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The Effect of Ecological Elasticity in Taiwan's Carbon Reduction Policies: The STIRPAT Model

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Abstract

The challenges from the climate change and the global warming have become one of the most important issues to solve in the world. Under the Kyoto Protocol, countries which have signed the Kyoto Protocol have faced the pressure of reducing greenhouse gas emissions. The two main policies for reducing carbon dioxide are "carbon tax" and "carbon trading". This research explores which policy will be more suitable for the society and economic environment of Taiwan. This research uses EIA database, the statistical data from the Taiwan Bureau of Energy, Ministry of Economic Affairs, and the data from AREMOS database from 1982 to 2010. The dependent variable is the emission of carbon dioxide, and the independent variables are premium diesel oil price index, population, GDP per capita and the squared term of GDP per capita. The research method is based on the Ordinary Least Squares to estimate the ecological elasticity in the STIRPAT model by analyzing the influence of the change of energy price to the change of the emission of carbon dioxide. From the empirical result, it was discovered that though the energy price and the emission of carbon dioxide was negatively correlated, the ecological elasticity was inelastic. As a result, carbon trading seems a more suitable policy for Taiwan.

Keywords: carbon tax, carbon trading, STIRPAT model, quantitative control, price control

1. Introduction

Recently, the threat posed by global warming and climate change is one of the world's greatest concerns. Under the regulation of the Kyoto Protocol, the signatory countries are all faced with the pressure of reducing the greenhouse gases. The Taiwanese government has set up the "Energy Saving and Carbon Reducing" directive and, afterwards, promoted further discussions about the policies related to this directive. Nowadays, there are two primary carbon-reducing policies in the global community: the first is the pricing "carbon tax" system, while the second is the amount-controlling "carbon trading" system. Therefore, the objective of this investigation is to examine whether the "carbon tax" system or the "carbon trading" system better caters to Taiwan's socio-economic environment. This investigation is conducted using the databases of the EIA, the AREMOS and the Bureau of Energy of the Ministry of Economic Affair. This study uses the data during 1982-2010 as sample groups. The dependent variable is the emission of the CO_2, and the independent variables are the price of the premium diesel, the size of the population, the GDP per capita and the square GDP per capita. This study adopts the ordinary least squares method to estimate the ecological elasticity of the STIRPAT model and analyzes the degree to which the energy prices in Taiwan influence the amount of the CO_2 emissions. According to the findings, although the energy prices and the amount of the CO_2 emissions are negatively correlated, the ecological price fluctuation is inelastic. Therefore, the amount-controlling carbon trading system is more suitable to be Taiwan's carbon reducing policy.

The Kyoto Protocol was signed in 1997, with the goal of maintaining the percentage of the greenhouse gases at a balanced level, to prevent the damage to the ecology on earth that is caused by climate change. With the regulatory power of the Protocol, it is believed that the emission of the greenhouse gases during 2008-2012 in all the signatory countries can be 5% fewer than those in 1990.

Among all the air pollutants that lead to climate change, CO_2 accounts for 58.8% of greenhouse gases (The World Bank, 2007). Huge amounts of the CO_2 accumulated in the atmosphere hinges the earth from cooling down, which gives rise to global warming and, hence, climate change. The global average temperature has risen to a historically high level, resulting in problems, such as flooding, drought, famine, and rise in sea level, etc, affecting all the living beings on earth. Thus, it is of vital importance in the global community to discover how to solve the problems related to climate change and global warming (Stern, 2008). Under the regulation of the Kyoto Protocol, the signatory countries are all faced with the pressure of reducing greenhouse gases. On the other hand, these countries also value the industries' potential of reducing emissions of greenhouse gases; those energy-consuming industries with great gas emissions are particularly targeted.

With the skyrocketing energy price, the threat of global warming and the pressure from the global community, the Taiwanese government has set up the "Energy Saving and Carbon Reducing" directive and, in the meantime, promotes further discussions about the policies related to this directive. The Executive Yuan has collaborated with the Council for Economic Planning and Development and other authorities concerned. They have drafted and approved the Strategic Plan for Energy Sustainability and the Guidelines for Energy Saving and Carbon Reducing as the main reference for all the other acts related to the sustainability. Related government divisions have started to realize the aforementioned directive in an effort to showcase the government's will to carry out the guideline-abiding approaches to gradually adjust the Taiwanese citizen's lifestyle and the domestic industrial structure. The Ministry of Finance has drafted the "Energy Tax Act". The Ministry of Economic Affairs drafted the Framework of "Taiwan's Renewable Energy Development Act, which was approved in 2009". The Environmental Protection Administration has drafted a "Greenhouse Gas Reduction and Management Act, which was passed in 2015". The act sets a mandatory reduction target for Taiwan's overall greenhouse gas emissions and paves the way for a carbon cap-and-trade system to be established in Taiwan. The Act aims to reduce Taiwan's greenhouse gas emission in 2050 to half of the volume emitted in 2005. In this way, the government showed determination in gradually adjusting the lifestyle of the Taiwanese people and transforming the domestic industrial structure via the guideline-abiding approaches. It is critical to figure out how to implement feasible, fair and effective carbon pricing policies and greenhouse gas reducing policies based on the principle of the "internalization of external costs".

