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The Study of Effect of Carbon Tax on the International Competitiveness of Energy-intensive Industries: An Empirical Analysis of OECD 21 Countries, 1992-2008

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Abstract

Carbon tax as a GHG-emission-reducing measure is strongly recommended by scholars and international organizations. But many countries are concerned about the potential negative impact of carbon tax on their international competitiveness of energy intensive industries. This paper analyzes this issue empirically. Based on the basic gravity model used by Harris, Kónya, and Mátyás (2002) and the World Bank report (2008), this paper improved the model by introducing a set of carbon tax policy variables to measure the impact of carbon tax on international competitiveness of energy-intensive industries using data of 21 OECD countries and 9 sample energy-intensive industries. The result shows that carbon tax has a statistically negative impact on the international competitiveness of energy-intensive industries. This is particularly true when the focus is on the non-resource based industries, which is possibly because different levels of subsidies and exemptions are granted for different industries affected by the carbon tax.

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Keywords: Climate Change; Carbon Tax; Energy-intensive Industry; Industrial International Competitiveness

1. Introduction

As we all know, climate change is the biggest threat to the sustainable development of the world. CO_2 is one of the major greenhouse gases causing global climate change. How to reduce the emission of CO_2 into the atmosphere is a big concern of the countries around the world. The reaching of Kyoto Protocol is a great progress in the process of mitigating climate change, but it is not enough.

Carbon tax, as a GHG-emission-reducing measure, is strongly recommended by scholars and international organizations. Carbon tax is one of the significant economic means of reducing carbon emissions, which is levied by the extend of carbon emissions caused by fossil fuel products such as petrol, aviation fuel and gas in order to reduce the consumption of fuel and emission of carbon dioxide. Some

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countries, for example, Denmark, Norway, Sweden, Finland, the Netherlands etc, have imposed carbon tax since 1990s. In the discussion of long-term strategy of reducing greenhouse gas emissions, carbon tax gradually won the attention of the international community for its economic efficiency and positive role in energy conservation and environmental protection.

As a developing country, China does not have to undertake GHG-emission-reducing obligation; but as a major emitter of greenhouse gases, China has become the global focus on the emission reduction, bearing enormous international pressure. Now we have to take measures to meet the requirements of the emission reduction strategy in the country. At present, China has put the levy of carbon tax on the agenda, which has turned into a hot issue. There are different views on this issue at home and aboard, one of which is that carbon tax might affect the industry's international competitiveness. Why did EU, which has already implemented emission reduction policies, propose to levy the border adjustment tax on the energy-intensive product from non emission reduction countries? Why did United States refuse to sign the Kyoto Protocol? The underlying reason behind is both of them concerned about the negative effect of carbon taxes on the competitiveness of its industries, particularly the energy-intensive industry competitiveness, which may put them in a difficult position in the international trade. Therefore, the empirical study of the impact of carbon taxes on the international competitiveness of energy-intensive industries is of great theoretical and practical significance.

The impact of carbon taxes on international competitiveness of industries determines whether or not it can be accepted politically to a certain extent. Zhongxiang Zhang(2004) reviewed the literatures in this area in details: the empirical study of the impact of industries' international competitiveness did not support the assumption that environmental standards of different countries is an important factor in affecting international trade; He also considered the findings--Some energy-intensive State-owned enterprises or multinational corporations might transfer investment or production to other countries (such as developing countries)--could not fully prove that carbon tax will lead to this result in the future. However, Tax rate may increase gradually leading to severe economic impact under the target limit of "United Nations Framework Convention on Climate Change" and the using of carbon tax revenue plays a decisive role in the ultimate economic impact of carbon tax policies.

