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Trade Liberalization, Financial Development and Chinese Inter-provincial Carbon Emissions

Chun-peng Zhang[1], Chen Feng[2], Rong Kang[1]
(1. Northwest University, China; 2. University of New South Wales, Australia)

Abstract: Based on the Global Malmquist-Luenberger (GML) index, this paper decomposed the source of carbon dioxide emissions into scale effect, structural effect and technological effect. And then authors used the panel differential Generalized Method of Moments (diff-GMM) model to estimate them. At last, the results show that: (1) carbon emissions in the last period have a significant demonstration effect on the current, so carbon emissions are self-motivated. (2) The scale effect and technological effect of trade liberalization are positive and the structural effect is negative. As a result, the total effect is positive. In a word, trade liberalization can increase carbon emissions. For financial development, the scale effect and structural effect are negative, while the technical effect is positive. So the total effect is positive, and the improvement of financial development level also promotes the increase of carbon emissions.

Key words: GML index; scale effect; structural effect; technological effect; diff-GMM
JEL codes: G10, F18

1. Introduction

G20 summit closed in Hangzhou on September 5th of 2016, "The G20's Leaders' Communique Hangzhou Summit" will consider climate change as a major global economic challenge affecting the world into the agenda, which will create a new era of sustainable development. China is also working to achieve the transition to a low-carbon economic development structure.

In the early 18th century, classical economist David Ricardo in the study of the relationship among economic growth, resources and the environment, pioneered the trade and the environment combination of research ideas. In the current context of the development of low-carbon economy, the relationship between carbon emissions and trade liberalization has become a microcosm of environmental quality and trade liberalization. Since 2007, China has become the world's largest carbon emissions of countries, in 2013, the emissions is reached 8977.1 Mt[1]. At the same time, China's foreign trade has made breakthrough progress, becoming an important engine of world

Chun-peng Zhang, Master in Economics, School of Economics and Management, Northwest University; research areas/interests: international trade, low-carbon economics. E-mail: chunpeng2016@sina.com.
Chen Feng, Master in Economics, Australia Business School, University of New South Wales; research areas/interests: international trade, low-carbon economics. E-mail: mailto:chen.feng@student.unsw.edu.au.
Rong Kang, Ph.D. in Economics, Professor, School of Economics and Management, Northwest University; research areas/interests: climate negotiations, low-carbon economics. E-mail: kangrong@nwu.edu.cn.

[1] Data are from the IEA website.

economic growth, import and export trade volume in 2013 as high as 4.16 trillion US dollars[2]. However, with the development of foreign trade and the growth of carbon emissions, China's financial system is also improving. The financial market reform has achieved great success. The level of financial development has gradually increased. In 2013, the broad money supply reached RMB 110.7 Trillion[3].

Trade liberalization and financial development are the important factors affecting carbon emissions. It is of great theoretical and practical significance to study the relationship between trade liberalization, financial development and carbon emissions.

2. Literature Review

There are many literatures on trade liberalization and carbon emissions, but the conclusions are not entirely consistent. Cole and Elliott (2003) conduct an empirical study of 32 countries and find that trade liberalization increased CO_2 emissions. The results of the study are supported by Niu et al. (2011) and Li et al. (2011). Grimes and Kentor (2003) have found that trade reduces CO_2 emissions, although the results are not significant.

