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# The Influence of FDI on Energy Consumption in Developing and Developed Countries: A Dynamic Panel Data Approach

## DYY'ların Gelişmekte ve Gelişmiş Ülkelerde' ki Enerji Tüketimi Üzerindeki Etkisi: Dinamik Panel Veri Analizi

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*Abstract: Although FDI is a source of financing in both developed and developing countries, it is also known as a source of innovation that could reduce the demand for energy. Thus, recent studies have started to focus on isolating the effect of FDI on energy consumption in the host country. However, the debate so far is inconclusive. The main objective of this study is to measure the effect of FDI on renewable and non-renewable energy consumption in 85 developed and developing countries from 2002 to 2014, employing a dynamic panel data method. The study demonstrated that FDI reduces energy consumption in developed countries but has no effect on energy consumption in developing countries. The study confirmed that the openness index and energy prices also explain energy consumption within developed countries.*

*Keywords: Energy Consumption, Renewable Energy, Non-renewable Energy, FDI, Panel Data*

*Öz: Doğrudan Yabancı Yatırımlar (DYY) gelişmiş ve gelişmekte olan ülkeler için sermaye finansman kaynağı olarak görünse de aynı zamanda enerji ihtiyacını azaltan teknoloji kaynağı olarak bilinmektedir. Dolayısı ile son zamanlardaki çalışmalar ev sahibi ülkedeki DYY ile enerji tüketimi arasındaki ilişkiyi bulmaya odaklanmıştır. Buna rağmen tartışma halen sonuçsuzdur. Bu çalışmanın amacı dinamik panel veri analizini kullanarak DYY'ların yenilenebilir ve yenilenemez enerji tüketimi üzerindeki etkilerini 85 gelişmiş ve gelişmekte olan ülkeler için 2002'den 2014 'e kadarki dönem için incelemektir. Çalışma, DYY'ların gelişmiş ülkelerdeki enerji tüketimini azaltıcı etkisini saptamış buna rağmen gelişmekte olan ülkelerdeki enerji tüketimi üzerinde herhangi bir etkisini bulamamıştır. Çalışma, dışa açıklık indeksi ve enerji fiyatlarının gelişmiş ülkelerdeki enerji tüketimi üzerinde açıklayıcı etkilerini desteklemektedir.*

*Anahtar kelimler: Enerji Tüketimi, Yenilenebilir Enerji, Yenilenemez Enerji, DYY, Panel Veri*

## 1. Introduction

Many researchers argue that Foreign Direct Investment (FDI) encourages energy-saving technologies, know-how, techniques, or new production methods that enhance the prevalence of renewable energy in the host country. FDI may affect renewable energy consumption through two processes. First, the presence of foreign firms in the host country's markets may force domestic firms to be more competitive, particularly because energy is typically the most important, scarce and expensive input for producing goods and services. Domestic firms may try to find new ways to demand renewable energy consumption to avoid higher production costs. Second, foreign firms may replicate energy-saving technologies if the source county has led them to adopt high environmental standards. Thus far, few studies have dealt with the relationships between FDI and energy consumption in the literature, and most of these have been ambiguous and provided mixed evidence. While some authors have argued that FDI may promote energy-saving technologies and reduce energy consumption, others have maintained that FDI may even increase energy consumption, as new foreign firms become active in these host markets.

We know that most developing countries are characterized as emerging markets and have not yet completed the process of industrialization. Such economies may not be quick to absorb new energy-saving technology sourced from developed countries. Furthermore, developed countries generally feature post-industrial economies that may force foreign firms to replicate their technology to follow their environmental policies. Therefore, contrary to previous studies, we hypothesize that FDI may have different effects on energy consumption in developing and developed countries. In addition, we have classified energy consumption into renewable and non-renewable categories to uncover any complementary or substitution effects among the two energy types. Renewable energy consumption may substitute for non-renewable in cases where the former is less costly and protects the environment as a clean energy type. Alternatively, renewable energy consumption may complement non-renewable energy consumption, as waste products of non-renewable energy production can be converted into renewable energy.