Under the assumption of only USA has implemented carbon tax policies, Aldy J., and B. Pizer（2008）estimated the impact of levying $ 15 / t CO2 unilateral carbon tax on output, consumption and competitiveness by using the sample of more than 400 manufacturing of the United States, did econometrical analyses of the effect of energy price volatility (electricity as an alternative variable) on employment, output and trade during 1986-1994. Research calculated that the range of the overseas transfer of production in these industries (loss of competitiveness called by author) would be 0.7% -0.9%, the impact on the competitiveness of some more narrowly defined energy-intensive industry was expected to be 0.3% -1.8%. Having adopted the estimation similar to the ones used by Morgenstern et al. (2007), however, the impact of output they calculated was 2-6 times higher than the Morgenstern et al' s. One of the reason is that the classification in their research specific to the particular sector, focusing on narrower range of activities in the energy-intensive industry. An empirical study of World Bank Report (2008), using the Gravity Model analyzed the impact of carbon taxes on the international competitiveness of the energy-intensive industry from the perspective of international trade, the result showed that carbon tax has significant negative impact on the international competitiveness of energy-intensive industries.

So far by now, the international competitiveness of the industry has not been given a strict definition by scholars. The competitiveness of an industry in a country can be measured by the international market share and profitability. The larger the share, the stronger the competitiveness of the industry. The impact of carbon tax on the international competitiveness of energy-intensive industries could be visually reflected by the import and export trade flows of energy-intensive products.

Theoretically, compared to the rivals who do not have carbon tax or implement loose carbon tax policies, without considering other factors (international politics, trade barriers, etc), levying strict carbon tax on a country might lead to some poor result, say, the declining of the competitiveness due to the rising cost, losing market shares, or moving of the industry to the other countries to avoid this kind of strict carbon tax. In this situation, exports of energy-intensive products of the countries which implement strict carbon tax will probably decline, while the imports may increase. Meanwhile, compared to the competitors, competitiveness has declined, the imports of energy-intensive products, therefore, might increase.

This paper analyzes the impact of a carbon tax on the international competitiveness of energy-intensive industries empirically from the perspective of international trade.

2. Model Construction

This paper chooses nine energy-intensive industries which most influenced by the carbon tax policy, using improved gravity model to measure the impact of carbon tax on selected 21 OECD countries exports. By adding carbon tax policy variables, the model was constructed for three cases on the basis of a standard gravity model and the improvement of the model by Harris, Kónya, Mátyás (2002) and World Bank (2008): only exporting country levies carbon tax, only the import country levy carbon tax, both of them have carbon tax.

Gravity model originated in " law of attraction" in the physics proposed by Newton in 1687, that is, the gravitational force between two objects is proportional to the quality and inversely proportional to the distance. Tinbergen (1962) and Poyhonen (1963) began to use gravity model in the research of international trade issue. Through empirical research they found that trade flows between the two economies is proportional to their individual economies scale (usually represented by GDP) and is inversely proportional to the distance between them. The initial equation of gravity model is:

$$T_{ij} = \frac{AY_iYj}{D_{ij}} \quad (1)$$

In this equation, A denotes a constant, Tij is trade value between regions or countries, Yi and Yj are the economic scales of two countries or regions, usually using a country's GDP, Dij is economic distance between the two countries, generally refers to the distance between two economic centers or major ports. Among this, Yi represents the potential supply of the exporting country and Yj measures the potential demand of the importing country, Dij is a proxy for resistance to trade. In the empirical test, they are usually taken logarithmic into linear form.

This model has been successfully verified by many scholars' empirical studies latterly and it is a powerful tool for analyzing bilateral trade flows. Compared with various trade theories, the trade gravity model quantified the bilateral trade between two countries or regions, opening up a space for econometric analysis in international trade.

For the extending use of trade gravity model, economists mainly modify original model through introducing new explanatory variables, which could be divided into two categories: one is exogenous variables affecting trade, such as GDP, population, per capita GDP, per capita income (PCY), etc.; the other is dummy variables, such as preferential trade agreements, integration organizations, the common language, etc. Linnemann (1966) applied the gravity model to measure the trade flows between the two countries by introducing two new explanatory variables, which are the endogenous variable(population) and the dummy variable(trade policies, such as preferential trade agreements). Casetti (1972) proposed extension methods in qualitative research through combining two series of exogenous variables Y0 (basic series and dual series). Extension methods provide a new empirical method for gravity model and make the model to explain the actual trade better.

