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Economic Growth, Foreign Direct Investment and CO_2 Emissions in China: A Panel Granger Causality Analysis

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Abstract: Using a sample of province-level panel data, this paper investigates the Granger causality associations among economic growth (GDP), foreign direct investment (FDI) and CO_2 emissions in China. By applying the bootstrap Granger panel causality approach (Kónya, 2006), we consider both cross-sectional dependence and homogeneity of different regions in China. The empirical results support that the causality direction not only works in a single direction either from GDP to FDI (in Yunnan) or from FDI to GDP (in Beijing, Neimenggu, Jilin, Shanxi and Gansu), but it also works in both directions (in Henan). Moreover, we document that GDP is Granger-causing CO_2 emissions in Neimenggu, Hubei, Guangxi and Gansu while there is bidirectional causality between these two variables in Shanxi. In the end, we identify the unidirectional causality from FDI to CO_2 emissions in Beijing, Henan, Guizhou and Shanxi, and the bidirectional causality between FDI and CO_2 emissions in Neimenggu.

Keywords: economic growth; foreign direct investment; CO_2 emissions

1. Introduction

Recent policymakers and academic scholars have shown increasing interest in the economic growth in China since the recent decades. How is it possible to speed up the economic growth without serious pollution? How can CO_2 emissions be reduced in the context of scarce energy? The answers to these questions are crucial for environmental sustainability in the context of economic globalization. Furthermore, foreign direct investment and CO_2 emissions are the two major factors interacting with economic growth. In this paper, we plan to investigate the possibility of Granger causality associations among economic growth (GDP), foreign direct investment (FDI) and CO_2 emissions.

Foreign direct investment (FDI) has become one of the most important economic forces for the Chinese economy since the Reform and Opening-up policy several decades ago. Similar to most developing countries, China's economy partly relies on polluting industries with high CO_2 emissions, most of which come from the consumption of fossil fuels. Therefore, the pollution fees caused by CO_2 emissions should also be taken into account when evaluating the value of economic growth. On one hand, it is highly possible that consumption of fossil fuels will positively influence economic growth since fossil fuels are inputs of production processes. On the other hand, causality can also be expected to run from economic growth to CO_2 emissions through the income effect. Some researchers proposed the concept of the environmental Kuznets curve (EKC), which is an inverted U–shape relationship between economic growth and environment quality. This might be taken to suggest future energy.

In this paper, we investigate the relations among economic growth, FDI and CO_2 emissions by focusing on a sample of province-level panel data in China. Three main Granger causality hypotheses are tested: Firstly, we investigate the "FDI-GDP" nexus, which includes "FDI-led GDP" and "GDP-led FDI" hypotheses, to figure out how and in which direction do FDI and the economic growth contribute to each other. Secondly, we examine the Granger causality between economic growth and CO_2 emissions to shed light on the question of the causal direction between GDP and CO_2 emissions. Besides the two nexuses mentioned above, the final objective is to study the relation between FDI and CO_2 emissions, which has been rarely taken into account in the literature. To our best knowledge, this is the very first study that targets the causality associations among economic growth, FDI and CO_2 emissions across different regions in China.

The rest of this paper is organized as follows: Section 2 introduces the literature review; Section 3 outlines the methodology framework; Section 4 presents and discusses the empirical results of the test; and the main conclusions and some policy implications are provided in the final section.

2. Literature Review

The theoretical links between GDP and FDI can be traced back to early neo-classical growth models, which state that FDI can increase the capital stock and thus promote economic growth. Moreover, the new growth theory suggests that both long- and short-run economic growth results from technology changes brought by FDI. According to these traditional theories, many studies are consistent with the primary idea that FDI is assumed to have positive impacts on economic growth. Nair and Winhold [1] have found that FDI, on average, has a significant and positive impact on economic growth in a sample of 24 developing countries. The study of Makki and Somwaru [2] provided evidence for a positive impact of exports and FDI on economic growth in a sample of data from 66 developing countries. In a heterogeneous panel data context, Hansen and Rand [3] tested for Granger causality between FDI and GDP, finding that FDI generally has a positive impact on GDP in the long run. Hsiao [4] found evidence that FDI has unidirectional effects on GDP, both directly and indirectly, through exports for a selected set of East and Southeast Asian economies. Faruku *et al.* [5] did a causality analysis of the impact of foreign direct investment on GDP in Nigeria; they established the fact that foreign direct investment has a positive impact on GDP and suggested that the government should strategize policies that would enhance foreign direct investment. Nosheen [6] investigated the impact of FDI on growth (GDO) for Pakistan, and proved a long-run positive relationship between GDP and FDI. Iamsiraroj and Ulubasoglu [7] also documented the positive effect of FDI on economic growth with a global sample of 140 countries. Additionally, this association holds globally as strongly as it does in the developing world. Carkovic and Levin [8], however, found that FDI does not exert a significant, positive impact on economic growth in developing countries. The study of Belloumi [9] even suggested no causality between FDI and economic growth in the short run for Tunisia. Moreover, Alfaro [10] found FDI exerts an ambiguous effect on growth; to be specific, FDI had a negative effect on growth in the primary sector and a positive one in manufacturing. Herzer *et al.* [11] also argued that the effect of FDI is based on the assumption that FDI does not "crowd out" substantial amounts of domestic investment. Therefore, there could also be a negative relationship between FDI and GDP. Furthermore, the causality relation between FDI and GDP is not necessary unidirectional; instead, the growth-led FDI hypothesis postulates a reverse relationship based on the fact that new markets and new economic activities might well be created by economic growth and, in turn, higher levels of FDI will be attracted. These two directions do not exclude each other. In this line of thinking, Basu *et al.* [12] found bidirectional causal links between FDI and economic growth in 23 developing countries.

