Electricity Co-operation in Asia: The Role of Import and Export in CO_2 Reduction

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Abstract : With the rapidly growing demand for electricity in developing countries, especially Asia, being largely responsible for increasing CO_2 emissions from electricity generation, it is vital to find a sustainable way of providing this energy. Focusing on Asia, this paper examines whether electricity co-operation regarding import and export between countries can assist in redressing the problem of CO_2 emissions. The work covers 33 Asian countries, divided by geography into 13 Middle East countries and the remaining 20 Asian countries, with 37 yearly samples provided for the period 1971 to 2007. Panel data analysis determines the CO_2 emissions function. Empirical results for the 20 Asian countries show, with high statistical significance, a marked decrease in CO_2 emissions from electricity import. This indicates that international electricity trade in this continent can play an effective role in the decarbonisation of energy supply in the fight against climate change. However, for the 13 Middle East countries, there is no impact on CO_2 emissions from electricity trade - possibly because of a lack of co-operation in this region.

Keywords : Electricity Trade, CO_2 Reduction, Asia, Co-operation, Panel Data

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1. Introduction

The greater part of carbon dioxide (CO_2) emissions comes from the production of energy, especially electricity, which no country can do without. In order to meet targets aimed at tackling climate change, many countries are increasing electricity generation from renewable energy sources and nuclear power. However, renewable energy has problems with regard to economic costs and instability of supply, while nuclear power generation involves issues of safety and radioactive waste management, as we can see from the very serious nuclear power situation in Japan, caused by the tsunami of 11th March, 2011. As a result, it would appear that, in the future, electricity generation by flue sources of coal, gas and oil will still be necessary, and these are the major players in the role of atmospheric carbonization.[1] Therefore, another approach is needed in the fight against global warming through CO_2 emissions from electricity generation.

As mentioned by the Treasury (2011), most electricity demand growth arises from developing countries, especially China and India. Therefore, international electricity trade among developing countries in Asia is of interest as an instrument for governments in meeting increasing demand for electricity. In 2008, the Asian and Pacific region accounted for 46% of global energy production making it easily the leading producer worldwide (IEA, 2011). All of this suggests that import and export of electricity may prove mutually beneficial for Asian countries. Such international trading could not only increase electricity supply for excess demand countries while providing an economic gain for excess supply countries, but should also decrease levels of CO_2 emissions from electricity generation.

Economic theories of international trade indicate that import and export bring enormous benefits to countries and their citizens. Through trade, nations have been able to benefit from specialization and the efficiency gains from economies of scale. In addition, productivity has been increased, the spread of knowledge and new technologies assisted and consumer choice made more varied and extensive (WTO, 2008). These benefits also apply to international trade in electricity. Such trade increases competition which encourages efficiency as well as facilitating the introduction of new ideas and technologies. Innovation, according to Pomeda and Camacho (2003), acts as a further mechanism to enhance electricity market efficiency. In addition, technological innovations lead towards electricity generation through renewable energies (Scheepers et al., 2003), resulting in lower CO_2 emissions. Moreover, electricity trade directly reduces emissions from

[1] The Treasury Department of the Australian government forecasts that, after 2050, more than half of the planet's electricity generation will be coal based. In 2005, the percentage breakdown of world electricity generation by fuel was coal (41%), gas (22%), renewable (16%), nuclear (14%) and oil (7%). By 2050, the percentage breakdown is expected to be coal (53%), gas (17%), renewable (11%), nuclear (14%) and oil (8%) (The Treasury, Australian Government, 2011, Chart 3.11).

generation in importing countries. All of these reasons support the claim that Asian electricity co-operation regarding import and export can decrease CO_2 emissions.

On the other hand, Billette de Villemeur and Pineau (2010) argue that, assuming reasonable demand and supply elasticities, trade in electricity can be damaging to the environment. It is their contention that trade results in higher levels of consumption by lowing price, and that there can exist a positive relationship between overall consumption (and, hence, electricity generation) and trade, with the likelihood of increased environmental impact, including CO_2 emissions. While it may be conceded that electricity trade increases demand by reducing price, in opposing their view of a resulting growth in emissions, there is little or no increase in damage to the environment because efficiency gains from specialization and economies of scale (WTO, 2008; Pomeda and Camacho, 2003; Unger and Ekvall, 2003) lead to a decrease in private and social costs, including CO_2 emissions. In addition, export countries do not usually use flue sources (coal, gas and oil) to generate electricity for export because of the financial risk of fluctuations in the price of fossil fuels. This can further explain why electricity export does not increase CO_2 emissions.

