1. Introduction

In 2003 renewable energy accounted for 13.3% of the world's total primary energy supply, even though its supply grew insignificantly between 1990 and 2003 at a 1.8% annual rate. With the rapid growth of crude oil prices recently, more attention has been drawn to the further exploitation of renewable energy by academics and industries. While renewable energy technologies are non-competitive on purely financial grounds, their cost gap has narrowed significantly over the past two decades (Owen, 2004).

1.1 Background of the Research: A Brief Review on Renewable Energy Issues

Because economies signing the Kyoto Protocol are CO_2-emission conscious, many of them will increase their renewable energy intensity. It is thus quite important to confirm if the increasing usage in renewable energy improves energy efficiency. Renewable energy systems are considered to be environmentally superior to traditional ones from the viewpoints of CO_2 mitigation and the effective utilization of resources. Many studies present that the substitution of conventional fossil fuels with biomass for energy production results both in a net reduction of greenhouse gas emissions and in the replacement of non-renewable energy sources (Schneider et al., 2003; Dowaki et al., 2005; Caputo et al., 2005).

Domac et al. (2005) argue that bioenergy should help improve macroeconomic efficiency. They claim that in most economies, regional employment created and economic gains are probably the two most important issues regarding biomass use for energy production. From the macro-economic level, bioenergy production to replace fossil fuels contributes to all the important elements of economy or regional development: (1) the business expansion and new employment brought by renewable energy industries result in economic growth. (2) The import substitution of energy has direct and indirect effects on increasing an economy's GDP and trade balance. For energy importing states, biomass or any other local renewable energy use translates into important local economic and employment multipliers. Domac et al. also conclude that although these economic effects differ in kind and depend on the development of states, generally the increasing use of bioenergy relates to an improvement in regional productivity, enhanced competitiveness, as well as further investment in resources to accommodate the economic development.

Aside from the benefits of bioenergy, its impacts on living nature should not be neglected. Increasing usage of bioenergy may result in further land claims leading to deforestation. In some Asian economies such as China, India, Sri Lanka, Malaysia and Thailand (Bhattacharya et al., 2003), production of bioenergy means conversion of forests into tree plantation for electricity generation to a considerable extent. As the world population grows, higher demand for land growing crops to feed the growing population has lead to the 'food versus fuel' debate. Sustainable bioenergy use also requires ecosystem services of the nature to be maintained (Reijnders, 2006). Hence, those areas allocated to nature and biodiversity should not be eliminated.

Since energy efficiency improvement relies on total-factor productivity improvement (Boyd and Pang, 2000), the technical efficiency (TE) index is computed to analyze the energy efficiencies of economies. The TE index incorporates energy, labor, and capital stock as multiple inputs so as to produce the economic output of GDP. The traditional energy efficiency index is also calculated for comparison. We use the data envelopment analysis to find the technical efficiency of each economy. We test whether or not bioenergy or any other renewable energy contributes to technical efficiency improvement through a hierarchical regression and comparisons of multivariate means with empirical data from 2001-2002.

Domac et al. (2005) also argue that there is a huge difference between developing and developed economies with respect to the understanding and interpretation of bioenergy as a sector. In developing economies, bioenergy is a source of fuel for subsistence which contributes to income particularly in off-harvest seasons. Many of the current practices are unsustainable: As a consequence of underdevelopment, bioenergy sometimes is associated with poor environment and health hazards. While in developed economies, bioenergy is actively promoted by governments due to its environmental benefits. The usage of bioenergy also potentially contributes to job creation, industrial competitiveness, and regional development. Domac et al. (2005) show the differences by giving a wage comparison among wood-energy workers of developing and developed economies. Wood-energy workers in developed economies earn wages equivalent to many other technically qualified workers and can have average lifestyle. However, wood-energy workers in developing economies earn wages below the average and are left in the lowest economic levels. They suggest approaches in order to modernize bioenergy systems in developing economies, which may lose some jobs but raise economic level.

We will test whether or not the energy profile of developed economies differs from that of developing economies. This thesis is organized as follows: Chapter 1 provides data and descriptive statistics of renewable energy. Chapter 2 reviews DEA methodology and displays the empirical results of the 45 economies. Chapter 3 shows the differences of OECD and non-OECD economies. The renewable energy target for each economy is given in Chapter 4. Chapter 5 reviews the macro-economic theory of the impact of renewables on GDP. Chapter 6 identifies how renewables influence GDP by path analysis. Chapter 7 concludes this research.

1.2 Data and Descriptive Statistics of Renewable Energy

According to the International Energy Agency statistics, renewable energy was the third largest contributor to global electricity production in the year 2003 (Figure 1). It accounted for 17.6% of world electricity generation, after coal (40.1%), and gas (19.4%), but ahead of nuclear (15.8%) and oil (6.9%). This is because the majority of renewable energy generated is consumed in the residential, commercial, and public service sectors (58.6%) (Figure 2), as a consequence of widespread biomass use in the residential sector of developing economies. For example, biomass energy is one of the main sources for non-commercial energy use in China's rural areas, constituting 19.9% of China's total energy consumption in 2000 (Chang et al., 2003), while more than half of the renewable primary energy supply in OECD economies is used in the transformation sector to generate electricity. From a global point of view, only 21.3% of renewable energy is used on electricity plants.

The renewable energy indicators by an economy are collected from Renewables Information (2004, 2005) published by IEA since 2002. The 1991 capital stocks in 1985 prices are obtained from Penn World Tables 5.6. The panel dataset of 45 economies from 2001-2002 is established for our analysis. Data on labor employment, energy consumption and GDP are collected from the World Development Indicators database. To the best of our knowledge, data of recent capital stock (after year 2000) are not available from any statistical yearbook or database. The capital stock is hence calculated by the following equation with the initial values obtained from Penn World Table (1998) and substituting into the equation with capital formation obtained from World Development Indicators database (2005):

$$K_t = K_{t-1} \times (1-\delta) + I_t, \quad (1)$$

where K_t = the capital stock in the current year;

K_{t-1} = the capital stock in the previous year;

δ = depreciation rate of capital stock;

I_t = capital formation in the current year.

The depreciation rate δ is set to be 6% according to the suggestions by many relevant studies such as Iyer et al. (2004). GDP and capital stock are transformed into constant 2000 US dollars by GDP deflators from the International Monetary Fund (2005) World Economic Outlook database.

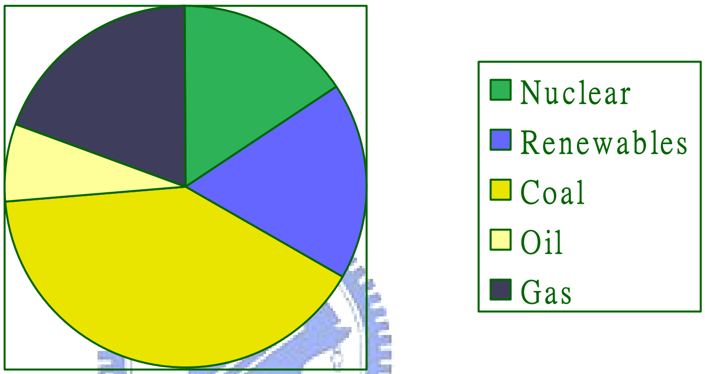

Figure 1. Fuel shares in world electricity production in 2003

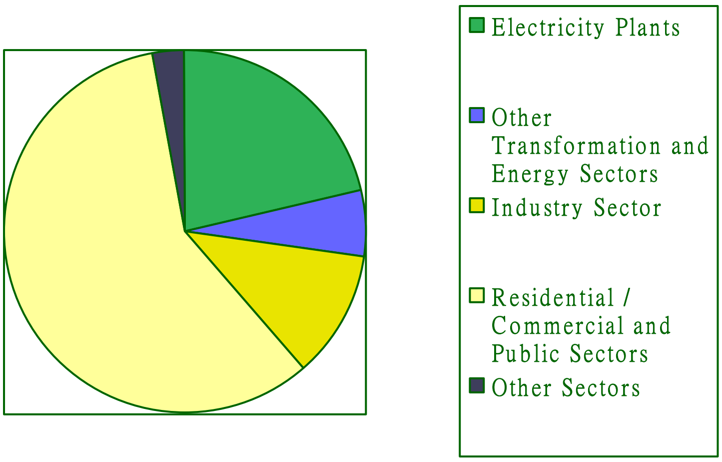

Figure 2. World sectoral consumption of renewable energy in 2003

A correlation matrix is shown in Table 1, whereby positive correlations exist between these inputs and the output. The correlation between capital and GDP, energy and GDP, and energy and capital are particular strong (0.981, 0.977, and 0.927). These results confirm isotonicity of the three inputs and the one output in our DEA model.

Table 1. Correlation matrix for inputs and the output (2001-2002)

	GDP	Labor	Capital	Energy
GDP	1.000			
Labor	0.313	1.000		
Capital	0.981	0.318	1.000	
Energy	0.977	0.369	0.927	1.000

2. Macroeconomic Technical Efficiency

2.1 Measuring Macroeconomic Technical Efficiency by DEA

Energy, labor, and capital stock are key inputs to produce the economic output - GDP (Hu et al. 2006 and 2007). It is desirable for an economy to increase its GDP and to decrease its inputs in order to maximize production efficiency. We use DEA to construct an efficiency frontier for each of the forty-five economies in each year. The macroeconomic technical efficiency is measured in each economy for how far apart they are from their efficiency frontier in that year. DEA is a mathematical programming technique to measure the efficiency frontier and assess the efficiencies of decision-making units (DMU, in this study, each individual economy is the decision-making unit). All DMUs devote the same categories of input to produce the same categories of output. The production efficiency of each DMU is estimated by its input and output level. DEA constructed the efficiency frontier of DMUs by locating the DMUs generating the maximal outputs with minimal inputs at the frontier.

Suppose there are J inputs and M outputs for each N DMU. For each DMU, to obtain a measure of the ratio of all outputs over all inputs, the envelopment form of this problem is:

$$\min_{\theta,\lambda} \theta, \qquad (2)$$

$$\text{st} \quad -y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\lambda \geq 0,$$

where θ is a scalar and λ is a N×1 vector of constants. This envelopment form satisfies θ ≤ 1, with a value of 1 indicating a point on the frontier and being a technically efficient DMU (Coelli et al., 1998). Further details of the DEA method are demonstrated in Coelli's (1996) article and other relevant literature. The constant returns to scale model proposed by Charnes et al. (1978) is employed to estimate the technical efficiency (TE) scores of these forty-five economies in years 2001 and 2002, respectively.

An index of partial-factor energy efficiency (PFEE) computing the efficiency ratio by dividing GDP by energy inputs is calculated for comparison. Table 2 shows the 2001-2002 TE and PFEE scores. Denmark, Ireland, Japan, Luxembourg, and the United Kingdom are found to have the optimal efficiency for both 2001 and 2002. Although Denmark, Ireland, Japan, Luxembourg, and the United Kingdom are on the frontier in our analysis, this does not mean that the five economies have the best energy technology levels. The fact that these five economies constitute the efficiency frontier simply means that their inputs and output level are operating at the optimal level.