Meanwhile, a lot of existing research has tested the relationship between CO_2 emissions and economic growth. However, there seems to be no consensus either on the existence or on the direction of causality between energy consumption and economic growth [13]. Granger causality tests among GDP and four types of emissions, CO_2, SO_2, NO_X and CO, have been conducted by Liu [14] for Norway. He provided evidence that a long-run relationship from GDP to CO_2 emissions exists. Sbia *et al.* [15] also proved the positive impact of economic growth on energy consumption, while Menyah and Wolde [16] found a unidirectional causality running from pollutant emissions to economic growth without feedback. Kim *et al.* [17] proved a two-way causality between CO_2 emissions and economic growth. The study of Saboori *et al.* [18] even presented an absence of causality between CO_2 emissions and economic growth in the short-run while demonstrating unidirectional causality from economic growth to CO_2 emissions in the long-run. Leitao [19,20] found the environmental consequences of economic growth are according to the environmental Kuznets hypothesis. Furthermore, Wang *et al.* [21] studied the CO_2 emissions, energy consumption and economic growth nexus, finding that economic growth and energy consumption are the long-run causes for CO_2 emissions, and CO_2 emissions and economic growth are the long-run causes for energy consumption. Shahbaz *et al.* [22] also examined this issue in the case of Indonesia and proved a bidirectional causality between economic growth and CO_2 emissions. Omri [23] found the same relationship for the Middle East and North Africa (MENA) countries as a whole. Cowan *et al.* [24] re-examined the causal link between electricity consumption, economic growth and CO_2 emissions in BRICS countries (Brazil, Russia, India, China and South Africa), regarding the GDP-CO_2 emissions nexus, a feedback hypothesis for Russia, a one-way Granger causality running from GDP to CO_2 emissions in South Africa, and found a reverse relationship from CO_2 emissions to GDP in Brazil. There is no evidence of Granger causality between GDP and CO_2 emissions in India and China. Bloch *et al.* [25] investigated the relationship between coal consumption and income in China and proved a unidirectional causality running from coal consumption to output in both the short and long run under the supply-side analysis, while there is also a unidirectional causality running from income to coal consumption in the short and long run under the demand-side analysis. Leitao [26] found a significant positive relationship between CO_2 emissions and economic growth in Portugal. Azam *et al.* [27] proved the same case for China, Japan, and the USA, while it is found significantly negative in case of India.

Although there exists voluminous empirical work covering "FDI-Growth" or "CO_2 emissions-Growth" nexuses, seldom have these three variables been taken together. Additionally, many existing studies employ earlier econometric methods without considering cross-sectional dependence and heterogeneity issues, which may lead to estimation bias and size distortions in the causality analysis. Besides, only a very limited number of empirical studies have targeted the case of China with different regions in particular. There is, therefore, a need for further research on Granger causality among the three variables, namely economic growth, foreign direct investment and CO_2 emissions, in China. That is exactly what this study aims to do. Contrary to previous empirical papers using data on an individual country or on several different countries, this paper employs a new panel data approach for a panel of different provinces in China. This testing method, developed in Kónya [28], is based on seemingly unrelated regression systems (SUR) and Wald tests with region-specific bootstrap critical values, allowing for research on each individual panel member separately and for no pretesting for unit roots and co-integration. These advantages are well suited for achieving the purpose of this study.

3. Materials and Methods

3.1. Study Sample

Through the Seventh Five-Year Plan (1986–1990), all the provinces in China are grouped into three economic belts. Considering the data availability, we select 16 provinces from three main regions, including Beijing, Hebei, Liaoning, Jiangsu, Fujian and Guangdong in the coastal region, Neimenggu, Heilongjiang, Henan and Hubei, Jilin and Shanxi in the central region, and Guizhou, Yunnan, Gansu and Guangxi in the western region. The data set consists of 448 observations on several provinces in China. All data come from China Statistical Yearbook and China Energy Statistical Yearbook. All variables are used in natural logarithms, and the sample period is 1985–2012.