Nowadays, there are two primary carbon-reducing policies in the global community: the first is the pricing "carbon tax" system, while the second is the amount-controlling "carbon trading" system. A flawless carbon tax system or carbon trading system can create a win-win situation for the environment and the economy. This study intends to discover whether the carbon tax system or the carbon trading system is more suitable for Taiwan by examining the correlation between the energy price index and the emissions of CO_2. Other than that, this study also includes the correlation between the population size and the CO_2 emission and also includes the correlation between the GDP per capita and the CO_2 emission. Therefore, this study will examine whether the "carbon tax" policy or the "carbon trading" policy will be more ideal for Taiwan's socio-economic environment. With thorough analysis, the author seeks to provide a reference for the authorities concerned when they implement related policies.

2. Theoretical Framework

2.1 Carbon Tax and Carbon Trading System

The positive aspect of the carbon tax system provides clear and transparent price information. Therefore, enterprises can carry out financial plans according to the statutory rate and also invest in carbon reducing facilities or technologies. However, the negative aspect of the carbon tax system is the difficulty to find the optimal tax rate. Without a specific tax rate, it is less likely to predict the amount of the emissions reduced in an industry. If the tax rate is too low, it would not provide enough incentives for the enterprise to reduce carbon emission; however, if the tax rate is set too high, it will have severe impact on the domestic economy.

The positive part of the carbon trading system is that clear objectives and specific amount of emissions to be reduced are stated beforehand, so it is easier to achieve the goals. The negative part of the carbon trading system is the difficulty to decide an optimal carbon quota for trading. If the quota is too large, the enterprises would have fewer incentives to develop carbon-reducing technology or to use substitute energy resources. On the other hand, the price information of the carbon trading system is unclear. Consequently, if the trading is not well regulated, the market might be manipulated.

2.1.1 Carbon Tax System

Carbon tax is levied on carbon emission. The purpose of this tax system is to alleviate global warming, reduce pollution, and provides incentives to use substitute energy and to protect the environment. Generally speaking, in

order to expand the tax base, carbon tax rate are usually set at a lower level. In this case, all the carbon-emitting economic activities are leviable.

The positive aspect of the carbon tax system is the clear price information provided. Enterprises can draw up and carry out their financial plans with accordance to the statutory tax rate and also invest in carbon reducing facilities or technologies. With proper design of the carbon tax system, carbon emission can be lowered. Besides, with tax revenue, the government can decrease the tax rates of other tax items, invest in the investigation and development of carbon-reducing technology or invest in green industries. Regarding the fiscal revenue of the government, when the carbon trading system is applied, the government earns revenue only from auctioning and trading the emission quota; nevertheless, under the carbon tax system, the government will gain long-term and steady fiscal income. Moreover, the imposition of the carbon tax can involve as many taxpayers as the entire population in the country, whereas, under the carbon trading system, the targets are limited to those carbon-emitting units.

The negative aspect of the carbon tax system is the difficulty to find the optimal tax rate. Without a specific tax rate, it is less likely to predict the amount of the emissions reduced in an industry. If the tax rate is too low, it would not provide enough incentives for the enterprise to reduce carbon emission; however, if the tax rate is set too high, it will have severe impact on the domestic economy. The imposition of the carbon tax is likely to draw backlash against the government. Considering the possible outcome of the elections, the policy-makers normally would not impose more tax. On the other hand, the imposition of the carbon tax depends on each country. It is difficult that all the countries in the globe agree on a common tax policy, even though climate change is a global environmental issue.

2.1.2 Carbon Trading System

Under the carbon trading system, the corresponding administrative department controls the total amount and the trading system of carbon emissions so as to fulfill the goal of reducing carbon emission. The idea is that, after determining a specific amount of total carbon emission, the administrative department then gives out carbon emission permits to enterprises through auctions or distribution of quotas. However, enterprises have different marginal costs of carbon reduction; those with lower marginal costs of carbon reduction can produce more carbon and even sell the remaining quota to those with higher marginal costs. Meanwhile, for the enterprises with higher carbon reduction costs, buying quota from others is cheaper than reducing carbon emissions themselves. For the economy, with the control of total amount of carbon emission, some enterprises can save the spending on carbon emission, while other enterprises can earn profits by selling unused quota. In this way, a carbon trading market is created.

