term, the use of panel ordinary least squares (OLS) estimator (with fixed and random effects) is problematic. The Arellano and Bond (1991) approach solves this problem by first differentiating the above equations. This removes country-specific effects.

4. Data and results

4.1. Data and descriptive statistic

Annual data for energy consumption (kg of oil equivalent per capita), GDP per capita (constant 2005 US$), foreign direct investment (FDI) net inflows (constant 2005 US$), Gross fixed capital formation (constant 2005 US$), total labor force (% of total population), inflation rate, trade openness (% of exports and imports of GDP), Financial development (total credit to private sector as a ratio of GDP), total population (in thousands), and real exchange rate (RER) are downloaded from the World Bank's World Development Indicators (2012). Data is for the period 1990–2011. GDP per capita, energy consumption, FDI, gross fixed capital formation, and population are measured in growth form in order to make them

stationary. Inflation rate, total labor force (% of total population), trade openness (% of GDP), and financial development (total credit to private sector as a ratio of GDP) are stationary in their level form. The specific countries selected for the study and the timeframe was dictated by data availability. These include: (1) high income, consisting of 26 countries (Australia, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States); (2) middle income, consisting of 26 countries (Albania, Algeria, Argentina, Botswana, Brazil, Bulgaria, Chile, China, Colombia, Egypt, Hungary, the Islamic Republic of Iran, Jamaica, Malaysia, Mexico, Morocco, Panama, Peru, Philippines, Sri Lanka, the Syrian Arab Republic, Thailand, Tunisia, Turkey, Uruguay, and Venezuela); and (3) low income, consisting of 13 countries (Bangladesh, Cameroon, the Democratic Republic of Congo, Ghana, India, Indonesia, Kenya, Mongolia, Mozambique, Nigeria, Pakistan, Vietnam, and Zambia).

The mean value, the standard deviation and the coefficient of variation of different variables for the sub-panels countries and also for the global panel are given below in Table 1. This table provides a statistical summary associated with the actual values of the used variables for each sub-panels.

Energy consumption is measured by kg of oil equivalent per capita. The mean growth rate of energy consumption per capita is the highest for the high-income countries, followed by middle- and low-income countries. It is also noted that the low-income countries are more volatile in energy consumption; its coefficient of variation is 0.507, which is the highest when compared to other panels' countries coefficient of variation.

Based on to the statistics recorded in Table 1, it is clear that the highest average of GDP per capita is recorded for the high-income countries compared to middle- and low-income countries. It is also worth highlighting that high-income countries' overall economic output is almost 9 times more than middle-income countries, and almost 45 times more than low-income countries. The coefficient of variation recorded in Table 1, reveals that low-income countries is the most volatile compared to other panels of countries in economic output; it has the highest coefficient of variation of 0.669, followed by middle- and high-income countries. In addition, the data reveals the same trend for trade measured as a percentage of GDP: high-income countries are more open compared to middle- and low-income countries. This finding is consistent international trade literature, which has showed that more advanced countries are more open to international trade (see, for example, Harrigan, 1996). Moreover, the average of

GFCF and the level of financial development are highest for high-income countries, followed by the middle- and low-income countries.

Finally, the mean FDI inflows are recorded highest for high-income countries, followed by middle- and low-income countries. It is also noted that the low-income countries are more volatile in FDI inflows; its coefficient of variation is 2.940, which is the highest when compared to other panels' countries coefficient of variation.

Table 1
Summary statistics by panel.

