Scientific Research Publishing

Open Journal of Social Sciences, 2017, 5, 27-36
http://www.scirp.org/journal/jss
ISSN Online: 2327-5960
ISSN Print: 2327-5952

A Model of Carbon Price Interactions with International Embodied Carbon

Yan Lin

School of Economics, Jinan University, Guangzhou, China
Email: 245053114@qq.com

How to cite this paper: Lin, Y. (2017) A Model of Carbon Price Interactions with International Embodied Carbon. *Open Journal of Social Sciences*, **5**, 27-36.
https://doi.org/10.4236/jss.2017.53004

Received: January 25, 2017
Accepted: March 13, 2017
Published: March 16, 2017

Abstract

This paper takes the EU as an example to discuss the relationship between international embodied carbon and carbon price through VAR model. The result shows that there is a long-term interaction but an asymmetric relationship between them: The impact of the scale of international embodied carbon on carbon futures price is significantly negative, while the impact of carbon futures price on the scale of international embodied carbon is negligible. Then this paper tries to come up with corresponding policy suggestion in the end based on empirical findings.

Keywords

International Embodied Carbon, Carbon Price, VAR Model

1. Introduction

Global warming has become an indisputable fact. After the industrial revolution, production and the emissions of greenhouse gases are considered to be the main cause of global warming. This problem has aroused the concern of the whole society. The carbon emissions trading market gradually developed since countries signed the "Kyoto Protocol" in Kyoto in 1997. Three kinds of mechanism (IET, JI and CDM) play an important role in carbon emissions trading market. IET and JI are used among developed countries, while the CDM project means that developed countries can get "extra" carbon quota from developing countries if the developed countries provide financial and technical help to them. Scholars all focus on the determination of carbon price, which is a key factor to control the global carbon emissions. Scholars have obtained many achievements in this field, such as the movement of the carbon price from the perspective of supply and demand, and the interactive relationship between the financial market and the carbon price. However, few people study the field which is from the perspective of the embodied carbon scale in international trade.

Under the trend of globalization, the volume of international trade is increasing rapidly. The products are not only used for domestic consumption, but also for the other countries. Some countries use the products but other countries produce them. The carbon emissions in the production progress are called international embodied carbon. For a country or a region, if the consumption of carbon emissions is greater than the production, it is known as the inflow of international embodied carbon, otherwise, the reverse. We can call them inflow countries and outflow countries for short. The developing countries, such as India and China, are generally outflow countries. They bear more carbon emissions but do not gain a dominant position in international trade. By contraries, the developed countries, such as Europe and the United States, are generally inflow countries. They not only get cheap goods in international trade, but also reduce their carbon emissions, thereby reducing the demand for carbon quotas. Therefore, the inflow of international embodied carbon will affect the regional carbon price theoretically. We need to explore the impact path between them. This paper attempts to take the EU as an example to discuss the relationship between international embodied carbon and carbon price, which will help us to assign emission carbon reduction tasks in all countries.