In the study of trade and environment issue, Van Beers and Van den Bergh (1997) added environmental regulation variable to the gravity model, analyzing three kinds of bilateral trade flows of 21 OECD countries in 1992. After that, Harris, Kónya, and Mátyás (2002) analyzed three types of bilateral trade flows in 24 OECD countries during 1990-1996 on the basis of the improved model. World Bank report 2008 "International Trade and Climate Change" introducing carbon tax policy variable to gravity model for the first time, analyzed the impact of the carbon tax on international competitiveness of industries.

The reasons of choosing gravity model as an analytical tool are based on two considerations:

Firstly, the carbon tax policy involves complex factors such as tax rate, object taxed, tax relief etc, which are difficult to be quantified, but we can introduce a dummy variable which represents whether or not to levy carbon tax into the gravity model in our research. As the current international dispute focus on impact of carbon tax on the competitiveness of energy intensive industries, the gravity model can answer this question.

Secondly, the advantage of discussing bilateral trade flows through gravity mode instead of multilateral trade flows model is that the multilateral trade flows model focusing on multilateral trade volume, the sum of which may offset the impact of different carbon tax policies between countries on trade flows. The bilateral trade flow data will reveal the impact of different carbon tax policies more clearly

Based on previous literatures, this paper constructs econometric model of impact of carbon taxes on international competitiveness of energy-intensive industries according to three cases: only the exporting country has carbon taxes, only the importing country has carbon taxes, both of them have carbon tax. The improved gravity model equation is:

$$\ln EXP_{ijt} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{jt} + \beta_3 \ln POP_{it} + \beta_4 \ln POP_{jt} + \beta_5 \ln LAND_i + \beta_6 \ln LAND_j + \beta_7 \ln DIST_{ij} + \beta_8 ADJ_{ij} + \beta_9 FTA_{ijt} + \beta_{10} CT_{it} + \beta_{11} CT_{jt} + \beta_{12} CT_{ijt} + u_{ijt}$$

Where ln denotes natural logarithm;

EXPijt, the exports of country *i* to country *j* in year *t*;

GDPit, *GDPjt*, the GDPs of countries *i* and *j*, respectively, in year *t*;

POPit, *POPjt*, the populations of countries *i* and *j*, respectively, in year *t*;

LANDi, *LANDj*, the land areas of countries *i* and *j*, respectively;

DISTij, the distance between countries *i* and *j*;

ADJij, a dummy variable, equal to 1 if countries *i* and *j* are adjacent, *i.e.* share a common land border, and zero otherwise;

FTAijt, a dummy variable, equal to 1 if countries *i* and *j* are both members of the FTA in year *t* and zero otherwise;

SCit, *SCjt*, scores measuring the relative strictness of environmental regulations in countries *i* and *j*, respectively, in year *t*;

CTit, CTjt, CTijt, dummy variables, when "only countries i have carbon tax" in year t, CTit equal to 1; when "only countries j have carbon tax" in the year t, CTjt equal to 1; when "both countries i and countries j have carbon tax policy" in the year t, CTijt equal to is 1, otherwise they to 0.

uijt, white noise disturbance term; and

$i = 1, \ldots, N$, $j = 1, \ldots, i - 1, i + 1, \ldots, N$, $t = 1, \ldots, T$.

Most previous studies did econometric analysis based on cross-sectional data of the sample in specific years, the results of which could not fully reflect the nature of objective due to the changing economic environment of the world. In this paper, we use panel data regression method to expand the sample size and to make our research more meaningful and valuable.