Panel	Descriptives statistics	GDP per capita (constant 2005 USD)	Energy consumption (kg of oil equivalent)	FDI	GFCF (constant 2005 USD)	Labor force (in%)	Real Exchange Rate	Financial development (in%)	Population (in thousand)	Inflation (in%)	Trade openness (in%)
High-income countries	Mean	33308.66	328.454	2.30e+10	2.28e+11	63.633	97.656	117.258	34742.53	91.865	93.978
	Std. dev.	13846.17	132.747	3.71e+10	4.11e+11	10.226	22.552	97.355	58276.58	15.030	70.409
	CV	0.415	0.404	1.613	1.802	0.160	0.230	0.830	1.680	0.163	0.749
Middle-income countries	Mean	3715.693	167.1862	6.95e+09	6.42e+10	71.623	105.703	42.356	83732.01	81.632	73.292
	Std. dev.	2248.099	80.712	2.01e+10	1.55e+11	6.864	22.788	33.516	238196	39.776	41.395
	CV	0.605	0.482	2.892	2.181	0.095	0.215	0.791	2.843	0.487	0.564
Low-income counries	Mean	732.072	80.440	1.70e+09	3.05e+10	69.586	103.540	22.308	132904.8	80.744	65.248
	Std. dev.	489.946	40.783	4.99e+09	6.87e+10	9.468	22.236	17.482	274205.5	46.627	34.872
	CV	0.669	0.507	2.940	2.252	0.136	0.214	0.783	2.060	0.577	0.534
Global panel	Mean	15032.29	193.601	1.21e+10	1.31e+11	68.015	100.959	68.059	73970.77	85.679	79.837
	Std. dev.	17499.11	128.088	3.38e+10	3.11e+11	9.587	17.051	56.615	200930.4	34.1495	55.039
	CV	1.164	0.661	2.793	2.374	0.140	0.168	0.801	2.716	0.398	0.689

Notes : Std. Dev. and CV indicate, respectively: standard deviation and countries coefficient of variation; FDI indicated foreign direct investment net inflows; GFCF indicates gross fixed capital formation.

4.2. Main results and discussions

We start the results by performing the panel unit root test proposed by Im et al. (2003). Our objective about this test is to decide which variables should enter the proposed modeling in growth form and which variables should enter the models in their level form. In all four panels (the high-income panel, the middle-income panel, the low-income panel, and the global panel), we found that for labor force, inflation rate, trade openness, real exchange rate, and financial development, the unit root null is rejected. This means that these variables are stationary and they can enter our proposed modeling without changing them in growth form, while for the five other variables (namely, per capita GDP, foreign direct investment, per capita energy consumption, gross fixed capital formation, and total population), the null hypothesis of the panel unit root is not rejected, indicating that these variables are non-stationary. This implies that there is a need to change these variables into the growth form.

After checking the form in which variables would enter the empirical modeling, we used the Arellano and Bond (AB, 1991) GMM estimator to find the three-ways linkages between energy consumption, foreign direct investment, and economic growth for all four panels. Each panel contains three different models (model 1, 2 and 3). These models present the estimated coefficients of Eq. (7), (8) and (9) which are given in Tables 2 and 3. We also present the most reasonable results, those that behave favorably in terms of the diagnostic tests of overidentification (Hansen-J test) and the absence of a 2nd order autocorrelation in first differences (AR2 test).

The results of the high-, middle-, and low-income panels are reported in Table 2. For the high-income countries, the findings reveal that there are bi-directional causal relationships between energy consumption, FDI inflows and economic growth. We have summarized these results in Fig. 1.

In model 1, we find that energy consumption and foreign direct investment have positive and statistically significant (at the 1% level) effects on economic growth. The magnitude of 0.644 and 0.390 implies that a 1% increase in the growth rate of energy consumption and FDI increases the economic growth of the high-income countries by 0.64% and 0.39%, respectively. Capital stock (GFCF) is also statistically significant determinant of economic growth, while labor and inflation remains statistically insignificant. In model 2, we find that the effects of economic growth and energy consumption on FDI inflows are positive and statistically significant at the 1% and 5% levels, respectively. The magnitude of 0.106 and 0.092 implies that a 1% increase in economic growth and in the growth rate of energy

consumption increases the FDI inflows of the high-income countries by around 0.10%. Capital stock and trade openness are also statistically significant determinants of FDI inflows, while labor and real effective exchange rate remains statistically insignificant. Finally, in model 3, we find that the effects of economic growth and foreign direct investment on energy consumption are positive and statistically significant at the 1% level. The magnitude of 0.430 and 0.129 implies that a 1% increase in economic growth and foreign direct investment increases the energy consumption of the high-income countries by 0.43% and 0.13%, respectively. This means that an increase in economic growth and in FDI inflows tends to more energy consumption (see, *inter alia,* Ang, 2008; Shahbaz et al., 2012; Islam et al., 2013; Lee, 2013). Financial development has a significant effect on energy consumption, while labor and population are remains statistically insignificant.