Table 2. 2001-2002 TE and PFEE scores for forty-five economies

	2001		2002	
Economy	TE	PFEE	TE	PFEE
Argentina	0.871	3.663	0.814	3.372
Australia	0.719	2.240	0.713	2.186
Austria	0.769	3.500	0.757	3.525
Belgium	0.794	2.940	0.780	2.949
Bolivia	0.573	2.462	0.616	2.416
Canada	0.765	1.514	0.776	1.534
Chile	0.715	1.971	0.737	1.944
Colombia	0.506	2.416	0.525	2.419
Denmark	1.000	4.936	1.000	5.014
Dominican Republic	0.757	3.191	0.776	2.911
Ecuador	0.419	2.068	0.408	2.034
Finland	0.738	1.568	0.739	1.555
France	0.816	3.378	0.805	3.439
Germany	0.769	3.733	0.764	3.788
Greece	0.704	2.619	0.717	2.601
Guatemala	0.984	4.726	0.961	4.656
Honduras	0.490	1.814	0.507	1.720
Hong Kong, China	0.903	4.458	0.887	4.446
Iceland	0.924	1.195	0.895	1.138
India	0.582	1.284	0.612	1.257
Ireland	1.000	4.808	1.000	4.928
Italy	0.798	3.938	0.775	3.882
Japan	1.000	4.939	1.000	4.830
Kenya	0.789	2.946	0.818	2.837
Luxembourg	1.000	3.527	1.000	3.562
Mexico	0.747	3.557	0.731	3.498
Morocco	0.810	2.634	0.808	2.596
Netherlands	0.800	3.773	0.775	3.770
New Zealand	0.652	1.632	0.682	1.617
Norway	0.903	1.528	0.903	1.606
Panama	0.615	3.010	0.610	3.024
Peru	0.611	2.915	0.635	2.884
Philippines	0.657	1.997	0.692	2.197
Poland	0.608	1.731	0.630	1.775
Portugal	0.646	2.711	0.640	2.621
Spain	0.654	2.875	0.659	2.854
Sweden	0.846	1.822	0.854	1.876
Switzerland	0.940	4.603	0.952	4.631
Syrian Arab Republic	0.383	1.156	0.413	1.133
Thailand	0.422	1.359	0.459	1.318
Turkey	0.601	1.934	0.660	1.960
United Kingdom	1.000	4.415	1.000	4.490
United States	0.983	2.840	0.970	2.856
Venezuela	0.581	1.887	0.551	1.771
Zambia	0.690	0.628	0.710	0.587

2.2 Second Stage Statistical Analysis

In order to verify the argument that the use of bioenergy or any other renewable energy contributes to efficiency improvement, we identify the relationship between renewable energy and efficiency by the following two analyses:

Analysis A:

Model 1:

$$\textit{Technical efficiency} = a_0 + a_1 Z_1 + a_2 Z_2 + a_3 Z_3 + a_4 Z_4 + a_5 Z_5; \quad (3)$$

Model 2:

$$\textit{Technical efficiency} = a_0 + a_1 Z_1 + a_2 Z_2 + a_3 Z_3 + a_4 Z_4 + a_5 Z_5 + a_6 Z_6 + a_7 Z_7; \quad (4)$$

where the samples in this analysis are 45 economies across the world;

Z_1 = GDP;

Z_2 = labor force;

Z_3 = capital stock;

Z_4 = traditional energy;

Z_5 = renewable energy;

Z_6 = share of hydro fuel in renewable energy;

Z_7 = share of geothermal, solar, tide and wind (GSTW) fuel in renewable energy.

We use the three variables of GDP, labor force and capital stock as controlling variables in this model. The input of energy is broken down into traditional energy and renewable energy in Model 1. Traditional energy is estimated by deducting renewable energy from total primary energy supply. By the definition of IEA, renewable energy is divided into the three categories of (1) hydro fuel, (2) geothermal, solar, tide and wind fuel, and (3) combustible renewable energy and waste. The three categories of energy are all very different in nature and cost (Owen, 2004). For

Model 2, renewable energy is broken down into the share of hydro fuel in renewable energy, the share of geothermal, solar, tide and wind fuel in renewable energy, and the share of combustible renewable energy and waste in renewable energy. Since shares of (1) hydro fuels, (2) geothermal, solar, tide and wind fuels, and (3) combustible and waste fuels in renewable energy add up to 100%, we omit the last one in the regression to avoid multicollinearity.

Results of Model 1 show that renewable energy does not significantly affect technical efficiency in the year 2001, but does affect technical efficiency in 2002. If we break down renewable energy into different categories of energy in Model 2, a significant positive relationship exists between renewable energy and technical efficiency. The behaviors of all the variables are quite consistent in 2001 and 2002. For Model 1, the variables of GDP, capital stock, and traditional energy are significant in both 2001 and 2002. For Model 2, the variables of GDP, labor force, capital stock, traditional energy, renewable energy, and hydro fuel share in renewable energy are significant in both 2001 and 2002.

Table 3. Regression results of all forty-five economies in 2001-2002

Coefficients (t-statistics)	2001 Model 1	2001 Model 2	2002 Model 1	2002 Model 2
Constant	0.738 (29.013***)	0.776 (20.070***)	0.741 (31.635***)	0.776 (22.414***)
GDP (unit: trillion)	0.937 (3.100***)	0.934 (3.118***)	0.936 (3.335***)	0.954 (3.560***)
Labor force (unit: billion)	-1.400 (-0.884)	-3.000 (-1.688*)	-1.500 (-1.028)	-2.800 (-1.831*)
Capital stock (unit: trillion)	-0.250 (-2.524**)	-0.240 (-2.448**)	-0.240 (-2.793***)	-0.240 (-2.890***)
Traditional energy	-0.002 (-3.146***)	-0.003 (-3.448***)	-0.002 (-3.512***)	-0.003 (-3.82***)
Renewables	0.005 (1.403)	0.009 (2.150**)	0.006 (1.662*)	0.008 (2.438**)
Hydro fuel share in renewable energy		-0.002 (-1.847*)		-0.002 (-1.999**)
GSTW share in renewable energy		0.001 (0.963)		0.002 (1.264)

Note: * represents significance at the 10% level;
** represents significance at the 5% level;
*** represents significance at the 1% level.

In Model 2 the coefficients of renewable energy are significant in years 2001 (0.009) and 2002 (0.008) and the t-statistics are 2.150 for 2001 and 2.438 for 2002. Thus, the prediction that increasing the share of renewable energy among total energy supply improves technical efficiency is confirmed by Model 2. It is worth noting that increasing the input of traditional energy decreases technical efficiency. For an economy to improve its technical efficiency, it is important not to increase the total input of energy. By substituting traditional energy with renewable energy, technical efficiency can be improved. This result is consistent even if we revise Model 2 to omit GSTW share in renewable energy instead of combustible renewable energy and waste share in renewable energy so as to avoid multicollinearity (see Table 4).

Table 4. Results of Model 2 when omitting the variable of share of GSTW fuels in renewable energy in 2001-2002

Coefficients (t-statistics)	2001 Model 2A	2002 Model 2A
Constant	0.900 (9.382***)	0.942 (7.694***)
GDP (unit: trillion)	0.915 (3.084***)	0.954 (3.561***)
Labor force (unit: billion)	-3.000 (-1.674*)	-2.800 (-1.832*)
Capital stock (unit: trillion)	-0.230 (-2.422*)	-0.240 (-2.891***)
Traditional energy	-0.003 (-3.401***)	-0.003 (-3.883***)
Renewables	0.008 (2.134**)	0.008 (2.440**)
Hydro fuel share in renewable energy	-0.003 (-2.358**)	-0.003 (-2.304**)
Combustible renewables and waste share in renewable energy	-0.001 (-1.234)	-0.002 (-1.270)

Note: * represents significance at the 10% level;
** represents significance at the 5% level;
*** represents significance at the 1% level.

It is argued that in every respect, there is a huge difference in the understanding and interpretation of bioenergy as a sector between developing and developed economies (Domac et al., 2005). Here, we use the term environment to describe factors which could influence the efficiency of an economy, where such factors are not traditional inputs and are assumed to be not under the control of a government in the short run. We use the method proposed by Charnes et al. (1981). We divide the samples into OECD (developed) economies and non-OECD (developing) economies and solve DEAs for each subgroup. The OECD members are considered more developed than other economies in the world, and so we use the status of membership in OECD as a proxy variable for being a developed economy. We use the new technical efficiency when comparing only OECD economies to verify Models 1 and 2. The results of the OECD relevant TE are shown in Table 5.

Denmark, Ireland, Japan, Luxembourg, and the United Kingdom are found to have optimal efficiency for both years 2001 and 2002 when comparing with OECD economies only. The values of PFEE do not vary when the reference group changes. It is very obvious that all the TE scores of OECD economies remain the same when they are calculated in their own subgroup. This is because in the CRS model the efficiency frontier is constructed by the more efficient economies. When the more efficient economies are separated from less efficient ones, the efficiency frontier does not change. As a result, the TE scoresof more efficient economies do not change.

Table 5. 2001-2002 TE scores for twenty-six OECD economies

	2001	2002
Economy	TE	TE
Australia	0.719	0.713
Austria	0.769	0.757
Belgium	0.794	0.780
Canada	0.765	0.776
Denmark	1.000	1.000
Finland	0.738	0.739
France	0.816	0.805
Germany	0.769	0.764
Greece	0.704	0.717
Iceland	0.924	0.895
Ireland	1.000	1.000
Italy	0.798	0.775
Japan	1.000	1.000
Luxembourg	1.000	1.000
Mexico	0.747	0.731
Netherlands	0.800	0.775
New Zealand	0.652	0.682
Norway	0.903	0.903
Poland	0.608	0.630
Portugal	0.646	0.640
Spain	0.654	0.659
Sweden	0.846	0.854
Switzerland	0.940	0.952
Turkey	0.601	0.660
United Kingdom	1.000	1.000
United States	0.983	0.970

Analysis B1:

Model 1:

Technical efficiency when comparing with OECD economies only

$= a_0 + a_1Z_1 + a_2Z_2 + a_3Z_3 + a_4Z_4 + a_5Z_5;$ (5)

Model 2:

Technical efficiency when comparing with OECD economies only

$= a_0 + a_1Z_1 + a_2Z_2 + a_3Z_3 + a_4Z_4 + a_5Z_5 + a_6Z_6 + a_7Z_7;$ (6)

where the samples in this analysis are 26 economies across the world;

The samples for analysis B1 are 26 OECD economies (all developed economies) while the samples for analysis B2 are 19 non-OECD economies (developing economies).

Table 6. Regression results for twenty-six OECD economies in 2001-2002

Coefficients (t-statistics)	2001 Model 1	2001 Model 2	2002 Model 1	2002 Model 2
Constant	0.834 (27.981***)	0.828 (17.048***)	0.826 (29.236***)	0.805 (18.651***)
GDP (unit: trillion)	0.712 (3.007***)	0.730 (2.911***)	0.727 (3.274***)	0.733 (3.056***)
Labor force (unit: billion)	-4.300 (-1.650)	-4.400 (-1.573)	-3.300 (-1.392)	-3.200 (-1.270)
Capital stock (unit: trillion)	-0.190 (-2.391**)	-0.190 (-2.347**)	-0.180 (-2.647**)	-0.190 (-2.574**)
Traditional energy	-0.002 (-2.376**)	-0.002 (-2.200**)	-0.001 (-2.741**)	-0.002 (-2.354**)
Renewables	0.001 (0.246)	0.001 (0.298)	0.001 (0.464)	0.001 (0.172)
Hydro fuel share in renewable energy		-0.0001 (-0.109)		0.0004 (0.357)
GSTW share in renewable energy		0.001 (0.641)		0.001 (0.761)

Note: * represents significance at the 10% level.
** represents significance at the 5% level.
*** represents significance at the 1% level.

Our results (Table 6) show that there is no significant relationship between renewable energy and technology efficiency when comparing all the developed economies together. We solve DEA for the non-OECD group, too. The resulting

TE scores by non-OECD economies in 2001-2002 are shown in Table 7.

