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The Environmental Consequences of Economic Growth Revisited

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Abstract

Although numerous studies on the economic growth-environment nexus exist, relatively little attention has been paid to model the effect of income on the environment, controlling for other relevant factors. The primary contribution of this paper is to examine the environmental consequences of economic growth for developed and developing countries in a dynamic cointegration framework by incorporating energy consumption and foreign direct investment (FDI). For this purpose, an autoregressive distributed lag (ARDL) approach to cointegration is applied to annual data for the period 1971-2005. Results show that economic growth improves environmental quality for developed countries in the long-run, but worsen the environment in developing economies. We also find that energy consumption has a detrimental long-run effect on environmental quality for both developed and developing countries. FDI, however, is found to have little long-run effect on the environment in both developed and developing countries. Finally, it is found that, in the short-run, income and energy play key roles in affecting the environment in developed and developing countries, but FDI does not.

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1. Introduction

Over the past decades numerous studies have analyzed the environmental consequences of economic growth. Initially, studies concentrate on identification of the existence of environmental Kuznets curve (EKC), an inverted U-shaped relationship between the level of economic activity (i.e., per capita income growth) and environmental quality (e.g., Holtz-Eakin and Selden 1995, DeBruyn et al. 1998, Heil and Selden 2001, Friedl and Getzner 2003, Dinda and Coondoo 2006). Later, the debate regarding the link between global warming and emission of greenhouse gases (GHGs) has received a great deal of attention. According to the various reports published by the Intergovernmental Panel on Climate Change (IPCC), among various GHGs, anthropogenic carbon dioxide (CO_2) emissions through the combustion of fossil fuels are considered to be the major culprit behind global warming. Accordingly, researchers have turned their attention to examine the relationship between energy consumption and environmental quality in addition to economic growth (e.g., Ang 2007; Soytas et al 2007; Halicioglu 2009; Sari and Soytas 2009; Jalil and Mahmud 2009).

Recent developments in the literature on this issue show that under the circumstances of the World Trade Organization (WTO) and other regional/bilateral trade treaties, globalization (trade) may result in more growth of pollution-intensive industries in developing countries as developed countries enforce strict environmental regulations, thereby contributing to deterioration of environmental quality (Copeland and Talyor 2004, Baek et al. 2009). Accordingly, empirical findings of earlier studies could suffer from specification bias, due mainly to omission of relevant variables (i.e., trade related variables such as foreign direct investment (FDI) and trade openness).

Baek et al. (2009) are perhaps the first study that has attempted to analyze the economic growth-environment nexus by incorporating a trade-related variable (i.e., trade openness) in their model. They find that income growth and trade tend to improve environmental quality in developed countries, while they have detrimental effects on environmental quality in most developing countries. However, their analysis includes only three variables − that is, income, trade, and environmental quality (i.e., SO_2 emissions). Given the contention that GHG emissions (i.e., anthropogenic carbon dioxide (CO_2) emissions) through fossil fuel burning accelerated by (trade-induced) economic growth appears to be the major contributor of global warming, it is indeed desirable to incorporate energy consumption when estimating the environmental consequences of economic growth.

The contribution of this study is to model the effect of economic growth on the environment, controlling for both energy and trade related variables. Special attention has been given to investigate the short- and long-run effects of per capita income, foreign direct investment (FDI) and energy consumption on CO_2 emissions for 40 individual countries. For this purpose, we use an autoregressive distribute lag (ARDL) approach to cointegration developed by Pesaran et al. (2001). Since an error-correction model (ECM) can be derived from the ARDL model via a simple linear transformation, the ARDL is widely used to estimate the short- and long-run parameters of the model simultaneously. The remaining sections present the model, empirical findings, and concluding remarks.