In addition, for the middle-income panel, the findings reveal that there is bi-directional causal relationship between economic growth and energy consumption, and between economic growth and FDI inflows; there is also uni-directional causal relationship from FDI to energy consumption (see Fig. 2). It follows that the results here are consistent with a recent studies on this subject by Lee (2013) and by Shahbaz et al., (2013).

In model 1, we find that energy consumption and foreign direct investment have positive and statistically significant effects (at the 1% level) on economic growth. The magnitude of 0.191 and 0.288 implies that a 1% increase in energy consumption and foreign direct investment inflows increases the economic growth of the middle-income countries by around 0.19% and 0.29%, respectively. Labor force has a positive and statistically insignificant effect on economic growth. Capital stock has a positive and statistically significant effect on economic growth, while the impact of inflation is found to be negative and statistically significant. In model 2, we find that the economic growth has a significant positive effect (at the 1% level) on FDI inflows. The magnitude of 0.392 implies that a 1% increase in economic growth increases FDI inflows by 0.39%. Energy consumption has an insignificant effect on FDI inflows. The findings reveal also that capital stock, labor force, trade openness and the real effective exchange rate have significant effects on FDI inflows. Capital stock, labor force and trade openness have positive impacts on FDI inflows, whereas the real effective exchange rate has a negative impact. In model 3, both economic growth and FDI inflows have positive and significant impacts on energy consumption at the 1% and the 5% levels, respectively. The magnitude of 0.249 and 0.204 implies that a 1% increase in economic growth and FDI inflows increases energy consumption by 0.25% and 0.20%, respectively.

Table 2
Results for the high-, middle-, and low-income panels.

	High-income countries			Middle-income countries			Low-income countries		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Independent variables	GDP	FDI	Energy consumption	GDP	FDI	Energy consumption	GDP	FDI	Energy consumption
GDP per capita	-	0.106* (0.009)	0.430* (0.009)	-	0.392* (0.000)	0.249* (0.001)	-	0.167*** (0.036)	0.154 (0.123)
FDI	0.644* (0.000)	-	0.129* (0.000)	0.191* (0.006)	-	0.204** (0.022)	0.256** (0.031)	-	0.267** (0.048)
Energy consumption	0.390* (0.002)	0.092** (0.028)	-	0.288* (0.000)	0.061 (0.633)	-	0.168** (0.019)	0.195 (0.115)	-
GFCF	0.193* (0.000)	0.372* (0.000)	0.181* (0.004)	0.193* (0.004)	0.210** (0.047)	0.318** (0.038)	0.098*** (0.086)	0.177*** (0.066)	0.194** (0.041)
Labor force	0.064 (0.564)	0.075 (0.358)	0.044 (0.502)	0.164 (0.119)	0.198*** (0.091)	0.009 (0.812)	0.214 (0.103)	0.099 (0.171)	0.009 (0.812)
Inflation	-0.003 (0.832)	-	-	-0.111** (0.022)	-	-	-0.216* (0.001)	-	-
Trade openness	-	0.567** (0.043)	-	-	0.567** (0.043)	-	-	0.107 (0.233)	-
Real exchange rate	-	-0.650* (0.003)	-	-	-0.132*** (0.087)	-	-	-0.078** (0.465)	-
Population	-	-	0.152 (0.508)	-	-	0.199*** (0.078)	-	-	0.342** (0.016)
Financial development	-	-	0.584* (0.000)	-	-	0.419** (0.013)	-	-	0.189*** (0.093)
Constant	0.152*** (0.078)	0.245** (0.014)	0.425** (0.033)	0.129*** (0.089)	0.116 (0.203)	0.315** (0.045)	0.193** (0.047)	0.111 (0.189)	0.265*** (0.072)
Hansen J-test (p-value)	24.31 (0.116)	24.822 (0.112)	19.39 (0.565)	22.32 (0.323)	16.32 (0.612)	15.42 (0.627)	15.55 (0.629)	26.13 (0.095)	22.19 (0.327)
AR2 test (p-value)	0.066 (0.955)	0.199 (0.842)	0.675 (0.512)	-0.197 (0.744)	0.255 (0.701)	-0.085 (0.921)	0.053 (0.960)	0.118 (0.689)	0.098 (0.941)

