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The impact of financial development on carbon emissions: an empirical analysis in China

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Abstract: Given the complexity between China's financial development and carbon emissions, this paper uses some econometric techniques, including cointegration theory, Granger causality test, variance decomposition etc., to explore the influence of financial development on carbon emissions. Results indicate that, first, China's financial development acts as an important driver for carbon emissions increase, which should be taken into account when carbon emissions demand is projected. Second, the influence of financial intermediation scale on carbon emissions outweighs that of other financial development indicators but its efficiency's influence appears by far weaker although it may cause the change of carbon emissions statistically. Third, China's stock market scale has relatively larger influence on carbon emissions but the influence of its efficiency is very limited. This to some extent reflects the relatively lower liquidity in China's stock markets. Finally, among financial development indicators, China's FDI exerts the least influence on the change of carbon emissions, due to its relatively smaller volume compared with GDP; but it is mainly utilized in carbon intensive sectors now, therefore, with the increase of China's FDI in the future, many efforts should be made to adapt its utilizing directions and play its positive role in promoting low-carbon development.

Key words: financial development; carbon emissions; China

1. Introduction

China now has become the largest carbon emitter in the world with the share 24.2% of the total in 2009 (BP, 2010). And in the long future, with the process of industrialization and urbanization, China's economy will continuously grow, which may inevitably cause ever-increasing carbon emissions. Under this circumstance, in order to effectively promote sustainable development of socio-economy and address global climate change, Chinese central government promised to reduce 40%-45% carbon emissions intensity (carbon emissions per unit of GDP) by 2020 compared with the 2005 level. Then, a dilemma has popped up for China between increasing national income and reducing carbon emissions, which has attracted extensive

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attention but the conclusions are not consistent and the solution proves unclear till now.

In fact, the carbon emissions in a country do not necessarily depend on its income level alone, financial development may be another source. In an economic entity with ever-deepening financial systems, the growing role of financial development in carbon emissions increase tends to be continuously augmented for several reasons. First, financial development may attract foreign direct investment (FDI) so as to accelerate economic growth and increase carbon emissions (Frankel and Romer, 1999). Second, prosperous and efficient financial intermediation seems conducive to consumers' loan activities, which makes it easier for consumers to buy big ticket items like automobiles, houses, refrigerators, air conditioners, washing machines etc. and then emit more carbon dioxide (Sadorsky, 2010). In addition, stock market development helps listed enterprises to lower financing costs, increase financing channels, disperse operating risk and optimize asset/liability structure, so as to buy new installations and invest new projects and then increase energy consumption and carbon emissions (Dasgupta et al., 2001).

However, there are also some authors opposing to the arguments above. For instance, Tamazian et al. (2009) emphasize that financial development helps listed enterprises to promote technology innovation and adopt new technologies, so as to increase energy efficiency and advance low-carbon economic development; consequently, the carbon emissions intensity may be cut significantly. Besides, Claessens and Feijen (2007) find that those enterprises with more advanced governance often are more willing to consider low-carbon development; therefore, financial development may spur enterprises' performance and then reduce energy consumption and carbon emissions.

As a result, it can be found that the nexus of financial development and carbon emissions appears unclear up to now, and further empirical study is necessary. In fact, this kind of work is of great importance for China to scientifically design the path for carbon emissions intensity reduction and reasonably evaluate the difficulty to realize the carbon emissions intensity reduction target by 2020. Because if there is a significantly positive relationship between financial development and carbon emissions, then further development in China's financial sector may increase emissions in a way that has not been accounted for. This will make it more difficult for China to meet its planned emissions reduction targets.

The rest of the paper is organized as follows. Section 2 presents the empirical literature review related with financial development and carbon emissions. Section 3 puts forward research data definitions and empirical methodologies in this paper. Empirical results are given in Section 4, and Section 5 concludes the paper.

2. Related literature review

Among empirical study literature, financial development mainly includes the development of financial intermediation, stock market and foreign direct investment (FDI) etc. In fact, a large body of research implies that financial development has become an integral part to spur economic development, and basically plays a positive role in adjusting economic development. Levine (1997) argues that due to the market conflicts caused by the existence of trading cost and information cost, the role of financial intermediation is to eradicate those conflicts so as to lubricate the savings and optimize the capital allocation. Han (2001) holds that well-built financial markets and smooth transferring mechanisms are conducive to saving increase and effective transformation from saving to investment, and then promote capital accumulation, technology advance and economic growth in the long run.