Grossman and Krueger (1993) use the "trade-environment" general equilibrium analysis model to classify the effects of trade on the environment as scale effect, structural effect and technological effect, and establish the basic framework for the analysis of trade environmental effects. The trade effect of trade liberalization on carbon emissions means that trade will increase the economic scale, bring more natural resources and lead to an increase in carbon dioxide emissions. Environmental Kuznets Curve (EKC) is the most widely used, most controversial and most directly applied hypothesis in the study of the relationship between economic development and carbon emissions 4. The environmental Kuznets curve of "inverted U-shape" has been confirmed in the literatures of many countries and regions (Ankarhem, 2005; Lin et al., 2009; Chen et al., 2012). However, a large number of studies show that due to the different research areas, time periods and measurement methods, economic development and carbon emissions curve will be different. Structural effect refers to the deepening of trade liberalization makes a country to specialize in the production of its comparative advantage industry, which makes an industrial adjustment having an impact on carbon dioxide emissions. For this theory, there are two kinds of fierce confrontation opinions: Factor Endowment Hypothesis and Pollution Refuge Hypothesis. Some scholars' research results tend to support the Factor Endowment Theory and deny the Pollution Refuge Hypothesis (Cole et al., 2005; Lu, 2009; Li et al., 2012). However, the research results of Fu et al. (2011), Peng et al. (2012) and Lopez et al. (2013) support the Pollution Refuge Hypothesis. Although the theoretical analysis of these different perspectives have been developed, but the empirical results of the two sides are very different. Copeland and Taylor (2004), Peng et al. (2013) and Zhang (2015) argue that interregional trade is influenced by the interaction of the above two mechanisms to determine their performance. Technological effect means that the free development of foreign trade enhances the flow of international technology. A country can reduce carbon dioxide emissions by introducing foreign advanced "clean" technology. Caselli and Coleman (2000), Guo et al. (2009) and Liu et al. (2011) all agree that trade facilitates the technological advancement, and the trade effect of trade liberalization has been studied extensively by domestic and foreign scholars. However, there are studies that there is a threshold effect of this promotion effect. The impact of technological progress on carbon emissions is not consistent in the current study. Fisher (2006), Cole et al. (2009), Wei and Yang (2010) believe that technological

[2] Data are from China National Bureau of Statistics website.
[3] Data are from the national economic and social development statistics bulletin of China in 2013.

progress will significantly reduce carbon emissions. However, Saunders (2000) and Zhou et al. (2007) deny the view that technological progress can reduce the total amount of carbon emissions on the grounds of "rebound effect". Yao et al. (2012) argue that the "lock-in effect" of technology also affects the effect of carbon reduction. Li (2012) argues that the impact of technological progress on China's carbon emissions is relative to the length of the period. There are also studies that the impact of technological progress on carbon emissions has a certain path dependence (Acemoglu, 2009; Shen et al., 2012). Therefore, the impact of technological progress on carbon emissions is uncertain, may increase carbon emissions, and also reduce emissions (Jaffe et al., 2002).

Financial development on the impact of carbon emissions is relatively small. Shahbaz et al. (2003) find that financial development contributes to the reduction of carbon dioxide emissions (Tamazion et al., 2009; Y. et al., 2012), but Boutabba's research in India suggests that financial development will increase carbon emissions (Zhang, 2011; Xiong, 2016). And Zhu (2015) argues that the financial development and carbon emissions have inverted "U"-shaped curve. Although the financial development of the carbon emissions will also produce scale effect, technical effect and structural effect, but the existing literature on its research is extremely rare. Scale effect means that financial development is conducive to the expansion of enterprises with effective financial expansion to expand production scale, rich marketing activities, resulting in increased carbon emissions. Structural effect refers to the financial development of enterprises updates facilities, guides the optimization of industrial and energy structure, and promotes low-carbon economic development. For the technical effect, the development of the financial system can attract high-tech foreign direct investment, provide local enterprises with technological transformation and upgrading opportunities and power, improve the efficiency of energy use and cleaner production capacity.

Based on the overview of trade liberalization, financial development and carbon emissions, this paper shows (1) There is no unified conclusion on the relationship between trade liberalization and carbon emission, financial development and carbon emission, and it is analyzed from a whole point of view, and there are relatively few regions in the study of trade openness and carbon emission. (2) There are few literatures that consider the impact of trade liberalization and financial development on carbon emissions, although in theory financial development and trade liberalization are mutually reinforcing and can influence carbon emissions. (3) Most of the literatures focused on the quantification of the effects of the study, very little in-depth study of its impact mechanism. Based on the data from 1996 to 2014 in China, the author will compare the regional research with the whole research from the scale effect, the structure effect and the technology effect, and deeply analyze the impact of trade liberalization and financial development on carbon emissions.