In this model, *GDPi measures* the potential supply of the exporting country, while *GDPj* represents the potential demand of the importing country. Therefore, the corresponding slope parameters, β1 and β2 are expected to be positive. POPit, POPjt are used to capture the effects of economies of scale in the exporting and importing countries, respectively. Since countries with large populations tend to be more self-reliant, one might expectβ3 and β4to be negative. However, the expansion of the scale of productive capacity causes long-run average costs to fall, giving more populous countries a competitive edge in exporting, so thatβ3 and β4 could also be positive.

LANDi and *LANDj* are the sheer sizes of the exporting and importing countries, respectively. Their slope parameters, β5 and β6, are probably negative since larger countries are more diverse and potentially richer in natural resources. One might also argue that the larger the area of a country, the more abundant natural resources, the higher the export competitiveness, which makes the symbols of β5 and β6 tend to be positive.

DISTij is a proxy for resistance to trade, thus it is anticipated that β7 will be negative.

The *ADJij* and FTAijt are dummy variables indicate whether the trading partners have a relatively stronger bond, so that β8 and β9 are expected to be positive.

Finally, CTit, CTtjt and Ctijt are dummy variables that were introduced to show whether counties i and j have carbon tax. Due to the concern about possible adverse impact which carbon tax might have upon industrial competitiveness, this paper assumes that if " only the exporting country have carbon tax", the carbon tax would have a negative influence on industrial competitiveness of exporting country i, or damaging its competitiveness ;if "the importing country j have carbon tax", the export of country i would increase; if "both exporting i and importing country j have carbon tax ", the impact of carbon tax on industry competitiveness of the country i might offset each other or not significant. Therefore, β10, β11, β12 were expected to be: negative, positive, positive or negative.

In summary, it is hypothesized that β1, β2, β8, β9, β11slope parameters are positive, β7, β10 are negative, while the signs ofβ3, β4, β5, β6 andβ12 are ambiguous.

3. Sample Selection

3.1. The sample of energy-intensive industries

Draw on the previous literatures (Harris, Kónya and Mátyás (2002) and the World Bank report (International Trade and Climate Change, 2008)), this paper selected petroleum products, other petroleum products, steel, organic chemicals, inorganic chemicals, fertilizers, and other chemicals, paper and paper products, lime, cement and other building materials industry as the sample of energy-intensive industries, which were classified according to Standard International Trade Classification system.

In addition, the industry sample we used was distinguished by whether it is resource based industries. Resource based industries are those whose production factors, resources are not mobile, and non-resource based industries (or foot-loose industries) are those whose production factors are mobile. Theoretically, resource based industries are not to migrate, and therefore more sensitive to the differences in the carbon tax policies. In contrast, non-resource based industries are not sensitive to differences in the carbon tax policy. Therefore, we introduced exports of both non-resource based industries and resource based industries as dependent variables into the model, contrastively analyze model coefficients to determine the impact of the differences in carbon tax policies on two types of industries.

Table 1 energy-intensive industries used in this paper

SITC-3	Industry	Non-resource based industries

334	Petroleum products	N
335	Other petroleum products	N
51	Organic Products	N
52	Inorganic chemicals	N
562	Fertilizer	N
59	Other chemicals	Y
64	Paper and paper products	N
661	Lime, cement and other building materials	Y
67	Steel	Y

3.2. Sample countries: OECD 21 countries

According to the availability of the data and research needs, 21 OECD countries were selected as the sample countries in this paper, including Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Hungary, Spain, Sweden, Switzerland, United Kingdom, and the United States. Using the bilateral trade flows of energy-intensive products between these countries as the objects of the study is mainly based on the following considerations:

Firstly, these countries have implemented or considered to have carbon taxes, and data of these countries are more available.

Secondly, there are many factors that affect the competitiveness of energy intensive industries except carbon tax, such as labor, technology, political stability etc, but these factors are difficult to quantify. We use these 21 OECD countries as a sample because the differences of these factors in those countries are relatively small.