3.2. Method

3.2.1. Panel Causality Test

The Granger causality test is a useful device for determining whether the past values of a variable (X) contribute to the better forecasting of another variable (Y). In the panel data context, Granger non-causality can be tested by using a finite order panel vector autoregression (VAR) model, where a random variable can be expressed as a function of its own past values and past values of other variables in the system.

There are three approaches which can be employed to test for Granger causality in a panel framework. The first one is based on the Generalized Method of Moments (GMM) which estimates the panel model by eliminating the fixed effect. However, it does not account for either the heterogeneity or the cross-sectional dependence, which have been proved to exist among panel members in some early studies ([28,29]).

A second alternative for testing Granger causality is to use the approach developed by Hurlin [30]. This approach can control for heterogeneity in panel data, but it is not able to deal with the cross-sectional dependence. The third approach developed by Kónya [28] is based on Seemingly Unrelated Regressions (SUR) systems that can account for both the cross-sectional dependence and the heterogeneity. Through Wald tests with country-specific bootstrap critical values, it enables us to test for Granger causality among each individual panel member separately. Therefore, we will implement the last approach in this paper.

The panel causality approach by Kónya [28] which examines the relationship between Y and X can be studied using the following bivariate finite-order vector autoregressive (VAR) model:

$$\begin{aligned} y_{i,t} &= \alpha_{1,i} + \sum_{k=1}^{ly_1} \varphi_{1,i,k} y_{i,t-k} + \sum_{k=1}^{lx_1} \beta_{1,i,k} x_{i,t-k} + \varepsilon_{1,i,t} \\ x_{i,t} &= \alpha_{2,i} + \sum_{k=1}^{ly_2} \varphi_{2,i,k} y_{i,t-k} + \sum_{k=1}^{lx_2} \beta_{2,i,k} x_{i,t-k} + \varepsilon_{2,i,t} \end{aligned} \tag{1}$$

where the index i $(i = 1, \ldots, N)$ denotes the province, the index t $(t = 1, \ldots, T)$ is the period, and ly_1, lx_1, ly_2 and lx_2 indicate the lag lengths. The error terms $\varepsilon_{1,i,t}$ and $\varepsilon_{2,i,t}$ are supposed to be white noises and may be contemporaneously correlated (*i.e.*, cross-sectional dependence); these equations compose the SUR system.

We consider three bivariate systems. In the first bivariate system, System 1: Y = LGDP, X = LFDI, where LGDP and LFDI denote the natural logarithms of GDP and FDI, respectively. In the second bivariate system, System 2: Y = LGDP, X = LCO_2, where LCO_2 denotes the natural logarithm of CO_2. In the third bivariate system, System 3: Y = LFDI, X = LCO_2. With respect to System 1, for instance, in province i there is one-way Granger causality running from X to Y if in the first equation of Equation (1) not all $\beta_{1,i,k}$ are zero, but in the second all $\phi_{2,i,k}$ are zero; there is one-way Granger causality from Y to X if in the first equation all $\beta_{1,i,k}$ are zero, but in the second not all $\phi_{2,i,k}$ are zero; there is two-way Granger causality between Y and X if neither all $\beta_{1,i,k}$ nor all $\phi_{2,i,k}$ are zero; and there is no Granger causality between Y and X if all $\beta_{1,i,k}$ and $\phi_{2,i,k}$ are zero.

3.2.2. Test for Cross-Sectional Dependence

In a panel data analysis, it is important to determine whether there exists cross-sectional dependence. The unobservable overall shock or special correlation (such as geographical position) may result in cross-sectional dependence. Ignoring this charecteristic can lead to a substantial bias and size distortions in the causality analysis [31]. Before estimating the models above, we first test for cross-sectional dependence. Breusch and Pagan [32] propose the Lagrange multiplier (LM) statistics for testing cross-sectional dependence,

$$CD_{BP} = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij}^{2} \tag{2}$$

where $\widehat{\rho}_{ij}$ is the estimated correlation coefficient among the residuals obtained from individual Ordinary Least Squares (OLS) estimations. Under the null hypothesis of no cross-sectional dependence with a fixed N and $T \to \infty$, CD_{BP} is asymptotically distributed as chi-squared with $N\,(N-1)/2$ degrees of freedom.

However, the CD_{BP} test is not applicable when $N \to \infty$. To overcome this drawback, there are two methods. The first method is a scaled version of Breusch and Pagan [32] (hereafter CD_{SBP}), which is applicable if $T \to \infty$ and $N \to \infty$. It is defined as,

$$CD_{SBP} = \sqrt{\frac{T}{N(N-1)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij}^{2}} \tag{3}$$

which is distributed as standard normal.

The second method is developed by Pesaran [31], where a Lagrange multiplier statistic for cross-sectional dependence is defined as following

$$CD_{LM} = \sqrt{\frac{1}{N(N-1)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(T\widehat{\rho}_{ij}^{2}-1)} \tag{4}$$

Under the null hypothesis of no cross-sectional dependence with $T \to \infty$ and $N \to \infty$, this test statistic is asymptotically distributed as standard normal.