Numerous empirical studies are found on the nexus between China's financial development and economic growth. Summarily, we may see that the research ways include three levels, i.e., on the national, regional and provincial ones (Tan, 1999; Zhou and Zhong, 2004; Du, 2008; Zhang and Hu, 2003; Hasan et al., 2009). In addition, the research methods mainly involve in some econometric models, such as cointegration theory, error correction model and Granger causality test approach etc. And the research conclusions basically argue that financial development spurs economic growth, but the magnitude varies in different regions of China.

Besides, a large number of studies focus on the relationship between economic growth and carbon emissions, especially the discussion about the Environmental Kuznets Curves (EKC) curve, but their conclusions differ a lot (Soytas et al., 2007; Soytas and Sari, 2009; Tamazian et al., 2009). As for that in China, existing research indicates that China's economic growth is closely related with carbon emissions; especially in the recent decade, we can see the significant driving influence of economic growth on carbon emissions (Zhang and Cheng, 2009) and the restraining influence of carbon emissions on economic growth (Chen et al., 2004).

Comparatively, little research analyzes the influence of financial development on carbon emissions and energy consumption. Sadorsky (2010) explores the influence of financial development in 22 emerging countries (including China) on energy consumption using a panel data model, and argues that, as a whole, financial development in these countries significantly promote the increase of energy consumption. Tamazian et al. (2009) investigate the relationship among economic growth, financial development and environmental quality in the BRIC countries, and find that financial development proves a key factor to cut carbon emissions. Similarly, Tamazian and Bhaskara Rao (2010) point out that financial development in

transition countries may exert evident influence on carbon emissions.

It should be noted that existing empirical research on financial development often takes FDI as one of the financial development indicators although traditional financial development theory does not necessarily cover FDI. In fact, there are many studies on the influence of FDI on environment quality, but the conclusions have not come to a consensus. For instance, List and Co (2000), Mielnik and Goldemberg (2002) find that the inflow of FDI helps to promote energy efficiency of the host countries and cut their environmental quality. Xing and Kolstad (2002), however, argue that there exists a positive relationship between FDI and pollutant emissions in the host countries. Therefore, we can say that the nexus between FDI and carbon emissions remains unclear up to now. Hence further study should be conducted to evaluate whether FDI has caused China to be a carbon dioxide haven of developed countries for its relatively loose environmental regulations.

As a whole, the previous related literature provides us with helpful references; however, as for the nexus of financial development and carbon emissions in China, there are at least two problems to be investigated further.

For one thing, existing literature often measures financial development in an aggregate way when the relationship between financial development and carbon emissions is concerned, while it seldom distinguishes the financial scale and efficiency and also rarely explores the role of stock markets in a specific way.

For another, the nexus between China's financial development and carbon emissions has not been discussed to our best knowledge. Actually, China's financial development has its own characteristics. For instance, numerous studies often use the ratio of deposits (or the sum of deposits and loans) to GDP to measure China's financial development level (Tamazian et al., 2009; Sadorsky, 2010), but according to the China Statistical Yearbook, there is substantial difference between the deposits and loans of China's financial institutions; specifically, about 20%-35% of deposits have been sleeping in banks in the past decade. Thus, the ratio of deposits to GDP can hardly describe the financial development level in China. And since the loans are closely related with the activities of enterprises, hence the ratio of the bank loans to GDP may be more reasonable, which in fact has been commonly used in some previous financial development literature for other research purposes (Giuliano and Ruiz-Arranz, 2009; Hasan et al., 2009; Yuxiang and Chen, 2010).

In response to these problems, this paper uses some quantitative methodologies, including Johansen cointegration test, modified Granger causality test and variance decomposition etc., to explore the influence

of China's financial development on carbon emissions from two perspectives, i.e., financial development scale and efficiency, not only for financial intermediation but also for stock markets.