The main objective of this study is to investigate the relationships between energy consumption and FDI in 85 developing[1] and developed countries[2] from 2002 to 2014. The study contributes to the literature by analyzing the effect of FDI on both renewable and non-renewable energy consumption within a simultaneous model specification to capture complementary and/or substitution relationships among renewable and non-renewable energy consumption.

The rest of the paper is organized as follows: the second section summarizes the theoretical background and literature review, the third section explains the data and methodology, the fourth section presents empirical results, and the last section offers the conclusions of the study.

## 2. Theoretical Background and Literature Review

The benefits of FDI flowing into developing and least-developed countries have been extensively analyzed and several potential outcomes have been identified. FDI theory suggests that FDI transfers new technology, creates new jobs, and brings new managerial skills into an economy by transferring human capital, so that foreign investment promotes economic growth overall. However, the opposing view claims that FDI may be a way of outsourcing "dirty industries" to developing and least-developed countries; because these countries have softer environmental regulations they are vulnerable to becoming pollution havens. Nonetheless, FDI may encourage a shift of energy production through technological diffusion, promoting the consumption of renewable energy while reducing energy demand in the host country. According to the International Energy Agency (IEA), world energy demand is expected to grow at an annual rate of 1.8% between 2005 and 2030; emerging economies are expected to contribute to the total world energy demand by 74% during this period. The 2016 IEA report has therefore noted the increasing importance of renewable energy consumption, as air pollution has become the world's fourth-largest threat to human health.

As globalization has become a more prominent issue since the 1990s, many studies have focused on the relationships between FDI and financial development, economic growth, and CO2 emissions. Yet, only a handful of studies have investigated the linkages between FDI and energy consumption, and these researches have failed to establish whether the relationship between energy consumption and FDI is positive or negative. Two opposite perspectives have been presented in this literature. Some researchers have argued that multinational firms based in developed countries where producers are exposed to strict environmental regulations tend to uphold high environmental standards in host countries as well. In this scenario, FDI may bring energy-saving technologies to host countries and reduce the demand for non-renewable energy. Meanwhile, according to the Pollution Haven Hypothesis (PHH), FDI may not have a positive effect on renewable energy consumption in emerging economies. As most middle-income countries have softer environmental regulations than developed countries, FDI may serve as a channel to outsource industries that use "dirty" energy to countries with less effective environmental standards. PHH was developed as a counter-argument to the Environmental Kuznets Curve (EKC) model used for developed countries. The EKC hypothesis proposed that while the poorest countries are exposed to the least pollution, the richest countries are likely to receive the most pollution due to the impact of industrialization and post-industrialization. Thus, the level of pollution produced by an economy shows an inverted U-curve. As their income levels increase, countries are likely to strengthen their environmental regulations. The pollution level countries experience will first increase due to industrialization until it reaches a peak level. The imposition of strict environmental regulations then leads to a turning point on the curve, accompanied by improvements in energy-saving technologies that reduce pollution. The PHH hypothesis developed as a criticism of the assumptions behind the EKC hypothesis. According to the PHH hypothesis, an inverted U-curve for national pollution levels that can be attributed to the willingness of high-income countries to export pollution-intensive industries to developing countries. Less-developed countries receiving capital inflows will realize economic growth only as they increase their demand for energy. Furthermore, emerging economies receive FDI mostly in capital-intensive industries that are also pollution-intensive. Thus, FDI flows into emerging countries are likely to create dirty industries, increasing the demand for energy.

Most previous studies have supported the idea that FDI promotes energy savings in the host country and reduces the demand for energy. For example, a study by Mielnik and Goldemberg (2002) has found that energy intensity is likely to decline as FDI per capita increases in the host country. They have attributed this reduction in energy intensity to the spillover effect of FDI through the introduction of new technologies. Furthermore, studies

[1] **Developing Country List Classified as Lower-Middle Income, Middle Income and Upper-Middle Income Countries by the World Bank**: Albania, Angola, Armenia, Azerbaijan , Bangladesh , Belarus, Bolivia, Brazil, Bulgaria, Cameroon, China, Colombia, Congo Rep., Congo, Dem. Rep, Costa Rica, Cote d'Ivoire, Dominican Rep., Egypt, Gabon, Georgia, Ghana, Guatemala , Haiti, Honduras , India, Iran, Jamaica, Jordan , Kazakhstan , Kenya, Kyrgyz Rep., Macedonia, Malaysia, Mauritius , Mexico, Moldova, Morocco, Myanmar, Namibia, Nigeria, Pakistan, Panama, Peru, Philippines, Romania, Russia, Senegal, Serbia, Thailand , Tunisia, Turkey.