2. The Model

In examining the environmental consequences of economic growth, controlling for energy consumption and FDI, we rely on a theoretical framework developed by Baek et al. (2009) and adopt the following long-run specification:

$$\ln C_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln E_t + \beta_3 \ln F_t + \varepsilon_t \tag{1}$$

where C_t is the measure of pollution emissions defined as carbon dioxide (CO_2); Y_t is the per capita real income; E_t the per capita energy consumption; F_t is the inflow of FDI; and ε_t is the regression error term. Assuming that the environmental Kuznets curve (EKC) holds for an economy, it could be hypothesized that emission levels tend to increase with growing income up to a threshold level ($\partial C_t/\partial Y_t > 0$) beyond which emission levels tend to decline with higher income level ($\partial C_t/\partial Y_t < 0$). Energy consumption could affect emission levels through an increase in the scale of economic activity ($\partial C_t/\partial E_t > 0$). The relationship between emission levels and FDI is ambiguous and uncertain. For example, if pollution-intensive foreign capital seeks the places with weaker environmental regulations, then the inflow of FDI causes environmental quality to deteriorate ($\partial C_t/\partial F_t > 0$). If a host country relies on technology transfer through FDI from foreign countries as a primary source of technology acquisition, then the inflow of FDI tends to enforce environmental regulations through income growth, thereby improving environmental quality ($\partial C_t/\partial F_t < 0$).

It is worth mentioning that equation (1) represents the long-run equilibrium relationships among the variables of interest. As discussed earlier, however, the main purpose of this study is to examine both the short- and long-run effects of changes in income, energy consumption and FDI on the environment. For this purpose, following Pesaran et al (2001), equation (1) is reformulated as the ARDL framework, which involves an error-correction modeling format as follows:

$$\Delta \ln C_t = \gamma_0 + \sum_{i=1}^{p} \eta_i \Delta \ln C_{t-i} + \sum_{i=0}^{p} \varphi_i \Delta \ln Y_{t-i} + \sum_{i=0}^{p} \xi_i \Delta \ln E_{t-i} + \sum_{i=0}^{p} \psi_i \Delta \ln F_{t-i} + \lambda_1 \ln C_{t-1} + \lambda_2 \ln Y_{t-1} + \lambda_3 \ln E_{t-1} + \lambda_4 \ln F_{t-1} + \mu_t \tag{2}$$

where Δ is the difference operator, p is lag order, and μ_t is an error term assumed serially uncorrelated. In equation (2), the coefficients of the summation signs ($\sum$) represent the short-run effects of income, FDI and energy consumption on CO_2 emissions. The estimates of λs correspond to the long-run (cointegration) relationship among the selected variables. Pesaran et al. (2001) show that in this type of specification, the selected variables are said to be cointegrated if all the lagged-level variables are jointly significant in the equation. This can be done by using an F-test with two sets of asymptotic critical values (upper and lower critical values) tabulated by Pesaran et al. (2001). An upper critical value assumes that all the variables are $I(1)$, or nonstationary, while a lower critical value assumes they all are $I(0)$, or stationary. If the computed F-statistic falls above the upper bound of critical value, the selected variables are said to be cointegrated.

The main advantage of this approach is that, unlike standard cointegration techniques (i.e., Johansen 1995), the ARDL can be applicable irrespective of their order of integration and avoids the pre-testing problems associated with unit root tests. Additionally, the ARDL has been proven to perform better for finite or small sample sizes (Pesaran and Shin 1999); hence, this makes it a good choice for our sample of 35 annual observations than other cointegration methods.

3. Empirical Results

The error-correction version of the ARDL outlined by equation (2) is estimated for 40 countries using annual data over the period from 1971 through 2005.[1] The data span has been chosen based on availability of the data for all the series.[2] For this purpose, we use the Akaike Information Criterion (AIC) to choose the optimal lags and carry out the F test at optimum lags. The results of *F*-test show that the calculated *F*-statistics are found to either lie outside the upper level (3.74) or fall between the two bounds (2.97, 3.74) of the 10% critical value bound for 21 countries out of the 40 countries (Table 1).[3] Additionally, the coefficients of the error-correction terms in which the computed *F*-statistics fall inside the 10% level are found to be negative and statistically significant at least at the 10% level for 10 out of the 11 countries (Table 2); hence, a highly significant error-correction term is proven to be the existence of a stable long-run relationship

[1] Our data come from the following sources; (1) per capita CO_2 emissions (measured in metric ton) and energy consumptions (measured in kg of oil equivalent per capita) from the World Development Indicators (WDI); (2) per capita real GDP (measured in real purchasing power parity (PPP) adjusted dollars) from the Penn World Table (PWT 6.3); and (3) inward FDI flows (measured in million U.S. dollars) from the World Investment Report (WIR).