This study examines whether international co-operation regarding electricity import and export between Asian countries can help redress the problem of CO_2 emissions. The aim is to provide a basis for comparison of CO_2 emissions between countries generating electricity by themselves and countries importing and exporting electricity. The work covers 33 Asian countries, divided by geography into 13 Middle East countries and the remaining 20 Asian countries, with 37 yearly samples provided for the period 1971 to 2007. Panel data analysis determines the CO_2 emissions function.

This paper is organized as follows: section two, research methodology; section three, results and discussion; section four, conclusion; section five, acknowledgements; and section six, references.

2. Research Methodology

Karakaya and Ozcag (2005) analyse human involvement in environmental change with regard to CO_2 emissions by focusing on the demand side. On the other hand, McFarland and Herzog (2006) concentrate on the supply side. They specify that production functions comprise determining the cost (C) of electricity from the technology, the factor shares of capital, labour, and energy needed for electricity production. They view the full cost of electricity as including the unit costs of electricity generation, transmission and distribution (*T&D*), sequestration, and value of carbon released to the atmosphere (P_{carbon}). This paper employs the concepts of McFarland and Herzog (2006) and the California Energy Commission (2010) to build the conceptual framework.

Figure 1: Conceptual Framework

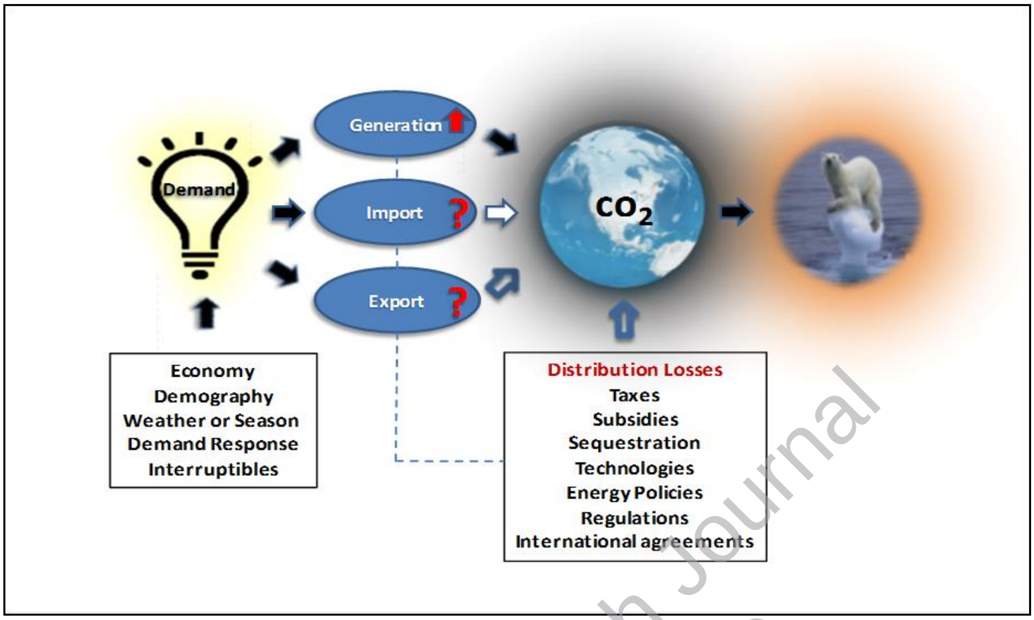

Figure 1 shows the conceptual framework of this study. Our need for electricity[2] causes electricity generation which is mostly produced from flue sources. Some countries have decided to import electricity instead of producing more by themselves. This decreases CO_2 from electricity generation. With regard to export, if countries have excess electricity supply, export will not increase generation and CO_2 levels, but if those countries do not have excess supply, then, of course, electricity export will increase CO_2 if they use flue sources.

Even though electricity is exchangeable and suitable for trading, it needs bounded conduction, hence no global market for electricity trade exists (Barouti and Hoang, 2011). Therefore, this study analyses the effect of electricity trading by continent. However, geography has, at times, linked or separated the Middle East and Asia. For the energy sector, the situation is one of separation demonstrated by an almost total lack of related infrastructure connecting the two areas. As a result, in this study, the Middle East is separated from Asia.