The positive part of the carbon trading system is that clear objectives and specific amount of emissions to be reduced are stated beforehand, so it is easier to achieve the goals. For example, according to Kyoto Protocol, within 2008-2012, all the signatory countries ought to reduce 5% of the amount of greenhouse gases emitted in 1990. Apart from CO_2, there are other greenhouse gases that may lead to global warming, such as CFCs. Compared with the carbon tax system, the emissions trading system is better regarding the management of other greenhouse gases. Considering the economic and industrial benefits, the emissions trading system is ideal: a well-developed carbon trading system with plenty of participants allow the enterprises to decrease the emission reduction to the minimum. Also, compared with the carbon tax system, the carbon trading policy would be more accepted in the private sector because the enterprises can gain benefits through the effort of reducing carbon emissions or through selling the unused emission quota. On the other hand, for the enterprises, the inter-departmental movement of the resources is far more acceptable than directly paying taxes to the government. Besides, the carbon trading policy can automatically adjust depending on the inflation rate, whilst carbon tax policy is unable to do so.

The negative part of the carbon trading system is the difficulty to decide an optimal emission quota for trading. If the quota is too large, enterprises would have fewer incentives to develop carbon-reducing technology or to use substitute energy resources. The market prices of the carbon trading are unstable, and the price information is unclear. For example, under the circumstances of economic growth, increasing energy price or strict control of total amount, the price of carbon emission will rise. On the contrary, under the circumstances of economic recessions, low energy price or less control on the total amount of carbon emission, the price of carbon emission will fall. The best known case took place in the European Union. The emissions trading system allowed too much quotas for carbon emission. As a result, the price of carbon emission dropped 60% in 2006. On the other hand, if the carbon trading system is not well regulated, it can be manipulated through lobbying, price rigging and bribery, etc.

The carbon trading system is backed up by the principle of the Coase theorem. The theorem states that, when there are external costs, the property right belongs to the contaminators, such as the enterprise, and those who are contaminated, such as the general public. Also, according to the theorem, when the transaction costs are low, the government should not interfere in the externality issues, it only needs to clarify the ownership of the property right and lower the transaction costs during the negotiations between the contaminators and the contaminated parties. Through the negotiations between the contaminators and the contaminated parties, the external costs can be internalized. In this way, the degree of contamination will be maintained at the optimal amount of emission and thus leads to maximum social welfare (Coase, 1959).

The current situation of the export market of Taiwan's carbon trading and the situations in other competing countries can be seen in Table 1 and Table 2. Although the EU, California-USA, Korea, Tokyo-Japan and China varied in societal, economical and environmental conditions, they have established different kinds of carbon trading system. Nonetheless, generally speaking, each system is made after proper legislation: they determine clear goals and timetables of reducing carbon emission and connect the domestic carbon trading market to the international one.

Table 1. Current situation of Taiwan's export market of carbon trading system

Country	**Reason**	**Timetable**	**Regulated industries**	**Distribution of emission permits**	**Goal**
EU	To reach the CO_2 reduction goals of Kyoto Protocol	Phase I：2005-2007 Phase II：2008-2012 Phase III：2013-2020	Energy industry, metallic industries, mining industries, paper-manufacturing industries and pulp industries. First stage manufacturers plus chemical manufacturers, aluminum industries, aviation industries, and large food manufacturing companies. Second stage manufactures plus petrochemical industries and ammonia plants.	Phase I：95% is free Phase II：90% is free Phase III：40% is free	Reduce 20% of the total emission (compared to 1990)
California-USA	Already has the experience of solving the CO_2 emissions problem	Phase I：2013-2014 Phase II：2015-2017 Phase III：2018-2020	The industrial department and energy department with an annual amount of CO_2e emission that exceeds 25,000 tons. The first stage manufacturers plus the transportation department, construction companies and commercial fuel with an annual amount of CO_2e emission that exceeds 25,000 tons.	Phase I：100% is free Phase II：50% is free Phase III：30% is free	The total amount of greenhouse gas emission in 2020 will be 40-45% less than the BAU of the current year.