Notes:
Values in parentheses are the estimated p-values.
Hansen J-test — overidentification test of restrictions in GMM estimation.
AR2 test — Arellano–Bond's test to analyse the existence of 2nd order autocorrelation in first differences.
* Coefficient significant at the 1% level; **Coefficient significant at the 5% level; ***Coefficient significant at the 10% level.

There are also positive and statistically significant impacts of capital stock, population and financial development on energy consumption, while labor force has a positive and insignificant effect on energy consumption.

For the low-income panel, the findings reveal that there is bi-directional causal relationship between economic growth and FDI inflows; there is uni-directional causal relationship from economic growth to energy consumption and from energy consumption from FDI inflows (see Fig. 3).

In model 1, we find that energy consumption and foreign direct investment have a positive and statistically significant effect (at the 5% level) on economic growth. The magnitude of 0.265 and 0.168 implies that a 1% increase in energy consumption and foreign direct investment inflows increases the economic growth of the low-income countries by around 0.27% and 0.17%, respectively. Capital stock and inflation have a positive and statistically significant impact on economic growth, while the impact of labor force is found to be statistically insignificant. Capital stock has a positive impact on economic growth, whereas inflation has a negative impact. In model 2, we find that the economic growth has a significant positive effect on economic growth at the 10% level. The magnitude of 0.167 implies that a 1% increase in economic growth increases FDI inflows by around 0.17%. The findings reveal also that energy consumption, labor force, and trade openness have insignificant effects on FDI inflows. Capital stock and the real effective exchange rate have significant effects on FDI inflows. Capital stock has a positive effect on FDI inflows, whereas the real effective exchange rate has a negative effect. In the final model, we find that FDI inflows have positive significant effects (at the 5% level) on energy consumption. The magnitude of 0.267 implies that a 1% increase in FDI inflows increases energy consumption by around 0.27%. We find also that economic growth and labor force have insignificant impacts on energy consumption, while capital stock, population, and financial development have significant impacts.

Table 3 reports the results for the global panel. Evidence from models 1, 2 and 3 reveals that there is bi-directional causal relationship between economic growth and energy consumption, and between economic growth and FDI inflows; there is also uni-directional causal relationship from FDI to energy consumption (see Fig. 4).

In model 1, we find that energy consumption and foreign direct investment have positive and statistically significant effects (at the 5% and the 1% levels) on economic growth. The magnitude of 0.241 and 0.227 implies that a 1% increase in energy consumption and foreign direct investment inflows increases the economic growth of the global panel by around 0.24%

and 0.23%, respectively. Labor force has a positive and statistically insignificant effect on economic growth. The findings reveal also that capital stock and inflation have significant effects on economic growth. Capital stock has a positive effect on economic growth, whereas inflation has a negative effect. In model 2, we find that the economic growth has a significant positive effect on FDI inflows at 5% level. The magnitude of 0.197 implies that a 1% increase in economic growth increases FDI inflows by around 0.20%. Energy consumption has an insignificant effect on FDI inflows. The findings reveal also that capital stock, trade openness and the real effective exchange rate have significant effects on FDI inflows. Capital stock and trade openness have positive impacts on FDI inflows, whereas the real effective exchange rate has a negative impact. The labor force has a statistically insignificant impact on FDI inflows. In the final model, we find that both economic growth and FDI inflows have positive and significant effects on energy consumption at the 5% and the 1% levels, respectively. The magnitude of 0.277 and 0.446 implies that a 1% increase in economic growth and FDI inflows increases energy consumption by around 0.28% and 0.45%, respectively. The findings reveal also positive and statistically significant impacts of capital stock, population and financial development on energy consumption, while labor force has a positive and insignificant effect on energy consumption.