3. Model Specification

In the current theoretical model of the factors affecting carbon emissions, the STIRPAT model has been widely used, as follows:

$$I_i = \alpha P_i^b A_i^c T_i^d \varepsilon_i \quad (1)$$

In this formula, P is the population, A is the wealth, T is the technical level, α is the coefficient, ε is the error term. Both sides of formula take logarithm, as follows,

$$LNI = \alpha' + bLNP + cLNA + dLNT + \varepsilon' \quad (2)$$

This paper takes carbon as the research object, and adds trade openness and financial development index into the model to study the carbon emission effect of trade liberalization and financial development according to the needs of the research. Taking into account the diversity of factors affecting carbon emissions, improve the model, adding elements of intensity, industrial structure, energy consumption structure, population size and other factors. Based on the above analysis, we can get the appropriate expansion of the model:

$$\mathrm{LNC} = \alpha' + \mathrm{aLNA} + \mathrm{bLNTRADE} + \mathrm{cLNFDL} + \mathrm{dLNXi} + \varepsilon' \quad (3)$$

X_i represents the factor intensity, industrial structure, energy consumption structure, population size and other variables. The corresponding panel data model is

$$\mathrm{LNC}_{it} = \mathrm{aLNC}_{it-1} + \mathrm{bLNTRADE}_{it} + \mathrm{cLNFDL}_{it} + \mathrm{d_i LNX}_{it} + \delta_t + \eta_i + \varepsilon_{it} \quad (4)$$

Where i is the provincial cross section, t = 1, 2 ..., 29; t is the time; LNTRADE is the trade openness of each region. LNFDL denotes the financial development level, and δ_t denotes the time non-observing effect. η_i denotes regional non-observational effect. ε_{it} is a random error term independent of time and region. X are the other control variables, including the factor intensity EI, industrial structure IS, energy consumption structure CCS, population size PP.

In order to further explore the mechanism of trade liberalization and the impact of financial development on carbon emissions, this paper decomposes the carbon emissions based on Global Malmquist-Luenberger index (GML) according to Sun et al. (2015).

The GML index reflects the ratio of total factor productivity (TFP) to the previous year under certain environmental regulations, which is considered as follows:

$$\mathrm{GML}_t^{t+1} = \frac{\mathrm{TFP}^{t+1}}{\mathrm{TFP}^t} \quad (5)$$

We decompose carbon emissions into economic scale changes, technological level changes and input-output structural changes:

$$\frac{C^{t+1}}{C^t} = \left\{\frac{\mathrm{RGDP}^{t+1}}{\mathrm{RGDP}^t}\right\} \times \left\{\frac{\mathrm{TFP}^t}{\mathrm{TFP}^{t+1}}\right\} \times \left\{\frac{\mathrm{RGDP}^t \times C^{t+1} \times \mathrm{TFP}^{t+1}}{\mathrm{RGDP}^{t+1} \times C^t \times \mathrm{TFP}^t}\right\} \quad (6)$$

Based on the transitivity of the GML index, the carbon emissions from the t-stage structural effects are represented by STEt, in the meantime, both sides of formula take logarithm, as follows,

$$\mathrm{LNC}^t = \mathrm{LNRGDP}^t - \mathrm{LNTFP}^t + \mathrm{LNSTE}^t \quad (7)$$

In view of the path dependence characteristics of production and discharge behavior and the reference to the research results of Li Kai and Qi Shaizhou (2011), Zhou Jieqi and Wang Tongsan (2015), this paper considers that the study should also consider the influence of the previous period. The lagged term of the variable is explained, and the estimation model of this paper is obtained:

$$\mathrm{LNRGDP}_i^t = \mathrm{aLNRGDP}_i^{t-1} + \mathrm{bLNTRADE}_i^t + \mathrm{cLNFDL}_i^t + \mathrm{dX}_{it} + \delta_t + \eta_i + \varepsilon_{it} \quad (8)$$

In the formula (8), if b is more than 0, the scale effect of trade liberalization will be positive. And if c is more than 0, the structural effect of financial development will be positive. When STE is used to replace RGDP in the formula, the results are similar. However, when TFP is used to replace RGDP, the results are opposite. The reason is that the sign in front of TFP in the formula (7) is negative. Specifically, if b is more than 0, the technological effect of trade liberalization will be negative.