Sources: Taiwan Research Institute (2012)

Table 2. Current situation of the carbon trading system of Taiwan's competitors

Country	Reason	Timetable	Regulated industries	Distribution of emission permits	Goals
Korea	To connect to the global community and improve the energy efficiency.	Phase I：2015-2017 Phase II：2018-2020	The enterprises with an annual CO_2e emission of more than 125,000 tons and the facilities with an annual CO_2e emission of more than 25,000 tons.	95% is free.	The total amount of greenhouse gas emission in 2020 will be 30% less than the BAU of the current year.
Tokyo-Japan	To reach the CO_2 reduction goals of Kyoto Protocol.	Phase I：2010-2014 Phase II：2015-2019	The enterprises and the facilities that consume annually 1,500 KLOE of fossil fuel energy, heat and electricity.	The average amount of CO_2 emissions minus carbon reducing factors.	The total amount of greenhouse gas emission in 2020 will be 25% less than the BAU of the current year.
China	China's 12th Five-Year Plan and its industries in transformation and its will to establish its own carbon trading platform.	Phase I：2013-2014 Phase II：2015-2020	The metallic industries, chemical industries, electricity powered and thermal powered petrochemical industries, oil and gas extraction industries and civil housing construction in 7 test-run cities (Beijing, Guangdong, Shanghai, Tianjin, Chongqing, Hubei and Shenzhen). The metallic industries, chemical industries, electricity, thermal power, petrochemical industries, oil and gas extraction and civil housing construction in all China.	Mainly gratuitous distribution and, in some cases, auctions.	The total amount of greenhouse gas emission in 2020 will be 40-45%% less than the BAU of the current year.

Sources: Taiwan Research Institute (2012), Council for Economic Planning and Development (2009), Chung-Hua Institution for Economic Research (2009).

2.2 STIRPAT Model

In the past, it was the general belief that human beings had drastically changed the environment on earth. However, people had limited knowledge about the factors responsible for these changes; for example, humankind is actually one of the contributing factors to the environmental changes. This phenomenon was caused by the lack of advanced analytical tools. Nowadays, the world-renown IPAT model and its derivative, STIRPAT model, can be used to examine and analyze the contributing factors of the environmental changes.

The IPAT model is lettering of the formula, I = P*A*T. The letter I means the human impact on the environment, which is a product of (P), population, (A), affluence, and (T), technology. With the assumption that an increase in human population will also increase human impact on the environment, the IPAT model is developed from an accounting format to create a formula to explain that human impact on the environment is affected by the population, affluence and technology of the human beings (Commoner, 1972, 1973, 1992; Ehrlich, 1968; Ehrlich & Holdren, 1971, 1972; Holdern & Ehrlich, 1974).

However, Bernstam (1990) and Dietz and Rosa (1994) criticized that the IPAT model was a random model without definition. They suggested that the environmental change was a hypothesis testing based on the idea that the human beings were the leading affecting factors. Nevertheless, that model still provides the scholars with an effective framework of investigation. The negative affecting factors of human's economic activities are the population and the affluence. Technology, on the contrary, lower the negative effects of those factors.

Dietz and Rosa (1997) re-designed the IPAT model and proposed the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model. The STIRPAT model is shown below:

$$I_{it}=aP^{b}_{it}A^{c}_{it}T^{d}_{it}e_{it} \quad (1)$$

In the equation, (a) is a constant to scale the model. The three drivers, (b), (c), (d), are the exponents. (I) stands for human impact on the environment. (P) means population. (A) represents affluence. (T) means technology. (e), error term, is a random residual. The subscripts (i) indicate different countries, while the subscripts (t) refer to the time. (I), human impact on the environment is measured in the quantity of CO_2 emissions. (P), population is measured in the population size of a single country. (A), affluence, is measured in GDP per capita. (T),

technology, represents the required technology to lower the environmental burden. If we input the aforementioned variables into the natural logarithm function, the new function will be the following model.

$$ln\ I_{it}=a+b(ln\ P_{it})+c(\ln A_{it})+d(\ln T_{it})+\ln e_{it.} \quad (2)$$

In the model, (I) represents CO_2 emissions. (P) is the population of one single country. (A) is the GDP per capita, (T) is the required technological advancement to lower the environmental burden. (a) is the constant. (b) is the coefficient to be estimated of ln P_{it}. (c) is the coefficient to be estimated of ln A_{it}. (d) is the coefficient to be estimated of ln T_{it}.

The evaluation of the STIRPAT on Ecological elasticity provides detailed explanation about the changes that the environment-affecting factors bring to Earth. The model not only determines the environment-affecting factors with scientific approaches, but also points out the degree to which each factor influence the environment. Moreover, the coefficients in the STIRPAT model can be considered to be Ecological elasticity or the degree to which the environment is affected due to the any change in the environment-affecting factors (York, Rosa, & Dietz, 2003).

York et al. (2003) points out that the coefficients in the STIRPAT model can be considered to be ecological elasticity, that is, the percentage change of CO_2 emissions triggered by 1% change of the environment-affecting factors.