[2] **Developed Country List Classified as High-Income Countries by the World Bank:** Australia, Austria, Belgium, Canada, Chile, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Korea Rep., Latvia, Lithuania, Luxemburg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Rep., Slovenia, Sweden, Spain, United Kingdom, USA, Uruguay.

by Dube (2009) and by Foon Tang (2009) have shown negative linkages between FDI inflows and demand for electrical energy in the cases of South Africa and Malaysia. Studies by Sadorsky (2011), He et al. (2012), Çoban and Topcu (2013), Jiang et al. (2014), and Azam et al. (2015) have all claimed that FDI introduces energy-saving technologies and conserves energy in the host market. A recent study by Doytch and Narayan (2016) has investigated the relationships between sectoral FDI and energy consumption by classifying energy consumption into two types as renewable and non-renewable energy. They have concluded that FDI promotes energy savings by increasing renewable energy consumption. Their study supports the idea that FDI inflows have a *halo effect*, suggesting that FDI inflows improve local environmental performance. However, they also confirmed that the *halo effect* of FDI in lower-middle income countries is less significant than the *halo effect* in upper-middle income countries. Other researchers have studied the environmental impact of FDI in the host country by measuring the effect of FDI on CO2 emissions. Although some of these studies claim that FDI may cause pollution-haven effects in host countries where environmental policies are weak, most have argued that foreign investors may be forced to follow high environmental standards in the host country, causing a reduction in energy demand (See the study of Zhang and Fu, 2008).

Meanwhile, a handful of studies have supported the PHH hypothesis, claiming that positive relationships can be seen between FDI inflows and energy consumption. For example, a recent study by Mohammad bin Mohamed (2016) examined the correlation among FDI, economic growth, energy consumption and exports in Yemen from 1994 to 2014, employing an Autoregressive Distributed Lag Model (ARDL). He identified positive relationships between FDI inflows and domestic energy consumption in Yemen, in both the short and the long run.

Furthermore, several authors found no measurable effects of FDI on domestic energy consumption. A study by Hüber and Keller (2010), employing fixed panel data and disregarding the endogeneity within the data, could not prove any effect of FDI on domestic energy consumption. Moreover, a study by Sadorsky (2010) investigated the impact of the stock market development and FDI on energy consumption, employing a GMM approach. He found that the degree of financial development had a significant effect on energy demand, but failed to find any relationships between FDI and energy consumption. Ting et al. (2011) tried to measure the effect of FDI on energy consumption in Jiangsu Province by decomposing the energy consumption intensity into an FDI scale effect, an FDI structure effect and an FDI technology effect by employing the Logarithmic Mean Divisia Index (LMDI) method. They found that the FDI scale effect reduces energy consumption but that FDI structure and technology effects do not promote a reduction in the energy intensity. Lee (2013) investigated the contributions of net FDI inflows to clean energy use, carbon emissions, and economic growth by examining a panel of 19 nations within the G20 from 1971 to 2009. He has found that FDI plays an important role in economic growth but failed to find any evidence supporting a positive linkage between FDI and clean energy. Another study by Zeeb et al. (2015) examined the impact of FDI on energy saving in seven South Asian countries from 1990 to 2013, employing pooled Ordinary Least Square (OLS), Random Effects (RE) and Fixed Effects (FE) models. This study failed to demonstrate any significant effect of FDI on energy consumption. The authors concluded that FDI helps to transfer new technology into this country group; however, the possible effect of FDI on energy intensity depends on national characteristics and energy policies. Similarly, Chang (2015) has also failed to find any effect of FDI on energy consumption in 53 countries, while analyzing the variables within a nonlinear framework.

