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## Does corruption matter for the environment? Panel evidence from China

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## **Does Corruption Matter for the Environment? Panel Evidence from China**

*Xianchun Liao, Eyup Dogan, and Jungho Baek*

**Abstract**

This paper examines the income-energy-SO<sub>2</sub> emissions nexus by taking a corruption variable into account. To that end, the panel cointegration methods are applied to 29 Chinese provinces over 1999–2012. The authors' empirical evidence shows that an increase in the number of anti-corruption cases tends to drive down SO<sub>2</sub> emissions in China. It is also found that income growth appears to have a beneficial effect on decreasing SO<sub>2</sub> emissions over the past two decades. Finally, energy consumption is found to increase SO<sub>2</sub> emissions.

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**Keywords** China; corruption; environment; EKC; panel; SO<sub>2</sub>

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## **1. Introduction**

China has achieved rapid economic growth at an average rate of almost 10 percent annually over the past three decades. This economic success, however, comes at the cost of deterioration of the environment. One of the most severe environmental problems that China is currently facing are air pollution. For example, the State Environmental Protection Administration of China (SEPA) reports that about 70% of the 300 cities in China fail to meet the air quality standards set by the World Health Organization (WHO) and seven out of the ten most polluted cities in the world are located in China. The World Bank estimates that the direct cost of air pollution - such as acid-rain damage to crops, medical bills and job-loss from illness - ranges between 8 percent and 12 percent of China's GDP annually. In addition, it is estimated that, because of heavy air pollution, more than three million people die prematurely each year and the average life expectancy is more than 5 years lower for residents in northern China than those living in the south (Wang, 2007; Pope III and Dockery, 2013).

The Chinese government has made substantial efforts to reduce air pollution by introducing various emission reduction measures such as environmental taxes/charges, pollution treatment programs and even closure of inefficient power/industrial facilities. Moreover, under the 12th Five-Year Plan (2011-2015), China has paid considerable attention to energy and climate change issues and has established a new set of targets and policies for the plan period. The main targets include a 16 percent reduction in energy intensity (energy consumption per unit of GDP), an increase in non-fossil energy up to 11.4 percent of total energy consumption and a 17 percent reduction in carbon intensity (carbon emissions per unit

of GDP). In 2015, however, China still recorded the world's largest increment in energy consumption for the thirteenth consecutive year and became the world's largest emitter of both carbon dioxide (CO<sub>2</sub>) and sulfur dioxide (SO<sub>2</sub>) emissions. Therefore, a fundamental question would be certain to arise regarding China's environment: what are the main determinants affecting air pollution in China?

A number of studies have sought to isolate the independent effects of various factors on air pollution in China. Traditional specification of this subject includes a growth variable (i.e., income per capita) and investigates the *environmental Kuznets curve* (EKC) - an inverted U-shaped relationship between income per capita and certain types of pollutants (typically measured by CO<sub>2</sub> emissions). Then, as we glance through the literature more, we come across empirical studies that claim that energy consumption could be an important determinant of environmental outcomes and analyze the so-called income-energy-environment relationship. Examples include, but are not limited to, Song et al. (2008), Jalil and Mahmud (2009), Baek et al. (2009), Baek and Koo (2009), Jalil and Feridun (2011), Wang et al. (2011), Govindaraju and Tang (2013), Michieka (2014), Qu and Yan (2014), Yuan et al. (2015), Wang et al. (2016) and Li et al. (2016). The findings from these studies generally show that there is the ambiguous evidence in favor of the EKC for China, and strong evidence that China's growth in energy consumption indeed causes environmental degradation.

Important but perhaps less widely recognized in the literature is the possibility that corruption could be an important factor of air pollution in China. In fact, domestic firms in China use a bribe to lobby officials to lower the environmental standards. Although China's

government vows to fight corruption, it appears that the level of corruption has constantly increased over the past decade. For the years 2002 through 2009, for example, the people's procuratorates at all levels investigated more than 240,000 cases of embezzlement, bribery, dereliction of duty and infringements on rights. In 2009 alone, more than 3,000 people were punished for their criminal liability in offering bribes (Information Office of China's State Council, 2010). Thus, a corruption variable should be accounted for when estimating factors affecting China's deteriorating environment properly. Up until now, many scholars have sought to address the impact of corruption on the environment. Examples include Damania et al. (2003), Fredriksson and Svensson (2003), Welsch (2004), He et al. (2007), Cole (2007) and Woods (2008). However, the existing literature does not directly address the issue in China.

The main objective of this paper is to take a measure of corruption into account in a model when examining the income-energy-environment relationship in China. Although China is currently the world's largest SO<sub>2</sub> emitting country along with CO<sub>2</sub> emissions, empirical studies have paid little attention to SO<sub>2</sub> emissions in their analyses.<sup>1</sup> Empirical focus is thus on assessing the effects of corruption, income and energy consumption on SO<sub>2</sub> emissions using panel data of 29 provinces in China from 1991 to 2012. To that end, the panel cointegration methods are utilized.