Table 3
Results for the global panel.

	Model 1	Model 2	Model 3
Independent variables	GDP per capita	FDI	Energy consumption
GDP per capita	-	0.197** (0.016)	0.277** (0.038)
FDI	0.241** (0.018)	-	0.446* (0.000)
Energy consumption	0.227* (0.009)	0.112 (0.237)	-
GFCF	0.161*** (0.034)	0.207*** (0.055)	0.201** (0.016)
Labor force	0.113 (0.146)	0.034 (0.621)	0.115 (0.341)
Inflation	-0.187*** (0.052)	-	-
Trade openness	-	0.366* (0.004)	-
Real exchange rate	-	-0.195** (0.027)	-
Population	-	-	0.186*** (0.044)
Financial development	-	-	0.349* (0.002)
Constant	0.364** (0.028)	0.217** (0.046)	0.268** (0.011)
Hansen J-test (p-value)	21.66 (0.135)	19.240 (0.239)	15.62 (0.295)
AR2 test (p-value)	0.149 (0.875)	0.095 (0.788)	0.193 (0.838)

Notes:
Values in parentheses are the estimated p-values.
Hansen J-test — overidentification test of restrictions in GMM estimation.
AR2 test — Arellano–Bond's test to analyse the existence of 2nd order autocorrelation in first differences.
* Coefficient significant at 1% level; **Coefficient significant at 5% level; ***Coefficient significant at 10% level.

Finally, we have summarized the above results concerning the three-ways linkages between energy consumption, FDI inflows and economic growth for the four panels in Fig.1, 2, 3 and 4 to make the comparison easier. The main findings, thus, can be summarized as follows. First, we have found that the effect of per capita GDP on FDI inflows is positive and statistically significant in the four panels. This suggests that higher economic growth does send positive signals to prospective foreign investors. This confirms the results showed by Borensztein et al. (1998), Bengoa and Sanchez-Robles (2003), and Soltani and Ochi (2012). It has also found that the impact of per capita GDP on energy consumption in the four panels of countries is positive, but statistically significant only in the global panel and in the high and middle-income countries. This implies that an increase in economic growth tends to more energy consumption (Shahbaz et al., 2012; Islam et al., 2013). The results are consistent with the findings of Belloumi (2009), Halicioglu (2009), Odhiambo (2009), and Omri (2013).

Second, FDI inflows are found to have a statistically significant effect on economic growth and on energy consumption in the four panels. This implies that the economic growth and energy demand are more closely related to the FDI inflows. This is consistent with the findings of Aitken et al. (1997), Hsiao and Shen (2003), Nguyen and Nguyen (2007), Anwar and Nguyen (2010); Sadorsky (2010), and Bekhet and Othman (2011). More recently, Lee (2013) suggest that FDI allows businesses cheaper and/or easier access to financial capital, which can be used to expand their existing operations or construct new plants and factories, all of which increase the demand for energy. Consistent with this view that FDI leads to greater economic growth is the likelihood that energy demand should be positively affected by increases in FDI.

Third, energy consumption has a statistically significant effect on economic growth in the four panels. This indicates that an increase in energy consumption tends to promote economic growth (Shahbaz et al., 2012). Since energy is an important ingredient for economic growth, strong energy policies are required to attain sustained economic growth. This result is consistent with the findings of Apergis and Payne (2010), Sharma (2010), and Omri (2013). It has also found that energy consumption has a significant impact on FDI inflows only in the high-income countries. This pattern is similar to the findings of Bekhet and Othman (2011) and Chandran and Tang (2013). This implies that a greater of energy consumption increases the demand of the technological progress accompanied by the inflows of FDI which lead to a rapid improvement in the efficient use of energy resources and thus resulted in a reduction of CO_2 emissions.