[2] When this study was conducted, for example, energy consumption could only be collected from 1971 to 2005 for many developing countries such as Argentina, Brazil, China and India. For empirical consistency, therefore, we chose the data for all countries to cover the period from 1971 and 2005.

[3] As Pesaran et al. (2001) emphasize: "there is a delicate balance between choosing p sufficiently large to mitigate the residual serial correlation problem and, at the same time, sufficiently small so that the conditional error-correction model in equation (2) are not unduly over-parameterized, particularly in view of the limited time series data which are available (p. 308)." For this reason, we use the Lagrange multiplier (LM) statistics for testing the hypothesis of no serial correlation against lag length 1. The results show that our models do not have serious problem with serial correlation (Table 1).

among variables.[4] For the remaining 19 countries, on the other hand, the computed *F*-statistics are found to fall below the lower bound of the 10% critical bounds, indicating the null of no long-run relationship cannot be rejected, thereby supporting lack of cointegration; hence, those 19 countries are removed from further modeling.[5]

Table 1 goes here

The results of the long-run coefficient estimates show that the real income is statistically significant at the 10% level in the majority of cases (13 out of the 21 countries) (Table 2). Of the 13 countries in which the income is found to be statistically significant, for example, 6 countries show a negative long-run relationship between CO_2 emissions and income, indicating that emission levels tend to decrease as a country's economy grows. Notice that those 6 countries fall into the category of developed countries according to the World Bank's country classification. For the remaining 7 countries, on the other hand, CO_2 emissions have a positive long-run relationship with income, suggesting that economic growth results in an increase in emission levels. Following Baek et al. (2009), these findings may be explained using the so-called emission intensity defined as the ratio of per capita CO_2 emissions to per capita real income. Improvement (deterioration) in emission intensity, for example, indicates that, since an economy has moved beyond (not reached) the EKC threshold level of income, CO_2 emissions tend to decline (increase) with higher income growth, which in turn suggests a negative (positive) relationship between CO_2 emissions and income. Indeed, the 6 countries showing a negative relationship between CO_2 emissions and income are found to have already crossed a wide range of the EKC threshold levels from $21,000 to $26,000 per capita income (in 2000 US dollar) in the 1970s; accordingly, the emission intensities of these 6 countries have improved over last 35 years (see U.S. and Germany in Figure 2). 7 countries in which CO_2 emissions have a positive relationship with income are found to have not reached income levels high enough to be able to derive the EKC turning point (see Korea and Israel in Figure 2); hence, the emissions intensities of those countries have deteriorated over the last 35 years (Figure 3). As a result, these findings provide an empirical evidence for the existence of the EKC in that as per capita income grows in developed (developing) countries, environmental quality tends to improve (deteriorate) after (before) a threshold level of income has been crossed.

[4] It should be noted that if the computed *F*-statistics falls between the two bounds, the inference is inconclusive. In this case, following Kremers et al. (1992) and Banerjee et al. (1998), the error-correction term in the ARDL model can be used to determine the existence of the long-run relationship; hence, if a negative and significant lagged error-correction term is found, the variables are said to be cointegrated.

[5] We initially select 50 countries and divide them into two groups such as developed and developing countries based on 2008 gross national income (GNI) per capita provided by the World Bank. Based on the availability of data, we then choose 40 countries - 20 developing countries (($976-$11,906) and 20 developed countries ($11,906 or more) – for our final modeling.