Table 7. TE scores for nineteen non-OECD economies in 2001-2002

	2001	2002
Economy	TE	TE
Argentina	1.000	1.000
Bolivia	0.608	0.653
Chile	0.816	0.896
Colombia	0.565	0.607
Dominican Republic	0.830	0.875
Ecuador	0.449	0.446
Guatemala	1.000	1.000
Honduras	0.521	0.538
Hong Kong, China	1.000	1.000
India	0.617	0.648
Kenya	0.837	0.866
Morocco	0.859	0.856
Panama	0.689	0.729
Peru	0.680	0.732
Philippines	0.696	0.733
Syrian Arab Republic	0.426	0.474
Thailand	0.466	0.523
Venezuela	0.667	0.676
Zambia	0.732	0.752

Table 8. Regression results for nineteen non-OECD economies in 2001-2002

Coefficients (t-statistics)	2001 Model 1	2001 Model 2	2002 Model 1	2002 Model 2
Constant	0.682 (14.024***)	0.772 (14.845***)	0.708 (15.447***)	0.792 (14.947***)
GDP (unit: trillion)	4.930 (3.558***)	5.040 (4.376***)	5.790 (3.286***)	6.160 (3.994***)
Labor force (unit: billion)	-0.980 (-0.166)	-6.200 (-1.179)	-4.700 (-0.692)	-6.900 (-1.142)
Capital stock (unit: trillion)	-1.400 (-1.588)	-1.900 (-2.342**)	-1.900 (-1.911*)	-2.400 (-2.609**)
Traditional energy	-0.006 (-1.129)	-0.001 (-0.108)	-0.002 (-0.589)	0.002 (0.368)
Renewables	0.008 (0.662)	0.013 (1.213)	0.011 (0.857)	0.012 (0.945)
Hydro fuels share in renewable energy		-0.003 (-2.665**)		-0.003 (-2.326**)
GSTW share in renewable energy		-0.003 (-1.158)		-0.003 (-1.063)

Note: * represents significance at the 10% level;
** represents significance at the 5% level;
*** represents significance at the 1% level.

Our results (Table 8) show that there is no significant relationship between renewable energy and technology efficiency when comparing all the developing economies together.

3. ANOVA Analysis

3.1 Comparing OECD and non-OECD economies

We assess the differences in the two subgroups by ANOVA analysis. In the comparisons of multivariate means analysis, the question of equality of mean vectors for the OECD group and non-OECD group is divided into several specific possibilities. Notations $\mu_{OECD,1}$, …, and $\mu_{OECD,13}$ represent the average values of GDP, labor force, capital stock, electricity consumption, TE, PFEE, total primary energy supply, traditional energy, renewable energy, share of renewable energy in total energy, hydro fuel share in renewable energy, GSTW fuel share in renewable energy, and combustible energy and waste share in renewable energy for OECD economies respectively. Notations $\mu_{non-OECD,1}$, …, $\mu_{non-OECD,13}$ show respectively the average values of GDP, labor force, capital stock, electricity consumption, TE, PFEE, total primary energy supply, traditional energy, renewable energy, share of renewable energy in total energy, hydro fuel share in renewable energy, GSTW fuel share in renewable energy, and combustible energy and waste share in renewable energy for non-OECD economies. We construct the profiles for the OECD group and non-OECD group for 2001 and 2002 separately. We formulate the question of equality in the following hypothesis.

[Hypotheses] The OECD profile is coincident with the non-OECD profile. The statistical forms of hypotheses are the following equations:

H_1: $\mu_{\text{OECD},1} = \mu_{\text{non-OECD},1}$

H_2: $\mu_{\text{OECD},2} = \mu_{\text{non-OECD},2}$

H_3: $\mu_{\text{OECD},3} = \mu_{\text{non-OECD},3}$

H_4: $\mu_{\text{OECD},4} = \mu_{\text{non-OECD},4}$

H_5: $\mu_{\text{OECD},5} = \mu_{\text{non-OECD},5}$

H_6: $\mu_{\text{OECD},6} = \mu_{\text{non-OECD},6}$

H_7: $\mu_{\text{OECD},7} = \mu_{\text{non-OECD},7}$

H_8: $\mu_{\text{OECD},8} = \mu_{\text{non-OECD},8}$

H_9: $\mu_{\text{OECD},9} = \mu_{\text{non-OECD},9}$

H_{10}: $\mu_{\text{OECD},10} = \mu_{\text{non-OECD},10}$

H_{11}: $\mu_{\text{OECD},11} = \mu_{\text{non-OECD},11}$

H_{12}: $\mu_{\text{OECD},12} = \mu_{\text{non-OECD},12}$

H_{13}: $\mu_{\text{OECD},13} = \mu_{\text{non-OECD},13}$

The results of the ANOVA analysis are shown in Tables 9 and 10. According to Table 9, there are significant differences in the indicators of GDP, capital stock, energy consumption, TE, renewable energy share in total energy, and GSTW fuel share in renewable energy between the OECD profile and non-OECD profile.

The empirical results in 2002 (Table 10) are very similar to those in 2001 (Table 9). There are significant differences in the indicators of GDP, capital stock, TE, PFEE, renewable energy share in total energy, and GSTW fuel share in renewable energy between the OECD profile and non-OECD profile. We demonstrate the mean differences in the two groups in Table 11.

Table 9. Mean difference tests of OECD and non-OECD economies in the year 2001

Source of differences	F-statistic	P-value
GDP	3.49	0.069*
Labor force	0.430	0.515
Capital stock	3.980	0.053**
Electricity consumption	2.780	0.103*
TE	13.060	0.001***
PFEE	2.640	0.112
Total primary energy supply	1.940	0.171
Traditional energy	2.310	0.136
Renewable energy	0.210	0.651
Renewable energy share in total energy	7.87	0.008***
Hydro fuel share in renewable energy	0.240	0.628
GSTW fuel share in renewable energy	4.520	0.039**
Combustible energy and waste share in renewable energy	0.880	0.355

Note: * represents significance at the 10% level;
** represents significance at the 5% level;
*** represents significance at the 1% level.

Table 10. Mean difference tests of OECD and non-OECD economies in the year 2002

Source of differences	F-statistic	P-value
GDP	3.47	0.069*
Labor force	0.450	0.507
Capital stock	3.970	0.053**
Electricity consumption	2.740	0.105
TE	13.01	0.001***
PFEE	3.310	0.076*
Total primary energy supply	1.900	0.175
Traditional energy	2.27	0.140
Renewable energy	0.200	0.660
Renewable energy share in total energy	7.230	0.010***
Hydro fuel share in renewable energy	0.004	0.851
GSTW fuel share in renewable energy	4.890	0.032**
Combustible energy and waste share in renewable energy	1.820	0.184

Note: * represents significance at the 10% level;
** represents significance at the 5% level;
*** represents significance at the 1% level.

Table 11. Average values of the 13 indicators for OECD economies and non-OECD economies in 2001-2002

	Year 2001		Year 2002	
	OECD economies	Non- OECD economies	OECD economies	Non- OECD economies
GDP (constant 2000 US$)	967639057846	84768701158	981005049346	84895533526
Labor force (persons)	20033098	33947209	20202573	34662794
Capital stock (constant 2000 US$)	1886676663516	202958029195	1975932871821	207682070554
Electricity consumption (kwh)	305479519530	44343433249	309690527806	46085834079
TE	0.814	0.650	0.815	0.660
PFEE	3.010	2.452	3.019	2.396
Total primary energy supply (Mtoe)	194.335	48.653	194.481	49.495
Traditional energy (Mtoe)	182.800	32.405	182.885	33.295
Renewable energy (Mtoe)	11.535	16.247	11.596	16.200
Renewable energy share in total energy (%)	13.482	30.669	13.615	30.449
Hydro fuel share in renewable energy (%)	30.219	26.426	28.677	27.226
GSTW fuel share in renewable energy (%)	12.638	2.874	12.669	2.774
Combustible energy and waste share in renewable energy (%)	57.142	65.442	58.654	70.000

To sum up, the average values of GDP and capital stock are higher in OECD economies than in non-OECD economies. Technical efficiency is higher in OECD economies than in non-OECD economies. The share of renewable energy in total energy supply is higher in developing economies than in OECD economies due to the widespread biomass use in the residential sector of developing economies as explained previously. The share of GSTW fuel in renewable energy is higher in OECD economies than in non-OECD economies.

Because the share of renewables in total energy supply and the composition of renewables are very different in OECD and non-OECD economies, the argument that renewable energy is very different in developed and developing economies is hence confirmed.

4. Estimating Target Energy Input

4-1. Slack and Radial Adjustments of Traditional and Renewable Energy Input

Our DEA approaches in Chapter 3 have identified the most efficient economies on the frontier as a target for other inefficient economies to achieve through a sequence of linear programming computations. Since the efficiency of energy consumption needs to be promoted, we would like to propose adjustments that reduce redundant energy consumption of traditional energy and renewable energy. The out-of-date technology level and the inefficient production process generate a redundant portion of traditional and renewable energy consumption which leads to a negative impact on technical efficiency. We have confirmed that when controlling the traditional energy input fixed, the replacement of traditional energy by renewables leads to positive impact on technical efficiency in previous chapters. However, to further improve technical efficiency, both the input of traditional energy and the input of renewable energy have to be reduced. We compute the amount of total adjustments, including slack and radial adjustments by DEA. The target levels of traditional energy and renewable energy use, called target traditional energy input and target renewables input, are obtained when the amount of total adjustments is estimated from the actual energy use amount when benchmarking with the efficient economies.

In the 1990, stimuli to further exploit renewables came from international environmental treaties such as the UN Framework on Climate Change in Rio (1992) and the Kyoto Protocol (1997). The Europeans Union's Directive in renewable energy sources (the 'RES Directive') aims to increase the share of electricity produced from renewable sources from 13.9 percent in 1997 to 22.1 percent in 2010 (EU, 2001). The use of wood fuel for energy production in the UK is set to increase in the near future as part of a government commitment to increase renewable sources to 10 percent by 2010 (Pitman, 2006). The Swedish government adopted a national planning goal of a yearly wind power generation of from 0.6 to10 Twh by 2015 (Soderholm et al., 2007). Further action and commitment on issues such as south-south cooperation and wider NGO participation on renewable energy was stressed at the Beijing International Renewable Energy Conference held in November 7-8, 2005 (Lin et al., 2007). Since energy consumption is inevitable for economic growth, it is important to adjust energy consumption so as to maximize efficiency.

There are many recent publications discussing ways to achieve the national target of renewables ratio in total energy input. Lund (2007) groups policies on renewable energy and efficient energy use into subsidy type and catalyzing measures based on the use of the public financial resources. Lund (2007) further indicates that more than 99.5 percent of the materials needed in the new renewable energy sources systems are basic construction materials and metals. Ford et al. (2007) discuss the price dynamics of the market for Tradable Green Certificates. These markets have been used in Europe to promote generation of electricity from renewables. Rathmann (2007) shows that most electricity from renewable energy sources support systems are financed via the electricity market. Green et al. (2007) claim that energy technology to deploy new energy sources and economics are complementary, with advances in the former requiring something more than a reliance on market-based instruments, such as carbon taxes and emission permits. Yue et al. (2006) adopts approach evaluates local potentials of renewable energy sources with the aid of geographic information systems.