## 3. Data and Methodology

### *3.1. Data*

The consumption of renewable and non-renewable energy, as a percentage of total energy consumption, is assigned as our dependent variables in both developed and developing countries. Renewable energy compromises hydro-electric power and nuclear, geothermal, and solar power production. Non-renewable energy consumption includes coal, oil, petroleum, and natural gas product consumption, whether for electrical generation or other uses. Furthermore, net FDI inflows as a percentage of Gross Domestic Product (GDP), the openness index, the Consumer Price Index (CPI) as an indicator of non-renewable energy prices and GDP per capita as a proxy for market size have been decided on as explanatory variables. We have also included time dummy variables to capture the effects of the Global Financial Crisis (GFC) on energy consumption. All variables are measured in US Dollars and obtained from World Bank Data retrieval tool (www.worldbank.org). The openness index is calculated simply by taking the ratio of the exports plus imports to GDP.

***3.2. Methodology***

A dynamic panel model typically can be formulated as $Y_{it} = \delta Y_{it-1} + X'_{it}\beta + u_{it}$ $(i = 1.............N; t = 1.............,T)$, where $\delta$ is a scalar, $X'_{it}$ is a vector of explanatory variables with dimensions of $1*K$, and $\beta$ is the vector of coefficients with $K*1$ elements. We will assume that $u_{it}$ follows a one-way error component model, shown as: $u_{it} = \eta_i + v_{it}$ ,

Here, $\eta_i$ is a unit-specific and time-invariant random variable, which is independently and identically distributed with a zero mean and a constant variance. Consequently, it can be formulated as $\eta \sim IID(0, \sigma_\eta^{\ 2})$. The other component is both unit- and time-varying and obeys the following distribution: $v_{it} \sim IID(0, \sigma^2_{\ v})$. The components are independent of one another and amongst themselves.

The basic problem stems from the inclusion of the lagged dependent variable. Since $Y_{it}$ is a function of $\eta_i$, it immediately follows that $Y_{i,t-1}$ is also a function of $\eta_i$. Therefore, $Y_{i,t-1}$ which is also an explanatory variable, is correlated with the error term, thus violating the condition of the independence of regressors and the error term within the regression framework. The consequence of the violation leads to biased and inconsistent OLS estimators, even if the $v_{it}$ are not serially correlated.

The fixed effects (FE) estimator can be used to wipe $\eta_i$ thus apparently relieving the problem mentioned above. However, since this estimator is based on an internal transformation, the result is $(Y_{i,t-1} - \overline{Y}_{j-1})$, where $\overline{Y}_{j-1} = \sum_{t=2}^{T} Y_{i,t-1} / (T-1)$, and the first term is still correlated with $(v_{it} - \overline{v}_i)$, even if the $v_{it}$ are not serially correlated. This is because $Y_{i,t-1}$ is correlated with $\overline{v}_i$ by construction; the latter time average of the group j includes $v_{i,t-1}$, which is *de facto* correlated with $Y_{i,t-1}$. Moreover, $v_{it}$ is correlated with $\overline{Y}_{j-1}$ because the latter average contains $Y_{it}$. These are the leading terms causing the correlation, and they are both of order T-1. This result was discovered by Nickell (1981).

Arrellano and Bond (1991) argued that there might be a Generalized Method of Moment (GMM) procedure that is both unbiased and efficient. The main principle of this method is based on the utilization of the orthogonatility conditions that exist between lagged values of $Y_{it}$ and the disturbance $v_{it}$.