2. Review of the Literature

Firstly, there are many literatures about the carbon price, but most of them use the theory of supply and demand to study the decision of the carbon price [1]. Supply factors include policy, regulation, weather, technology and so on. Blyth and Bunn (2011) discussed that policy uncertainty is the main factor leading to the risk of carbon emissions price volatility. Parsons *et al.* (2009) found that the excess carbon quota which can't be stored in next period is the cause of the May 2006 incident [2]. And the energy is the most important demand factor, which has been recognized by many scholars. Aatola (2013) further study and show that the impact of the European integrated electricity market on the price of carbon emissions market do exist [3]. Zhu (2014) using structural breakpoint test to analyze the carbon emission market, the result shows that unexpected events led to structural changes in the carbon market and there are cointegration relationship exists among the carbon price, energy price, industrial production, temperature and other factors [4]. Secondly, some people study carbon prices from financial markets. Chevallier (2014) found that the carbon futures have the ability to predict the carbon spot price [5]. Aatola *et al.* (2013) analyze the behavior of enterprises in the pursuit of profit maximization from the micro point of view in the carbon emissions market, the results show that there is a strong correlation between the carbon futures market and the spot market [3]. Thirdly, many scholars have studied the international embodied carbon. We found that international trade has an important impact on global greenhouse gas emissions. Based on the traditional statistical methods of carbon emissions can easily distort the true situation of a country's carbon emissions, which will not only cause the "carbon leakage" from the developed countries to the developing countries, but also may indirectly increase the global emissions of carbon dioxide [6]. Mongelli *et al.* (2006) discovery that nearly 25% of imported embodied carbon is derived from the developing countries by input-output method [7]. Sánchez-Chóliz and Duarte (2004) take Spain for an example and use single regional input-output model. The results showed that net exports of carbon emissions in Spain's domestic emission accounted for only 1.31%, but the import and export of embodied carbon emissions accounted for about 36% and 37% of the total demand emission [8]. Due to the low level of technology and energy efficiency in developing countries, there is a higher carbon emission than the developed countries. In summary, scholars are focus on the determination of carbon price. However, there is few articles research this field on the scale of Embodied Carbon in international trade. This paper attempts to discuss the relationship between the international embodied carbon and carbon price.

3. Theoretical Analysis

3.1. Carbon Price Has a Positive Impact on the International Embodied Carbon

Due to the high energy technical level, it is hard to form a technical breakthrough to reduce the cost, so the EU enterprises generally purchase carbon futures and derivatives to complete the task of reducing emissions. Above that, we know that the rise in the carbon price led to a cost increase. Enterprises will reduce production and increase imports. Finally it will increase the size of the inflow of international embodied carbon. Otherwise, the reverse.

3.2. International Embodied Carbon Has a Negative Impact on Carbon Prices

This paper makes a detailed analysis of the influence mechanism with the help of Figure 1. Starting from demand, developed countries directly reduce the production of imported goods, thereby reducing the production of materials and carbon quotas. With the supply unchanged, carbon price will reduce. From the view of supply, assuming there is no international trade, and the developed countries will produce all the goods they need. They will be confined to the

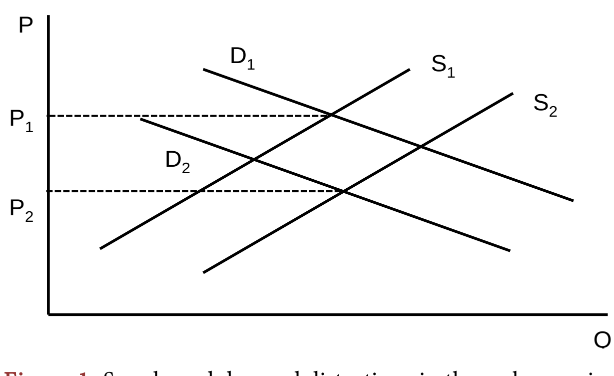

Figure 1. Supply and demand distortions in the carbon emissions market. Note: Figure 1 is drawn by the author himself.

country's carbon emission reduction task in the production process, which leads to reduce carbon dioxide emissions or increase the demand for carbon quotas. But under the background of international trade, most of the goods can be imported from the developing world, so domestic enterprises in carbon emissions market change roles from the demand side to the supply side. They can be sold on the market because of the reduction of production and the remaining carbon quotas, which further reduce carbon emissions price. Therefore, in the case of other conditions unchanged, the increasing of inflow embodied carbon will reduce the demand for carbon credits (D1→D2) and increase carbon emission right supply (S1→S2). There is no doubt that carbon quota price will decline (P1→P2).

4. Calculation Method of International Embodied Carbon

At present, the world has not yet formed a unified global carbon emissions trading market. The EU carbon emissions trading system has now become the world's largest regional carbon emissions. We might take the European Union as an example to analyze the interaction between the carbon price and the international embodied carbon.