Our study in Chapter four concentrates specifically on the national target of traditional and renewable energy use where improvements can be executed by individual economy. It is of particular importance to meet the national renewable target for each economy in order to sustain energy security, mitigate green house gas emission and reduce local environmental impacts. However, if the target of saving total energy could be met, is it necessarily to set percentage target of renewables in total energy to improve technical efficiency?

The data of GDP, labor force, capital stock, traditional energy and renewable energy are collected from World Bank indicators database and Renewables Information (IEA, 2004, 2005, 2006). The 42 economies are the 45 economies from previous chapters excluding France, Hong Kong and Luxembourg. France is excluded due to its lack of capital formation information in 2003 when the analysis is conducted. Hong Kong and Luxembourg are excluded due to their renewables usage are both zero in 2003. When we conduct DEA, any of the input or output variable should be nonzero.

We adopt the constant returns to scale (CRS) DEA model to compare the technical efficiency of 42 economies. Both output-oriented and input-oriented CRS DEA model generate exactly the same efficiency scores, target inputs, and target outputs. We adopt the input-oriented CRS DEA model because it is generally more possible for an economy to improve its input level than its output level.

DEA identifies the most efficient point on the frontier as a target for other less efficient economies to achieve through a sequence of linear programming computation (Coelli, 1996). For the *i*th economy, the distance from an inefficient point where it is located to the projected point on the frontier by radial adjusting the level of inputs, $(1-\theta)x_i$, is called 'radial adjustment'. Moreover, the mostly seen piecewise linear form of the non-parametric frontier causes the second stage to shift from the projected point to a point at the practical minimum level of the inputs with the frontier in between is called slack. The summation amount of slack and radial adjustment for inputs is called the amount of total adjustments meaning that it is the total amount of input adjustments to reach the optimal production efficiency by an economy. The adjustments require both a promotion of technology level and an improvement of production process so that technical efficiency is optimized. The amount of total adjustments therefore decreases and the output level is maximized. The economy thus could operate at the frontier of production efficiency. The practice minimum input level is called the target input level for an economy.

When incorporating energy as an input into an economy's production, the target level of energy input is named 'target energy input', which represents a practical minimum level of energy input to be taken as a target in an economy in order to perform at the optimal efficiency of energy consumption. To estimate the optimal ratio of renewable energy in total energy, we break up total energy consumption into traditional energy consumption and renewable energy consumption. The levels of target traditional and renewable energy input are identified through DEA in conjunction with other inputs so as to produce real GDP. An energy-efficient economy has to be operated at the maximum economic output by taking the minimum level of traditional and renewable energy consumption. The optimal ratio is obtained by

$$\text{Optimal ratio of renewable energy} = \frac{\text{total renewables input - total adjustments for renewables consumption}}{\text{total energy input - total adjustments for energy consumption}}, \qquad (7)$$

where the total energy input equals traditional energy input plus renewable energy input. Total energy adjustments equal total adjustments for traditional energy adjustments plus renewable energy adjustments.

To estimates traditional energy input targets and renewable energy input targets, we use the variable of total primary energy supply as total energy input by each economy. The estimation of total primary energy supply of each economy is defined as the following equation by IEA (2004):

Total primary energy supply

= indigenous production + imports - exports - international marine bunkers +/- stock changes (8)

A correlation matrix is shown in Table 12, whereby positive correlations exist between these inputs and the output. The correlation between capital and GDP, traditional energy and GDP, traditional energy and capital, and renewable energy and labor are particular strong (0.981, 0.968, 0.910, and 0.975). These results confirm isotonicity between these four inputs and one output in our DEA model.

Table 12. Correlation matrix for inputs and the output (2001-2003)

	GDP	Labor	Capital	Traditional energy	Renewable energy
GDP	1.000				
Labor	0.350	1.000			
Capital	0.981	0.351	1.000		
Traditional energy	0.968	0.441	0.910	1.000	
Renewable Energy	0.369	0.975	0.349	0.485	1.000

4.2 Measuring energy input targets by DEA

From the previous analysis, we know that OECD economies are operated at a more optimal level than non-OECD economies. To compare economies of more similar technical efficiency together, we separate the two groups of OECD and non-OECD economies apart. Energy, labor, and capital stock are key inputs to produce the economic output - GDP (Hu et al., 2006 and 2007). It is desirable for an economy to increase its GDP and to decrease its energy inputs in order to maximize production efficiency.

We use DEA to construct an efficiency frontier for each of the forty-two economies in the year 2001, 2002 and 2003. The macroeconomic technical efficiency is measured in each economy for how far apart they are from their efficiency frontier in that year. All economies devote the same categories of input to produce the same category of output and DEA constructs the efficiency frontier of economies by locating the economies generating the maximal outputs with minimal inputs at the frontier. We then employ the constant returns to scale model proposed by Charnes et al. (1978) to estimate the technical efficiency (TE) scores of forty-two economies in years 2001, 2002 and 2003, respectively.

Table 13 shows the 2001-2003 TE scores. Ireland, Japan, Norway, Switzerland, the United Kingdom and the United States are found to have the optimal efficiency for 2001, 2002 and 2003. Although Ireland, Japan, Norway, Switzerland, the United Kingdom and the United States are on the frontier in our analysis, this does not mean that the six economies have the best energy technology levels. The fact that these six economies constitute the efficiency frontier simply means that their inputs and output level are operating at the optimal level.

Table 13. 2001-2003 technical efficiency scores for forty-two economies

Economy	2001TE	2002TE	2003TE
Argentina	0.873	0.812	0.889
Australia	0.728	0.725	0.738
Austria	0.840	0.860	0.799
Belgium	0.938	0.953	0.877
Bolivia	0.572	0.604	0.619
Canada	0.777	0.788	0.797
Chile	0.712	0.724	0.734
Colombia	0.528	0.565	0.589
Denmark	1.000	1.000	0.997
Dominican Republic	0.861	0.993	1.000
Ecuador	0.338	0.353	0.373
Finland	0.760	0.767	0.784
Germany	0.797	0.792	0.787
Greece	0.707	0.717	0.724
Guatemala	0.950	0.930	0.930
Honduras	0.509	0.511	0.520
Iceland	1.000	1.000	1.000
India	0.587	0.605	0.600
Ireland	1.000	1.000	1.000
Italy	0.760	0.767	0.732
Japan	1.000	1.000	1.000
Kenya	0.949	0.945	0.947
Mexico	0.721	0.718	0.718
Morocco	0.816	0.818	0.818
Netherlands	0.840	0.808	0.769
New Zealand	0.651	0.679	0.696
Norway	1.000	1.000	1.000
Panama	0.603	0.634	0.700
Peru	0.692	0.728	0.753
Philippines	0.645	0.686	0.714
Poland	0.625	0.645	0.664
Portugal	0.689	0.662	0.657
Spain	0.711	0.699	0.696
Sweden	0.888	0.893	0.898
Switzerland	1.000	1.000	1.000
Syrian Arab Republic	0.390	0.428	0.441

Thailand	0.421	0.458	0.476
Turkey	0.601	0.659	0.678
United Kingdom	1.000	1.000	1.000
United States	1.000	1.000	1.000
Venezuela	0.581	0.544	0.521
Zambia	0.762	0.845	0.819

From the previous chapters, we have identified that OECD non-OECD economies are significantly different in technical efficiency, the ratio of renewable energy in total energy and the ratio of GSTW energy in renewable energy. Since efficiency scores obtained are only relative to the best firms among the comparing economies, it is necessary to separate the samples into OECD and non-OECD economies and compare efficiencies within each group. The total adjustments of traditional energy and renewable energy reflect the dispersion of efficiencies within the OECD or non-OECD group. The efficiency results could not be interpreted as one group relative to the other group.

In the previous chapters, we control the input of labor force, capital stock, and traditional energy input and find that replacing traditional energy input by renewable energy would lead into the increase of technical efficiency. To further improve the technical efficiency, it is obvious that each economy should reduce total energy input into an economy's production. The total adjustments amounts represent a practical level of energy input to be reduced to in an economy to perform at the optimal efficiency of energy consumption.

Table 14 lists the technical efficiency scores when comparing OECD economies. Iceland, Ireland, Japan, Norway, Switzerland, the United Kingdoms and the United states are the seven efficient economies in year 2001-2003.

Table 14. 2001-2003 technical efficiency scores for OECD economies

Economies	2001TE	2002TE	2003TE
Australia	0.728	0.725	0.738
Austria	0.840	0.860	0.799
Belgium	0.938	0.953	0.877
Canada	0.777	0.788	0.797
Denmark	1.000	1.000	0.997
Finland	0.760	0.767	0.784
Germany	0.797	0.792	0.787
Greece	0.707	0.717	0.727
Iceland	1.000	1.000	1.000
Ireland	1.000	1.000	1.000
Italy	0.760	0.767	0.732
Japan	1.000	1.000	1.000
Mexico	0.721	0.718	0.725
Netherlands	0.840	0.808	0.769
New Zealand	0.651	0.679	0.696
Norway	1.000	1.000	1.000
Poland	0.625	0.645	0.675
Portugal	0.689	0.662	0.657
Spain	0.711	0.699	0.696
Sweden	0.888	0.893	0.898
Switzerland	1.000	1.000	1.000
Turkey	0.601	0.659	0.695
United Kingdom	1.000	1.000	1.000
United States	1.000	1.000	1.000

The levels of total adjustments for traditional energy and renewable energy are identified through DEA in conjunction with other inputs so as to produce economic output. The total adjustments amount of traditional energy for OECD economies is shown in Table 15. Canada is the economy that needs to make most adjustments in traditional energy input in 2001-2003 among the OECD economies.

Table 15. Total adjustments amount of traditional energy for OECD economies (Unit: Mtoe)

Economies	2001	2002	2003
Australia	47.077	43.119	48.084
Austria	3.862	3.307	5.344
Belgium	27.182	25.285	28.474
Canada	99.071	100.318	113.515
Denmark	0	0	0.047
Finland	6.292	6.475	8.885
Germany	69.456	69.664	71.538
Greece	8.879	9.539	9.383
Iceland	0	0	0
Ireland	0	0	0
Italy	38.995	38.161	45.849
Japan	0	0	0
Mexico	44.828	54.979	55.555
Netherlands	21.688	23.304	28.963
New Zealand	4.768	4.581	3.805
Norway	0	0	0
Poland	59.114	58.829	61.548
Portugal	6.619	7.703	7.244
Spain	34.434	37.532	38.595
Sweden	4.053	3.953	3.919
Switzerland	0	0	0
Turkey	33.973	35.596	37.405
United Kingdom	0	0	0
United States	0	0	0

Table 16 shows the total adjustments amount of renewable energy for OECD economies. Canada is also the economy that needs to make most adjustments in renewable energy input in 2001-2003 among OECD economies.

Table 16. Total adjustments amount of renewable energy for OECD economies (Unit: Mtoe)

Economies	2001	2002	2003
Australia	5.099	6.965	5.181
Austria	1.058	0.935	1.326
Belgium	0.037	0.028	0.098
Canada	36.548	39.503	38.925
Denmark	0	0	0.006
Finland	5.929	6.775	7.126
Germany	1.869	2.242	2.385
Greece	1.101	1.19	1.259
Iceland	0	0	0
Ireland	0	0	0
Italy	2.305	2.147	2.71
Japan	0	0	0
Mexico	14.512	13.986	14.274
Netherlands	0.176	0.23	0.408
New Zealand	4.908	4.902	4.405
Norway	0	0	0
Poland	3.806	3.795	4.555
Portugal	1.057	1.216	1.442
Spain	2.369	2.14	2.798
Sweden	10.467	10.67	11.793
Switzerland	0	0	0
Turkey	9.087	9.755	9.6
United Kingdom	0	0	0
United States	0	0	0

The technical efficiency scores when comparing the non-OECD economies together are shown in Table 17. Argentina, Guatemala Kenya, Morocco, Peru and Zambia are the six efficient economies in non-OECD economies in year 2001-2003.