2.3 Environmental Kuznets Curve

Recently, many scholars of environmental economics have been investigating the correlation between economic development and the environmental burden. They have discovered that there is a certain correlation between GDP and environmental burden. The statistical analysis shows that there is an inverted-U relationship between the GDP per capita and environmental burden. According to the analysis, when the GDP per capita rises, the environmental burden also rises. However, when the GDP per capita reaches a turning point, the environmental burden will decrease as GDP per capita grows. Although the turning points of different pollutants may vary, the turning points in most cases are around GDP $8000 (Grossman & Krueger, 1995).

The Environmental Kuznets Curve describes that, when the economy is growing, the environmental condition will, first, deteriorate, and then as the GDP per capita reaches the turning point, the environmental condition will improve; thus, the curve forms the shape of an inverted U. There are two different theories regarding the inverted U shaped relationship between the environmental burden and the GDP per capita. First theory states that environmental condition is a luxury good. When the economy is growing, people are less likely to invest money in improving the environment. As a result, the environmental condition deteriorates. However, when the GDP per capita rises continually and reaches the turning point of the Environmental Kuznets Curve, people are more likely to spend money on the improvement of the environment. As a consequence, when the GDP per capita passes the turning point, the environmental burden will fall. The second theory argues that the inverted-U relationship between the GDP and the environmental burden insinuates a structural change in the domestic industries, namely, a transformation from the agricultural society to the industrial society and then to service-oriented society. During the transformation from an agricultural society to an industrial society, rapidly growing consumption gives rise to mass-production and consequently increases the environmental burden. Afterwards, from an industrial society to a service-oriented society, the highly polluting secondary industries are replaced by the less polluting tertiary industries; as a result, the environmental burden decreases. Regarding the idea of Environmental Kuznets Curve, some scholars remain doubtful toward its robustness; for example, Managi (2006) argues that the inverted-U curve occurs only under the premise of certain assumptions.

3. Research Hypothesis and Method

3.1 Research Framework and Hypothesis

This study analyze with Ordinary Least Squares. According to IPAT model:

$$I=P*A*T \quad (3)$$

The human impact on the environment (I) is the product of the population (P); affluence (A); technology (T) function (Commoner, 1972; Ehrlich & Holdren, 1971). In order to apply this model in the hypothesis testing, Dietz and Rosa (1994) re-designed the original model and created the STIRPAT model:

$$I_i=aP^b{}_iA^c{}_iT^d{}_ie_i \quad (4)$$

This multiplication model can be transformed into a linear estimating methodas follow:

$$log\ I_i=a+b(logP_i)+c(logA_i)+e \quad (5)$$

The error term (e) adjusts the variable, (T). Moreover, according to some article of environmental economics, a more common estimating function that complies with the hypothesis of Environmental Kuznets Curve (York et al, 2003):

$$log\ I_i=a+b(logP_i)+c(logA_i)+d(logA_i)^2+e \quad (6)$$

The assumption of the Environmental Kuznets Curve emphasizes that, when the GDP per capita starts to grow, the environmental conditions deteriorate. Afterwards, as the GDP per capita rises to the turning point, the environmental conditions start to improve; this insinuates c>0 and d<0. Grossman & Krueger (1995) has discovered that, even in poverty-stricken countries, the increase of GDP still comes with the deterioration of the environmental conditions, but when people's income reaches a certain level, the economic growth will lead to an improvement in the quality of air and water. However, regarding the idea of the Environmental Kuznets Curve, some scholars question its robustness. Apart from the GDP per capita, CO_2 emissions and the population size are also positively correlated (Dietz & Rosa, 1997; Shi, 2003), which insinuates b>0.

The model of this study includes the energy price index that replaces the original variable, (T) (Carol & Arvid, 2010). The new regression model is shown below:

$$ln(I_j)=\beta_0+\beta_1(lnEnergy\ Price\ Index_j)+\beta_2(lnP_j)+\beta_3(lnA_j)+\beta_4(lnA_j)^2+\varepsilon_j \quad (7)$$

In the equation, *(I)* means CO_2 emissions. (*Energy Price Index)* means the energy price index. (*P)* is the population. *(A)* means the GDP per capita. The subscript *(j)* signifies the time range of 1982-2010.