4.1. Technical Level Revision Coefficient

Based on the Walras-Cassel model, the input-output table (2002 and 2007) with 42 sectors and 44 sectoral energy consumption data, Yang Huimin (2011) estimated China's carbon emissions embodied in import and export trade in 2002 and 2007 [9]. According to Yang Huimin (2011) the calculation method of embodied carbon, K_t is used to express the level of average carbon emission intensity of EU's major trading partner t, which is equivalent to the EU carbon emissions intensity. It is called the technical level of the revised coefficients, which can simplify the calculation process. This method can quickly calculate the import and export of carbon emissions in various countries and has a certain convenience and practicality although it is used in recent years. Specific calculation formula is as follows:

$$K_t = \sum_{j=1}^{11}\left[\left(\sum_{i=1}^{12} U_{ij}^{t}\right) * V_j^t\right]$$

j represents the EU's 11 major trading partners, they are the United States, Australia, HK, Canada, Chinese, Chinese, Japan and South Korea, Russia, Brazil, India and South Africa; i represents January to December; t is from 2005 to 2015. U_{ij}^{t} Represents the share of the EU's imports from J countries or regions in the i month of t year; V_j^t represents the ratio of the carbon emission intensity of the j countries or regions to the EU's carbon emission intensity in t year. Since Croatia joined the European Union in July 2013, it is still using the list of former members of the EU in the statistics of the EU data, that is, 27 countries. In the calculation of U_{ij}^{t}, the whole industry import and export data of the EU's major trading partners from June 2005 to April 2015 can be obtained from Wind database; when calculating V_j^t, it is available to get the carbon dioxide emissions of carbon emission intensity index from the World Bank. Since it is difficult to get the formation of a great technological breakthrough in such a short time, we use the annual data to measure index. The paper established a power exponential function to estimate the carbon emission intensity index from June 2005 to April 2015.

4.2. Calculation Method

Note Q for carbon emissions, Y for product or commodity quantity (total output). P is the carbon emission coefficient of energy, R is the energy consumption of per unit GDP. The relationship between them is as follows:

$$Q = P * \frac{Y}{R}$$

Therefore, we can get the calculation formula of EU import and export international embodied carbon:

Import international embodied carbon content for the i months of t year:

$$MQ_i^t = P * \frac{K^t * M_i^t}{R}$$

Export international embodied carbon content for the i months of t year:

$$EQ_i^t = P * \frac{E_i^t}{R}$$

Net flow international embodied carbon content for the i months of t year:

$$NQ_i^t = MQ_i^t - EQ_i^t = P * \frac{K^t * M_i^t}{R} - P * \frac{E_i^t}{R} = P * \frac{K^t * M_i^t - E_i^t}{R}$$

When NQ_i^t is greater than 0, it implies a net inflow of international embodied carbon; when NQ_i^t is less than 0, the net outflow of the international embodied carbon is indicated. Among them, EQ_i^t is the industry wide exports of the EU in t year i month. MQ_i^t is the industry wide import of the EU in t year i month. The data of P and R can be obtained from the World Bank.

5. Empirical Research

Vector autoregressive model (VAR) has been widely used in the analysis of multivariate time series data. This method is used in this paper. The idea is that, for all the factors that affect the price of carbon futures, in addition to the scale of international embodied carbon, there are many other factors, such as temperature, wind, policy and energy prices, etc. The VAR model uses the linear combination of the two values to represent the other factors, and then solves the problem that it is difficult to construct multivariate time series variable vector autoregressive model.

5.1. Variable Selection

EU international embodied carbon scale (expressed in Q): In this paper, the EU international embodied carbon data obtained by the above method (Section 4), including the import and export data of the whole industry, which can be used to more accurately measure the monthly international embodied carbon data.

Carbon futures prices (expressed in *P*): Here we use carbon futures prices of the ECX's carbon quota futures contract to measure the monthly growth rate. Carbon futures have the function of price discovery, which can reflect the true value of carbon assets more quickly and truly. The data is from the WIND database.