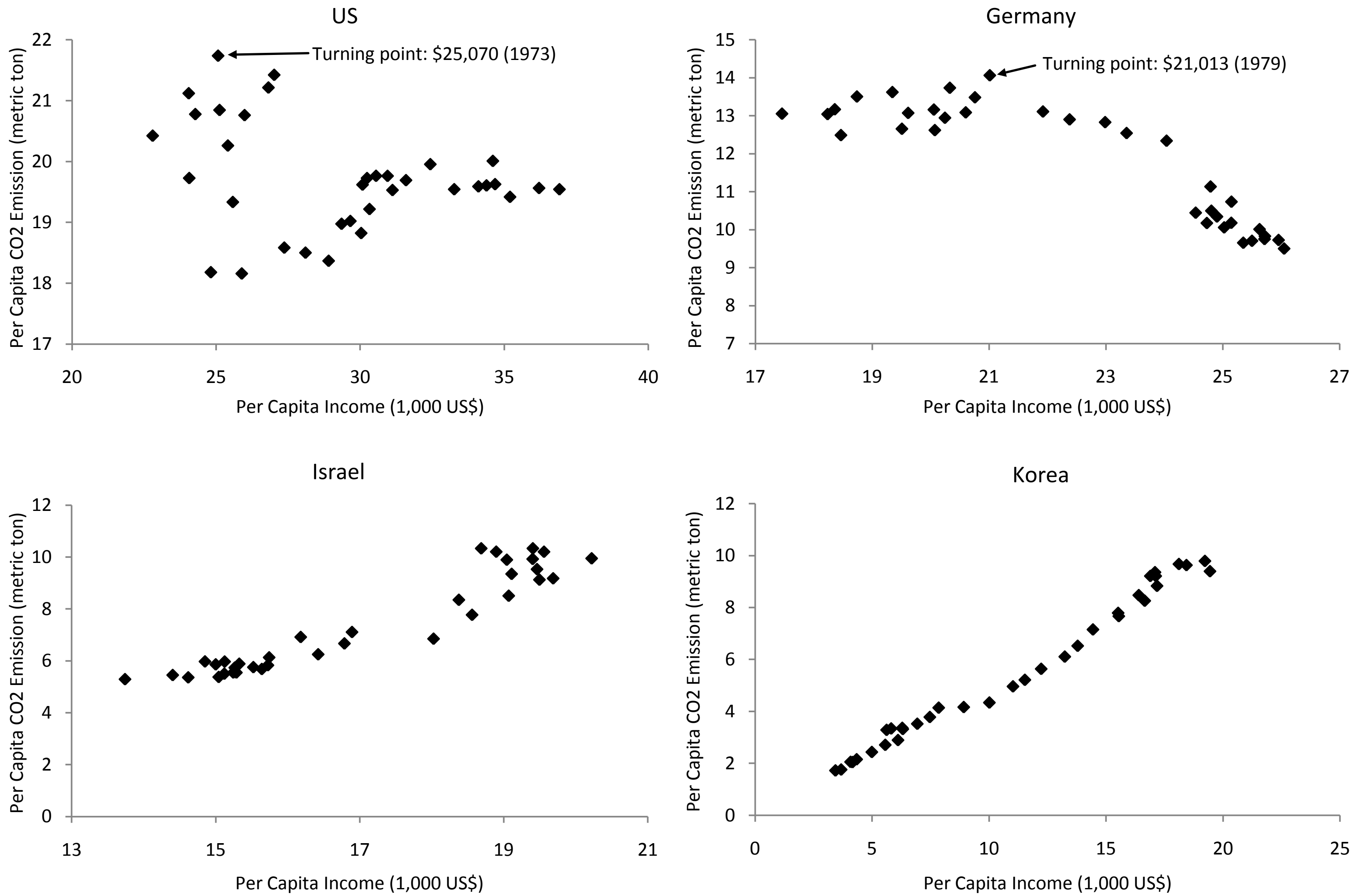

FIGURE 1: Per capita CO_2 Emissions and Per Capita Income for United States, Germany, Israel and Korea.