Table 17. 2001-2003 technical efficiency scores for non-OECD economies

Economies	2001TE	2002TE	2003TE
Argentina	1.000	1.000	1.000
Bolivia	0.644	0.663	0.651
Chile	0.832	0.914	0.873
Colombia	0.684	0.745	0.735
Dominican Republic	0.968	1.000	1.000
Ecuador	0.415	0.453	0.445
Guatemala	1.000	1.000	1.000
Honduras	0.596	0.595	0.574
India	0.623	0.609	0.600
Kenya	1.000	1.000	1.000
Morocco	1.000	1.000	1.000
Panama	0.852	0.987	1.000
Peru	1.000	1.000	1.000
Philippines	0.695	0.726	0.756
Syrian Arab Republic	0.452	0.518	1.000
Thailand	0.477	0.505	0.505
Venezuela	0.688	0.696	0.588
Zambia	1.000	1.000	1.000

Table 18 shows the total adjustments amount of traditional energy for non-OECD economies. India is the economy that needs to make most adjustments in traditional energy input in 2001-2003 among non-OECD economies.

Table 18. Total adjustments amount of traditional energy for non-OECD economies (Unit: Mtoe)

Economies	2001	2002	2003
Argentina	0	0	0
Bolivia	1.841	1.145	1.258
Chile	2.976	1.805	3.28
Colombia	6.69	4.975	5.402
Dominican Republic	2.567	0	0
Ecuador	4.331	4.156	4.331
Guatemala	0	0	0
Honduras	0.688	0.728	0.809
India	239.164	167.019	166.71
Kenya	0	0	0
Morocco	0	0	0
Panama	0.371	0.029	0
Peru	0	0	0
Philippines	10.077	6.198	5.539
Syrian Arab Republic	9.186	12.2	0
Thailand	38.893	34.124	36.715
Venezuela	21.535	25.682	27.459
Zambia	0	0	0

Table 19 shows the total adjustments amount of renewable energy for non-OECD economies. India is also the economy that needs to make most adjustments in renewable energy input in 2001-2003 among non-OECD economies.

Table 19. Total adjustments amount of renewable energy for non-OECD economies (Unit: Mtoe)

Economies	2001	2002	2003
Argentina	0	0	0
Bolivia	0.321	0.303	0.314
Chile	3.812	4.283	4.07
Colombia	2.525	2.016	2.118
Dominican Republic	0.049	0	0
Ecuador	0.761	0.766	0.722
Guatemala	0	0	0
Honduras	0.607	0.647	0.724
India	79.63	178.543	179.071
Kenya	0	0	0
Morocco	0	0	0
Panama	0.104	0.258	0
Peru	0	0	0
Philippines	5.88	5.321	4.734
Syrian Arab Republic	0.493	0.434	0
Thailand	7.058	7.072	8.38
Venezuela	7.742	2.727	3.399
Zambia	0	0	0

The European Parliament and many other economies set up the national target that the electricity produced from renewables should account for 7% or more in the overall electricity production by 2010. Individual state also sets up a feasible objective for itself, for example, Lithuanian establishes the objective for renewables to account for 12% in its fuel mix by 2010. However, in the future, if the energy technology permits the total adjustments to be achieved, the ratio of renewables in total technology may not necessarily be a good index to monitor energy policy. We list the target renewable ratio in total energy after total adjustments by the reduction of traditional energy and renewable energy in Table 20 and 21. Table 20 displays the renewable ratio after total adjustments for OECD economies.

Table 20. Renewable energy ratio for OECD economies

	2001		2002		2003	
	Current renewable ratio (%)	Target Renewable ratio (%)	Current renewable ratio (%)	Target Renewable ratio (%)	Current renewable ratio (%)	Target Renewable ratio (%)
Australia	5.709	2.367	7.365	2.132	5.684	2.054
Austria	21.498	21.497	22.039	22.039	19.880	19.879
Belgium	1.017	1.771	1.054	1.811	1.351	2.292
Canada	15.753	2.267	16.600	1.813	15.656	1.734
Denmark	10.606	10.606	12.183	12.183	12.019	12.021
Finland	22.485	7.744	21.910	4.586	20.745	3.122
Germany	2.620	2.620	3.118	3.118	3.227	3.227
Greece	4.530	1.063	4.828	1.149	5.017	1.251
Iceland	73.529	73.529	73.529	73.529	73.529	73.529
Ireland	2.000	2.000	1.923	1.923	1.987	1.987
Italy	5.581	5.581	5.327	5.327	5.580	5.580
Japan	3.054	3.054	3.482	3.482	3.520	3.520
Mexico	10.177	1.063	9.536	1.148	9.631	1.250
Netherlands	1.425	1.670	1.540	1.784	1.733	1.929
New Zealand	27.322	1.067	27.778	1.151	28.161	5.386
Norway	44.361	44.361	47.547	47.547	45.064	45.064
Poland	4.525	1.062	4.596	1.148	5.229	1.250
Portugal	13.765	13.763	13.636	13.638	16.601	16.600
Spain	6.436	6.436	5.395	5.396	6.760	6.760
Sweden	29.354	12.392	27.647	9.429	25.437	3.652
Switzerland	16.786	16.786	15.498	15.498	15.129	15.129
Turkey	12.966	1.063	13.395	1.148	12.658	1.250
United Kingdom	1.063	1.063	1.148	1.148	1.250	1.250
United States	4.344	4.344	4.178	4.178	4.178	4.178

Table 21 displays the renewable ratio after total adjustments for non-OECD economies.

Table 21. **Renewable energy ratio for non-OECD economies**

	2001		2002		2003	
	Current renewable ratio (%)	Target Renewable ratio (%)	Current renewable ratio (%)	Target Renewable ratio (%)	Current renewable ratio (%)	Target Renewable ratio (%)
Argentina	10.764	10.764	10.835	10.835	10.184	10.184
Bolivia	20.930	27.081	20.930	20.933	20.000	20.014
Chile	25.630	13.449	25.506	10.837	22.814	10.185
Colombia	27.397	27.396	28.832	28.830	28.169	28.170
Dominican Republic	19.231	27.990	18.293	18.293	18.750	18.750
Ecuador	14.943	14.939	15.556	15.547	14.286	14.282
Guatemala	56.164	56.164	54.054	54.054	56.164	56.164
Honduras	46.875	46.877	47.059	47.062	47.222	47.218
India	39.774	61.949	39.718	18.293	39.393	18.750
Kenya	81.818	81.818	84.314	84.314	83.333	83.333
Morocco	4.545	4.545	4.630	4.630	5.505	5.505
Panama	21.875	21.872	23.333	16.292	26.923	26.923
Peru	31.405	31.405	32.500	32.500	32.500	32.500
Philippines	45.735	51.137	46.190	46.189	46.081	46.080
Syrian Arab Republic	6.429	9.419	4.972	8.525	1.117	1.117
Thailand	17.881	21.801	17.167	17.167	17.230	15.833
Venezuela	19.126	10.764	10.185	10.836	10.701	10.286
Zambia	92.188	92.188	93.846	93.846	92.537	92.537

Having estimating the targeted traditional energy and renewable energy input, we achieved the new ratio of renewable energy after total adjustments. We find that the new ratios of renewable energy after total adjustments for each economy are lower than before adjustments. As a matter of fact, if we calculate the total renewable ratio among OECD economies we find that it reduces from 5.879% to 4.335% in 2001, 5.950% to 4.289% in 2002 and 5.899% to 4.250% in 2003. Moreover, the total renewable ratio among non-OECD economies increases from 33.994% to 43.342% in 2001, but reduces from 33.301% to 22.722% in 2002 and 32.903% to 22.072% in 2003. That means that if we could reduce both traditional energy input and renewable energy input, there is no need to set up national target of renewables ratio. The reduction of traditional energy input and renewable energy input could lead to greater improvement of technical efficiency.

5. Macro-Economic theory of the impact of Renewable Energy on GDP

Recently, much attention has been given to the notion of 'sustainable energy consumption'. This paper broads the perspective of environmental economics to include analysis of renewables usage directly contributing to the important elements of economies or regional development. This objective is to suggest policies that link not only to price incentives influencing consumers or industries to use renewable energy, but also especially to persuasive instruments, such as education and information provision of more replacement of traditional energy by renewable energy.

As mentioned in the previous chapters, Domac et al. (2005) suggest that renewable energy increase the macroeconomic efficiency by the following process: (1) The business expansion and new employment brought by renewable energy industries result in economic growth. (2) The import substitution of energy has direct and indirect effects on increasing an economy's GDP and trade balance. This chapter will include tests of whether the influences of renewables on GDP are valid.

For energy importing states, local renewable energy use translates into important local economic and employment multipliers, and we will test the translation process by path analysis. This article presents a first macro-economic analysis of economic growth brought by renewable energy usage.

It is well known that GNP is estimated by commonly used 'expenditure approach' or 'value-added approach'. The expenditure approach estimates GNP by the following equation:

$$GNP = C + I + G + X - M, \tag{9}$$

where C: final household consumption expenditure, we will use consumption for household consumption through the article;

I: gross domestic capital formation;

G: general government final consumption expenditure;

X: export;

M: import.

The deduction of imports from exports (X-M) is trade balance. The value-added approach estimates GNP by the following equation:

$$GNP = w + r + i + \pi + \delta, \tag{10}$$

where w is wage; r: rent; i: interest; π: revenue; δ: depreciation.

The article evaluates the impact of renewables on GNP by the expenditure approach because the import substitution effect of renewable seems to have direct impact on trade balance. The difference between GDP and GNP is that GDP only includes economic output within the national boundary while GNP includes the output of overseas citizen. The notion of GDP is used for the following analysis.

6. The Path Analysis of the impacts of Renewable Energy on GDP

The influences of renewables on GDP are illustrated by the following diagrams.

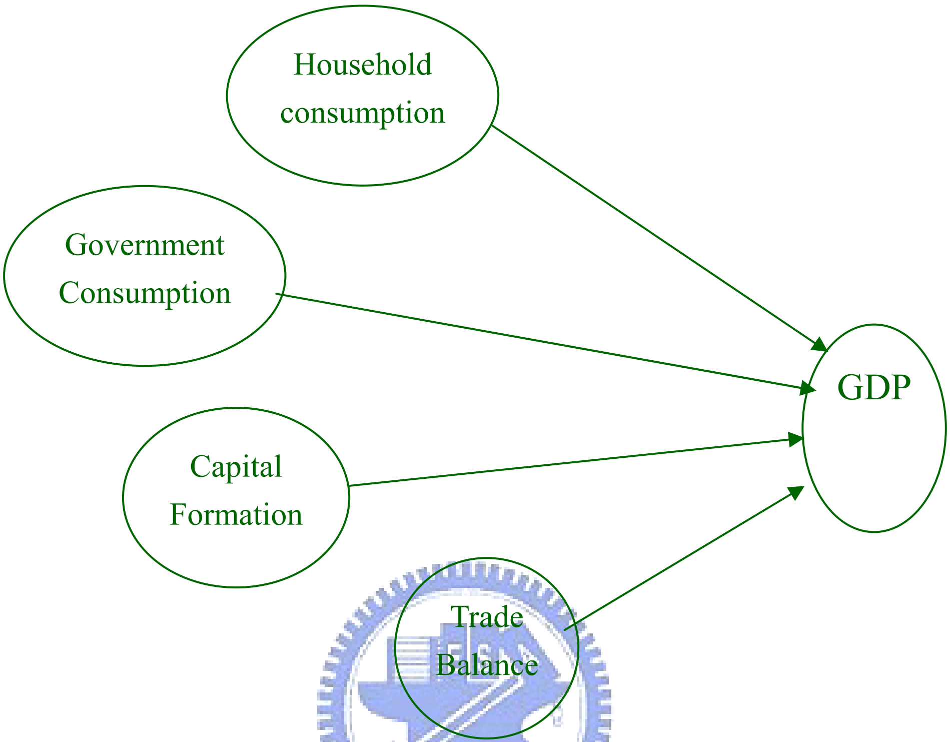

Figure 3. Conceptual framework of GDP constitution

Figure 3 represents the original constitution of GDP by household consumption, government consumption, capital formation and trade balance. In Figure 4, the diagram shows that use of renewables influences GDP through two paths: (1) the emergence of renewable energy industries bring about business expansion which results in the increase of capital formation; and (2) the import substitution of traditional energy by locally produced renewable energy has direct and indirect effects on increasing an economy's trade balance. The increases of capital formation and trade balance would lead to the increase of GDP.