3. Data definitions and empirical methodologies

3.1. Data definitions

When financial development is concerned, one of the popular definitions focuses on its scale, such as the sum of bank loan, stock market capitalization and bond market capitalization divided by GDP, but China's bond market emerged in 2005, with very short time series, and its influence on the whole financial system of China appears limited till now; therefore, this paper does not consider bonk market capitalization temporarily. In fact, financial development also covers the efficiency issue, which will be involved in this paper. Meanwhile, as discussed above, although financial development does not cover FDI in theory, FDI is often taken as a financial development indicator in empirical studies (see Sadorsky (2010)), so this paper also incorporates FDI as one of the financial development variables. Besides, in order to avoid the omitted variable bias, we also introduce economic growth as an explanatory variable when the Johansen cointegration and Granger causality are tested.

All the variables in this paper and their data definitions are shown in Table 1. It should be noted that all the data are the annual items and are transformed into logarithmic values for further investigation except *FDI*.

Table 1
Variables and data definitions. [a]

Variable	Definition	Sample period	Variable reference	Data source
CO2	It denotes China's carbon emissions.	1980-2009	——	BP Statistical Review of World Energy 2010.
GDP	It denotes China's economic growth, represented by real GDP per capita measured at constant 2000 US dollars.	1980-2009	Sadorsky (2010)	WDI&GDF database of World Bank.
FS	It denotes China's financial intermediation scale, represented by the ratio of loans in financial intermediation to GDP.	1980-2009	Yuxiang and Chen (2010)	Wind database
FE	It denotes China's financial intermediation efficiency, represented by the ratio of the sum of loans to township enterprises, enterprises with foreign funds and private enterprises and self-employed individuals to GDP.	1994-2009	Zhou and Zhong (2004)	Most data is from the China Statistical Yearbook and the 2009 data is from the monthly report of the Peoples' Bank of China.
SS	It denotes China's stock market scale, represented by the ratio of stock market capitalization to the GDP.	1992-2009	Tan (1999), Sadorsky (2010)	Wind database
SE	It denotes China's stock market efficiency, represented by the ratio of stock market turnover to GDP.	1992-2009	Tan (1999), Sadorsky (2010)	Wind database
FDI	It denotes China's foreign direct investment, measured as net inflows as percent of GDP.	1984-2009	Tamazian et al. (2009)	WDI&GDF database of World Bank.

[a] The dependent variable in each model is *CO2*, and all variables are transformed into the logarithmic items except *FDI*.

The annual data of carbon emissions, GDP per capita and financial development indicators of China can be seen from Figure 1. We find that most variables experience a steady rise across respective sample period, except financial intermediation efficiency with a relatively stable level even a mild declining trend in recent years.

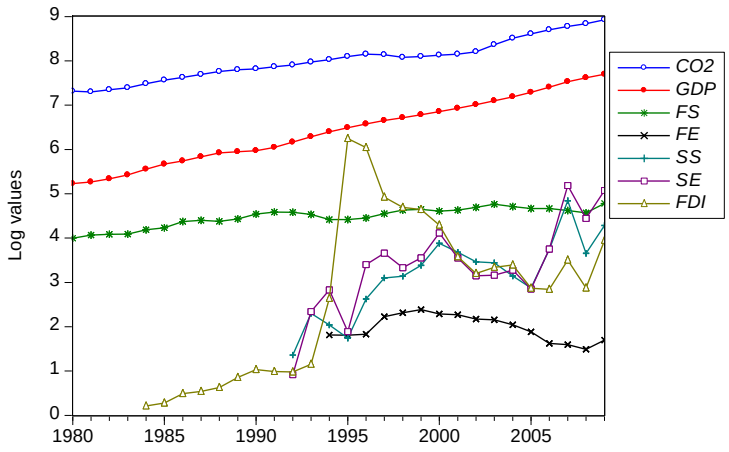

Fig. 1 Annual log values of all variables in this paper

3.2. Empirical methodologies

This paper investigates the influence of China's financial development on carbon emissions from two perspectives. One is to conduct the Granger causality and Johansen cointegration tests to explore the influencing directions between different financial development indicators and carbon emissions respectively; the other is to compare the influencing magnitude of different financial development indicators on carbon emissions based on the vector error correction model (VECM) and variance decomposition approach.