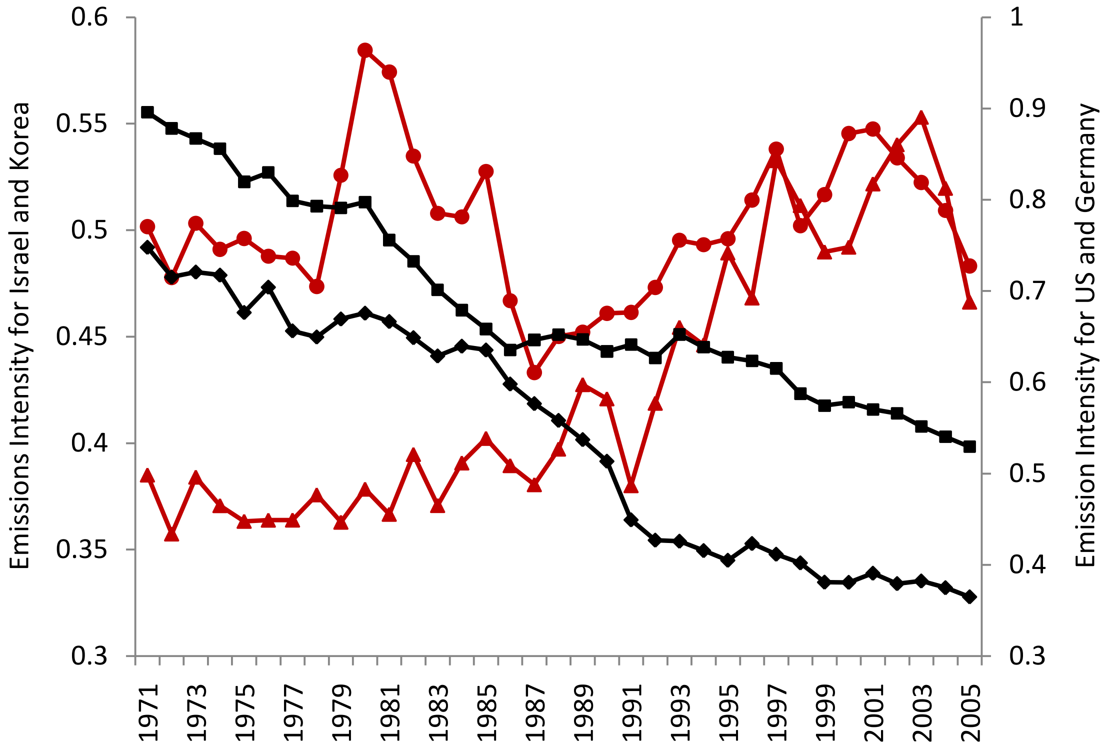

FIGURE 2: Emissions Intensities for Unite States, Germany, Israel and Korea.

Table 2 goes here

In addition, the coefficients of the energy consumption are found to be statistically significant at least at the 10% level in almost all cases (17 out of the 21 countries). Of the 21 countries in which all four variables are cointegrated, for example, 17 countries are found to have a significantly positive long-run relationship between energy consumption and CO_2 emissions, indicating that an increase in energy consumption results in environmental degradation (Table 2). The results thus, by and large, provide empirical evidence that energy consumption has been a significant detrimental effect on environmental quality in both developed and developing countries over the past four decades. Further, this finding could be interpreted to support the claim that CO_2 emissions through the combustion of fossil fuels appear to be the major culprit behind global warming. The coefficients of the FDI, on the other hand, are found to be statistically insignificant for most cases (15 countries), indicating that FDI has little effect on the environment. This finding thus could be interpreted to mean that, when compared to other relevant variables (i.e., energy consumption), FDI does not seem to play a significant role in catalyzing environmental degradation in both developed and developing countries.