5.2. Unit Root Test

P and *Q* were tested by unit root ADF respectively and the results show in Table 1. It is obvious that the variables *P* and *Q* are stable, and the VAR model can be established directly.

5.3. Lag Selection

The choice of lag period is a very important step in vector autoregressive model. Statistics of different lag periods are shown in Table 2. The results show that the optimal lag order is 1, so we establish VAR (1) model.

5.4. Grainger Causality Test

Grainger causality test is to study whether there is a causal relationship between the two data, thus eliminating the possibility of pseudo regression. The results from Table 3 show that there is a causal relationship between the scale of international embodied carbon and carbon futures prices.

Table 1. ADF test values of relevant variables.

Variable	(*t*, *c*, *n*)	ADF Value	Mackinnon critical value (Significant level)
P	(1, 1, 0)	−5.5838	−4.148 (1%)
Q	(1, 1, 0)	−11.0490	−4.1485 (1%)

Note: * is significant at 1% level.

Table 2. Optimal lag selection.

Lag	Log	LR	FPE	AIC	SC	HQ
0	−360.4027	NA	12,386.58	15.10011	15.17808*	15.12957
1	−354.7	10.69254*	11,541.88*	15.02917*	15.26307	15.11756*
2	−350.8832	6.838432	11,644.18	15.0368	15.42663	15.18412
3	−350.2362	1.105181	13,425.95	15.17651	15.72228	15.38276
4	−346.7256	5.704796	13,768.31	15.1969	15.8986	15.46207

Table 3. Grainger causality test results.

Original hypothesis	Lags	Obs	F-statistic	P value	Result
P does not Granger cause *Q*	2	118	1.4858	0.0372	*P* is Granger cause *Q*
Q does not Granger cause *P*	2	118	0.4786	0.2327	*Q* is not Granger cause *P*

Next, we need to test the stability of the estimated model. In this paper, we use AR root to test and verify that all the unit roots fall within the unit root circle. Therefore, the model is stable, and there is a long-term stable relationship between the two variables. Then the impulse response function and variance decomposition are used to analyze the interaction between them.

5.5. Impulse Response Function

According to the Choleski decomposition method, the scale of international embodied carbon is less affected by other factors than carbon futures price, so we choose it as the first variable of impulse response.

Figure 2 shows the impulse response function of each variable. P was hit by a positive impact on Q, P rapidly deviate from the steady level of −3.21 percentage points at the first phase, then rapidly rise to negative 0.27 percentage points at the second phase. And after the fourth period, it constantly wanders around stable level. In general, a percentage of the positive impact of Q on the P will lead to a significant negative deviation from the steady level. It affects a relatively short duration.

From the right side, Q on the P shock response curve experiences a process from negative to positive until convergence. Q was hit by a positive impact on P, the Q is not affected in the first period. But it dropped slightly to negative 0.82 percentage points in the third period, then the impact force is reduced rapidly. The impact force increases to 0.74 percentage points in the fourth period, then tend to infinity zero, finally converge to a stable level at stage seventh. It can be seen that the carbon futures price has a small positive impact on the scale of international embodied carbon. The carbon futures price will not immediately cause the change of current embodied carbon emissions. Because manufacturers can't adjust the scale of production and imports when the carbon futures price just rises. That is time lag effect. However, producers are aware of the increase in production costs, they will quickly adjust the scale of production and international trade to maximize profits. It also explains why the Q is not affected in the first period when Q was hit by a positive impact on P. Therefore, on the whole, the carbon futures prices have a positive but lag and weak impact on the scale of international embodied carbon.