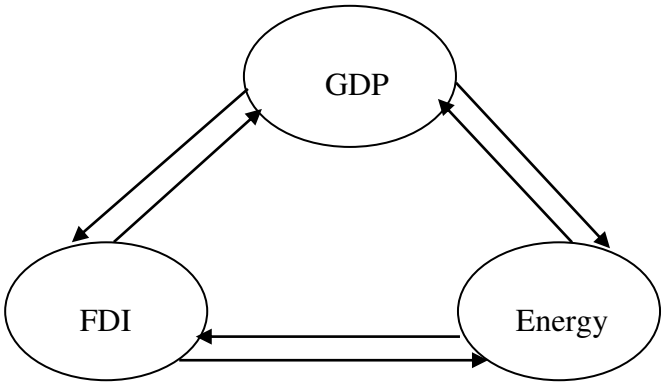

Fig. 1 Interactions between Energy, FDI and GDP for the high-income countries.

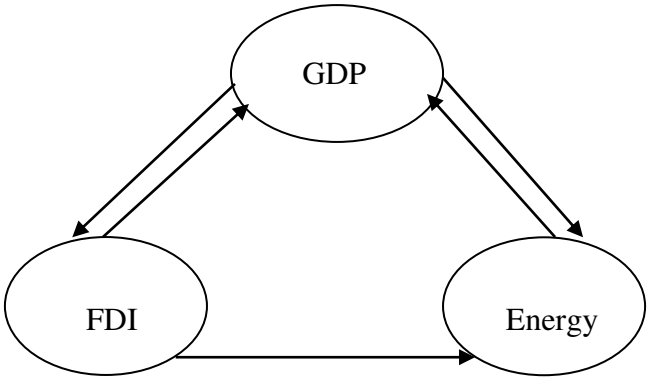

Fig. 2 Interactions between Energy, FDI and GDP for the middle-income countries.

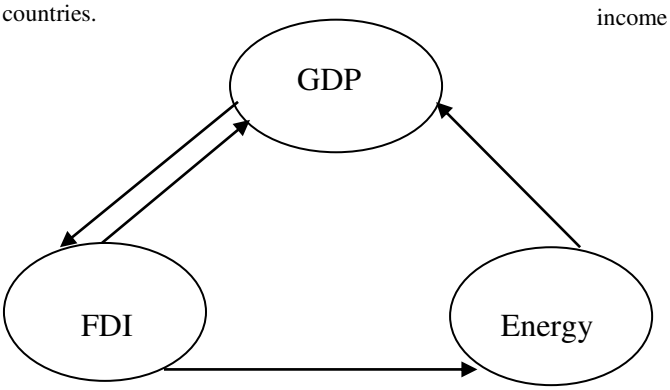

Fig. 3 Interactions between Energy, FDI and GDP for the low-income countries.

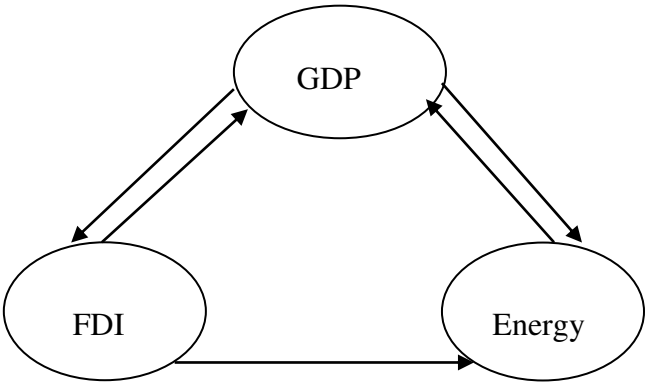

Fig. 4 Interactions between Energy, FDI and GDP for the global panel.

Fourth, the results show that there is bi-directional causal relationship between economic growth and FDI inflows in the four panels of countries. This confirms that, in overall terms, an increase in the stock of FDI increases economic growth which attracts further FDI into these countries. This result is in line with Kim and Seo (2003), Anwar and Nguyen (2010). The results reveal also that there is bi-directional causal relationship between economic

growth and energy consumption only for the global panel and for the high- and middle-countries. This pattern is similar to the findings of Mahadevan and Asafu-Adjaye (2007), Ang (2008), and Apergis and Payne (2009). Consequently, we conclude that energy consumption is a determinant factor of the GDP growth in these countries, and, therefore, a high level of economic growth leads to a high level of energy demand. Our results also show that there is a uni-directional causal relationship from energy consumption to economic growth for the low-income countries. This result is consistent with the finding of Altinay and Karagol (2004) for Turkey. We find also that there is uni-directional causal relationship from FDI inflows to energy consumption except in the high-income countries. This result is similar to the findings of Bekhet and Othman (2011), and Lee (2013).