Table 3 goes here

The results of the short-run coefficient estimates show that the income is statistically significant at the 10% level in the majority of cases (15 out of the 21 countries). Similarly, the energy consumption is found to be statistically significant at the 10% level in almost all cases (20 out of the 21 countries). These findings indicate that, in the short-run, energy consumption and income play key roles in affecting environmental quality in both developed and developing countries. As seen in the long-run results, however, the FDI has little effect on the environment

in the short-run; of 21 countries found to be cointegrated, only 7 countries – accounting for 33% of all cases- are found to be statistically significant even at the 10% level. From these findings, therefore, the results of the short-run analysis seem to be consistent with those of long-run analysis; in the short- and long-run, income and energy have a significant effect on the environment for both developed and developing countries, but FDI has little impact. Notice that the coefficients of error correction term (ec_{t-1}) are found to be statistically significant at the 10% level for all countries except for India (Table 2), suggesting further proof of the validity of cointegrating relationship in equation (2).[6]

4. Concluding Remarks

The main objective of this paper is to examine the economic growth-environment nexus. Although numerous empirical studies on the issue exist, relatively limited efforts have been made to the dynamic effects of income, energy and trade related variables on the environment in the framework of dynamic time-series modeling. Therefore, this paper has attempted to identify the short- and long-run relationships among economic growth (proxied as per capita real income), energy (proxied as per capita energy consumption), FDI (proxied as inflow of FDI) and environmental quality (proxied as per capita CO_2 emissions) using an autoregressive distributed lag (ARDL) approach to cointegration.

The results show that income and CO_2 emissions generally have a negative long-run relationship for developed countries and a positive long-run relationship for developing countries; that is, environmental quality tends to improve (deteriorate) with higher economic growth in developed countries (developing countries), providing empirical evidence of the existence of environmental Kuznets curve (EKC). We also find that energy consumption has a significant positive relationship with CO_2 emissions for most countries in the long-run; that is, an increase in per capita energy consumption leads to environmental degradation. The long-run relationship between FDI and CO_2 emissions, however, is found to be insignificant in most countries, indicating that, compared to other factors, changes in the inflow of FDI has little effect on changes in environmental quality in both developed and developing countries. Finally, in short-run, income and energy consumption are found to have a significant effect on the environment in developed and developing countries, but the inflow of FDI has little effect.

[6] For completeness, we examine the stability of the long-run parameters together with the short-run movement for the model. For this purpose, we use the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests to the residuals of equation (2). The results show that the estimated coefficients are generally stable over the sample period.

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TABLE 1: Results of F-Test for Cointegration among Variables for Developed and Developing Countries

Developed Countries	Lags	χ^2_{sc}	F-statistic	Developing Countries	Lags	χ^2_{sc}	F-statistic
Australia	5	1.65	1.24	Argentina	5	0.07	1.34
Austria	5	0.56	4.15	Bolivia	3	0.32	2.04
Canada	2	0.25	1.37	Brazil	2	0.04	3.21
Denmark	4	1.18	2.73	Chile	1	1.18	2.92
Finland	3	0.02	6.32	China	3	0.40	6.38
France	1	2.48	8.37	Costa Rica	2	2.49	6.80
Germany	4	0.07	3.13	Ecuador	3	0.63	4.77
Japan	2	2.21	3.61	El Salvador	4	1.32	1.10
Korea	3	0.35	3.08	Guatemala	3	0.05	3.81
Israel	3	0.98	3.42	Honduras	3	0.01	2.42
Italy	3	1.79	3.50	India	4	1.69	4.02
Netherlands	4	0.01	5.38	Malaysia	4	0.78	3.00
New Zealand	2	1.63	1.76	Mexico	4	0.98	3.93
Norway	3	0.5	1.51	Nicaragua	3	0.62	2.59
Portugal	5	0.09	1.31	Paraguay	2	1.23	4.23
Singapore	4	2.32	3.51	Peru	4	0.01	2.03
Spain	5	1.75	1.34	Thailand	1	0.77	3.03
Sweden	3	1.92	3.01	Turkey	5	2.32	2.16
UK	4	1.06	2.33	Uruguay	2	0.59	0.98
United States	2	0.36	3.73	Vietnam	5	0.02	1.58

Note: A lag order is selected based on AIC. χ^2_{sc} is Lagrange Multiplier (LM) statistics for testing no serial correlation against lag order 1. *F*-statistics for 10% critical value bound is (2.97, 3.74), which is obtained from Table CI in Pesaran et al. (2001).