However, these two tests are likely to exhibit substantial size distortions when N is large relative to T. A new test for cross-sectional dependence of Pesaran *et al.* [33] can be used where N is large and T is small. The bias-adjusted LM statistic is calculated as follows:

$$LM_{adj} = \sqrt{\frac{2T}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\frac{(T-k)\hat{\rho}_{ij}^{2}-\mu_{Tij}}{\sqrt{v_{Tij}^{2}}} \tag{5}$$

where μ_{Tij} and v_{Tij}^{2} are the exact mean and variance of $(T-k)\hat{\rho}_{ij}^{2}$, respectively. Under the null hypothesis of no cross-sectional dependence, the test statistic is asymptotically distributed as standard normal. Pesaran's approach has remarkable positive qualities in samples of practically all relevant sizes and remains robust in a variety of settings [33].

3.2.3. Test for Slope Homogeneity

For Equation (1), the most common way to test the null hypothesis of slope homogeneity, H_0: $\beta_i = \beta$, for all i against the alternative hypothesis of heterogeneity, H_1: $\beta_i \neq \beta_j$, for a non-zero fraction of pair-wise slopes for $i \neq j$ is to apply the standard F test, which is valid when the error variances are homoscedastic. The homogeneity assumption for the parameters cannot capture heterogeneity, due to province-specific characteristics. By relaxing the homoscedasticity assumption, Swamy [34] developed the slope homogeneity test on the dispersion of individual slope estimates from a suitable pooled estimator.

$$\tilde{S} = \sum_{i=1}^{N}(\widehat{\beta}_i - \tilde{\beta}_{WFE})'\frac{x_i' M_{\tau} x_i}{\widehat{\sigma}_i^{2}}(\widehat{\beta}_i - \tilde{\beta}_{WFE}) \tag{6}$$

where $\widehat{\beta}_i$ is the pooled OLS estimator, $\widetilde{\beta}_{WFE}$ is the weighted fixed effect pooled estimator, M_τ is an identity matrix, and $\widehat{\sigma}_i^2$ is the estimator of error variance, σ_i^2.

However, Swamy's test requires panel data models where N is small relative to T [35]. Based on Swamy's test, Pesaran and Yamagata [35] proposed a Delta test which is valid for small samples:

$$\widetilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\widetilde{S} - E(\widetilde{z}_{it})}{\sqrt{\mathrm{var}(\widetilde{z}_{it})}}\right) \tag{7}$$

where the mean $E(\widetilde{z}_{it}) = k$ and the variance $\mathrm{var}(\widetilde{z}_{it}) = 2k(T-k-1)/(T+1)$.

3.2.4. Estimating CO_2 Emissions

CO_2 emissions can be estimated following the International Panel on Climate Change (IPCC, Houghton *et al.* [36]) formula:

$$CO_{2i} = \sum_{j=1}^{3} CO_{2j} = \sum_{j} E_{ij} \times CEF_j \times COF_j \tag{8}$$

where CO_{2i} is the CO_2 emissions of the ith sector and CO_{2j} is the CO_2 emissions from the jth fossil source (three major fossil sources are taken into account: coal, oil and natural gas). E_{ij} is the consumption of the jth fossil source in the ith region, being typically measured in tons of coal equivalent (tce), the assumed transformation rates are as follows: coal, 1 t = 0.7143 tce, oil, 1 t = 1.4286 tce; natural gas, 1 m^3 = 0.00133 tce. CEF_j is the CO_2 emissions factors for the jth fossil source, which are assumed to be 0.7266 for coal, 0.5588 for oil and 0.4224 for natural gas. COF_j is the carbon oxidization factors, which are 0.98 for coal, 0.99 for oil and 0.995 for natural gas.

4. Results and Discussion

As outlined earlier, testing for cross-sectional dependence and slope homogeneity is crucial for selecting the appropriate estimator. Once cross-sectional dependence and heterogeneity exist across the provinces, we employ the bootstrap panel causality test proposed by Kónya [28] which can account for these dynamics. The results of the cross-sectional dependence and the slope homogeneity tests are reported in Table 1. We carried out four different tests to investigate the existence of cross-sectional dependence. The null hypothesis of no cross-sectional dependence across the panel members is strongly rejected at the 1% level of significance, suggesting that the SUR method is appropriate, rather than province-by-province OLS estimation. The cross-sectional dependence tests confirm that strong economic links exist in different provinces in China. Moreover, the null hypotheses of the slope homogeneity are rejected, supporting the province-specific heterogeneity. The rejection of slope homogeneity implies that the panel causality analysis by imposing homogeneity restriction on the variables results in misleading inferences.

Table 1. Results for cross-sectional dependence and homogeneity tests.