It should be noted that the Granger causality test approach is the modified approach provided by Granger (1988). Given empirical studies below show that all the financial development indicators in this paper are I(1) series but some of them do not have cointegration relationship with carbon emissions, so the traditional Granger causality test approach proposed by Granger (1988) may cause biased results. Therefore, similar to Menyah and Wolde-Rufel (2010), this paper uses a modified version of traditional Granger causality test approach proposed by Toda and Yamamoto (1995), which is valid regardless whether a time series is I(0), I(1) or I(2), non-cointegrated or cointegrated of any arbitrary order.

The novelty of the procedure proposed by Toda and Yamamoto (1995) is that it does not require pre-testing for the cointegrating properties of the system and thus avoids the potential bias associated with unit root and cointegration tests (Rambaldi and Doran, 1996). As has been pointed out by Clarke and Mirza (2006),

pre-tests for unit root and cointegration might suffer from size distortions, which often implied the use of an inaccurate model for the causality test. To obviate some of these problems, the new approach used here, based on augmented VAR modeling, introduces a Wald test statistic that asymptotically has a chi-square (χ^2) distribution irrespective of the order of integration or cointegration properties of the variables. The approach fits a standard vector auto-regression (VAR) model on level variables (not on their first differences) and therefore makes allowance for the long-term information often ignored in systems that require first differencing and pre-whitening (Clarke and Mirza, 2006). The approach employs a modified Wald test for restrictions on the parameters of the VAR model with the lag length *k*. The basic idea of the modified approach is to artificially augment the correct order *k*, which is set according to the least AIC and SC values, by the maximal order of integration, say d_{max}. Once this is done, a $(k+d_{max})^{th}$ order of VAR is estimated and the coefficients of the last lagged d_{max} vectors are ignored (Caporale and Pittis, 1999).

For example, in order to undertake the modified version of Granger causality test for a VAR model with 3 lags (k=2 and d_{max}=1), we estimate the following system of equations:

$$\begin{bmatrix} CO2_t \\ FS_t \\ GDP_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} CO2_{t-1} \\ FS_{t-1} \\ GDP_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} CO2_{t-2} \\ FS_{t-2} \\ GDP_{t-2} \end{bmatrix} + A_3 \begin{bmatrix} CO2_{t-3} \\ FS_{t-3} \\ GDP_{t-3} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \quad (1)$$

where A_1, A_2, A_3 are three 3×3 matrices of coefficients with A_0 being a 3×1 identity matrix, and ε_s are the disturbance terms with zero mean and constant variance. From Equation (1) we can test the hypothesis that China's financial intermediation scale does not Granger cause carbon emissions with the following hypothesis: $H_0^1 = a_{12}^1 = a_{12}^2 = 0$, where $a_{12's}^i$ are the coefficients of the financial intermediation scale variable in the first equation of the system presented in Equation (1). Besides, we can test the opposite causality from China's carbon emissions to financial intermediation scale in the following hypothesis: $H_0^2 = a_{21}^1 = a_{21}^2 = 0$, where $a_{21's}^i$ are the coefficients of the carbon emissions variable in the second equation of the system presented in Equation (1). It should be noted that we incorporate the variable *GDP* into Equation (1) to avoid the omitted variable bias when we examine the Granger causality between financial intermediation scale and carbon emissions.

4. Empirical result discussions

4.1. Cointegration among China's financial development indicators and carbon emissions

This paper aims to investigate the long-term equilibrium relationship between financial development and

carbon emissions based on the Johansen cointegration theory proposed by Johansen (1988) and Johansen and Juselius (1990), due to its advantages over traditional cointegration theory proposed by Engle and Granger (1987). Therefore, first of all, we conduct the augmented Dickey-Fuller (1981) (ADF) unit root tests for all variables in this paper in their respective sample periods with regard to their stationary properties and detailed results are shown in Table 2. We find that all variables in this paper are I(1) series at 10% level in their respective sample periods.

Table 2

ADF tests for variables regarding their stationary properties.