TABLE 2: Estimated Long-Run Coefficients using the ARDL Bound Tests

	Countries	Income	Energy Consumption	FDI	ec_{t-1}
Developed Countries	Austria	-0.311 (-2.783)**	-0.711 (-0.624)	-0.029 (-1.759)*	-0.569 (-3.348)**
	Finland	-0.459 (-2.685)**	1.779 (2.628)**	0.028 (1.645)	-0.353 (-2.633)**
	France	-0.564 (-2.277)**	-1.833 (-1.196)	0.306 (2.025)*	-0.166 (-2.478)**
	Germany	-0.263 (-4.470)**	2.003 (10.95)**	-0.001 (-0.094)	-0.797 (-4.467)**
	Japan	-0.167 (-2.854)**	1.064 (4.827)**	-0.003 (-0.888)	-0.356 (-2.263)**
	Korea	0.126 (2.059)**	0.936 (6.201)**	0.001 (0.087)	-0.687 (-4.351)**
	Israel	0.300 (2.023)*	0.981 (5.262)**	0.052 (3.345)**	-0.665 (-3.999)**
	Italy	0.025 (0.661)	0.725 (4.876)**	0.010 (1.805)*	-0.248 (-2.147)**
	Netherlands	-0.052 (-0.270)	2.146 (2.011)*	-0.051 (-0.669)	-0.517 (-2.509)**
	Singapore	-0.137 (-0.711)	0.834 (3.776)**	-0.008 (-0.147)	-0.795 (-3.030)**
	United States	-0.073 (-2.196)**	1.016 (13.180)**	-0.002 (-0.322)	-0.880 (-11.766)**
Developing Countries	Brazil	0.056 (0.344)	0.980 (1.782)*	0.038 (1.640)	-0.372 (-2.503)**
	China	0.555 (3.175)**	0.540 (2.322)**	-0.012 (-1.448)	-0.572 (-4.138)**
	Costa Rica	0.280 (1.512)	0.919 (3.878)**	0.295 (4.811)**	-0.866 (-5.593)**
	Ecuador	1.011 (3.475)**	0.609 (1.311)	0.026 (1.062)	-0.863 (-4.508)**
	Guatemala	0.294 (4.945)**	1.490 (8.236)**	0.028 (1.080)	-0.763 (-5.322)**
	India	0.616 (2.308)**	3.524 (2.555)**	0.046 (1.363)	-0.296 (-1.196)**
	Malaysia	-0.108 (-0.217)	-0.076 (-0.101)	0.017 (0.264)	-0.463 (-2.899)**
	Mexico	-0.006 (-0.011)	1.773 (1.943)*	-0.178 (-1.682)	-0.664 (-4.674)**
	Paraguay	-0.103 (-1.147)	0.915 (2.413)**	0.052 (2.224)**	-0.679 (-4.435)**
	Thailand	0.352 (4.666)**	1.311 (11.734)**	0.024 (0.995)	-0.640 (-6.308)**

Note: ** and * denote significance at the 5% and 10% level, respectively. Parentheses are *t*-statistics. ec_{t-1} refers to error correction term.