	CD_{BP}	CD_{SBP}	CD_{LM}	LM_{adj}	$\widetilde{\Delta}_{adj}$
System 1 (GDP)	1710.866 ***	22.087 ***	102.690 ***	40.705 ***	50.158 ***
System 1 (FDI)	372.538 ***	4.809 ***	16.301 ***	15.337 ***	31.442 ***
System 2 (GDP)	1434.383 ***	18.518 ***	84.843 ***	36.866 ***	35.679 ***
System 2 (CO_2)	631.652 ***	8.155 ***	15.337 ***	14.948 ***	23.475 ***
System 3 (FDI)	229.575 ***	2.964 ***	7.073 ***	9.531 ***	22.458 ***
System 3 (CO_2)	541.413 ***	6.990 ***	27.202 ***	10.428 ***	19.335 ***

Note: *** indicates rejection of the null hypothesis at 1% level of significance.

4.1. System 1: GDP-FDI

The existence of the cross-sectional dependence and the heterogeneity across provinces supports evidence on the suitability of the bootstrap panel causality approach. The causality relations for System 1 are presented in Table 2. The Wald test statistics and bootstrapped critical values for the null hypothesis that GDP does not cause FDI are provided in the first column, which reveals that the null hypothesis is rejected only for Yunnan and Henan.

Table 2. Results of panel Granger causality test based on bootstrapped Wald statistics.

States	H_0: GDP Does not Cause FDI				H_1: FDI Does not Cause GDP			
	Wald Stat.	Bootstrap Critical Values			Wald Stat.	Bootstrap Critical Values		
		1%	5%	10%		1%	5%	10%
Beijing	1.34	68.92	33.74	28.08	58.31 ***	48.71	22.84	16.25
Hebei	0.79	112.3	53.28	38.32	1.83	57.15	30.71	21.54
Neimenggu	66.29	366.5	109.1	77.8	18.42 *	30.76	24.65	12.72
Liaoning	16.72	87.80	49.43	31.40	18.32	43.69	31.47	24.29
Jilin	0.44	163.4	67.01	38.55	13.17 **	25.68	11.07	7.90
Heilongjiang	3.37	105.5	62.86	41.65	15.21	47.09	19.93	15.75
Jiangsu	17.65	95.59	61.86	40.52	6.51	43.23	29.01	18.24
Fujian	23.35	121.5	74.50	50.87	1.86	64.81	32.04	23.32
Henan	82.32 **	133.8	74.47	48.70	40.37 **	42.38	23.63	18.59
Hubei	0.17	49.09	39.63	32.93	6.24	26.87	18.07	13.51
Guangdong	6.61	71.67	59.04	51.42	0.99	85.48	24.28	19.85
Guangxi	11.91	167.9	46.32	37.31	1.47	58.93	16.69	11.50
Guizhou	0.29	110.4	73.86	52.25	11.14	32.13	21.89	17.46
Yunnan	56.61 *	183.1	71.21	54.44	4.79	58.72	36.49	26.04
Shanxi	16.42	134.0	113.4	76.28	32.05 **	69.20	23.05	18.2
Gansu	2.29	109.7	66.14	41.36	9.33 *	28.05	12.77	7.07

Note: ***, **, * indicate rejection of the null hypothesis at the 1%, 5%, 10% levels of significance, respectively (the same below).

For Yunnan, a western province with a backward economy, we do not find a significant impact of FDI on its economic growth. This might be due to the very low levels of FDI inflows to Yunnan, and its lack of ability to utilize FDI efficiently. However, there exists a reverse causality direction from GDP to FDI. Along with the development of Yunnan's economy, foreign investors have been gradually attracted by its special advantages. Yunnan is located at the joint of several southeast Asian countries, serving as the transportation junction to south Asia, mid-east Asia, South Africa, North Africa and Europe. In addition, Yunnan possesses rich natural resources, which contribute to its tobacco industry, mineral industry, tourist industry, and electricity and biological development.

The second column of Table 2 presents the test results for the null hypothesis that FDI does not Granger-cause GDP, which can be rejected for Beijing, Neimenggu, Jilin, Henan, Shanxi and Gansu.

As the capital city in China, Beijing becomes a metropolitan center gathering numerous headquarters or representative offices of big multinational corporations. All of these foreign companies located in Beijing have left huge externality impacts on the local economy through their advanced technology, management experience and operation philosophy, thus stimulating indigenous companies to compete for market shares. Moreover, a lot of pillar industries such as transportation, electronic communication, mechanical instruments, and food are mainly financed by FDI. Particularly, FDI contributes more than 70% to the food industry and more than 80% to electronic communication. In Jilin, an old industry base, FDI has increased fast since the 16th CPC National Congress aimed at adjusting the development of old industry bases by improving the extent of its financial openness. Jilin's FDI primarily targets the secondary industry, occupying more than 80% of the total value. This case is also true for Shanxi, a heavy industry province with a high financial openness degree in manufacturing. However, in recent years, the mining industry, business service industry and scientific research services have become new targets of FDI. Neimenggu and Gansu, located in the more inland and western region, attract much smaller FDI inflows than coastal regions because of their relatively backward economy levels. The empirical results, nevertheless, show that FDI in these two places is indeed the cause of their economic growth. The FDI of Neimenggu concentrates in manufacturing, agriculture, real estate and mining, while that of Gansu mainly centralizes in resource-intensive industries such as electricity and gas energy, retail, and manufacturing. Although the total value of FDI in these western regions cannot compare with that in the eastern area, their importance to local economic growth should be brought to the forefront.