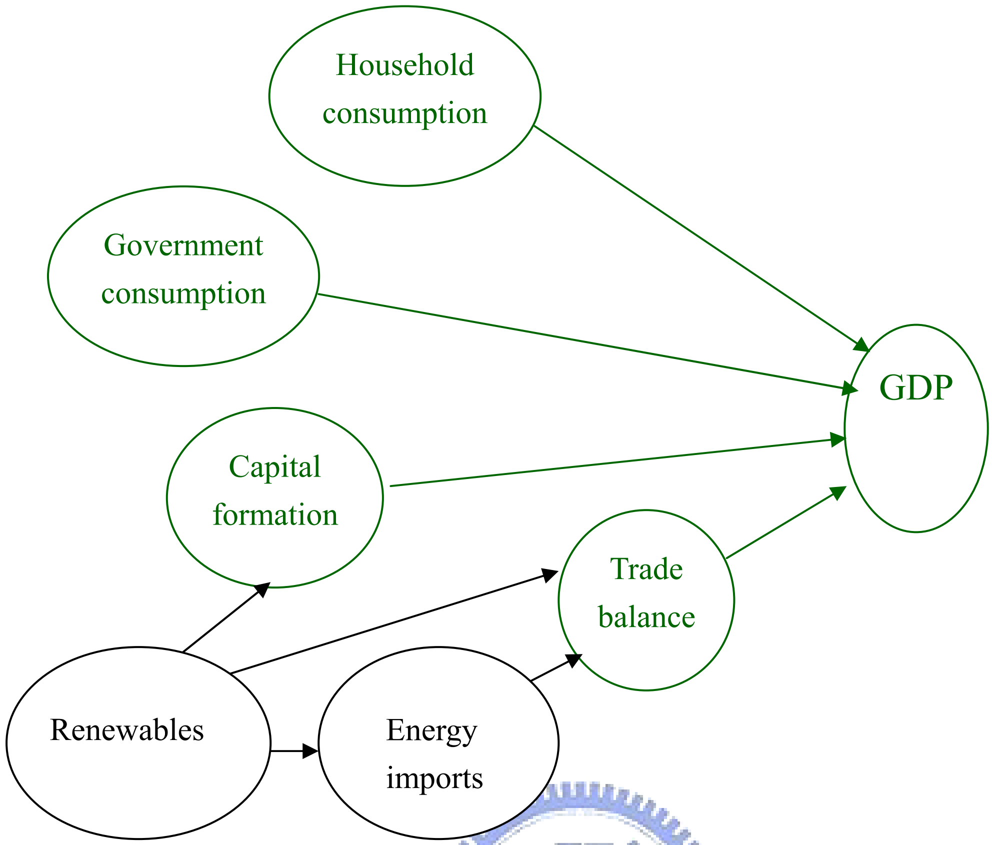

Figure 4. Conceptual framework of the influences of renewables on GDP

Motivated by Neoclassical equilibrium analysis, economists have developed a preference for market or price based environmental policies. There is much social and political resistance against the implementation of price policies in general, including those that directly affect consumers. These problems imply that environmental policies based on direct regulation or information provision should not be dismissed. A more important question is on which link of the mechanism renewable energy creates the economic impact.

Path analysis of Structural Equation Modeling (SEM) is used in this article to test the conceptual model specifying causal relationships between renewables and the other relevant variables. Path analysis can be used to determine whether the theoretical model accounts for the actual relationships in the observed data. The output of path analysis provides significance tests for specific causal paths. The significant links point out where the policies should be executed. Our sample profile contains 116 economies. The economic indicators of the 116 economies are retrieved from the World Bank Indicators online database.

The path coefficients are estimated using the maximum likelihood estimation in the structural equation modeling (SEM). Since our data such as GDP and the usage of renewables are of great differences in standard deviations, the estimation by SAS package may encounter difficulty in estimating the model. For example, the output may show that not all parameters are identified or near-zero standard errors for parameters estimate t tests. To avoid the problems of inputting raw data, we rescale the six variables so that they are all on approximately the same scale. Besides the analysis of rescaled raw data, we also conduct analysis performed on the covariance matrix to produce more valid standard errors for parameters estimates. Finally, G = GDP – C – I – Trade balance, so the variable of G has to be eliminated from our model to avoid multicollinearity. Our theoretical model is composed of the following equations:

$$GDP = a_1CF + a_2TB + a_3C + a_4EI + a_5RN + E_1, \quad (11)$$

$$CF = b_1RN + b_2C + E_2, \quad (12)$$

$$TB = c_1EI + c_2RN + E_3, \quad (13)$$

$$EI = d_1RN + E_4, \quad (14)$$

$$C = f_1 EI + f_2TB + E_5, \quad (15)$$

where *CF*: capital formation;

TB: trade balance;

C: consumption;

EI: energy imports;

RN: renewables;

$E1, \ldots, E5$: residuals.

In equation (11), GDP is influenced by capital formation, trade balance and consumption. In addition, from the DEA model in Chapter 3, it is possible that energy input may increase GDP, so energy import and renewables are included in equation 11. In equation (12), capital formation is influenced by renewables since theory predicts that increasing use of renewables would result in business expansion and thus capital could be accumulated. Also from the economic point of view, the following equations show that if income (Y) is not used in consumption, it would be used in savings, and savings could be translated into investment (I: capital formation).

$$AE = C+I, \tag{16}$$

$$AE = Y, \tag{17}$$

$$I = I(Y). \tag{18}$$

In macroeconomic theory, when the autonomous expenditure increases from C_0 to C_1, the aggregate demand (AE) increases from AE_0 to AE_1. The equilibrium output (Y) increases from Y_0 to Y_1 as a result. If I is a function of Y, I increases as C.

In equation (13), energy imports influence trade balance because trade balance equals exports minus imports. In addition, the theory proposed by Domac et al. (2005) suggesting that the use of renewables would result in import substitution by domestic produced renewable energy, and so trade balance would be increased by the use of renewables. Further more, if renewables could cause import substitution, the imports of energy should be reduced by the increase of renewables (equation 14). In equation (15), according to international trade theories, the domestic price of goods increased as same kind of goods are exported while the domestic price of goods decreased as same kind of goods are imported. Thus, trade balance (exports - imports) influences consumption through the changes of domestic prices. The imports of energy influence domestic energy prices and the consumption of energy and energy related products.

To sum up, to confirm the relationship between the increase of renewables and the increase of GDP, we need to test whether renewables could increase capital formation or trade balance. The rest of the paths are relevant economic relationships predicted by general economic theories. The initial SEM model is displayed in Figure 5.

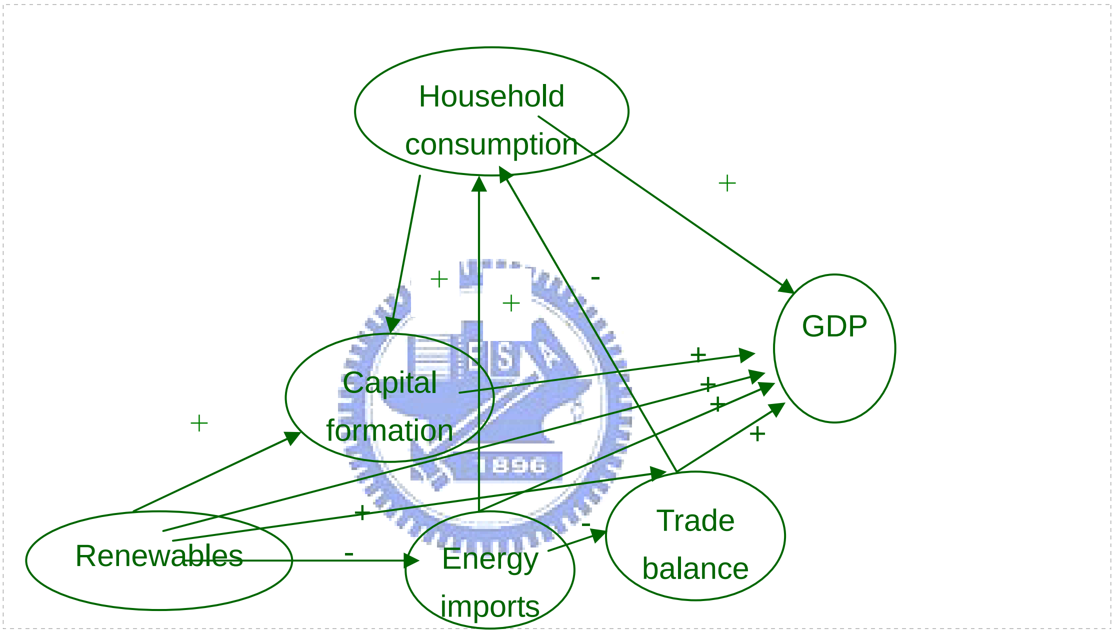

Figure 5. The initial SEM model

Table 22 shows the simple descriptive statistics for the six variables of GDP, capital formation, trade balance, energy imports, renewables and household consumption, including the means, standard deviations and correlations. The path coefficients are reported in Table 23.

Table 22. Summary of descriptive statistics for SEM model

Measure	Means	SD	GDP	Capital formation	Trade balance	Energy imports	Renew-ables	Consump-tion
GDP	310.975	113	1.000	0.985	-0.744	0.685	0.343	0.995
Capital formation	65.358	220.006	0.985	1.000	-0.671	0.686	0.426	0.966
Trade balance	0.236	493.798	-0.744	-0.671	1.000	-0.529	-0.174	-0.800
Energy imports	-0.243	107.854	0.685	0.686	-0.529	1.000	0.191	0.680
Renewables	113.319	327.367	0.343	0.426	-0.174	0.191	1.000	0.309
Consumption	190.547	775.74	0.995	0.966	-0.800	0.680	0.309	1.000

Note:
GDP = 2003 GDP / 10^9 (current US$)
Capital formation = 2003 Capital formation / 10^{11}(current US$)
Trade balance = 2003 Trade balance / 10^{10} (current US$)
Energy imports = 2003 Energy imports / 10^9 (kg of oil equivalent)
Renewables = 2003 Renewables × 10 (Mtoe)
Consumption = 2003 Consumption / 10^9 (current US$)

The maximal likelihood estimation results show goodness-of-fit indices are greater than 0.839. Bentler and Bonett's Normed Fit Index (NFI) is 0.942 indicating an acceptable fit of the model of the data. Bentler and Bonett's Non-normed Fit Index (NNFI) is 0.718 which is less desirable. Bentler's comparative fit index (CFI) is 0.944 indicating a relatively good fit. However, the χ^2-test appearing above is a large value of 90.973 with 3 degrees of freedom, which indicates that the model does not provides a good fitting of the real data. Although the chi-square test is a useful index, it is generally accepted that it should be interpreted with caution and supplemented with other goodness of fit indices. This is because the chi-square test can be influenced by factors in addition to the validity of the theoretical model such as departures from multivariate normality, sample size, and complexity of the model.