Variables	Level	First difference
CO2	-2.1948 (0.4740)	-2.7098 (0.0850)
GDP	-3.2003 (0.1062)	-3.4643 (0.0180)
FS	-2.8320 (0.1984)	-3.0759 (0.0034)
FE	-1.6766 (0.7106)	-2.9672 (0.0067)
SS	-3.0737 (0.1430)	-4.9330 (0.0001)
SE	-3.2597 (0.1064)	-4.9755 (0.0001)
FDI	-1.5192 (0.7953)	-3.5626 (0.0010)

Note: the significance probabilities for ADF test are reported in parentheses. Additionally, it should be noted that the ADF test for each variable is conducted in their respective sample periods but not in the same period.

Then we take China's carbon emissions as the dependent variable and each financial development indicator and *GDP* together as the independent variables respectively, and then the Johansen cointegration among them is tested according to Johansen (1988). From the results in Table 3, we find that except *FDI*, all other financial development indicators have at least one cointegration relationship with carbon emissions at 5% level in their respective sample periods. Therefore, we may say that, for the most part, China's financial development has significant long-term equilibrium with carbon emissions, which covers not only the financial intermediation but also the stock market, and not only the financial scale but also the financial efficiency.

Table 3

The results of Johansen cointegration tests. [a]

	Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.
Panel A: Series: *CO2, FS, GDP* (1980-2009)	None *	0.8202	57.2473	29.7971	0.0000
	At most 1	0.3999	14.344	15.4947	0.0740
	At most 2	0.0611	1.5748	3.8415	0.2095
Panel B: Series: *CO2, FE, GDP* (1994-2009)	None *	0.8791	38.7677	24.2760	0.0004
	At most 1	0.5697	11.3019	12.3209	0.0736
	At most 2	0.0257	0.3390	4.12991	0.6230
Panel C: Series: *CO2, SS, GDP* (1992-2009)	None *	0.8950	51.9488	29.7971	0.0000
	At most 1 *	0.6152	18.1393	15.4947	0.0195
	At most 2	0.2245	3.8143	3.8415	0.0508
Panel D: Series: *CO2, SE, GDP* (1992-2009)	None *	0.9489	77.9242	29.7971	0.0000
	At most 1 *	0.8084	33.3096	15.4947	0.0000
	At most 2 *	0.4334	8.5216	3.8415	0.0035
Panel E: Series:*CO2,FDI,GDP*	None	0.5258	24.2038	29.7971	0.1920
	At most 1	0.2332	7.0410	15.4947	0.5729

(1984-2009)	At most 2	0.0398	0.9353	3.8415	0.3335

[a] The dependent in each Johansen cointegration test is *CO2*. * denotes rejection of the hypothesis at the 5% level.

4.2. Causality among China's financial development indicators and carbon emissions

According to Equation (1), we conduct the modified Granger causality tests by Toda and Yamamoto (1995) for China's financial development variables and carbon emissions. It should be noted that the variable *GDP* is incorporated as an explanatory variable to avoid the omitted variable bias and not all the tests are conducted in the same sample periods. Results are shown in Table 4.

We may see that the pushing effect of China's financial intermediation development on carbon emissions appears statistically significantly; specifically, both financial intermediation scale and efficiency are the Granger causes of carbon emissions increase at 10% level; however, the pulling effect of carbon emissions on financial intermediation development proves insignificant at 10% level. Besides, stock market scale and efficiency, and FDI does not Granger cause the change of carbon emissions statistically at 10% level. The results reflect that China's financial intermediation scale proves closely related with economic growth and carbon emissions. In fact, it has been for a long time that China's enterprises' main access to external finance is provided by bank loans.

Table 4
Causality test results among China's financial development indicators and carbon emissions.

Null hypothesis	Sample period	Chi-sq statistic	Prob.
CO2 does not Granger cause the change of *FS*	1980-2009	0.7387	0.6912
FS does not Granger cause the change of *CO2*		5.3274	0.0697
CO2 does not Granger cause the change of *FE*	1994-2009	0.9728	0.3240
FE does not Granger cause the change of *CO2*		3.2391	0.0719
CO2 does not Granger cause the change of *SS*	1992-2009	2.7304	0.0985
SS does not Granger cause the change of *CO2*		0.4162	0.5188
CO2 does not Granger cause the change of *SE*	1992-2009	8.8469	0.0120
SE does not Granger cause the change of *CO2*		3.7482	0.1535
CO2 does not Granger cause the change of *FDI*	1984-2009	2.3468	0.3093
FDI does not Granger cause the change of *CO2*		2.2618	0.3227

Note: the modified Granger causality test approach used in the table is provided by Toda and Yamamoto's (1995). And the causality tests between financial development indicators and carbon emissions are based on the significance of Chi-sq statistics for Wald tests of VAR models in Equation (1), respectively.