To illustrate this idea, one can formulate a simple autoregressive model with no regressors: $Y_{it} = \delta Y_{i,t-1} + u_{it}$ $(i = 1..........,N; t = 1.............,T)$, where $u_{it} = \eta_i + v_{it}$ with $\eta_i \sim IID(0, \sigma^2_{\ \eta})$ and $v_{it} \sim IID(0, \sigma^2_{\ v})$ independent of one another and amongst themselves. In order to get a consistent estimate of $\delta$ as $N \to \infty$ with a fixed T, we first differentiate the $Y_{it} = \delta Y_{i,t-1} + u_{it}$ to eliminate individual effects, such that $Y_{it} - Y_{i,t-1} = \delta(Y_{i,t-1} - Y_{i,t-2}) + (v_{it} - v_{i,t-1})$. The error term of this transformed equation is now of a moving average, or MA (1), type with a unit root. Let us reformulate the $Y_{it} = \delta Y_{i,t-1} + u_{it}$ when t=3, such that

$Y_{i3} - Y_{i2} = \delta(Y_{i2} - Y_{i1}) + (v_{i3} - v_{i2})$. In this case, $Y_{i1}$ is a valid instrument, since $E(Y_{i1}(Y_{i2} - Y_{i1})) \neq 0$ (highly correlated with $Y_{i2} - Y_{i1}$, but uncorrelated with $v_{i3} - v_{i2}$, so that $E(Y_{i1}(v_{i3} - v_{i2})) \neq 0$. When we advanced the time index by 1, such that t=4, we observe:

$$Y_{i4} - Y_{i3} = \delta(Y_{i3} - Y_{i2}) + (v_{i4} - v_{i3})$$

In this case, we have one additional instrumental variable, $Y_{i2}$. Specifically, one can show that:

$E(Y_{i1}(v_{i4} - v_{i3})) = 0$ And $E(Y_{i2}(v_{i4} - v_{i3})) = 0$

So, we have two instrumental variables: $Y_{i1}$ and $Y_{i2}$. One can easily generalize this by observing that, with each forward period, the addition of extra instruments become possible. Consequently, for period T, the set of valid instruments becomes $(Y_{i1}, Y_{i2}..........Y_{i,T-2})$.

Furthermore, the basic idea of the test for over-identification can be explained within the framework of the simple autoregressive model. Assume there are only four periods (i.e., T=4). Then, Arellano-Bond (1991) gives us three moment conditions with which to identify one parameter:

$E\left[(Y_{i1}(u_{i3}-u_{i2})\right]=0$ , First Condition

$E\left[(Y_{i1}(u_{i4}-u_{i3})\right]=0$ , Second Condition

$E\left[(Y_{i2}(u_{i4}-u_{i3})\right]=0$ , Third Condition

Any of these moments' conditions can be used as instrument. Once we pick up any of these three conditions, the remaining ones are so called as over-identification restrictions.

### *3.3. Model Specification*

We capture the effect of FDI on renewable and non-renewable energy consumption by adopting a one-step system Generalized Method of Moments (GMM) dynamic panel data model. System GMM models are superior to fixed effects models when endogeneity poses problems in the data. The inclusion of lagged dependent variables into the model causes bias because of the correlation between these variables and individual effects and cannot be controlled by time averaging. System GMM models are also superior to difference GMM models in three specific situations: (i) if a dependent variable follows a random walk that causes the first lag to be a poor instrument for its difference, (ii) if the explanatory variables are persistent over time, leading their lagged levels to be weak instruments for their differences, and (iii) if the time dimension of the sample is small.

Our model can be written as follows:

$$EnCons^{k}{}_{i,t} = \beta_0 + EnCons^{k}{}_{i,t-1} + \sum_{i=2}^{4}\beta_{i,t-1} + \mu_i + \varepsilon_{i,t} \quad (1)$$

With $\mu_i \sim i.i.d(0,\sigma_{\mu_i})$, $\varepsilon_{i,t} \sim i.i.d(0,\sigma_{\varepsilon})$ and $E[\mu_i\varepsilon_{i,t}]=0$, where $EnCon^{k}{}_{i,t}$ represents energy consumption as a percentage of total energy consumption. The superscript k stands for renewable and non-renewable energy consumption as a percentage of total energy consumption. Furthermore, $\sum_{i=2}^{4} B_{i,t-1}$ stands for the explanatory variables incorporated into the specification, while $\mu_i$ indicates country specific effects, and $\varepsilon_{i,t}$ represents the error term.