Interestingly, it is also noted that there is bidirectional causality between FDI and GDP in Henan, one of the biggest provinces in the central region with a large population and large agricultural production. Over recent decades, FDI has mainly come from the USA, Taiwan, Hong Kong and Singapore. The contributions made by FDI to economic growth are attributed to two major points. Firstly, FDI to Henan primarily targets the secondary industry, including manufacturing, electricity and construction, which contribute to more than half of the total GDP of this province. Secondly, the import and export coming from FDI accounts for more than 30% of the total international trade in Henan, thus stimulating local economic growth. On the other hand, the economic development in turn improves FDI inflows to Henan as follows. With the acceleration of financial openness in the central region, the government of Henan has been exerting efforts to encourage foreign direct investment by supporting sole proprietorship which is especially beneficial to foreign companies intending to invest domestically. The number of sole proprietorship companies in Henan first exceeded that of joint venture companies in 2004, and the former has taken the dominant role after 2006. Besides, the secondary industry, with the highest opening degree and huge monopoly profit, has in turn attracted a lot of FDI in recent decades.

4.2. System 2: GDP-CO_2 Emissions

The empirical results for System 2 are provided in Table 3. At the given level of significance, we fail to provide empirical support for the GDP-led CO_2 emissions hypothesis for Beijing, Hebei, Liaoning, Jilin, Heilongjiang, Jiangsu, Fujian, Henan, Guangdong, Guizhou and Yunnan.

Table 3. Results of panel Granger causality test based on bootstrapped Wald statistics.

States	H_0: GDP Does Not Cause CO_2				H_1: CO_2 Does Not Cause GDP			
	Wald Stat.	Bootstrap Critical Values			Wald Stat.	Bootstrap Critical Values		
		1%	5%	10%		1%	5%	10%
Beijing	17.78	253.1	70.30	53.48	24.59	93.58	60.88	26.12
Hebei	24.45	75.06	63.86	42.70	3.42	114.9	81.25	57.52
Neimenggu	209.3 ***	177.5	103.2	66.16	26.17	93.42	39.73	32.05
Liaoning	27.21	64.81	47.02	32.04	1.12	98.60	84.51	65.67
Jilin	21.12	87.92	50.85	33.13	2.73	72.60	59.54	46.80
Heilongjiang	11.56	75.08	56.55	38.61	12.15	72.53	51.84	33.64
Jiangsu	7.17	86.00	48.12	34.22	4.70	210.9	130.1	78.17
Fujian	12.43	102.4	50.82	35.41	2.66	97.89	69.31	43.34
Henan	12.33	193.9	71.86	32.33	7.28	50.63	32.55	18.68
Hubei	73.53 **	133.68	62.51	47.99	4.64	58.52	29.88	18.48
Guangdong	2.98	75.21	61.16	41.53	6.60	202.4	101.0	68.28
Guangxi	61.61 **	98.96	56.81	41.89	0.24	106.3	62.40	37.16
Guizhou	36.72	163.6	81.46	51.04	7.73	76.75	61.08	35.88
Yunnan	39.24	111.0	62.59	47.53	3.38	49.47	23.32	18.16
Shanxi	132.3 ***	84.68	62.02	35.84	12.62 *	31.99	23.19	11.66
Gansu	28.97 *	64.90	43.72	28.60	5.09	232.0	126.6	96.16

In other words, there exists unidirectional causality from GDP to CO_2 emissions in Neimenggu, Hubei, Guangxi and Gansu, which are comparatively less developed than provinces in the coastal region. Neimenggu, for example, buries abundant natural resources including coal, rare earth metals and iron which are important raw materials for the heating and power industry, chemical industry and metallurgy. As a province with a large number of energy-intensive industries, Neimenggu has the biggest coal mine in the world, the largest thermal power stations in Asia and the greatest melting production bases. The pillar industries in Hubei are automobile, steel, shipbuilding as well as metallurgy. Gansu mainly focuses on energy exploitation, raw material processing and the military industry, while Guangxi depends partly on the mechanical industry and nonferrous metal industry. These industries are the primary contributors to the economic growth of these provinces, but they are also the original sources of heavy CO_2 emissions. Moreover, the fact that CO_2 emissions are not the Granger cause of economic growth in these provinces might be explained by their efforts to control the CO_2 emissions and make use of clean energy or nuclear energy. Besides, they also have other big industries emitting relatively little CO_2, such as the sugarcane industry in Guangxi and animal husbandry in Neimenggu.