In brief, when China's future carbon emissions demand is projected, the change of financial intermediation development should be taken into account; otherwise, further development in China's financial industry may increase emissions in a way that has not been accounted for, which makes it more difficult for China to meet its planned emissions reductions targets.

4.3. Variance decomposition analysis

In order to compare the contribution extents of China's various financial development indicators to the change of carbon emissions, the variance decomposition approach is adopted in the same period. First, we take the carbon emissions as the dependent variable and all financial development indicators and *GDP* together as independent variables, and conduct the Johansen cointegration test among these variables (Johansen, 1988; Johansen and Juselius, 1990) in the sample period 1994-2009. [i]The results indicate that there exists statistically significant cointegration among China's financial development variables and carbon emissions during 1994-2009. Then we apply the variance decomposition approach based on the vector error correction model (VECM) to explore the influence of China's financial development indicators on carbon emissions, and compare their contribution difference. Results are shown in Figure 2.

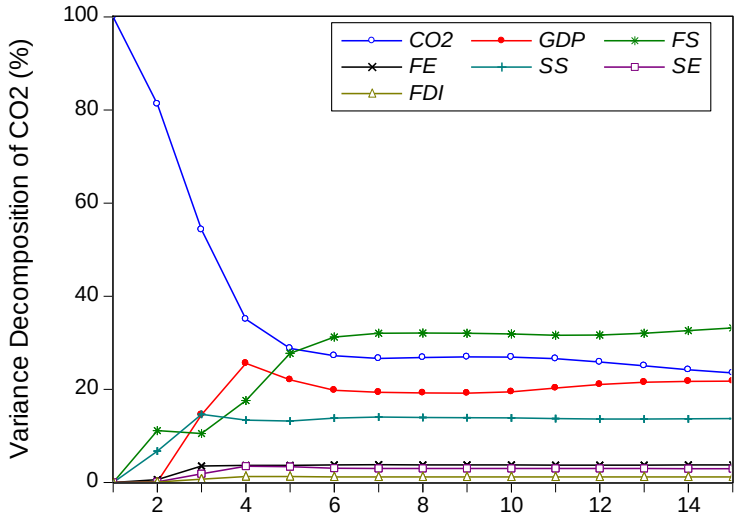

Fig. 2 The variance decomposition results of China's financial development on carbon emissions.

We may find that, among all financial development indicators, financial intermediation scale exerts the largest influence, whose steady contribution level for carbon emissions changes approaches to 33%; while the influence of stock market scale, financial intermediation scale and stock market efficiency follows, with steady contribution level of 14%, 4%, 3% respectively. It should be noted that the influence of FDI seems relatively the least, only about 1%. The results above have three important implications at least.

First, the influence of China's financial intermediation scale on carbon emissions proves significant. One of the main reasons is that the bank loans provide solid support for China's enterprises to access external finance and expand investment scale. Therefore, we can see that China's economic growth and carbon emissions increase have evident dependence on the bank asset scale expansion. Additionally, it should be

noted that the influence magnitude of China's financial intermediation efficiency on carbon emissions appears relative smaller, so it has not acted as a significant impetus to mitigating carbon emissions although it may cause the change of carbon emissions (see Table 4). In fact, as can be seen from Figure 1, the trend of financial intermediation efficiency appeared relatively stable and even experienced a mild decline these years, which caused that the negative influence of financial intermediation efficiency on carbon emissions fell linearly. Therefore, Chinese government should take effective measures to promote the banks to optimize the loan structure in the future so as to spur energy saving and carbon emissions reduction.