By adopting a system GMM model, we ensure that there will be no second order correlation in the error term:

$$E\left[EnConsi_{i,t} - s(\varepsilon_{i,t}-\varepsilon_{i,t-1})\right]=0;\ E\left[\sum_{i=2}^{S}\beta i,t - s(\varepsilon_{i,t}-\varepsilon_{i,t-1})\right]=0 \text{ for s≥2 and t=3,….T} \quad (2)$$

By adopting system GMM, we also ensure that there is no autocorrelation of country-specific effects with their differences by adding additional moment conditions:

$$E\left[/\,EnCons_{i,t-1} - EnCons_{i,t-2})(\mu_i\varepsilon_{i,t})\right]=0;\ E\left[(\sum_{i=2}^{S}\beta_{i,t-1} - \sum_{t=2}^{s}\beta_{i,t-2}) - (\mu_i\varepsilon_{i,t})\right]=0 \quad (3)$$

Thus, even if the unobserved country-specific effect is correlated with the level of the regressors, it is not correlated with their differences.

## 4. Empirical Results

Before performing the estimation of one-step system GMM models, we have carried out a Lagrange Multiplier (LM) Test to find any cross-sectional dependency across the series in the analysis. The LM test checks for the presence of heterogeneity by testing the null hypothesis $H_0 = \sigma^2{}_a = 0$ against the alternative $H_1 = \sigma^2{}_a > 0$. If the null hypothesis is rejected, a random effect has been observed. Otherwise, failing to reject the null hypothesis implies that $a_i = 0$ for every country and there are no cross-sectional differences among countries and no heterogeneity to account for.

The results of one-step system GMM estimation are presented in Table 1 and Table 2, with Table 1 showing the result for renewable energy consumption, and table 2 exhibiting the result for non-renewable energy consumption. In each case, the first column shows the explanatory variables, and the second and third columns present the results for developed and developing countries. To ensure the robustness of our estimates, we have also incorporated LM and post-estimation test results at the bottom of each Table. With respect to the LM test statistics, Arellano Bond AR (2) test results and Hansen test results, we have ensured the existence of random effects among countries and confirmed that there is no second-order serial autocorrelation in the error terms or over-identification problems among instruments.

Table 1. Estimation Results for Renewable Energy Consumption

| *Variables* | *System-GMM Developed Countries* | *System-GMM Developing Countries* |
|---|---|---|
| *Renewable $_{t-1}$* | 0.9881<br>(0.000)** | 0.9417<br>(0.000)** |
| *Non-renewable* | -0.8499<br>(0.000)** | -0.6039<br>(0.013)** |
| *Non-renewable $_{t-1}$* | 0.8157<br>(0.000)** | 0.5711<br>(0.008)** |
| *FDI* | 0.0049<br>(0.058)* | 0.0393<br>(0.383) |
| *Openness* | -0.0059<br>(0.054)* | 0.0010<br>(0.830) |
| *CPI* | -0.0196<br>(0.841) | -0.0103<br>(0.419) |
| *GDP* | 0.0259<br>(0.057)* | -0.0044<br>(0.297) |
| *d2002* | —— | —— |
| *d2003* | 2.1972<br>0.454) | 0.1797<br>(0.853) |
| *d2004* | 2.4035<br>(0.427) | 0.2976<br>(0.725) |
| *d2005* | 2.4782<br>(0.429) | 0.0935<br>(0.912) |
| *d2006* | 1.9861<br>(0.492) | 0.0344<br>0.965) |
| *d2007* | 2.3585<br>(0.440) | 0.1945<br>(0.771) |
| *d2008* | 1.9836<br>(0.518) | 0.2999<br>(0.698) |
| *d2009* | 1.9430<br>(0.497) | 0.5468<br>(0.470) |
| *d2010* | 1.5795<br>(0.590) | 0.9114<br>(0.305) |
| *d2011* | 2.0596<br>(0.492) | 0.1427<br>(0.805) |
| *d2012* | 1.7603<br>(0.543) | 0.5521<br>(0.495) |
| *d2013* | 1.8617<br>(0.492) | 0.4779<br>(0.529) |
| *d2014* | 1.9685<br>(0.501) | 0.7205<br>(0.258) |

| | | |
|---|---|---|
| *Wald $Chi^2(20)$ Prob>$Ch^2$* | 106709 (0.000)** | 20605.91 (0.000)** |
| *Instruments* | 56 | 56 |
| *Observations* | 420 | 612 |
| *LM Test* | 2334 (0.000)** | 3523 (0.000)** |
| *Arellono Bond AR(2)* | 0.410 | 0.156 |
| *Hansen Test* | 0.941 | 0.440 |