2.1 Data

The data of all variables in this study are sourced from the International Energy Agency (IEA). The dataset involves 33 Asian countries, divided by geography into 13 Middle East countries and the remaining 20 Asian countries, with 37 yearly samples provided for the period 1971 to 2007.

[2] Electricity demand is the cause of electricity supply, so CO_2 emissions of the electricity sector can be affected by both demand and supply aspects. The demand side includes such factors as economy, demography, weather or season, demand response, and interruptibles. On the supply side, the factors are resource addition and retirement, local generation, generator outage, line outage, fuel availability and net electricity import (California Energy Commission, 2010: Figure 3).

Total maximum observations for the Middle East and the other 20 Asian countries are 481 (13 x 37) and 740 (20 x 37) respectively (see Table 1).[3] The dependent variable of this study is CO_2 emissions from main activity electricity plants with a measure of million tons (MT) of CO_2 per year. Independent variables are electricity generation for countries, import, export and distribution loss, all having the same measure of total MWh per year.[4]

Table 1: Descriptive Statistics

Asia (20 countries) 1971-2007 (Unbalanced Panel)						
	Name	Obs	Mean	Standard Deviation	Min	Max
CO_2 emissions (*MT*)	CO_2	702	49,208.98	187,470.80	0	1,135,718.00
Generation for country (*MWh*)	GC	702	133,829.90	324,776.50	86	3,296,608.00
Generation minus DL (*MWh*)	GD	702	122,160.10	302,448.30	55	3,095,344.00
Import (*MWh*)	M	702	403.75	1,763.18	0	16,287.00
Export (*MWh*)	X	702	282.54	1,676.37	0	18,602.00
Distribution loss: DL (*MWh*)	DL	702	11,669.86	28,041.45	11	201,264.00
Asia: Middle East (13 countries) 1971-2007 (Balanced Panel)						
	Name	Obs	Mean	Standard Deviation	Min	Max
CO_2 emissions (*MT*)	CO_2	481	13.35	19.69	0.01	115.52
Generation for country (*MWh*)	GC	481	20,789.77	33,276.69	13.00	201,466.00
Generation minus DL (*MWh*)	GD	481	18,692.57	29,523.96	11.00	175,074.00
Import (*MWh*)	M	481	64.14	281.42	0.00	2,540.00
Export (*MWh*)	X	481	90.89	342.45	0.00	2,775.00
Distribution loss: DL (*MWh*)	DL	481	2,097.21	4,391.06	0.00	38,714.00

Source: IEA

[3] There are missing observations for the following countries: Cambodia (1971-1994) and Mongolia (1971-1984).

[4] Using logarithms of variables enables coefficients to be interpreted easily when variables are measured on different scales, as well as being an effective method of shrinking the distance between values. After taking the natural logarithmic form, data of some countries which have no import and no export will disappear ($ln(0)$). Then variables are generated by plus one before taking the natural logarithmic form.

2.2 Panel Data Analysis

Econometric methodology of panel data analysis is employed to determine the effects of electricity import and export on CO_2 emissions. For this paper, the problem of unobserved variables is solved by the use of panel data which controls for unobserved cross section heterogeneity (Wooldridge, 2002, p. 169).

The POLS estimator makes use of variation of both time and cross sectional units to estimate β by stacking data over *i* and *t* into one long regression with *NT* observations, and estimating by ordinary least square (OLS). The POLS model can be shown as

$$CO_{2,it} = \alpha + \sum_{j=1}^{k} \beta_j x_{j,it} + \sum_{p=1}^{s} \gamma_p z_{p,i} + \varepsilon_{it} \tag{1}$$

where $CO_{2,it}$ stands for the dependent variable which is CO_2 emissions; *x* stands for independent variables which are electricity generation, electricity import, electricity export, and distribution loss; *z* stands for unobserved variables including taxes, government subsidies, national energy policies, regulations and international agreements (see Figure 1); α is the intercept which represents the individual-specific constants; β is a k-dimensional column vector of parameters; γ is an s-dimensional column vector of parameters; ε_{it} is an error term; *i* is country; and *t* is year.