This paper is organized as follows: in Section II, we outline the empirical model to be estimated and the data used for the estimation. In Sections III and IV our empirical procedures

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<sup>1</sup> Baek et al. (2009) is perhaps the only study addressing the issue; they find that growth has a beneficial effect on reducing SO<sub>2</sub> emissions in China. However, they only examine the income-environment nexus.

and major findings are discussed, respectively. Finally, section V makes some concluding remarks.

## 2. Methodology

### 2.1. The model to be estimated

In the empirical model adopted here, we extend the so-called standard model of the income-energy-environment nexus to include a measure of corruption. Letting  $i$  denote the cross-sectional unit (Chinese provinces in this paper) and  $t$  the time period, we can write a model in a log-linear form as:

$$\ln(so_2)_{it} = \alpha + \beta_1 \ln y_{it} + \beta_2 \ln y_{it}^2 + \beta_3 \ln ec_{it} + \beta_4 cor_{it} + \varepsilon_{it} \quad (1)$$

where  $(so_2)_{it}$  is the sulfur dioxide (SO<sub>2</sub>) emissions for province  $i$  in China;  $y_{it}$  is the 2000 real income for province  $i$ ;  $y_{it}^2$  is the square of the 2000 real income for province  $i$ ;  $ec_{it}$  is the energy consumption for province  $i$ ;  $cor_{it}$  is a measure of corruption for province  $i$  and is the number of anti-corruption cases; and  $\varepsilon_{it}$  is the error term. The variables are measured on a per capita basis. We are particularly interested in the parameter  $\beta_4$  – that is, the ceteris paribus effect of corruption on SO<sub>2</sub> emissions.

Given that numerous studies commonly show the crucial role of income plays in influencing environmental outcomes, it would be proper to directly test the Environmental Kuznets Curve (EKC) hypothesis into our modeling. In Eq. (1), to the extent that  $\beta_1 > 0$  and  $\beta_2 < 0$ , the EKC hypothesis is predicted to hold; that is, income has a diminishing effect on SO<sub>2</sub> emissions after the turning point (or maximum point of the income), achieving a parabolic shape.

It is expected that  $\beta_3 > 0$  due to the fact that an increase in energy consumption mainly driven by growth is likely to push  $\text{SO}_2$  emissions up. Finally, it is expected that  $\beta_4 < 0$  because the increasing number of anti-corruption cases is likely to result in improved environmental regulations, thereby reducing  $\text{SO}_2$  emissions.

## 2.2. Data

$\text{SO}_2$  emissions are used as a proxy for a measure of air pollution. China is the world's largest coal consumer, accounting for about 50% of the world's total coal. Coal combustion generates more than 90% of  $\text{SO}_2$  emissions in China. As a result, China currently ranks the largest  $\text{SO}_2$  emitter worldwide. To ensure comparability with income per capita in Eq. (1), the  $\text{SO}_2$  emissions per capita for individual provinces (measured in 10 thousand metric tons) are calculated using their population size. The provincial gross domestic product per capita (measured in constant 2000 Chinese Yuan) is used as a proxy for real per capita income for each province. The energy consumption is measured in 10 thousand metric tons of coal equivalent per capita. The number of anti-corrupt cases is used as a measure of the degree of corruptibility and is intended to allow for the likelihood that higher anticorruption efforts are likely to less environmental degradation.<sup>2</sup> The data on  $\text{SO}_2$  emissions are collected from China Environmental Statistical Yearbooks. All the remaining variables are from China's Statistical Yearbooks.

Our (balanced) panel dataset contains the 29 Chinese provinces from 1999 to 2012

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<sup>2</sup> Some scholars (e.g., Damania et al., 2003; Cole, 2007) use governmental honesty taken from the International Country Risk Guide (ICGR) as a proxy for corruption in their models. At the sub-national level, however, the data are not available.

( $N \times T = 406$  observations, where  $N = 29$  provinces and  $T = 14$  years). This time period is chosen by availability of the data for all the variables. All variables are converted into natural logarithms.

### 3. Empirical Results

The first requirement for estimating our model in Eq. (1) using the panel cointegration method is that the variables must be nonstationary  $I(1)$  series. Accordingly, the panel cointegration modeling normally starts with testing whether a panel series follows a unit root. However, the possibility of cross-sectional dependence in panels is likely to invalidate the test statistics of conventional panel unit root tests such as the LLC (Levin et al., 2002) and IPS tests (Im et al., 2003). These tests commonly assume the cross-sectional independence in panels. Before applying a unit root test, therefore, we must test whether a panel series is cross-sectionally independent. A cross-sectional dependence (CD) test of Pesaran (2004) can be used to achieve this goal. The results show that the null hypothesis of no cross-sectional dependence can be strongly rejected (the  $p$ -values for all five variables are zero to two decimal places), providing compelling evidence of the cross-sectional dependence in the sample (Table 1).