From the second column, there is no sufficient evidence against the null hypothesis that CO_2 emissions do not cause GDP in all provinces except for Shanxi. So, Shanxi has causality in both directions. This conclusion might be the result of high investment, high growth and a high emission pattern adopted by Shanxi for an extremely long time. An increase in GDP will necessarily cause an increase in CO_2 emissions. On the contrary, a sudden drop in CO_2 emissions will lead to a drop in GDP. Such a stable relationship between economic growth and CO_2 emissions indicates a serious problem: economic growth along with high emissions is very dangerous to the environment as well as development itself.

4.3. System 3: FDI-CO_2 Emissions

We show the test results for System 3 in Table 4. The first column presents Wald test statistics and bootstrapped critical values, and the null hypothesis that FDI does not cause CO_2 emissions is rejected for five provinces, namely Beijing, Neimenggu, Henan, Guizhou and Shanxi.

Table 4. Results of panel Granger causality test based on bootstrapped Wald statistics.

States	H_0: FDI Does Not Cause CO_2				H_1: CO_2 Does Not Cause FDI			
	Wald Stat.	Bootstrap Critical Values			Wald Stat.	Bootstrap Critical Values		
		1%	5%	10%		1%	5%	10%
Beijing	68.74 ***	62.13	28.34	19.41	5.49	63.55	39.30	35.26
Hebei	3.53	66.43	27.36	20.19	0.26	56.47	40.09	22.22
Neimenggu	25.74 *	49.51	28.97	16.31	25.85 *	85.99	33.34	25.08
Liaoning	10.24	53.52	32.95	22.24	3.54	106.6	55.32	41.23
Jilin	4.70	47.07	31.63	23.20	0.95	92.49	57.62	33.57
Heilongjiang	0.80	65.22	38.78	27.35	7.21	50.76	36.95	30.41
Jiangsu	0.55	120.7	55.72	28.47	0.52	58.04	41.79	25.62
Fujian	6.17	59.46	38.76	21.28	0.21	82.01	36.75	18.37
Henan	31.05 **	63.81	27.36	20.76	0.80	79.45	49.71	30.10
Hubei	1.36	57.01	21.74	15.67	1.93	48.55	31.48	25.79
Guangdong	0.64	48.65	30.60	23.21	0.42	26.77	21.38	14.15
Guangxi	1.06	48.22	24.10	14.25	2.54	28.45	19.19	12.49
Guizhou	11.57 *	37.80	25.83	11.01	1.06	65.96	35.04	25.79
Yunnan	3.38	60.15	35.28	29.61	9.41	32.49	20.08	16.17
Shanxi	25.82 *	36.68	26.73	18.81	1.29	55.52	30.89	23.86
Gansu	1.84	38.21	15.59	10.41	11.44	86.75	38.16	21.13

As mentioned in Section 4.1, most FDI inflows to Beijing, Henan and Shanxi remain in the secondary industries, which are most likely to incur large amount of CO_2. As for Guizhou, a southwestern province whose economy lags behind many other provinces, it seems to not be an attractive place for FDI. Nonetheless, its potential should not be underestimated since it holds the fifth-largest amount of underground coal, laying a solid foundation for the thermal power industry which is gradually targeted by foreign direct investment. So there is no doubt that FDI to Guizhou can Granger-cause CO_2 emissions.

When causality is detected from CO_2 emissions to FDI, the test statistics shown in the second column suggest that the CO_2 emissions–led FDI hypothesis is supported only in Neimenggu, where there also exists a reverse causality from FDI to CO_2 emissions. From the previous discussion in Section 4.1, we have mentioned that FDI inflows into Neimenggu highly centralize in manufacturing and mining, which are the main sources of CO_2 emissions. As oil prices have risen fast in recent years, the energy market continues to heat up. In Section 4.2, we mentioned that Neimenggu is an energy-powerful province rich in coal, rare earth metals and iron, and thus an ideal place to seek fortune in the energy industry. Statistics indicate that FDI inflows to the energy industry in Neimenggu increased to 80% in 2009, showing an increasing attraction of energy industry to foreign companies. Therefore, it is not difficult to understand that CO_2 emissions, caused by energy consumption, will lead to FDI inflows in Neimenggu.

4.4. Panel Regression

In addition to the causality analysis, we also employ a panel model to investigate the impact of economic growth and foreign direct investment on CO_2 emissions using the data of China's eastern, central and western regions according to the economic division. The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan; the central region includes Neimenggu, Shanxi, Jilin, Heilongjiang, Henan, Hubei, Hunan, Anhui and Jiangxi; the western region includes Guangxi, Sichuan, Guizhou, Yunnan, Shanxi, Gansu, Ningxia, Xinjiang and Qinghai. The model is as follows and the results are presented in Table 5.

$$LnCO_{2i,t} = a_o + \sum_{j=0}^{p} b_{ji} LnGDP_{i,t-j} + \sum_{m=0}^{q} f_{mi} LnFDI_{i,t-m} + e_{i,t} \quad (9)$$

Table 5. Panel regression results for eastern, central and western regions.