5. Conclusion and policy implications

While the literature on energy–FDI–GDP for singular countries and for panels of countries has increased over the last few years, there is no study that examines the interaction between energy consumption, foreign direct investment and economic growth using a growth framework and simultaneous equations models. The objective of the present work is to fill this research gap by examining the above interaction over the period 1990-2011. We go a step further and examine this relationship for not only a global panel consisting of 65 countries but also for a number of sub-panels. These sub-panels are constructed based on the income level of countries.

Our main findings are as follows. First, for the high-income countries, we find that there are bi-directional causal relationships between energy consumption, FDI inflows and economic growth. Second, for the middle-income countries, the findings reveal that there is bi-directional causal relationship between economic growth and energy consumption, and between economic growth and FDI inflows; there is also uni-directional causal relationship from FDI to energy consumption. Furthermore, for the low-income countries, it has also found that there is bi-directional causal relationship between economic growth and FDI inflows; there is uni-directional causal relationship from economic growth to energy consumption and from energy consumption to FDI inflows. Finally, for the global panel, the findings reveal that there is there is bi-directional causal relationship between economic growth and energy consumption, and between economic growth and FDI inflows; there is also uni-directional causal relationship from FDI to energy consumption.

The main policy implications emerging from our study is as follows. First, we find that there is bi-directional causal relationship between energy consumption and economic growth only for the global panel and for the high- and middle-income countries. Our results seem to significantly reject the neo-classical assumption that energy is neutral for growth. As such, it is important to take into account their possible negative effects on economic growth in establishing energy conservation policies. These policies will be beneficial for these countries in terms of saving energy and making efficient use of it as energy is one of the major source for goods and services production.

Second, we find that there is bi-directional causal relationship between FDI inflows and economic growth in the four panels of countries. This implies that an increase in the stock of FDI inflows increases economic growth which attracts further FDI into these countries. This suggests that policy makers in these countries to consider more prudent policies might involve eliminating barriers that prevent local firms from establishing adequate linkages, improving local firms' access to inputs, technology, and financing, and streamlining the procedures associated with selling inputs. But we might also seek to improve domestic conditions, which should have the dual effect of attracting foreign investment (Alfaro et al., 2006) and enabling host economies to maximize the benefits of such foreign investment. Furthermore, in order to provide a more efficient platform for attracting and optimize the environment for FDI, it is necessary for the local government to improve laws and statutes and make reasonable industrial policies to guide the industry distribution of FDI, which will be helpful for the local government to play a positive role in upgrading the industrial structure, reducing energy consumption, and establishing an energy-saving city.

Third, we find that the effect of FDI on energy consumption is expected to be remarkable in middle- or low-income countries than high-income countries (a 1% increase in FDI yields 0.13%, 0.20%, and 0.27% increases in energy consumption for high-, middle-, and low-income countries, respectively). The weak influence of FDI on energy consumption in high-income countries than middle- and low-income countries can be explained by the construction of infrastructure, development of manufacturing sector, and encouragement R&S in green technlogy in most of these countries before 1990s. For these reasons, policymakers in the middle- and low-income countries should implement a dual principal strategy that, on one hand, increases investment in energy infrastructure and encourages R&D in green technology such as exercising proper soil conservation techniques and sustainable farming practices in order to reduce the consumption of fossil fuels, while, on the other, some efforts must be put on attracting foreign investors which address the renewable energy and green technology.

Hence, the integration of foreign capital may be a sensible way to mitigate the climate change and continue to boost economic growth. The governments of these countries should also consider the inflows of foreign direct investment when formulating energy policies because our results confirm that these are important factors that influence the energy consumption and economic growth.

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