Hence, Equation (1) can be written in the regression model as

$$CO_{2,it} = \alpha + x'_{it}\beta + \mu_i + \varepsilon_{it} \tag{2}$$

where $x'_{it}\beta = \sum_{j=1}^{k} \beta_j x_{j,it}$ and $\mu_i = \sum_{p=1}^{s} \gamma_p z_{p,i}$

Unobserved characteristics (μ_i) are ignored by POLS, and under the restriction $\sum \mu_i = 0$, there is a limited POLS estimation. Usually, POLS produces inefficient estimates and invalid standard errors due to the presence of the unobserved effect, even if this effect has no correlation with any of the explanatory variables (Dougherty, 2011, p. 411).

An important reason to use panel data is its ability to control for unobserved heterogeneity which can be solved by fixed effects.[5] Under fixed effects assumption, the unobserved variables which are the country-specific effect (μ_i) and the intercept (α) are constant, hence they are both cancelled.

$$\dot{C}\dot{O}_{2,it} = \ddot{x}'_{it}\beta + \ddot{\varepsilon}_{it} \tag{3}$$

where $\dot{C}\dot{O}_{2,it} = CO_{2,it} - \overline{CO}_{2,it}$, $\ddot{x}_{itk} = x_{itk} - \bar{x}_{itk}$ and $\ddot{\varepsilon}_{it} = \varepsilon_{it} - \bar{\varepsilon}_{it}$.

Fixed effects regressions are not suitable when the variables to be examined are constant for each individual due to elimination of these variables. For this reason, random effects regression

[5] After taking first differences for all variables, POLS estimation in this study is equal to fixed effects (first differences) estimation before taking first differences for all variables. Hence, only fixed effects (within) is employed for the analysis.

will be used in this section because it includes time invariant variables which disappear under fixed effects. From regression Equation (2), the basic unobserved effects model (UEM) is given for a randomly drawn cross-section observation which, for this study, is country (*i*). Under certain assumptions, the POLS estimator for obtaining a consistent estimator of β in the model can be used. The random effect model is shown as

$$CO_{2,it} = \alpha + x_{it}'\beta + u_{it} \tag{4}$$

where $u_i = \mu_i + \varepsilon_{it}$, stands for the composite errors, μ_i ~ *i.i.d* (0, σ_μ^2) and ε_i ~*i.i.d* (0, σ_ε^2), and μ_i is independent of ε_i (Baltagi, 2005, p. 14).

Hence, Equation (4) can be written in the regression model as

$$CO_{2,it} = \alpha + x_{it}'\beta + \mu_i + \varepsilon_{it} \tag{5}$$

where μ_i is between-entity error and ε_{it} is within-entity error.

Equation (5) is similar to Equation (2) of POLS, but the different is that the variation across country (μ_i) is not assumed to be zero. Random effects assumes μ_i is random and uncorrelated with the independent variables (x_i). It is reasonable to assume that the unobserved variables have some influence on the dependent variable ($\mu_i \neq 0$), so random effects is more applicable than POLS.

2.3 Panel Unit Root Test

Before conducting tests of panel data on these variables, it is necessary to perform unit root tests. This study considers two panel unit root tests: the Im, Pesaran and Shin (IPS) test and the Fisher-ADF test. The two tests show the combining of individual unit root tests to derive a panel-specific result, and allow for unbalance panel (Levin et al., 2002). The results for panel unit root tests suggest that taking first differences of all variables should be carried out to avoid the non-stationary process.

2.4 Pearson's Correlation Test

In order to avoid the problem of multicollinearity where high correlation exists between two or more independent variables (Blalock, 1963), this analysis employs the Pearson correlations test. The results show there is high correlation between electricity generation for country minus distribution loss (*GD*) and distribution loss (*DL*) for the 20 Asian countries (0.86) and for the Middle East (0.83). Hence, care should be taken in interpreting these results for Model 1. For Model 2, which eliminates distribution loss (*DL*), there is no problem of multicollinearity.

2.5 A Lagram-Multiplier Test for Serial Correlation

For the study, before the model can be set up, serial correlation tests which have application to macro panels with long time series (37 years) must be implemented. The effect of serial correlation is in reducing the size of the standard errors of the coefficients and giving them higher R-squared values (Wooldridge, 2002). A Lagram-Multiplier serial correlation test is selected here, with the null hypothesis being no serial correlation. The following is given by running both the original models for CO_2 emissions.