Table 23 shows that all the paths predicted in our model are significant at the 0.05 level except three paths. The three paths failing to reach the 0.05 significance level are the path between energy imports and GDP, the path between renewables and GDP and the path between renewables and trade balance. It is highly possible that since GDP equals the sum of capital formation, trade balance, consumption and government expenditure, the variances of the first three variables can already capture almost all of GDP variations. This may explain why the two paths (path between energy imports and GDP, path between renewables and GDP) are not significant.

Our theory predicts positive effects of renewables on capital formation and trade balance. The results show that renewables have a significant positive influence on capital formation but its influence on trade balance is not significant. All the signs of the significant paths are as the theory predicted excepting the path between energy imports and renewables. GDP is positively influenced by capital formation, trade balance and consumption. Capital formation is positively influenced by renewables. Energy imports influence trade balance negatively. In equation (15), according to international trade theories, the domestic price of goods increased as these kinds of goods are exported while the domestic price of goods decreased as these kinds of goods are imported. Therefore, trade balance (exports - imports) influences consumption through the changes of prices. The imports of energy influence consumption positively and trade balance influences consumption negatively as predicted.

However, the relationship between renewables and energy imports is significantly positive. Possible explanations are when an economy is in great demand of energy, it not only exploits more renewable energy but also imports more energy, so the two sources of energy tend to increase together. Combining the results that renewables do not have significant impact on trade balance and that renewables and energy imports move together, the data shows that renewables do not have import substitution effect and could not influence trade balance.

Table 23. Estimated path coefficients for the initial SEM model

Endogenous Variables	GDP	Capital formation	Trade balance	Energy imports	Consumption
Capital formation	1.284*** (35.192)				
Trade balance	0.167*** (27.871)				-0.960*** (-10.724)
Energy imports	0.003 (0.148)		-2.355*** (-6.406)		2.564*** (6.255)
Renewables	-0.005 (-0.778)	0.095*** (6.739)	-0.114 (-0.944)	0.063** (2.087)	
Consumption	1.194*** (113.6)	0.262*** (44.089)			

Note: sample size = 116
* represents significance at the 10% level;
** represents significance at the 5% level;
*** represents significance at the 1% level; and
numbers in the parentheses are t statistics.

To improve the fit of the present model, step-by-step modifications are made. Table 24 shows the rank order of the 10 largest normalized residuals and there are no absolute values of entries in the normalized residual matrix exceeding 2.000. It is clear that no new path could be added into the present model. It is statistically more desirable to drop non-significant paths than to add new paths. The three non-significant path coefficient estimates would be reviewed and dropped one by one.

Table 24. Rank order of the 10 largest normalized residuals for the initial SEM model

Row	Column	Residuals
Renewables	GDP	1.485
Consumption	Renewables	1.424
Renewables	Capital formation	1.297
Trade balance	Capital formation	0.787
Energy imports	Capital formation	0.295
Capital formation	Capital formation	0.275
Capital formation	GDP	0.240
Trade balance	GDP	0.194
Consumption	Capital formation	0.149
GDP	GDP	0.098

The modifications start with dropping the path with the smallest t-statistic, i.e., the path between energy imports and GDP. Figure 6 displays the revised SEM model 1. The path coefficient estimates are shown in Table 25.

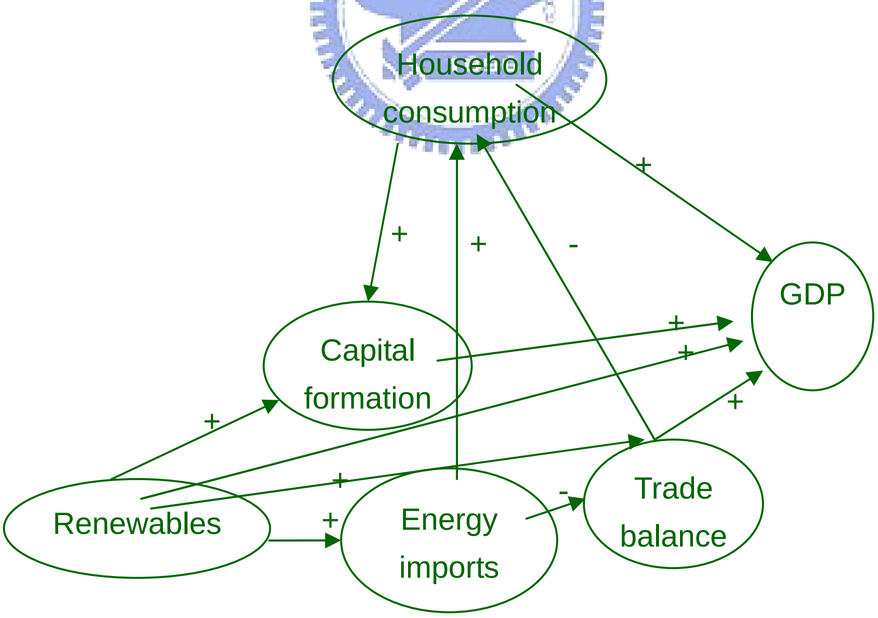

Figure 6. Revised SEM model 1

Table 25 shows that all the paths significant in the theoretical model are again significant at the 0.05 level. The two paths failing to reach the 0.05 significance level are again the path between renewables and GDP and the path between renewables and trade balance.

Table 25. Estimated path coefficients for revised SEM model 1

Endogenous Variables	GDP	Capital formation	Trade balance	Energy imports	Consumption
Capital formation	1.286*** (35.239)				
Trade balance	0.167*** (27.871)				-0.960*** (-10.724)
Energy imports			-2.355*** (-6.406)		2.564*** (6.255)
Renewables	-0.005 (-0.808)	0.095*** (6.739)	-0.114 (-0.944)	0.063** (2.087)	
Consumption	1.194*** (116.1)	0.262*** (44.089)			

Note: sample size = 116
* represents significance at the 10% level;
** represents significance at the 5% level;
*** represents significance at the 1% level; and
numbers in the parentheses are t statistics.

The least significant path in revised model 1 (the path between renewables and GDP) is dropped in Revised SEM model 2. Figure 7 displays the revised SEM model 2. The path coefficient estimates are showed in Table 26.

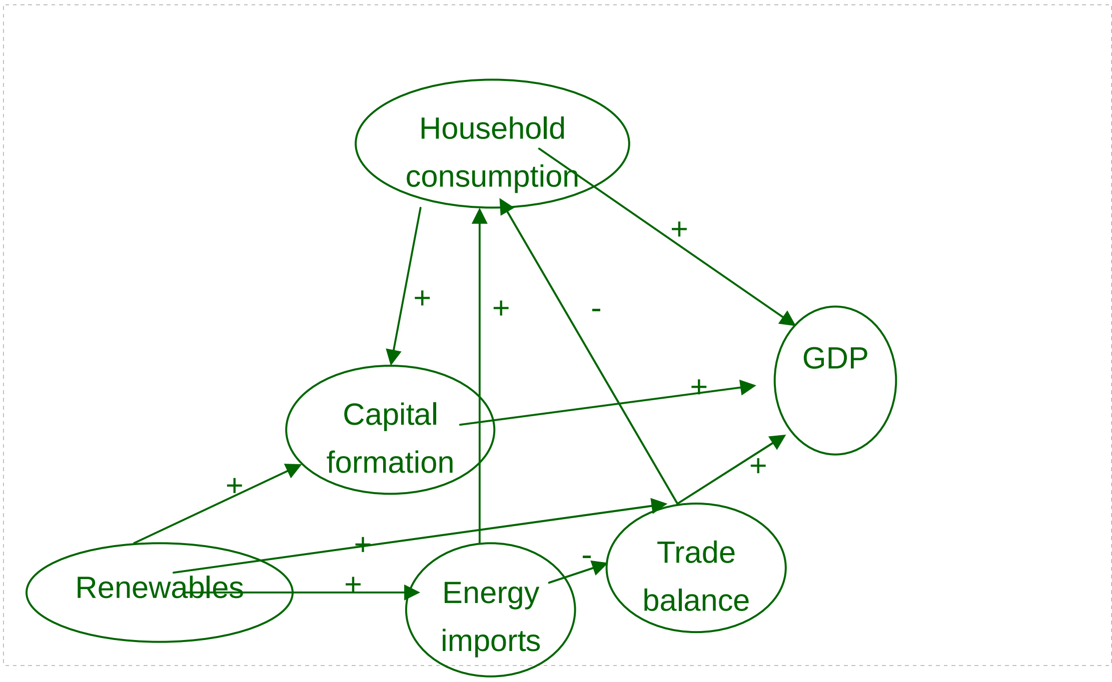

Figure 7. Revised SEM model 2

Table 26 shows all the paths significant in the revised model 1 are again significant at the 0.05 level. The only path failing to reach the 0.05 significance level is the path between renewables and trade balance.

Table 26. Estimated path coefficients for revised SEM model 2

Endogenous Variables	GDP	Capital formation	Trade balance	Energy imports	Consumption
Capital formation	1.264***				
	(40.792)				
Trade balance	0.169***				-0.960***
	(28.169)				(-10.724)
Energy imports			-2.355***		2.564***
			(-6.406)		(6.255)
Renewables		0.095***	-0.114	0.063**	
		(6.739)	(-0.944)	(2.087)	
Consump-tion	1.200***	0.262***			
	(132.3)	(44.089)			

Note: sample size = 116
* represents significance at the 10% level;
** represents significance at the 5% level;
*** represents significance at the 1% level;
and numbers in the parentheses are t statistics.

The only insignificant path in revised model 2 (the path between renewables and trade balance) is dropped in the final SEM model. Figure 8 displays the final SEM model. The path coefficient estimates are shown in Table 27.