The prediction of this study is $\beta_1<0$, which insinuates that people will consume less energy due to the rising energy price index, and, thus, CO_2 emissions decreases. β_1 can be considered to be the elasticity of CO_2 emissions over the energy price. $\beta_2>0$ is another prediction of this study because the bigger the population size is, more energy will be consumed; this means that CO_2 emissions increase. Lastly, this study predicts that the GDP per capita is a quadratic relationship. That is to say, when the level of GDP per capita is lower, the increment of GDP per capita and CO_2 emissions will be positively correlated, according to the prediction of this study. However, when the level of GDP per capita is higher, this study predicts that the increment of GDP per capita and CO_2 emissions will be negatively correlated, complying with the inverted U-shaped Environmental Kuznets Curve and insinuating $\beta_3>0$ and $\beta_4<0$. Therefore, there are three hypothesis proposed in this study as shown below.

Hypothesis 1: $\beta_1<0$, the energy price index and CO_2 emissions are negatively correlated.

Hypothesis 2: $\beta_2>0$, the population size and CO_2 emissions are positive correlated.

Hypothesis 3: $\beta_3>0$, $\beta_4<0$, the relationship between the GDP per capita and CO_2 emissions complies with the inverted U-shaped Environmental Kuznets Curve Hypothesis.

3.2 Data and Samples

The information selection process of this study starts from acquiring data. Taiwan's CO_2 emission data during 1980-2010 are acquired from the U.S. Energy Information Administration. The data of energy price indexes during 1982-2011 are acquired from the MOEA Economic Statistics Datebase of the Bureau of Energy, Executive Yuan. The data regarding Taiwan's population and GDP per capita during 1951-2011 come from the AREMOS of the Taiwan Economic Data Center. The next step is to find the intersection of the time periods. The study uses the data during 1982-2010 as the samples; that is to say, there are 29 final samples of the study.

3.3 Definition of Variables and Measurement

3.3.1 Dependent Variable

According to the definition of the STIRPAT model, the dependent variable is the natural logarithm of (I), the human impact on the environment. This study adopts the measuring approach of Carol and Arvid (2010), using the natural logarithm of quantity of CO_2 emission to measure the natural logarithm of the human impact on the environment. The data of CO_2 emissions comes from the International Energy Statistics Database of the US Energy Information Administration, and the measurement is in million tons.

3.3.2 Independent Variable

According the method of Carol & Arvid (2010), the three independent variables of this studies are the natural logarithm of the energy price index, the natural logarithm of the population size and the natural logarithm of the GDP per capita. According to the Bureau of Energy, Ministry of Economic Affairs, the main energy price indexes are those of premium gasoline, premium diesel, fuel oil, natural gas, household electricity and industrial electricity. This study finds a representative energy price index according to the correlation coefficient between

each energy price index and CO_2 emissions. Analyzing based on the results of Pearson correlation coefficient analysis shown in Table 3, the study discovers that the premium diesel index and CO_2 emissions have a correlation coefficient of 0.74, which is the largest. Therefore, the study adopts the energy price index of the premium diesel to represent the energy price index, and it is measured based on the exponent of 2006=100. The population data comes from the AREMOS of the MOEA Economic Statistics Database, and its measurement is in each person. The data of GDP per capita is acquired from the AREMOS of the MOEA Economic Statistics Database, and its measurement is in New Taiwan Dollars.

Table 3. Pearson correlation coefficients analysis

	premium gasoline	**premium diesel**	**fuel oil**	**natural gas**	**household electricity**	**industrial electricity**	**CO_2 emissions**
premium	1.0000	0.8409	0.8631	0.7488	0.3961	0.3988	0.3807
gasoline		<.0001	<.0001	<.0001	0.0334	0.0321	0.0416
premium diesel	0.8409	1.0000	0.9597	0.7889	0.5023	0.5165	0.7381
	<.0001		<.0001	<.0001	0.0055	0.0041	<.0001
fuel oil	0.8631	0.9597	1.0000	0.8562	0.5213	0.5479	0.6839
	<.0001	<.0001		<.0001	0.0037	0.0021	<.0001
natural gas	0.7488	0.7889	0.8562	1.0000	0.6799	0.7333	0.5765
	<.0001	<.0001	<.0001		<.0001	<.0001	0.0011
household	0.3961	0.5023	0.5213	0.6799	1.0000	0.7589	0.5590
electricity	0.0334	0.0055	0.0037	<.0001		<.0001	0.0016
industrial	0.3988	0.5165	0.5479	0.7333	0.7589	1.0000	0.3425
electricity	0.0321	0.0041	0.0021	<.0001	<.0001		0.0690
CO_2 emissions	0.3807	0.7381	0.6839	0.5765	0.5590	0.3425	1.0000
	0.0416	<.0001	<.0001	0.0011	0.0016	0.0690	

Pearson Correlation Coefficients, N = 29
Prob > |r| under H0: Rho=0

4. Result

4.1 Descriptive Statistics

The priority of the investigation is to understand the descriptive statistics, such as the mean, the standard deviation, the minimum and the maximum, of the dependent and independent variables. Through these data, the complete information can be discovered (as shown in Table 4). In order to explain the idea of elasticity, it is necessary to find the natural logarithm of all the data before the positive analysis.