Second, China's stock market scale has a relatively larger influence on carbon emissions while the influence of stock market efficiency on carbon emissions appears fairly weaker. In fact, this is mainly due to the characteristics of China's stock markets (Han, 2001). For instance, ① compared with developed countries, the history of China's stock markets is pretty shorter, hence the related market mechanism design is not complete and standardized; ② China's stock market trading behavior and price are affected not only by the economic factor but also by some other factors, such as domestic political situation, stock market participators' psychology and illegal activities; and sometimes the influence of the latter even outweighs that of the former; ③ governmental actions about stock market operations often appears irrational, which makes related policies lacking consistency, succession and transparency; ④ the external finance of some listed enterprises is not fully used for productive projects or even the assigned projects. As a result, due to the investing enthusiasm of Chinese citizens to stock market has seen a continuous promotion, China's stock market scale has seen a sharp increase these years and becomes an important driver of economic growth and carbon emissions currently, but the influence of its efficiency on carbon emissions has not been evident.

Third, the influence of China's FDI on carbon emissions proves fairly slight, and this is mainly because the change of China's FDI actually utilized has not significantly influenced economic growth, which is consistent with the finding of Sadorsky (2010). As can be seen from Figure 3, China's FDI actually utilized experienced a continuous increase in the last decade; for instance, its volume in 2009 was increased by 78.5% compared to that in 2000 (in US dollar constant price in 2000); however, its increasing trend appears relatively stable, and the average annual growth rate during 2000-2009 is 6.6%, which is less than China's carbon emissions growth rate 8.8% at the same period. Besides, the increase of carbon emissions follows a linear form, which is evidently inconsistent with that of FDI increase.

More importantly, China's net inflow of FDI only accounts for less than 5% of GDP in recent years (see Figure 3), which further limits the influence magnitude of FDI on China's macroeconomic growth, thus

now it is hard for the change of FDI to become a significant driver on carbon emissions.

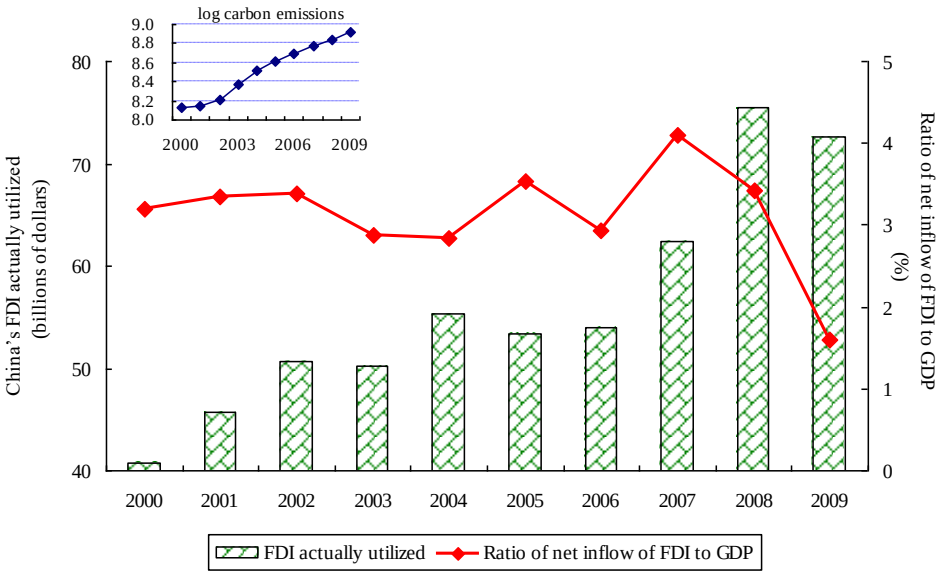

Fig. 3 The evolution of China's FDI actually utilized and carbon emissions during 2000-2009.

However, it should be noted that although the influence of FDI on carbon emissions proves by far weaker, its influence on carbon emissions should also be taken into close consideration since the relatively higher ratio of FDI was poured into China's carbon intensive industries. For instance, in 2009, China's FDI actually utilized was focused on the Manufacturing (52.0%) and Real Estate (18.7%); while the ratios of modern service industries appeared relatively lower, such as Leasing and Business Services (6.8%), Wholesale and Retail Trades (6.0%), Transport, Storage and Post (2.8%). In the long future, with the acceleration of China's industrialization and urbanization, China's domestic huge potential may be released constantly; meanwhile, China has adopted a series of effective measures to address the financial crisis, such as expanding domestic demand, maintaining financial stabilization, promoting industry revitalization and technology innovation etc., which may provide new developing opportunities and help to continuously expand the scale of China's FDI actually utilized. In view of this, close attention should be paid to the quality of FDI inflow; and it is an urgent task for Chinese government and enterprises concerned to bring the positive role of FDI into full play and contribute to low-carbon development in China.