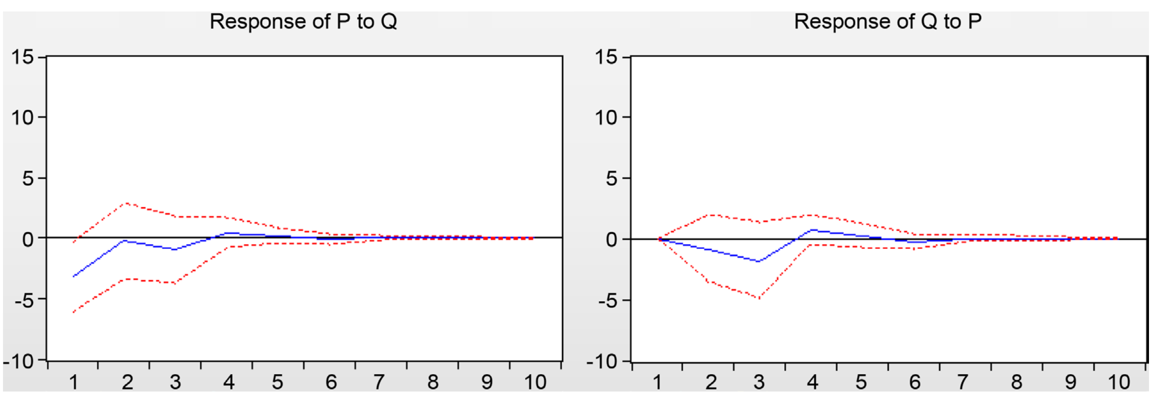

Figure 2. Impulse response diagram.

5.6. Variance Decomposition Model

In fact, the variance decomposition is a process of information calculation, which decomposes the variance of forecast into the contribution of each variable. We decompose the variance based on the VAR model, and the results are as Figure 3.

The image on the left shows the influence of *P* and *Q* on the change of *P*. It can be seen that *Q* has a greater impact on the *P*. The contribution rate is 9.22% in the first phase, slightly decreases to 8.74 in the second phase, finally stabilized at around 9.55%. In a word, the change of carbon futures price is mainly affected by its own, and has been stable at around 90.44%.

The image on the right shows the influence of *P* and *Q* on the change of *Q*. It can be seen that the impact of carbon futures price on the scale of international embodied carbon is very low, only 3.67%, which can be ignored. The scale of international embodied carbon has a significant contribution to its own changes, which is stable at 96.33%.

6. Conclusion and Analysis

This paper takes the EU as an example to discuss the relationship between international embodied carbon and carbon price through VAR model. The result shows that there is a long-term interaction but an asymmetric relationship between them: The impact of the scale of international embodied carbon on carbon futures price is significantly negative, while the impact of carbon futures price on the scale of international embodied carbon is negligible.

In the background of international trade, inflow country has two benefits. On the one hand, inflow country reduces their absolute carbon emissions from demand-side to supply-side. So they gain both the available surplus carbon quota income and the opportunity cost of its own carbon reduction. On the other hand, international carbon quota equilibrium price will decline thanks to the international embodied carbon resulted in a reduction of the demand of carbon quotas; the developed countries can buy more low-cost carbon quotas from the