Table 4. Descriptive statistics of variables (1982-2010)

Variable	Samples	Mean	Standard deviation	Minimum	Maximum
Premium diesel price index	29	63.75586	21.43299	42.19000	120.68000
Population size	29	21227617	1486566	18354855	23140948
GDP per capita	29	348860	158756	105758	588317
Square GDP per capita	29	1.46038E11	1.09228E11	1.11848E10	3.46117E11
CO_2 emissions	29	85.88483	53.01363	14.03000	165.15000

Note. 1. The benchmark of premium diesel price index: 2006=100; 2. Units of the population: per person; 3. Units of the per capita GDP: NT dollar; 4. Units of the CO_2 emissions: One million tones.

4.2 Regression Analysis

This study analyzes the relationship between CO_2 emissions and other variables, such as the energy price index, the population size, the GDP per capita, and square GDP per capita, by using the Ordinary Least Squares (OLS). The regression analysis of the model in this study is show in table 5.

Table 5. Parameter estimation

variables	Coefficient	t Value	Pr > |t|
Intercept	-165.32004	-4.38	0.0002
(ln Premium diesel price index)	-0.28365	-2.81	0.0096
(ln Population size)	13.39565	6.10	<.0001
(ln GDP per capita)	-8.56716	-3.41	0.0023
(ln GDP per capita)^2	0.33131	3.26	0.0033

The Adjusted R-Square is 0.9914. That means the model of this study has great explanatory ability. As shown in table 5, there is a positive correlation between the population size and CO_2 emissions. At the 95% confidence level, it is statistically significant; that is to say, the population growth will lead to an increase in CO_2 emission.

The relationship between GDP per capita and CO_2 emission forms a U-shape; that is to say, GDP per capita and CO_2 are negatively correlated, while the square GDP per capita and CO_2 emission are positively correlated. At the 95% confidence level, it is statistically significant. That is, as GDP per capita begins to rise, CO_2 emission will start to fall, but, when GDP per capita rises to a certain level, CO_2 emission will start to rise; this does not comply with the EKC hypothesis. It is deduced that, because Taiwan's GDP per capita is based on high energy-consuming industries, an increase in the GDP per capita insinuates more pollution. As a consequence, the GDP per capita and CO_2 emissions have a U-shape relationship instead of the inverted U-shape of the EKC hypothesis. On the other hand, the energy price index and CO_2 emission are negatively correlated. At the 95% confidence level, it is statistically significant. It means if the energy price index rise, CO_2 emissions will fall.

York et al. (2003) points out that the coefficients in the STIRPAT model can be explained as the ecological elasticity. In this study, the ecological elasticity regarding the energy price index is -0.28. The -0.28 ecological elasticity means that Taiwan's CO_2 emission is inelastic. That is, each 1% increase in the energy price, only 1% of CO_2 emission is reduced Since CO_2 emissions are inelastic to the energy price change, the amount-controlling carbon trading policy is more effective regarding reducing CO_2 emission in Taiwan.

5. Conclusions and Implications

5.1 Conclusions

This study has three major findings. First, when the energy price rises, the CO_2 emission fall. However, the absolute value of the coefficient, $ß_1$, is <1, so it is inelastic; that is to say, when the energy price rise for 1%, CO_2 emissions fall for less than 1%. As a result, the carbon trading policy is better than the carbon tax policy. Second, the bigger the population, the higher CO_2 emission. As for the relationship between the GDP per capita and CO_2 emissions, they have a U-shaped relationship; this means that, at first, an increase in the GDP per capita would decrease CO_2 emissions, but, when GDP per capita exceeds a certain level, CO_2 emission will start to rise.

According to this study, in the case of Taiwan, CO_2 emissions and the population size are positively correlated, while CO_2 emissions and the energy price are negatively correlated. However, the study discovers that the increase in the energy price would not have an effective impact on Taiwan's CO_2 emission, for the ecological elasticity of the energy price is -0.28, which means it is inelastic. That is to say, when the energy price rises for 1%, CO_2 emissions are reduced for less than 1%. Therefore, in order to effectively reduce Taiwan's CO_2 emission, the amount-controlling carbon trading policy is more advantageous than the price-controlling carbon tax policy.