Thirdly, these countries have similar energy price system, so we can assume that the effect of differences of energy price systemis negligible.

The data we used in this paper is during the period 1992-2008. This is mainly based on the following considerations: firstly, in the early 1990s, the Nordic countries began to have carbon tax, among them Finland in 1990 and other Nordic countries in 1992; secondly, part of the data of 2009 was not yet available by the time we write this paper.

4. The Data Resource

The data used in this paper was drawn from the official database of international organizations, published publicly or online, including:

The data of EXPijt is from the United Nations trade statistics web site (WITS) of the United Nations Trade Database (COMTRADE). The data of GDPit, GDPjt, POPit and POPjt come from the World Bank WDI (World Bank's World Development Indicators) database. We use national population as demographic data.

The data of LANDi, LANDj, ADJij and DISTij come from the French Institute for International Economics (CEPII). DISTij represents the distance between economic centers in two trading countries. We use weighted distance, that is the weighted distance between major cities;

The data of FTAijt were sort out according to the time when sample countries joined a trade group.

The data of CTit, CTjt, CTijt were organized according to the process of carbon tax / energy tax in each country, which partly from the World Bank report, "Trade and Climate Change " (2008) and partly from the OECD and the International Energy Agency (IEA) website.

Table 2 Status of Carbon Tax Regimes in Selected OECD Countries

Country	Status	Tax type
Australia	Proposed in 1994, not adopt	Greenhouse levy
Austria	1996 , updated in 2000	Energy tax
Belgium	Planned	Energy tax
Canada	In Quebec in2007	Carbon tax
Denmark	1993 ,updated in 1996	Carbon tax（part of tax reform）
Finland	1990 , updated in 1998	Carbon / energy tax
France	1999 (proposed), 2000 (suspended)	Energy / carbon tax
Germany	1999	Energy tax(ecotax)
Greece	Not implemented	Carbon tax
Hungary	Not implemented	Carbon tax
Ireland	2010	Carbon tax
Italy	1998 (implemented), 1999(revised), then suspended	Energy tax reform
Japan	Pending	Carbon tax
Netherlands	1992	Carbon tax
New Zealand	2007 (planned)	Carbon tax
Norway	1991 (implemented), 1999 (updated)	Carbon tax
Spain	Pending	Carbon tax
Sweden	1991 (implemented), 2001 (updated)	Carbon tax（part of tax reform）
Switzerland	2005	Carbon tax
United Kingdom	2001	Climate change l
United States	Proposed in 1993, not adopted	BTU tax

Sources: IEA, OECD, EEA (various years).

5. Results and Discussion

We introduced panel data to analyze the impact of carbon tax on international competitiveness of energy-intensive industries, using the data of 9 energy-intensive industries of 21 OECD countries during 1992-2008. When we estimate equation, panel data are more inclined to be used as cross-sectional data in the analysis because it is "wide and narrow" , including both time series and section data, which may bring serial correlation and heteroscedastic problems, causing the failure of ordinary least squares method. Therefore, we conduct multiple linear regression analysis through GLS (Cross section weights) to eliminate heteroscedasticity and guarantee validity of the model. Test results also show that this method is more reasonable than estimation by ordinary least squares (OLS). We use Eviews5.0 to regress the total trade flows of energy-intensive industry in the sample countries. The model estimation results are shown in Table 3.

From the regression results, we can see that the Adjusted R-squared $\bar{R}^2$ =0.948342, indicating that the sample regression line fit sample observations well; And given 1% level of significance, critical value of F statistic is 2.3, the value of F statistic is 5987.316 in the model estimation results, apparently passed by F test, indicating that overall linear relationship of the equation was significantly established; With regard to significant test of single independent variable, the symbols of the rest of regression coefficients are the same as expected and passed by test in 1% level of significance except the coefficients of carbon tax policy variables CT1 and CT2. Only the coefficient of CT1t is not significant. From the above analysis, we can see that independent variables in regression equations fully explain the dependent variable; general linear test was significant; overall model is correct; each explanatory variable of model has a significant effect on the dependent variable with high interpretations; only carbon tax policy variables do not match assumptions.