*Note: While ** refers to a 1% significance level, * refers to a 5% significance level. The probability values of standard errors are given in parentheses.*

As seen from Table 1, while FDI has a positive and significant effect on renewable energy consumption in developed countries; it does not have any effect on renewable energy consumption in developing countries. In other words, FDI promotes energy savings as shown in an increase in renewable energy consumption in developed countries but does not reduce energy consumption in developing countries. There are two possible explanations for this result. First, foreign investors in developed countries consist mostly of large multinational firms, but they may be forced to replicate energy-saving technologies prevalent in these host economies regardless of the environmental policies of their home countries, which may be more lax. One may therefore easily argue that a *halo effect* of FDI prevails for developed countries. Second, developing countries may fall behind in automation and industrialization so they may not be able to absorb advanced technologies coming from developed countries. Thus, any predicted spillover effect of FDI through diffusion of new technology or know-how may not be realized in emerging economies. Furthermore, developing countries are generally characterized as having weak environmental regulations and policies. Thus, multinational firms based in developed countries investing in developing countries may seek to avoid the high production costs arising due to strict environmental regulations. Moreover, we have demonstrated statistically that while the openness index is negatively correlated with renewable energy consumption, GDP per capita is positively correlated with renewable energy consumption in developed countries. As developed countries engage more extensively in international trade, they demand more non-renewable energy to meet the excess demand from abroad. As GDP per capita increases, however, they are likely to demand more renewable energy to make more efficient use of scarce environmental resources in the home country. As noted earlier, the PHH hypothesis argues that countries with high incomes are likely to export pollution-intensive industries to developing countries. Thus, higher GDP per capita may lead high-income countries to export "dirty" industries to developing countries while imposing strict domestic environmental regulations that enhance the consumption of renewable energy.

Table 2. Estimation Results for Non-renewable Energy Consumption

| *Variables* | *System-GMM Developed Countries* | *System-GMM Developing Countries* |
|---|---|---|
| *Non-renewable $_{t-1}$* | 0.9172 (0.000)** | 0.9765 (0.000)** |
| *Renewable* | -0.9741 (0.000)** | -0.9908 (0.000)** |
| *Renewable $_{t-1}$* | 0.9492 (0.000)** | 0.9940 (0.000)** |
| *FDI* | 0.0041 (0.248) | 0.0354 (0.080) |
| *Openness* | -0.0003 (0.942) | 0.0023 (0.310) |
| *CPI* | -0.2385 (0.056)* | -0.0045 (0.561) |
| *GDP* | -0.0075 (0.759) | 0.0066 (0.068) |
| *d2002* | ___ | ____ |

| | | |
|---|---|---|
| *d2003* | -0.3205<br>(0.525) | _____ |
| *d2004* | -0.6525<br>(0.149) | -0.2891<br>(0.287) |
| *d2005* | -0.7669<br>(0.119) | -0.1286<br>(0.472) |
| *d2006* | -0.4935<br>(0.170) | -0.2387<br>(0.304) |
| *d2007* | -0.8478<br>(0.119) | 0.0076<br>(0.696) |
| *d2008* | _____ | -0.4006<br>(0.118) |
| *d2009* | -1.4290<br>(0.053)* | -0.4753<br>(0.147) |
| *d2010* | -0.4331<br>(0.536) | -0.5197<br>(0.020)* |
| *d2011* | -0.9609<br>(0.088) | -0.2073<br>(0.420) |
| *d2012* | -0.9308<br>(0.139) | -0.3444<br>(0.245) |
| *d2013* | -1.6298<br>(0.039)* | -0.6238<br>(0.018)** |
| *d2014* | -2.2124<br>(0.000)** | -0.4515<br>(0.180) |
| *Wald* $Chi^2(20)$<br>*Prob>*$Ch^2$ | 9134.40<br>(0.000)** | 105429.17<br>(0.000)** |
| *Instruments* | 40 | 56 |
| *Observations* | 420 | 612 |
| *LM Test* | 2310<br>(0.000)** | 3045<br>(0.000)** |
| *Arellono Bond AR(2)* | 0.685 | 0.083 |
| *Hansen Test* | 0.193 | 0.467 |