Independent Variable	Eastern Region	Central Region	Western Region
Intercept	11.50068 *** (7.15)	6.384717 *** (23.20)	6.131282 *** (26.04)
Ln(*FDI*)	0.296575 * (1.77)	−0.059138 *** (−3.63)	−0.046356 ** (−2.32)
Ln(GDP)	−0.290481 (−1.15)	0.440188 *** (12.42)	0.440894 *** (13.85)
Adjusted R^2		0.999797	

Note: standard errors are in parentheses.

For the eastern region, FDI has a positive effect on CO_2 emissions while GDP exerts a negative impact. The latter is not statistically significant, however. Since FDI in the eastern region occupies more than 80% of the total FDI in China, the large amount of FDI inflows contributes greatly to economic growth in this area but also inevitably results in environmental pollution and a rise in CO_2 emissions. Intuitively, economic growth resulting from FDI inflows will increase CO_2 emissions, but this is not the case in the eastern region. This is probably because the relationship between economic growth and the environment in this region is in line with the environmental Kuznets curve, which is an inverted U–shape characteristic, and has passed the turning point.

When it comes to the central and western regions, it is the other way around. Specifically, FDI will negatively influence CO_2 emissions while GDP exerts a significant positive effect. Due to the relatively backward production technology, and insufficient environmental awareness and management experience in the central and western regions, FDI inflows bring advanced technology and equipment so that foreign enterprises can follow higher environmental standards than local firms. Therefore, FDI inflows help to decrease CO_2 emissions in these regions. However, local firms still occupy a large part in the central and western regions. While promoting economic growth in these regions, they also increase the environmental pollution. Thus, GDP exerts a positive effect on CO_2 emissions. The environmental Kuznets curve may also be valid in these regions while they are still on the left side of the turning point.

5. Conclusions

In this paper, we investigate the Granger causality associations among economic growth, foreign direct investment and CO_2 emissions using a sample of 1985–2012 province-level data in China, and taking into account the cross-sectional dependence and heterogeneity across different provinces. The empirical results reveal that the bidirectional relations between GDP and FDI apply only in Henan. Unidirectional causality from FDI to GDP works in five provinces (Beijing, Neimenggu, Jilin, Shanxi and Gansu), and the reverse causality from GDP to FDI exists only in Yunnan. More specifically, we document that FDIs are more likely to flow into the secondary industries, e.g., manufacturing, mechanical and mineral industry, thus becoming the Granger causes for economic growth of provinces which depend greatly on these industries. On the other hand, economic growth can also promote FDI given that some local advantages might be favored by the government policies or there are some irreplaceable natural resources such as Henan and Yunnan. In order to improve the economic performance, the government in these provinces should continue supporting FDI by discovering their own advantages and providing better investment environments for foreign companies.

When it comes to the nexus of GDP and CO_2 emissions, we identified only in one province (Shanxi) where CO_2 emissions are Granger-causing GDP and *vice versa*. Test results also suggest that economic growth increases the growth of CO_2 emissions in five provinces, where high emission industries have taken up a significant proportion of the whole industries. However, if this type of "high investment–high growth–high emission" pattern is adopted in the long run, CO_2 emissions might become the major driver of local economic growth at the expense of environmental sustainability, which is a warning for policymakers to improve their mode of production and take into account environmental problems.

The results of the tested FDI-CO_2 emissions nexus indicate that FDI inflows contribute significantly to CO_2 emissions in five provinces (Beijing, Neimenggu, Henan, Guizhou and Shanxi) while there is a reverse causation direction in Neimenggu. In other words, FDI flowing into high-emission industry is more likely to be the Granger cause of CO_2 emissions. In turn, CO_2 emissions will become the cause for further FDI inflows, potentially due to highly centralized FDI inflows to those profitable but pollutant industries due to the low level of awareness of controlling CO_2 emissions. Thus, local governments should pay more attention and transfer some FDI from secondary industries to tertiary industries, and diversify more fields attractive to FDI inflows.

Moreover, we investigate the impact of economic growth and FDI on CO_2 emissions. In east China, FDI has a positive effect on CO_2 emissions while GDP exerts a negative impact. Therefore, local governments should conduct *ex-ante* screening to introduce FDIs which are resource-saving and environmentally friendly. On the one hand, the introduction of foreign capital can be shifted from material capital to information and intellectual capital. On the other hand, local governments should improve industrial guidance policy in this region and encourage foreign capital to invest in high technology and value-added industries. The case is completely opposite in the central and western regions, where the local government should take the initiative to transfer industries from the eastern region for industrial upgrading. In this way, local governments will be able to attract more FDI with the advantage of low labor costs and rich natural resources, thus promoting economic growth. In addition, the central and western regions should draw lessons from the eastern region by avoiding taking the road of "treatment after pollution". They should ensure sustainable economic development under the premise of protecting the local environment.

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