Model 1

$$\Delta\ln(CO_{2,it}) = \alpha_0 + \beta_1\Delta\ln(GD_{it}) + \beta_2\Delta\ln(M_{it}) + \beta_3\Delta\ln(X_{it}) + \beta_4\Delta\ln(DL_{it}) + u_{it} \qquad (6)$$

Model 2

$$\Delta\ln(CO_{2,it}) = \alpha_0 + \beta_1\Delta\ln(GC_{it}) + \beta_2\Delta\ln(M_{it}) + \beta_3\Delta\ln(X_{it}) + u_{it} \qquad (7)$$

The results for the 20 Asia countries (F = 56.083, Prob > F = 0.00) and the Middle East (F = 13.814, Prob > F = 0.03) reject the null hypothesis in both models. As a result of the Wooldridge test for autocorrelation in panel data detecting the presence of AR1, lagged dependent variables are added on the right-hand side for both regions.

2.6 Empirical Models

The altered models with lagged dependent variables for Asia and the Middle East appear as

Model 1

$$\Delta\ln(CO_{2,it}) = \alpha_0 + \beta_1\Delta\ln(CO_{2,i,t-1}) + \beta_2\Delta\ln(GD_{it}) + \beta_3\Delta\ln(M_{it}) + \beta_4\Delta\ln(X_{it}) + \beta_5\Delta\ln(DL_{it}) + u_{it} \qquad (8)$$
$$i = 1,2.....N, \qquad t = 1,2.....T$$

where Δ is a difference operator, *ln* is the natural logarithm, *i* denotes countries, *t* denotes years, α_0 is a constant term and u_{it} is the error term assumed to be independent over (*i*) countries.

In Model 1, the explained variable is CO_2 emissions from main activity electricity plants (CO_2). The explanatory variables are CO_2 emissions from main activity electricity plants of the previous period ($CO_{2,\ t-1}$), electricity generation for country minus distribution loss (*GD*), electricity import (*M*), electricity export (*X*) and distribution loss (*DL*).

Model 2

$$\Delta\ln(CO_{2,it}) = \alpha_0 + \beta_1\Delta\ln(CO_{2,i,t-1}) + \beta_2\Delta\ln(GC_{it}) + \beta_3\Delta\ln(M_{it}) + \beta_4\Delta\ln(X_{it}) + u_{it} \qquad (9)$$
$$i = 1,2.....N, \qquad t = 1,2.....T$$

In Model 2, the explained variable is CO_2 emissions from main activity electricity plants (CO_2). The explanatory variables are CO_2 emissions from main activity electricity plants of the previous period ($CO_{2,\ t-1}$), electricity generation for country ($GC = GD + DL$), electricity import (*M*) and electricity export (*X*).

3. Results and Discussion

3.1 Panel Data Analysis Results

Table 4: Standard Linear Panel Model Estimator Results for the 20 Asian Countries

Asia (20 countries)
1971-2007 (Unbalanced Panel)

Model 1: $\Delta\ln(CO_{2,it}) = \alpha_0 + \beta_1\Delta\ln(CO_{2,i,t-1}) + \beta_2\Delta\ln(GD_{it}) + \beta_3\Delta\ln(M_{it}) + \beta_4\Delta\ln(X_{it}) + \beta_5\Delta\ln(DL_{it}) + u_{it}$

Model 2: $\Delta\ln(CO_{2,it}) = \alpha_0 + \beta_1\Delta\ln(CO_{2,i,t-1}) + \beta_2\Delta\ln(GC_{it}) + \beta_3\Delta\ln(M_{it}) + \beta_4\Delta\ln(X_{it}) + u_{it}$

	POLS		FIXED (WITHIN)		RANDOM	
	(1)	(2)	(1)	(2)	(1)	(2)
$\Delta ln(CO_{2,t-1})$: lag1_CO_2 emissions	-0.002 (0.025)	-0.006 (0.025)	-0.013 (0.025)	-0.017 (0.025)	-0.002 (0.025)	-0.006 (0.025)
Δln(GC): Generation for country		0.903*** (0.031)		0.899*** (0.031)		0.903*** (0.031)
Δln(GD): Generation minus DL	1.079*** (0.060)		1.074*** (0.061)		1.079*** (0.060)	
Δln(M): Import	-0.158*** (0.021)	-0.160*** (0.021)	-0.153*** (0.021)	-0.155*** (0.021)	-0.158*** (0.021)	-0.160*** (0.021)
Δln(X): Export	0.025 (0.024)	0.034 (0.024)	0.027 (0.024)	0.036 (0.024)	0.025 (0.024)	0.034 (0.024)
Δln(DL): Distribution Loss	-0.188*** (0.056)		-0.186*** (0.056)		-0.188*** (0.056)	
α_0	-0.002 (0.016)	-0.001 (0.017)	-0.002 (0.016)	-0.001 (0.017)	-0.002 (0.016)	-0.001 (0.017)
σ_μ			0.063	0.063	0	0
σ_ε			0.432	0.440	0.432	0.440
ρ			0.021	0.021	0	0
F-Statistics	185.40***	218.42***	180.59***	212.78***		
χ^2					927.00***	873.67***
Observations	696	696	696	696	696	696