The group of dummy variables, CTit, CTjt, CTijt, were introduced in this paper to investigate the impact of carbon taxes on the competitiveness of the carbon-intensive industries selected. Due to the concern that carbon tax might have adverse impact w upon industrial competitiveness, this paper assumes that if " only the exporting countries have carbon tax", the carbon tax would exert a negative influence on industrial competitiveness of exporting country i, or damaging its competitiveness ;if "the importing country j has carbon tax", the carbon tax of the importer is conducive to the export of the exporting country i; if "both exporting i and importing country j have carbon tax", the impact of carbon tax on industry competitiveness of the country might offset each other or not significant. The empirical results show that when only the importing countries have carbon tax, the carbon tax exerts a negative influence on industrial competitiveness of exporting country i; when only the exporting countries have carbon tax, the effect on industrial competitiveness of exporting country i is little ;when both exporting i and importing country j have carbon tax, the impact of carbon tax on industry competitiveness of the country might offset each other to some extent ,but the negative impact is still significant for the exporting countries. The results is not in line with the hypothesis probably because these energy-intensive industries often are more competitive in these countries, which countries implement proactive subsidies or a more lenient exemption policy at the same time, aims at eliminating the impact of carbon taxes on international competitiveness of its industries.

Table 3 Estimated Results of Total Exports of Energy-intensive Industry

Dependent variables：LNEXPTOTAL				
Number of Section：334				
Number of samples：3914				
Variable	Variable Coefficient Name	Coefficient	Std. Error	T statistic
C	C	-10.07988	0.262200	-38.44356
LNGDP1	β1	0.821111	0.021335	38.48711
LNGDP2	β2	0.517342	0.015033	34.41379
LNPOP1	β3	-0.230332	0.023752	-9.697551
LNPOP2	β4	0.132075	0.016940	7.796491
LNLAND1	β5	0.059607	0.006215	9.590636
LNLAND2	β6	0.155787	0.004895	31.82404
LNDIST	β7	-0.960094	0.009173	-104.6683
ADJ	β8	0.379690	0.016276	23.32862
FTA	β9	0.075107	0.015124	4.966194
CT1	β10	0.006523	0.015195	0.429284
CT2	β11	-0.332192	0.017010	-19.52886
CT12	β12	-0.220726	0.020532	-10.75058
R-squared $\mathbf{R}^2$	0.948501			
Adjusted R-squared $\mathbf{R}^{-2}$	0.948342			
F statistic	5987.316			

Many countries have different subsidies and exemption policy for non-resource based industries and resource based industries. In order to figure out whether carbon tax will exert negative influence on energy-intensive industries in depth, we would like to do regression for non-resource based industries and resource based industries respectively.

Under the assumption that carbon tax will reduce the international competitiveness of energy-intensive industries, carbon tax might have a more significant negative impact on non-resource based industries. The regression results show that, when only the importing country have carbon tax, carbon tax does exert prominently negative influence on international competitiveness of non-resource based industries of exporting countries and a tiny positive influence on international competitiveness of resource based industries. The reason might be that, compared to resource based industries, non-resource based industries are very competitive and important to employment and national security of a country, and the negativity of carbon tax will be also taken into consideration by the government. Thus, the positive subsidy policies, tax incentives, innovation incentive fund or tax exemption policies could be carried out to eliminate its negative effect. Indeed, there are over-subsidies in some OECD countries which benefit energy-intensive industries.