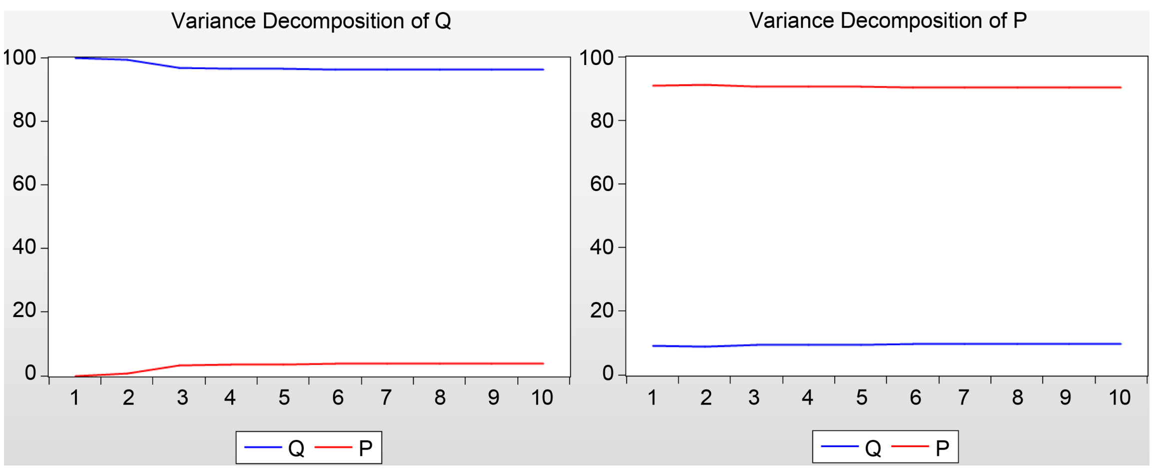

Figure 3. Variance decomposition.

market. Both the low carbon price and quotas to a welfare net loss in developing countries.

The CDM project allows the developed countries to get a cheaper carbon quota, which leads to the fact that the impact of carbon prices on the international embodied carbon is not significant. It is noteworthy that the lag effect exists with regard to the impact of the carbon price on the scale of international embodied carbon, which enterprises can't make a decision to reduce production and increase imports immediately. On the one hand, the production plan is difficult to adjust in a short period. On the other hand, the developed countries can obtain long-term cheaper carbon quota from the CDM project. Therefore, it is better for enterprises to meet the demand of carbon quota by CDM project, and not to adjust the production plan through the domestic carbon emission market.

Therefore, the developed countries should correctly understand the impact of the scale of international embodied carbon on carbon prices. It is necessary to encourage enterprises to reduce carbon emissions through technological innovation and green energy. Besides, we need to improve the quality of the audit standards to develop CDM projects to weaken the impact of the CDM project on the effectiveness of carbon emissions trading system. Developing countries should also upgrade their industrial structure and establish domestic carbon emissions trading system as soon as possible to change the passive status in CDM projects.

References

[1] Christiansen, A.C., Arvanitakis, A., Tangen, K., *et al.* (2005) Price Determinants in the EU Emissions Trading Scheme. *Climate Policy*, **5**, 15-30. https://doi.org/10.1080/14693062.2005.9685538

[2] Blyth, W. and Bunn, D. (2011) Coevolution of Policy, Market and Technical Price Risks in the EU ETS. *Energy Policy*, **39**, 4578-4593. https://doi.org/10.1016/j.enpol.2011.04.061

[3] Aatola, P., Ollikainen, M. and Toppinen, A. (2013) Impact of the Carbon Price on the Integrating European Electricity Market. *Energy Policy*, **61**, 1236-1251. https://doi.org/10.1016/j.enpol.2013.06.036

[4] Zhu, B.Z. (2014) Research on the International Carbon Price Driving Factors—A Case Study of the European Union Emission Trading Scheme. *Journal of Beijing Institute of Technology* (*Social Sciences Edition*), **16**, 22-29.

[5] Chevallier, J. (2014) Understanding the Link between Aggregated Industrial Production and the Carbon Price. *Green Energy and Technology*, **6**, 111-132.

[6] Schaeffer, R. and Leal de Sá, A. (1996) The Embodied of Carbon Associated with Brazilian Imports and Exports. *Energy Conversion and Management*, **37**, 955-960. https://doi.org/10.1016/0196-8904(95)00283-9

[7] Mongelli, I., Tassielli, G. and Notarnicola, B. (2006) Global Warming Agreements, International Trade and Energy/Carbon Embodiments: An Input-Output Approach to the Italian Case. *Energy Policy,* **34**, 88-100. https://doi.org/10.1016/j.enpol.2004.06.004

[8] Sánchez-Chóliz, J. and Duarte, R. (2004) CO_2 Emissions Embodied in International Trade: Evidence for Spain. *Energy Policy*, **32**, 1999-2005.

https://doi.org/10.1016/S0301-4215(03)00199-X

[9] Yang, H.M., Wang, Y. and Liu, G.F. (2011) A Study on Carbon Emissions Embodied in China' s Import and Export in 2002 and 2007. *Resources Science*, **33**, 1563-1569.