4. Data Sources and Descriptions

In this paper, 1996-2014 is the study interval. 29 provinces except Tibet, Hong Kong, Macao and Taiwan are selected as the study objects (Chongqing is incorporated into Sichuan Province). The data mainly come from China Statistical Yearbook, China Energy Statistical Yearbook, China Financial Statistical Yearbook and provincial statistical yearbook.

4.1 The Calculation of CO_2 Emissions

According to international practice, CO_2 emissions are mainly from four aspects: fossil fuel combustion, cement production, land use and secondary energy net export. According to the data from the International Energy Agency (IEA), fossil fuel combustion accounts for about 80% in the total carbon emissions. According to data from the Carbon Sequestration Information Center (CDIAC) at Oak Ridge National Laboratory, CO_2 emissions from cement production in China exceed 10%. What's more, the secondary energy net exports for the regions can be ignored, and CO_2 emissions from land use lack of relevant data. Therefore, authors calculate the inter-provincial carbon emissions from fossil fuel combustion emissions and cement production emissions. At the same time, authors use the method of Li Huaizheng, Lin Jie (2013) and Zhao Zhiyun, Yang Chaofeng (2012) according to the following formula to calculate the carbon emissions.

$$\mathrm{CO2} = \sum_{i=1}^{8}(E_i \times \theta_i) + CE \times \varphi = \sum_{i=1}^{8}(E_i \times N_i \times CC_i \times COF_i \times 3.67 + CE \times \varphi) \qquad (9)$$

In the above formula (9), i means the eight fossil fuels in Table 1, E is the consumption of fossil fuels, CE represents the cement production. θ and φ respectively stand for CO_2 emission factors for different fossil fuels and cement. N indicates the calorific value of fossil energy. CC represents fossil energy content. COF means oxidizing factors of fossil fuels.

Table 1 CO_2 Emission Factors

T/Billion Cubic meters	Coal	Natural gas	coke	Fuel oil	crude	gasoline	kerosene	diesel	cement
CO_2 emission factors	1.776	21.67	2.848	3.064	3.0665	3.045	3.174	3.15	0.496

4.2 Input-output Variables

Charnes, Cooper and Rhodes proposed Data Envelopment Analysis (DEA) for the first time in 1978. DEA is the nonparametric technique efficiency analysis based on the relative comparisons among the evaluated objects. In this paper, authors use the MAXDEA software to measure the GML index.

(1) Input variable

Energy consumption: All kinds of energy consumption are converted into standard coal, and then add up.

Human capital: Learning from the paper of Zhu Pingfang & Lilei (2004), authors use the numbers of scientific and technological activities as the proxy variable.

Physical capital: Learning from the paper of Zhangjun et al. (2004), authors use the perpetual inventory method and choose 1990 as the basing period. In addition, the depreciation rate is 9.6%. The initial capital stock is 10% of the total fixed assets.

(2) Output variable

Expected output: It is represented by per capita GDP in each province. Considering the comparability of the study, it is converted to the comparable prices in 1990.

Non- expected output: carbon dioxide emissions.

4.3 Variables in the Model

(1) Explained variables: LNRGDP, LNTFP, LNSTE

(2) Explanatory variables.

Trade liberalization: It is represented by the proportion of the total import and export in GDP.

Financial development: Authors use the development level of financial intermediaries to express the financial development level. Specifically, it is represented by the proportion of the residents' saving deposits in GDP. This index reflects the savings behavior of residents more exactly. In this situation, the effects from government policy distortions are weaker.

(3) Control variables

Factor intensity: According to the leibzinski theorem, if the ratio of capital to labor increases, the output of capital-intensive sector will rise. In general, capital-intensive sectors are pollution-intensive. As a result, pollution emissions increases.

Industrial structure: The increase in the proportion of tertiary industry is conducive to carbon emissions reduction. This paper used the proportion of tertiary industry in GDP to measure the industrial structural index.