TABLE3: Estimated Short-Run Coefficients using the ARDL Bound Tests

	Countries	Variable	Lag order 0	1	2	3
Developed Countries	Austria	ΔE_t	0.574** (2.576)	0.004 (0.015)	0.386 (1.449)	
		ΔY_t	0.654* (1.988)	0.058 (0.242)	1.114** (4.575)	
		ΔF_t	-0.008 (-1.169)			
	Finland	ΔE_t	1.674** (8.756)			
		ΔY_t	-0.559** (-2.742)			
		ΔF_t	0.004* (1.807)			
	France	ΔE_t	1.216** (7.232)			
		ΔY_t	0.639** (2.625)			
		ΔF_t	0.012 (0.691)			
	Germany	ΔE_t	1.310** (12.228)	-0.557** (-3.773)	-0.226* (-2.013)	
		ΔY_t	-0.187 (-0.981)	-0.395** (-2.281)		
		ΔF_t	-0.001 (-0.094)			
	Japan	ΔE_t	0.956** (10.572)	0.278 (1.512)		
		ΔY_t	0.328** (2.770)			
		ΔF_t	-0.001 (-1.131)			
	Korea	ΔE_t	0.643** (5.681)			
		ΔY_t	0.393** (2.180)			
Developing Countries	Brazil	ΔE_t	0.886** (2.994)	-0.718* (-2.028)		
		ΔY_t	0.393* (1.801)			
		ΔF_t	0.014 (1.181)			
	China	ΔE_t	0.924** (7.162)	0.414** (2.301)		
		ΔY_t	0.318** (2.742)			
		ΔF_t	-0.007 (-1.397)			
	Costa Rica	ΔE_t	0.214 (0.966)	-0.629** (-2.926)		
		ΔY_t	0.242 (1.416)			
		ΔF_t	0.095* (1.931)			
	Ecuador	ΔE_t	0.525 (1.417)			
		ΔY_t	0.872** (2.414)			
		ΔF_t	-0.003 (-0.020)			
	Guatemala	ΔE_t	1.138** (4.771)			
		ΔY_t	0.224** (3.380)			
		ΔF_t	0.021 (1.097)			
	India	ΔE_t	0.568 (1.581)	1.438** (2.229)	0.923 (1.720)	
		ΔY_t	-0.110** (-0.504)	-0.004 (-0.028)	-0.365** (-2.547)	

	ΔF_t	0.001			
		(0.087)			
	ΔE_t	0.385**	-0.283**	-0.209**	
		(2.962)	(-2.189)	(-2.193)	
Israel	ΔY_t	-0.205			
		(-0.910)			
	ΔF_t	0.020*			
		(2.035)			
	ΔE_t	0.925**			
		(9.689)			
Italy	ΔY_t	0.249**	-0.023	0.184**	
		(2.301)	(-0.238)	(2.339)	
	ΔF_t	0.002**			
		(3.572)			
	ΔE_t	1.110**			
		(4.446)			
Netherlands	ΔY_t	-0.776	1.180		
		(-1.032)	(1.606)		
	ΔF_t	0.001	0.068**	0.009	0.041
		(0.056)	(2.565)	(0.353)	(1.632)
	ΔE_t	0.942**	-0.082	-0.019	-0.349*
		(5.832)	(-0.442)	(-0.100)	(-1.992)
Singapore	ΔY_t	-0.109			
		(-0.784)			
	ΔF_t	-0.006			
		(-0.149)			
	ΔE_t	0.894**			
		(11.174)			
US	ΔY_t	-0.065**			
		(-2.039)			
	ΔF_t	0.006			
		(1.276)			
	ΔF_t	-0.014**			
		(-5.925)			
	ΔE_t	0.615**			
		(2.525)			
Malaysia	ΔY_t	0.293	0.387	0.322	0.592**
		(0.886)	(1.367)	(1.188)	(2.111)
	ΔF_t	0.008			
		(0.262)			
	ΔE_t	1.176**			
		(2.333)			
Mexico	ΔY_t	-0.004			
		(-0.011)			
	ΔF_t	-0.013	0.077*	0.079**	0.064**
		(-0.388)	(1.864)	(2.287)	(2.480)
	ΔE_t	1.395**	0.574*		
		(4.967)	(1.843)		
Paraguay	ΔY_t	-0.070			
		(-1.174)			
	ΔF_t	0.002	-0.016		
		(0.166)	(-1.339)		
	ΔE_t	0.839**			
		(5.988)			
Thailand	ΔY_t	0.226**			
		(4.945)			
	ΔF_t	0.015			
		(0.989)			

Note: E_t, Y_t, and F_t represent energy consumption, income and FDI, respectively. ** and * denote significance at the 5% and 10% level, respectively. Δ denotes the first differences of the variables.