Notes: (1) Standard errors in ( )

(2) *** illustrates significance at 1% level.

(3) Intraclass correlation $\rho = \dfrac{\sigma_\mu^2}{\sigma_\mu^2 + \sigma_\varepsilon^2}$

Table 5: Standard Linear Panel Model Estimator Results for the Middle East

Asia: Middle East (13 countries) 1971-2007 (Balanced Panel)						
Model 1: $\Delta\ln(CO_{2,it}) = \alpha_0 + \beta_1\Delta\ln(CO_{2,i,t-1}) + \beta_2\Delta\ln(GD_{it}) + \beta_3\Delta\ln(M_{it}) + \beta_4\Delta\ln(X_{it}) + \beta_5\Delta\ln(DL_{it}) + u_{it}$ Model 2: $\Delta\ln(CO_{2,it}) = \alpha_0 + \beta_1\Delta\ln(CO_{2,i,t-1}) + \beta_2\Delta\ln(GC_{it}) + \beta_3\Delta\ln(M_{it}) + \beta_4\Delta\ln(X_{it}) + u_{it}$						
	POLS		FIXED (WITHIN)		RANDOM	
	(1)	(2)	(1)	(2)	(1)	(2)
$\Delta ln(CO_{2,\,t-1})$: lag1_ emissions	0.018 (0.018)	0.016 (0.018)	0.013 (0.018)	0.011 (0.019)	0.018 (0.018)	0.016 (0.018)
Δln(GC): Generation for country	0.611*** (0.021)		0.609*** (0.021)		0.611*** (0.021)	
Δln(GD): Generation minus DL		0.595*** (0.012)		0.593*** (0.012)		0.595*** (0.012)
Δln(M): Import	-0.008 (0.008)	-0.009 (0.009)	-0.007 (0.009)	-0.008 (0.009)	-0.008 (0.008)	-0.009 (0.009)
Δln(X): Export	0.006 (0.009)	0.006 (0.009)	0.006 (0.009)	0.006 (0.009)	0.006 (0.009)	0.006 (0.009)
Δln(DL): Distribution Loss	-0.008 (0.015)		-0.007 (0.015)		-0.008 (0.015)	
α_0	-0.001 (0.008)	-0.001 (0.008)	-0.001 (0.008)	-0.001 (0.008)	-0.001 (0.008)	-0.001 (0.008)
σ_μ			0.023	0.024	0	0
σ_ε			1.177	0.178	0.177	0.178
ρ			0.017	0.018	0	0
F-Statistics	513.78***	636.07***	503.01***	623.49***		
χ^2					2,568.92***	2,544.28***
Observations	479	479	479	479	479	479

Notes: (1) Standard errors in ( )

(2) *** illustrates significance at 1% level.

(3) Intraclass correlation $\rho = \dfrac{\sigma_\mu^2}{\sigma_\mu^2 + \sigma_\varepsilon^2}$

Table 4 and Table 5 show the estimation results of Model 1 and Model 2 by three estimation methods (POLS, fixed effects and random effects), and it is evident that the findings appear similar.

3.2 Hausman Test

The Hausman test (1978) is used to compare the preferred model which is random effects (RE) versus the alternative model which is fixed effects (within [WI]) (Green, 2008, Ch. 9), basically determining whether the unique errors (μ_i) are correlated with the regressors - the null hypothesis being that they are not. The results show that random effects estimation is accepted for the 20 Asian Countries and the Middle East. Under random effects, the regression model retains observed characteristics that remain constant for each country making it more attractive than fixed effects estimation where those characteristics have to be discarded (Dougherty, 2011).