Energy consumption structure: At present, China's energy consumption is dominated by traditional fossil fuels. At the same time, coal is the main fossil fuel. So authors use the proportion of coal consumption in the total energy consumption.

Population size: When the population size increases, basic household consumption rises. Thereby, carbon dioxide emissions will also increase.

Table 2 Descriptive Statistical Indicators of Variables

Logarithm of the variable	Mean	Standard deviation	Minimum value	Maximum value	Number of observations
LNRGDP	9.6229	0.8795	7.6246	11.5639	551
LNTFP	-1.8848	0.9108	-3.4916	0	551
LNSTE	-1.7150	0.5026	-3.1564	1.3943	551
LNTRADE	-1.7471	1.0325	-3.4534	0.5432	551
LNFDL	-0.3930	0.2229	-0.9738	0.2095	551
LNIS	3.6991	0.2040	3.3214	4.4485	551
LNPP	8.1431	0.7997	6.1369	9.5786	551
LNCCS	4.1430	0.3094	3.1355	4.6634	551
LNEI	-1.4301	1.0086	-4.0157	2.5665	551

5. Empirical Analysis

Due to endogenous existence, the static panel model is not available. Arellano and Bond proposed the difference GMM (diff-GMM) in 1991. Diff-GMM can eliminate non-observational effects and variables which do not change with time. In order to enhance the robustness of the results, the model introduces some control variables. And the regression results are shown in Table 3.

(1) The first-order lagged terms of explained variable in three models are significant at the level of 5%. But the influence of lagged terms for economical scale and input-output structure are much greater than the term of technical efficiency. So authors believe that economical scale and input-output structure in the last period have significant demonstration effect on the current. Considering economical scale and input-output structure have impacts on carbon emissions. So carbon emissions are self-motivated.

(2) In general, the scale effect of trade liberalization is positive. From the estimation results in model 1, the coefficient of primary item is 0.1325, which is significant at 1% level. And the coefficient of the quadratic term is -0.2052, which is significant at the level of 10%. Obviously, the curve shows a inverted "U" type between trade openness and economic growth. At this point, it is consistent with the research of Bao Qun (2008): At the initial stage of economic opening-up, the development of foreign trade will promote the economic growth; but the

further increase of trade openness will lower the economic growth rate when it exceeded the certain critical value. And Michaely (1977), Papageorgiou (2002) also confirmed the existence of critical effect.

It is also known that the scale effect of financial development is negative. In model 1, the coefficient of the first term for financial development is -0.1034, which is significant at 1% level. It means that financial development is negatively correlated with per capita GDP. Authors believe that it may be caused by this reason — per capita income level in China is not high. As Le vine (1992) and Zhang Ke etc. (2009) believed that, financial development and economic growth have a double threshold effect: In the region with high level of economic development, financial development has obviously promoted economic growth. On the contrary, financial development has hindered economic growth in the low level areas.

(3) The structural effects of trade openness and financial development are negative. According to the results of model 2, the coefficient of trade openness is -0.1910, which is significant at the level of 10%. And the coefficient of financial development is -0.3832, which is also significant at the level of 10%. If the trade openness increased by 1%, Input and output structure will be improved 0.1910%, correspondingly carbon emissions decrease by 0.1910%. While the financial development level increased by 1%, input and output structure will be improved 0.3832%, correspondingly carbon emissions decrease by 0.3832%. These mean that trade liberalization and financial development can reduce carbon emissions by accelerating the optimization of input-output structure. As known to us, China's trade liberalization can share the benefits of global trade, and promote the upgrading of economic structure through the international industrial transfer. Financial development can promote the investment on the environmentally friendly projects in China, provide facilitation of financing and incentives for the energy-saving projects, guide the upgrading of industry and energy structure, and promote low-carbon economic development.