When only importing countries have carbon tax, it has negative influence on both non –resource based industries and resource based industries, the influence on non-resource based industries is less. The reasons might be as follows: firstly, the importing countries that have carbon tax would have environmental tariffs and strict rules, or imposing relative border regulation tariff for the import of energy-intensive products; secondly, the fact that rigid carbon tax policy of importers will divert the non-resource based industries from importers to countries without carbon tax. So, as it is illustrated that the β11 for non-resource based industries regression equation is less than it for resource based industries regression equation, which means there is more demand for non-resource based industries than resource based industries industries. It can also be deduce that regional economic integration plays a greater role in non-resource based industries of exporters and resource based industries migration is apt to happen in a economic integration region from the estimating equation that β9 from non-resource based industries are much more than it from resource based industries.

When the exporting and importing countries both have carbon tax, the coefficient β12 of resource based industry is negative, while coefficient β12 of non-resource based industry is positive, and both are smaller than they are in the case of only one country levy carbon tax. This shows that the impacts of carbon tax of two countries on energy-intensive products of exporting countries are offset to some extent, for resource based industry, this negative impact is still significant, while for non-resource based industry it is showing a slight positive impact. There are two possible reasons for this: on one hand, when both countries have carbon tax, the demand for products of both non-resource based industry and resource based industry may switch to the substitute which are encouraged by the country or are less affected, leading to the lower demand of trade between the two countries and the loss of competitiveness of resource based industry of the exporting countries; on the other hand, compared to resource based industries, non-resource based industries are much easier to move to the countries without carbon taxes.

Table 4 Estimated Results of Non-resource Based Industry and Resource Based Industry

Variables	Coefficient	LNEXPRB (resource based industry)	LNEXPNRB (non-resource based industry)
C	C	-12.31295***	-16.79463***
LNGDP1	β1	1.006213***	0.978349***
LNGDP2	β2	0.575109***	0.412059***
LNPOP1	β3	-0.46275***	-0.049867**
LNPOP2	β4	0.110472***	0.29459***
LNLAND1	β5	0.070738***	-0.077957***

LNLAND2	β6	0.11917***	0.256079***
LNDIST	β7	-0.981777***	-1.153839***
ADJ	β8	0.356598***	0.434125***
FTA	β9	0.022946*	0.125776***
CT1	β10	0.012302	-0.053155***
CT2	β11	-0.505747***	-0.169571***
CT12	β12	-0.314534***	0.082655***
R-squared $\mathbf{R}^2$		0.926047	0.99347
Adjusted R-squared $\mathbf{R}^{-2}$		0.925826	0.993456
F statistic		4184.481	71938.93
Number of Section		346	403
number of samples		4023	5687

Note: *** means passed the significant test at 1% level, ** means passed the significant test at 5% level, *** means passed the significant test at 10% level

In order to investigate the impact of carbon tax on energy-intensive industries in short-term and long-term. This paper divides the data into two period 1992-2000 and 2000-2008, and does empirical study respectively. The results are shown in Table 5.

By examining the regression results of the two period, we can tell that when only the exporting country have carbon tax, carbon tax exerts positive influence on the international competitiveness of the energy-intensive industries of the exporting countries during1992-2000 and 2000-2008, the difference is that the impact during 1992-2000 (β10 = 0.143086) is much larger than that of during 2000-2008 (β10 = 0.016906), and the former was significant in the level of α = 1%, the latter had no significant effect. Reasons for this may be that, with the carbon tax policy are propagated widely in OECD countries, they gradually expand the scope of the carbon tax, increase the tax rates, improve the carbon tax policy(related subsidies, tax circulation policies etc), making the impact of carbon tax on energy-intensive industries gradually reduced to minimal.

When only the importing country have carbon tax, it exerts negative influence on the international competitiveness of the energy-intensive industries of the exporting countries during1992-2000 and 2000-2008, and this effect increased from -0.227457 during the period 1992-2000 to -0.341732 during the period 2000-2008. There might be two reasons for this: firstly, as it are propagated widely in OECD countries, the carbon tax is more stringent, hindering the trade in energy-intensive products even more; secondly, stronger consciousness of reducing carbon emissions makes substitute of energy-intensive products more popular, which cut the demand of energy-intensive products trade.