*Note: While ** refers to a 1% significance level, * refers to a 5% significance level. The probability values of standard errors are given in parentheses.*

With respect to the effect of FDI on non-renewable energy consumption, one may easily observe from Table 2 that non-renewable energy consumption is negatively related with CPI and the time dummy variable for 2009, in the developed countries. Developed countries are very sensitive to energy prices, so as energy prices increase, they shift their demand from non-renewable to renewable energy. In other words, developed countries are likely to demand renewable energy to avoid high energy costs. In addition, developed countries have a comparative advantage in terms of high technology in converting waste from non-renewable resources to renewable energy, compared to developing countries. Thus, higher energy prices may motivate developed countries to convert this waste into renewable energy to avoid higher production costs.

Furthermore, developed and developing countries experienced reductions in non-renewable energy consumption in 2009 and in 2013. The GFC at the end of 2007 and the financial crisis in 2012, originating in the USA and in Europe, respectively, affected the production levels of both developed and developing countries and caused a decline in the demand for non-renewable energy. Finally, we have demonstrated that renewable energy and non-renewable energy consumption substitute for each other in terms of their levels, but show complementary relationships in terms of their rates of change.

## 5. Conclusions

Although an abundant literature has studied the interplay between FDI, economic growth, financial development, and CO2 emissions, few studies have examined the impact of FDI, specifically, on energy consumption. Also, these studies have reached conflicting results regarding the real effect of FDI on energy consumption. Therefore, the main objective of this study was to measure the effect of FDI on renewable and non-renewable energy consumption for 85 developing and developed countries from 2002 to 2014, employing a one-step system GMM model.

In the course of the study, we have empirically shown that FDI promotes energy savings in developed countries but does not have any effect on energy demand in developing countries. High-income countries are mostly associated with strict environmental regulations and energy policies. Therefore, multinational firms investing in developed countries may be obligated to uphold the high environmental standards of the host country. Meanwhile, we could not find any positive or negative effects of FDI on renewable or non-renewable energy consumption in developing countries. One could easily argue that neither the *Halo effect* of FDI nor the PHH hypothesis hold for the developing countries in this analysis. A possible explanation can be derived as follows: first, developing countries do not have post-industrial economies, as developed countries do, so they may not easily absorb new technology or skills. Thus, FDI may not affect renewable energy in a positive way or create a *halo effect* in these countries. Second, developed countries may invest in developing countries to avoid higher production costs due to strict environmental regulations in their home countries. Therefore, foreign investors may relax these strict regulations and not replicate energy-saving technologies prevalent in the developing countries. On the other hand, the PHH hypothesis assumes that developed countries are likely to shift "dirty" industries to developing countries. However, we could not find any effect supporting the PHH hypothesis for developing countries in our analysis. This result may be attributed to the type of investments made in the developing country. It is well-known that capital-intensive investments tend to represent pollution-haven industries more than they do labor intensive industries. Furthermore, we know that most of FDI originating from developed countries and directed to other developed countries is situated in the service sector rather than in manufacturing. Therefore, the PHH hypothesis does not hold for the developing countries in the analysis.

Additionally, we have empirically demonstrated that the openness index, GDP per capita, and CPI have power to explain renewable and non-renewable energy consumption in developed countries. However, they have no effect on energy consumption in developing countries. Furthermore, we have empirically confirmed the negative effects of GFC on non-renewable energy consumption in both developed and developing countries. Finally, we have also shown that renewable and non-renewable energy consumptions are substitutes for each other in terms of their levels, but their rates of change are complements to one another.

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