5.2 Managerial Implications

Because the absolute value of the ecological elasticity of the energy price is less than 1, it is more advantageous to adopt the amount-controlling carbon trading policy. Under the carbon trading system, those governmental departments that emit huge amounts of carbon will be forced to reduce their emissions; otherwise, the costs will be extremely high and, thus, affect its benefits. Moreover, the carbon trading provides incentives for the internalization of the externalities and, hence, provides more social welfare. The ecological elasticity of the energy price is -0.28, and the absolute value of it is less than 1. It means that the price-controlling carbon-reducing policy is not effective. Each time when the energy price rise for 1%, less than 1% of CO_2 emissions is reduced. The reason why the absolute value of the ecological elasticity of the energy price is less than one is that the characteristics of the energy consumption is similar to those of the basic food consumption; because it is a basic need, even when the price rises, there is little reduction in the quantity demanded.

The absolute value of the ecological elasticity of the energy price is less than 1. Therefore, the amount-controlling carbon trading policy will be the better option. The idea of the carbon trading system is that

each department or carbon-emitting unit has its own emission quota and is allowed to purchase emission permits within a certain quota. If CO_2 emissions exceed the quota, these carbon-emitting units need to purchase the quota from others. The department that is most efficient in reducing CO_2 emissions is able to produce CO_2 within the limit. Therefore, those major carbon-emitting governmental departments, such as Taiwan Power Company, CPC Taiwan and China Steel, are forced to reduce their CO_2 emission; otherwise, the costs will be extremely high so as to affect the benefits. If the public sector can improve in reducing CO_2 emission, the government can further cooperate with the private sector and help reduce CO_2 emissions of the enterprises. Moreover, the carbon trading policy will encourage the development of the green industries. In this way, this kind of policy provides incentives so as to internalize the externalities and increase the social welfare.

The second finding of this study is that the carbon trading system creates an elimination mechanism. This mechanism can transform Taiwan's industrial structure and, under these circumstances, the green industries will bloom. The green industries can assist other industries in reducing CO_2 emissions or can simply sell their emission permits to gain profits or raise the adding value of their products. In this way, a benign circle is formed. This effect might raise a question for Taiwan, which is a country that depends greatly on exports (if the prices are too high, the quantity exported will decrease): How to manufacture products with high adding value when the energy and power costs soar drastically under the carbon trading system. Energy consumption is necessary for production, so enterprises that manufacture products with high adding value will be more likely to survive. On the contrary, those enterprises that manufacture products with low adding value will be less likely to survive because of the high price caused by the failure to lower energy costs or the price of emission permits. Therefore, the carbon trading system will create an elimination mechanism in Taiwan, and, thus, transform Taiwan's industrial structure, benefiting the green industries.

Last but not least, all the carbon-trading countries implemented the carbon trading system after proper legislation and establishment of clear goals and timetable. These countries also connected their domestic carbon-trading market to the international market. Taiwan can use the foreign examples as a reference and develop the carbon trading system that best caters to Taiwan's conditions.

Although the European Union, California-USA, Korea, Tokyo-Japan and China have different socio-economic characteristics, and thus designed different carbon trading system. However, generally speaking, each country implements the carbon trading system after proper legislation and the establishment of clear goals and timetable. These countries also connect their domestic carbon-trading market to the international market. Taiwan has not yet ratified the Kyoto Protocol and is, hence, not regulated by the Protocol. However, with the rising energy price, the threat of global warming and the pressure of reducing greenhouse gases from the international community, Taiwan may need to develop its own carbon trading system. In this case, those foreign examples can serve as a reference for Taiwan.

5.3 Limitations and Future Research

This study only examines whether the carbon trading system or the carbon tax system is more suitable for Taiwan but is without further investigation on this matter. In the future, it is encouraged to investigate: How can Taiwan adapt the experience of foreign countries, such as the European Union, USA, South Korea, China and Japan, to develop its own carbon-reducing policy? Besides, this study only examines the possibility of whether the carbon trading policy or the carbon tax policy is better, but has not considered the possibility of adopting both policies. Therefore, it is recommended for the future investigations to further examine the feasibility of adopting both carbon trading policy and the carbon tax policy. One example of the combination of the carbon trading policy and carbon tax policy would be subsidizing the public transportation, such as the High Speed Rail or the Mass Rapid Transit (MRT), so as to reduce people's incentives to drive cars or motorcycles. In many foreign counties, taking the bus is actually free-of-charge. The logic is that people do not have an incentive to change their lifestyle, so compensation from the government is necessary for the change. Lastly, this study examines from the perspective of a country, evaluating whether the carbon trading system or the carbon tax system is more suitable for Taiwan. In the future, it would be more recommendable to conduct an investigation with a more specific topic, such as comparing the adaptabilities of the carbon-reducing policy in the industrial sector and in the household sector.

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