(4) The technological effects of trade liberalization and financial development are positive. For model 3, the coefficient of trade openness is -0.2949, which is significant at 1% level. And the coefficient of financial development is -1.0245, which is significant at the level of 1%. If the trade openness increased by 1%, the technical level will drop by 0.2949%. Correspondingly carbon emissions increased by 0.2949%. While the financial development level increased by 1%, the technical level will decrease 1.0245%, correspondingly carbon emissions increased by 1.0245%. In the new growth theory, trade liberalization will accelerate domestic technological progress and increase total factor productivity. In this paper, the empirical result of trade liberalization is contrary to the new growth theory. So We can see that the domestic R & D department does not have access to external technical information, Imitate and learn advanced technology from outside, improve R & D capabilities and efficiency, achieve technology spillover. Foreign direct investment and R & D investment attracted by financial development have not been significantly transformed into technological progress, which confirms the ability of Chinese enterprises to digest and absorb foreign clean technology.

(5) As can be seen in Table 3, the P values of the Arellano-Bond second-order test in models 1, 2 and 3 are both greater than 0.5. These mean that there is no second-order autocorrelation at the 5% significance level and the estimator of the GMM is consistent. As a result, the differential GMM can be established. In addition, the P value of Hansen test is more than 0.5. So The hypothesis that the selected instrument variable is valid cannot be rejected at the significance level of 5%. Therefore, the estimator of differential GMM is effective.

Table 3 Empirical Results

Explained variables	LNRGP	LNSTE	LNTFP
	Model 1	Model 2	Model 3
First-order lagged term	0.9546*** (0.0196)	0.5088*** (0.1040)	0.0780** (0.1674)
LNTRADE	0.1325*** (0.0489)	-0.1910* (0.1003)	-0.2949*** (0.1130)
(LNTRADE)^2	-0.2052* (0.0119)	---	---
LNFDL	-0.1034*** (0.0401)	-0.3832* (0.2263)	-1.0245*** (0.2504)
LNIS	-0.3365*** (0.0622)	-0.2385*** (0.2558)	-0.8931*** (0.3137)
LNEI	0.0109* (0.0065)	0.1149*** (0.0463)	0.3233*** (0.0449)
LNCCS	0.0811** (0.0402)	0.5080** (0.2360)	0.2432* (0.0528)
LNPP	0.6029** (0.2389)	-0.5610 (0.7000)	2.4359* (1.2995)
AR (2)	0.534	0.052	0.097
Hansen Test	1.00	1.00	1.00
Number of observations	522	522	522

Notes: The figures in brackets are robust standard errors; *, ** and *** means variables are significant at 10%, 5% and 1% level; the output value of AR (2) and Hansen Test are the P value. Empirical results are achieved in Stata12.0 by the command of xtabond2. In Table 3, Model 1 is added to the square of trade openness.

6. Conclusions

This paper estimates carbon dioxide emissions from 29 provinces in China, and uses the GML index to decompose CO_2 emissions into Per capita GDP changes, structural changes and technological changes. Then on the basis of the extended STIRPAT model, the dynamic panel differential GMM model is used to measure and analyze the effects of trade liberalization and financial development on carbon emissions, and the following conclusions are drawn.

The last stage of the economic scale, input-output structure has a significant demonstration effect on the current period. And carbon emissions are self-motivated. These indicate that people’s consumption concept and lifestyles have a significant impact on carbon emissions. We can reduce regional carbon emissions by instilling low-carbon ideas to transform people’s high-carbon lifestyles.

The scale effect of trade liberalization is positive, and trade liberalization can increase carbon emissions by increasing economical scale. Trade liberalization has a negative effect on the structural effect of trade liberalization, which accelerates the optimization of input-output structure. The technological effect of trade liberalization has not brought about the spillover effect of technology. In general, trade liberalization increases carbon emissions. Correspondingly, the scale effect and structural effect of financial development are negative, but the technological effect is positive. In short, the total effect is positive, and the promotion of financial development level promotes the increase of carbon emissions. Taking into account the environmental costs of trade liberalization, China should formulate policies to make trade open, financial development and carbon emission reduction together. And take comprehensive measures to change the traditional mode of trade development. Gradually, green trade development achieves in China. In addition, the promotion of green finance is necessary. For example, green financial system and green financial markets should be set up.

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