3.3 Breusch-Pagan Lagrange Multiplier (LM) Test

This paper employs a Lagrange Multiplier (LM) test to decide between a random effects regression and POLS regression (Breusch and Pagan, 1980). From Equation (5), the composite disturbances in panel data model are generated by $u_i = \mu_i + \varepsilon_{it}$, and the LM hypotheses are H_0: $\sigma_\mu^2 = 0$ and H_1: $\sigma_\mu^2 \neq 0$. In Model 1 and Model 2, the LM test results show failure to reject the null hypothesis leading to the conclusion that random effects is not appropriate. There is no evidence of significant differences across countries, therefore POLS is the preferred option.

3.4 Results for the 20 Asian Countries

Model 2, which excludes distribution loss, is used to explain the results for this region, in order to avoid the problem of multicollinearity in Model 1. From Table 4, the POLS estimation results of the 20 Asian countries show that a rise of 1% in electricity generation for country (β_2) (GC = GD + DL) is highly significant in increasing CO_2 emissions by about 0.9%, while a rise of 1% in electricity import (β_3) is highly significant in decreasing CO_2 emissions by about 0.16%. Following expectation, the results confirm that electricity import is a better choice than electricity generation in regard to CO_2 emissions reduction. As for export (β_4), a rise of 1% is shown to increase CO_2 emissions by about 0.03%, but the result is not statistically significant.[6]

3.5 Results for the Middle East

From Table 5, the POLS estimation results of the Middle East show that a rise of 1% in electricity generation for country (β_2) (GC = GD + DL) is highly significant in increasing CO_2 emissions by about 0.6%, while a rise of 1% in electricity import (β_3) decreases CO_2 emissions by about 0.01%, but the result is not statistically significant. With regard to export (β_4), a rise of 1% is shown to increase CO_2 emissions by about 0.01% which is close to zero and not statistically significant.

3.6 Discussion

Billette de Villemeur and Pineau (2010) maintain that increased electricity consumption as a result of trade is detrimental to the environment due to an increase in electricity

[6] CO_2 emissions from electricity generation of the previous year ($CO_{2,\,t-1}$) is included in the models in order to avoid serial correlation.

generation. However, the empirical results of this study show that, while a rise of 1% in electricity generation for country is expected to increase CO_2 emissions for the 20 Asian countries (0.9%) and the Middle East (0.6%), a similar rise in electricity import is expected to decrease CO_2 emissions for the 20 Asian countries (-0.16%) and the Middle East (-0.01%). For both regions, the results indicate that there is no effect on CO_2 emissions from electricity export (see Table 4 and Table 5). All of this supports the contention that international trade does not increase CO_2 emissions overall.

For the Middle East, electricity import and export have no impact on CO_2 emissions (see Table 5). This might be due to there being little electricity co-operation in this continent as a result of political issues. Data from IEA indicate that, from 1971 to 2007, the levels of import and export of electricity in the Middle East were the lowest when compared with other continents (IEA, 2010), except Australia which had no international electricity trade. Lack of trust between countries is a major stumbling block to progress in electricity co-operation in this continent.

Electricity trade reduces electricity cost (private and social) by increasing market efficiency and encourages innovation in electricity generation through competition resulting in less CO_2 production (Pomeda and Camacho, 2003). Following free trade theories, trade allows each country to specialize in production of those products that it can produce most efficiently, thus electricity surplus should decrease. Not surprisingly, following this idea, the findings for both regions under study show that electricity import is expected to decrease CO_2 emissions (see Table 4 and Table 5). Hence, it is clear that, when governments focus on environmental concerns, international trade is the better choice for energy policy.

4. Conclusion

With a focus on Asia, this paper investigates the effect of electricity co-operation, in the form of import and export between countries, on CO_2 emissions. The study involves 33 Asian countries geographically separated into 13 Middle East countries and 20 other Asian countries. Thirty-seven yearly samples are employed for the time period 1971 to 2007 with the CO_2 emissions function determined by panel data analysis. For the 20 Asian countries, the results show, with a high level of statistical significance, a pronounced reduction in CO_2 emissions from electricity import. Such a finding provides affirmation that international electricity trade in this region can be influential in resisting climate change through promoting a less carbon-intensive electricity supply. With regard to the 13 Middle East countries, an absence of electricity trade impact on CO_2 emissions may be attributable to a lack of co-operation within this region. The study reveals that electricity co-operation can have a positive impact on efficient management of decarbonisation of energy supply and be instrumental for governments in the fight against global warming.

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