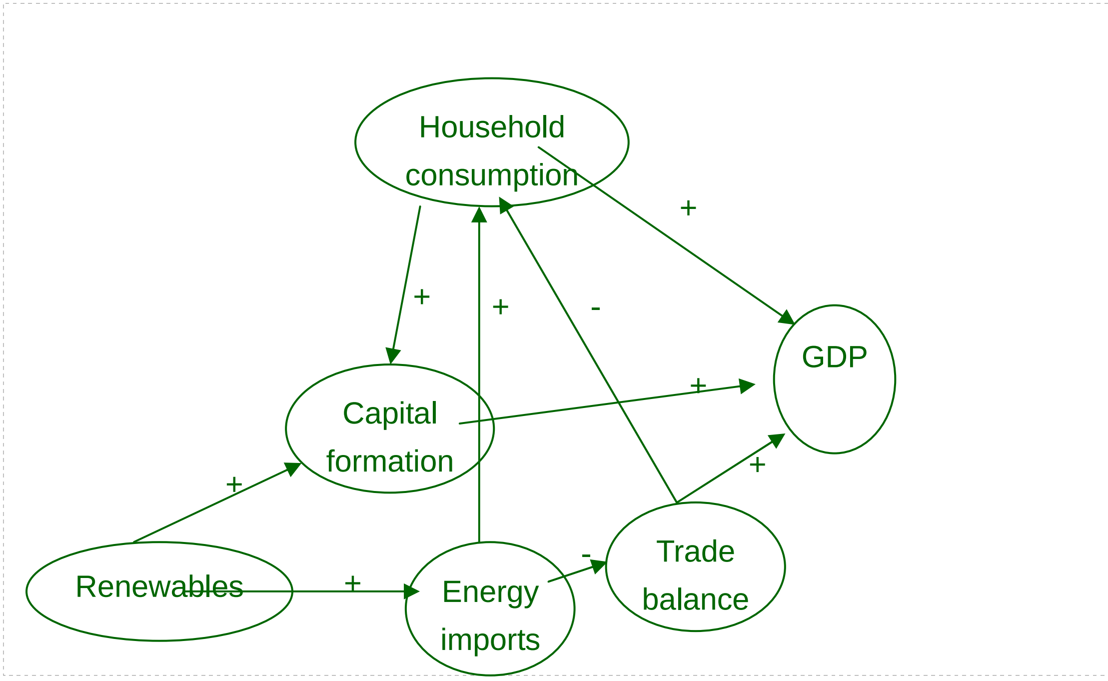

Figure 8. Final SEM model

Table 27. Estimated path coefficients for final SEM model

Endogenous Variables	GDP	Capital formation	Trade balance	Energy imports	Consumption
Capital formation	1.264*** (40.897)				
Trade balance	0.169*** (29.565)				-0.960*** (-11.763)
Energy imports			-2.422*** (-6.093)		2.564*** (6.408)
Renewables		0.095*** (6.789)		0.063** (2.087)	
Consumption	1.200*** (132.0)	0.262*** (45.614)			

Note: sample size = 116
* represents significance at the 10% level;
** represents significance at the 5% level;
*** represents significance at the 1% level;
and numbers in the parentheses are t statistics.

All the paths are significant in Table 27, and there are no further modifications that could be made. The mediating effect of capital formation is thus confirmed, i.e., capital formation is the variable that conveys the effect of increasing the use of renewables onto increasing GDP. Notice a single-headed arrow goes from renewables to capital formation, and that a separate single-headed arrow goes from capital formation to GDP. This indicates that renewables have only an indirect effect on GDP; renewables influence GDP by first influencing capital formation. The goodness of fit indices for the initial model, revised model 1, revised model 2, and final SEM model are displayed in Table 28.

Table 28. Goodness of fit indices for various models

	Chi-square	df	p	NFI	NNFI	CFI
Initial model	90.973	3	<0.0001	0.942	0.718	0.944
Revised model 1	90.994	4	<0.0001	0.942	0.791	0.944
Revised model 2	91.549	5	<0.0001	0.942	0.833	0.945
Final SEM model	94.288	6	<0.0001	0.940	0.858	0.943

As shown in Table 28, NNFI are improving from the initial theoretical model to revised model 1, from revised model 1 to revised model 2, and final SEM model has the best results. Although, the Chi-square values are not desirable, the Chi-square values are normally not essential (Hatcher, 1994).

Finally, we need to check the R^2 for each endogenous variable in the final model (table 29). The R^2 are as large as desirable. The R^2 of GDP, capital formation, and consumption are relatively high as we desired (0.9997 for GDP, O.951 for capital formation and 0.745 fro consumption). However, the R^2 of the trade balance and energy imports are relatively low (0.244 for trade balance and 0.037 for energy imports). These two R^2 numbers are obviously low due to the facts that there are other variables more significantly influencing the variables of trade balance than energy imports (for examples, exchange rate), and there are other variables more significantly influencing the variables of energy import than renewables (fro example, the demand and supply of crude oils). Since the factors influencing these two variables are not in the scope of this article, we will leave it like this and not including new variables in the model.

Table 29. R- square for each endogenous variable in final SEM model

GDP	0.9997
Capital formation	0.951
Trade balance	0.244
Energy imports	0.037
Consumption	0.745

The 10 largest normalized residuals of final SEM model are shown in Table 30. They are all below 2.000.

Table 30. Rank Order of the 10 largest normalized residuals in final SEM model

Row	Column	Residuals
Renewables	GDP	1.877
Consumption	Renewables	1.857
Renewables	Capital formation	1.717
Trade balance	Capital formation	1.292
Trade balance	Trade balance	-0.968
Trade balance	GDP	0.796
Renewables	Trade balance	-0.729
Consumption	Trade balance	0.678
Consumption	Consumption	-0.393
Consumption	GDP	-0.322

7. Concluding Remarks and Policy Implications

We use the DEA method to estimate the technical efficiency for the forty-five economies in the years 2001 and 2002 in Chapter 3. Increasing the share of renewable energy among total energy supply will significantly improve technical efficiency. It is worth noting that increasing the input of traditional energy decreases technical efficiency. For an economy to improve its technical efficiency, it is important not to increase the total input of energy. By substituting traditional energy with renewable energy, an economy's technical efficiency can be significantly improved. Thus, the hypothesis that renewable energy improves technical efficiency is confirmed if we take into account the effect of different categories of renewable energy.

We also verify the hypothesis that the use of renewable energy is very different in developed economies and developing economies. We use the status of OECD and non-OECD economies as a proxy variable for developed and developing economies respectively. We then compare the mean differences of OECD and non-OECD economies by ANOVA analysis and find that there are significant differences in some variables.

The TE is higher in OECD economies than in non-OECD economies. The share of renewable energy in total energy supply is higher in non-OECD (developing) economies than in OECD (developed) economies. If we neglect the controlling variables for TE, then these two results combined may lead to the incorrect conclusion that the OECD economies with lower renewable energy share have higher technical efficiency, and thus renewable energy has a negative effect on technical efficiency. It is vital to recognize that technical efficiency is significantly affected by the inputs and output. It is necessary to evaluate the effect of renewable energy on technical efficiency from economies of similar conditions. Therefore, we need to evaluate the effect of renewable energy on technical efficiency by controlling the variables of inputs and output. When the variables of inputs and output are treated as controlling variables in our hierarchical analysis, the results show that renewable energy has a positive effect on the technical efficiency. The share of geothermal, solar, tide, and wind fuel in renewable energy is higher in OECD economies than in non-OECD economies. The differences of renewable energy existing between developed and developing economies are thus confirmed.

The technical efficiency being significantly higher in OECD economies than in non-OECD economies may also explain why renewable energy does not have a significant effect on technical efficiency when we do the regressions separately for the OECD group and non-OECD group. The reason is that when we separate the two groups, each group becomes more homogeneous in technical efficiency, and the effect of renewable energy on technical efficiency becomes less obvious since the dependent variables are similar within the same group.

Having confirmed that increasing the use of renewables can significantly improve an economy's technical efficiency, we suggest that governments should adopt comprehensive strategies to promote the use of renewable energy. The European Parliament and Council Directive 2001/77/EC requires its member states to set the national target that the electricity produced from renewables should account for 7% in the overall electricity production by 2010. Individual state could set up a feasible objective for itself, for example, Lithuanian establishes the objective for renewables to account for 12% in its fuel mix by 2010 (Katinas and Markevicius, 2006). Governments should adopt institutional measures such as sponsoring the research on enhancing renewables utilization and legislative measures such as enforcing replacement of traditional fuels by renewables. Subsidies also provide economic incentives for enterprises and households to use renewables.

If we fix the total amount of traditional energy input, we could increase the technical efficiency of an economy by replacing traditional energy with renewable energy. However, to further increase technical efficiency, we could reduce both the traditional energy input and renewable energy input. The target traditional energy and renewable energy input are estimated by DEA in Chapter 4. Although many economies have set up national targets of renewable energy in total energy ratio to be achieved in the next few years, we achieve the new ratio of renewable energy in total energy after total adjustments. We find that the new ratios of renewable energy after total adjustments for each economy are not greater than before adjustments. That means that if we could reduce both traditional energy input and renewable energy input, there is no need to set up national target of renewable energy ratio. The reduction of traditional energy input and renewable energy input could lead to greater improvement in technical efficiency.

To sum up, there are two approaches to improve macroeconomic efficiency through energy policy: (1) when the traditional energy input could not be reduced, replace traditional energy input by renewables. (2) Reduce traditional energy input and renewable energy input. If both inputs could be reduced, the ratio of renewable energy in total energy does not need to be increased.

In order to understand the mechanism of how the use of renewables improves macroeconomic efficiency, we need to review the relationship between the increase of renewables and the increase of GDP, i.e., we need to test whether renewables could increase capital formation or trade balance.

We show that all the paths predicted in our theoretical model are significant except three paths: the path between energy imports and GDP, the path between renewables and GDP and the path between renewables and trade balance.

The results show that GDP is influenced positively by capital formation, trade balance and consumption. Moreover, capital formation is influenced positively by renewables and consumption. Energy imports influences trade balance negatively. Trade balance influences consumption negatively. The imports of energy influence consumption positively.

The path between energy imports and GDP and the path between renewables and GDP are not significant. It is highly possible that since GDP equals the sum of capital formation, trade balance, consumption and government expenditure, the variances of the first three variables can already capture almost all of GDP variations.

Our theory predicts positive effects of renewables on capital formation and trade balance. The results show that renewables have a significant positive influence on capital formation but its influence on trade balance is not significant. All the signs of the significant path are as the theory predicted excepting the path between energy imports and renewables.

Our results show that the relationship between renewables and energy imports is significantly positive. One of the possible explanations is: when an economy is in great demand of energy, it not only exploits more renewable energy but also imports more energy, so the two sources of energy tend to increase together.

Combining the results that renewables do not have significant impact on trade balance and that renewables and energy imports move together, the data shows that renewables do not have import substitution effect and could not influence trade balance.

To improve the fit of the model, we modify the initial theoretical model by dropping the three insignificant paths on by one. NNFI and other relevant indices are improving from the initial theoretical model to final SEM model. Although, the Chi-square values are not desirable, the Chi-square values are normally not essential (Hatcher, 1994). Thus, we confirm the positive relationship between renewable energy and GDP through the path of increasing capital formation but not the path of increasing trade balance.

Renewables Information has been published by IEA since 2002. The time series analysis should be more robust for the long-term effect of renewable energy when more annual data are available. As shown in most relevant productivity studies, the availability of information for capital stock limits the number of research objects in our study. In addition, the reasons why the share of hydro fuel energy in renewable energy reduces technical efficiency need further clarification.

Although the result of the chi-square test in the final SEM model is not good enough, it is generally accepted that the chi-square test should be interpreted with caution and supplemented with other goodness of fit indices. This is because the chi-square test can be influenced by sample size. Yet, in the final SEM model, it is quite impossible to increase the sample size. The number of economies in the world could not be easily increased, and the number of economies with sufficient data of all the relevant indicators could not be increased either.

The R^2 of the two endogenous variables of trade balance and energy imports are relatively low in the study results. These two R^2 are low obviously due to the facts that there are other variables more significantly influencing the variables of trade balance than energy imports, and there are other variables more significantly influencing the variables of energy import than renewables. Since the factors influencing these two variables are not in the scope of this article, we will leave it like this and not including new variables in the model.

The cost gap between renewables and traditional energy still exists. Having reviewed the merits of renewables, we should not forget that there are still obstacles to overcome to more utilize renewable resources. For example, Wamukonya (2007) review the effectiveness of solar home systems in Africa and finds that these systems are not cost effective and questions the wisdom of using public funds to support the systems. Anderson et al. (2004) also indicates that if renewable energy technologies are eventually to supply significant share of total energy supply, the energy storage problem has to be solved in advance. There seems to be a long way to go to fully utilize renewable resources.

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