In brief, we can see that China's financial development, especially the financial intermediation development, has become an important driver for carbon emissions increase. Therefore, although the financial intermediation sector is an integral part of the modern service industry and the promotion of the sector proves one of the important directions of China's socio-economic low-carbon and sustainable development, however, with the evolution of financial development, the inflow of financial funds should be

taken seriously so as to support the advance of low-carbon industries and technologies.

5. Conclusions and future work

China has become the largest carbon emitter in the world and the 40%-45% carbon emissions intensity reduction target by 2020 has been announced to the whole world; meanwhile, China's financial system is still in its infancy but has begun the fast take-off especially since the new century, which may foster an important impetus for economic growth and carbon emissions. Under this circumstance, the influence of China's financial development on carbon emission becomes a crucial issue. Therefore, using some econometric techniques including cointegration theory, variance decomposition, Granger causality test etc., this paper explores the influence of China's financial development on carbon emissions, and some conclusions and policy implications are obtained.

First, China's financial development, especially its financial intermediation scale, proves an important driver for carbon emissions increase. Therefore, when the carbon emissions demand projection is concerned, it can not only consider the influence of income increase. And when making related policies to cut China's carbon emissions intensity, we should not only reckon on the relationship adjustment between carbon emissions and income level. Otherwise, the real carbon emissions may be underestimated, and it will be harder to meet China's 40%-45% carbon emissions intensity reduction target by 2020.

Second, the influence of financial intermediation scale on carbon emissions outweighs that of other financial development indicators but its efficiency does not have a large influence extent on carbon emissions although it may cause the change of carbon emissions. This not only reflects the close relationship among China's financial intermediation scale, economic growth and carbon emissions, but also suggests China's future financial reform direction and target formulation should further emphasize the quality of financial intermediation asset use and play positive role of financial system in the allocating efficiency of financial resources.

Third, China's stock market scale has relatively larger influence on carbon emissions but the influence of its efficiency appeared fairly weaker. This is closely related with the characteristics of China's stock market evolution. In the future, many efforts should be made to improve the standardization of stock markets and enhance the trading liquidity.

Finally, among the financial development indicators concerned, FDI has the least influence on carbon emissions. The main reason is that China's FDI actually utilized only accounts for less than 5% of GDP and has not become an important impetus to boost China's economic growth and carbon emissions up to now.

Besides, in recent years, China's FDI actually utilized is increasing in a relatively mild way, which is not in line with the linearly increasing trend of carbon emissions. However, China's FDI is mainly utilized in carbon intensive sectors in the past years, so its role in carbon emissions demand projection also should be emphasized.

It should be noted that, China's current financial system is bank-dominated, while by financial liberalization, financial deepening and risk management and financial innovation, China's financial system may be constantly enriched, especially the fast development of capital markets, and the share of bank loans may be diminished (Shahid Ebrahim and Hussain, 2010). Meanwhile, it is critical to improve the functioning of financial markets for boosting long-term economic growth. Therefore, the integration of banks and capital markets may be a reasonable direction for a promising financial system so as to promote low-carbon development.

Overall, there are still much work to do concerning the influence of financial development on carbon emissions in China, such as the comparison of influencing mechanism of financial development on carbon emissions among different provinces in China, different interaction between financial development and carbon emissions among China and some developed countries (including the US, Japan, Germany and Sweden etc.). And we also can examine whether there exists an inverted U shape between financial development and carbon emissions in China and other BRIC countries based on the rich data. In brief, due to limited dataset available, the results in this paper can be much enriched in the future, but hopefully the research is conducive to not only China's financial reforms but also carbon emissions intensity reduction efforts.

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[i] The detailed estimation results can be obtained upon request.