When both the exporting countries and importing countries have carbon tax, it exerts little influence on the international competitiveness of the energy-intensive industries of the exporting countries during1992-2000, while the negative impact is significant during 2000-2008. The reason may be that: in the early stage of levying carbon tax, tax rates in OECD countries are often low, the scope of tax is narrow and there are more lenient exemption policies and subsidies. As implementation of the carbon tax policy was gradually improved and more stringent, which makes low-carbon substitution industries expand, dramatically reducing the bilateral trade needs. Gradually, the anticipation of carbon tax to be increasingly stringent makes energy-intensive non-resource based industries transfer to the countries without carbon tax (mainly developing countries).

Table 5 Estimated Results of Total Exports of Energy-intensive Industry Samples during 1992-2000 and 2000-2008

Variables	Coefficient	1992-2000	2000-2008
C	C	-9.996164***	-14.11338***
LNGDP1	β1	0.808441***	1.10622***
LNGDP2	β2	0.553584***	0.617231***

LNPOP1	β3	-0.293456***	-0.487279***
LNPOP2	β4	0.077658***	0.065178***
LNLAND1	β5	0.141186***	0.007693
LNLAND2	β6	0.153286***	0.144706***
LNDIST	β7	-0.917347***	-0.992458***
ADJ	β8	0.368593***	0.403759***
FTA	β9	0.093954***	0.102694***
CT1	β10	0.143086***	0.016906
CT2	β11	-0.227457***	-0.341732***
CT12	β12	0.027033	-0.22138***
R-squared $\mathbf{R^2}$		0.990337	0.99408
Adjusted R-squared $\mathbf{R^{-2}}$		0.990276	0.994048
F statistic		16295.03	31049.35
Number of Section		313	326
Number of Samples		1921	2232

Note: *** means passed the significant test at 1% level, ** means passed the significant test at 5% level, *** means passed the significant test at 10% level

6. Conclusions and Further Research

6.1. Conclusions

It is assumed that carbon tax might have effect on international competitiveness of energy-intensive industry, especially for the non-resource based industries without government subsidies. But it seems that results of empirical study don't support this hypothesis.

When only the importing countries have carbon tax, carbon tax exerts negative influence on competitiveness of energy-intensive industries of exporting countries; in case of only the exporting countries have carbon tax, the effect is very little; when both exporting country and importing country have carbon tax, the impact of carbon tax on industry competitiveness of the country might offset each other to some extent, but the negative impact is still significant for the exporting countries.

By examining the impact of carbon tax on energy-intensive industries in short-term and long-term, we find that, when only the exporting countries have carbon tax, the carbon tax policy exerts positive influence on the international competitiveness of the energy-intensive industries of the exporting countries during1992-2000 and 2000-2008; this impact during 1992-2000 is much larger than that 0f 2000-2008. When only the importing countries have carbon tax, it exerts negative influence on the international competitiveness of the energy-intensive industries of the exporting countries during 1992-2000 and 2000-2008, and this effect increased with the time. When both the exporting countries and importing countries have carbon tax, it exerts little influence on the international competitiveness of the energy-intensive industries of the exporting countries during 1992-2000, while it has significant negative impact during 2000-2008.

6.2. Further Research

This paper empirically analyzes bilateral trade data of energy-intensive industries in OECD 21 countries through gravity model. Due to the limitations of gravity model, carbon tax policy was only introduced as a dummy variable into the model. This dummy variable could not reflect the diversity of carbon tax policy in different countries, but the differences, say, tax rate, scope of taxation, reduction policy, may have influence on the international competitiveness of energy-intensive industries. Thus we could only concluded that whether or not carbon tax affect the international competitiveness of energy intensive industries. Therefore, introducing complex differences of the carbon tax policies of different countries into the empirical model is the direction of further research.

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