Given that the panel series are found to be cross-sectionally dependent, it is no longer appropriate to use conventional panel unit root tests. Hence, we employ more powerful tests that allow for cross-sectional dependence such as the cross-sectionally Im-Pesaran-Shin (CIPS) and cross-sectionally augmented Dickey-Fuller (CADF) tests.<sup>3</sup> The CIPS test results show that we

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<sup>3</sup> The resulting tests are known as the second generation tests for a panel unit root in order to distinguish them from the conventional tests or the first generation tests.



cannot (can) reject the unit root hypothesis for the levels (first differences) of all series, indicating that all five variables are  $I(1)$  processes (Table 2). The CADF test largely confirms this finding, although we can reject a unit root in the level of  $cor_{it}$ ; when  $cor_{it}$  is differenced, however, the null is strongly rejected and this leads us to believe that  $cor_{it}$  is  $I(1)$  variable. The upshot of the unit root tests is that all five series in Eq. (1) appear to be nonstationary  $I(1)$  processes.

When estimating a nonstationary panel model, there is serious concern about spurious regression. In one important case, a regression estimating nonstationary  $I(1)$  series is not spurious, and that is when the series are cointegrated. Hence, the presence of cointegration relationship among the variables is tested using the various tests developed by Pedroni (1999 and 2004) and Kao (1999). The results show that the null hypothesis of no cointegration can be rejected even at the 1% level of significance for all five tests, evidence that  $SO_2$  emissions and its determinants have a long-run relationship (Table 3). In other words, whenever deviations from the long-run equilibrium take place, they would be transient: there are economic forces that drive  $SO_2$  and its main factors back to restore the long-run equilibrium relationship.

Having learned about a potential long-run relationship among the five series, we now apply the FMOLS and DOLS panel estimators of Mark and Sul (2003) and Kao and Chiang (2000) to Eq. (1) in order to estimate the long-run parameters. We also report the estimated effects of the fixed effects estimator here for comparison.

#### 4. Discussion

Table 4 reports the long-run effects for all independent variables and for each of the three estimated models. The estimates generated by the models seem remarkably consistent. The signs of the coefficients are the same across models, and the same variables are generally statistically significant in each model.

The coefficients on the income and the quadratic term are similar across models. Because the coefficient on  $y_{it}$  is always positive and the coefficient on  $y_{it}^2$  is always negative, this equation literally implies that, at low value of income, an additional rise in income tends to increase SO<sub>2</sub> emissions. At some point, the effect becomes negative, and the quadratic shape means that the elasticity of SO<sub>2</sub> emissions with respect to income is decreasing as income increases. In other words, the finding seems to be supportive of the EKC hypothesis for Chinese SO<sub>2</sub> emissions. It turns out, however, that all of the 29 provinces in the sample have more than the calculated turnaround values of income, and so the part of the curve to the left can be ignored. Thus, SO<sub>2</sub> emissions in fact have monotonically fallen with income growth in China over the past decade. From policy perspectives, this result can be interpreted that the Chinese government's policies targeted to reducing air pollution are likely to work effectively without costing economic growth.

The partial effect of energy consumption on SO<sub>2</sub> emissions is always positive, and the magnitudes of the coefficient estimates are very similar across all three models. In the FMOLS model, for example, a one percent increase in energy consumption is estimated to increase SO<sub>2</sub> emissions by about 0.80% in China. Given the fact that growth largely leads to an increase in

energy use, this finding suggests that any favorable growth effect on air pollution could be offset by a detrimental energy consumption impact.

The key policy variable,  $cor_{it}$ , seems to have the desired effect. The estimated coefficient is negative for all three models. For example, the FMOLS coefficient (-0.17) implies that, for other things being equal, China can reduce SO<sub>2</sub> emissions by about 0.17% as the number of anti-corruption cases increases by one percent. As a policy matter, this suggests that effective anti-corruption measures would improve the environment through the enforcement of environmental regulations in China. The statistical significance is high for the FMOLS and fixed effects, and lacking for the DOLS.

Finally, in addition to learning about the long-run relationship in Eq. (1), utilizing the notion of causality enriches our understanding of the variables by providing causal inference (i.e., direction of causality). For completeness, therefore, the bootstrap panel Granger causality test developed by Emirmahmutoglu and Kose (2011) is utilized. This method is most useful when dealing with cross-sectional dependence in panels as we identify in our model. The results show strong bidirectional causation for 4 cases and unidirectional causation for 5 cases (Table 5). For example, the relationships between SO<sub>2</sub> emissions and energy consumption, and SO<sub>2</sub> emissions and corruption are characterized by bidirectional causality. This means that SO<sub>2</sub> emissions are significantly affected by changes in energy consumption (corruption) and energy consumption (corruption) is also influenced by changes in SO<sub>2</sub> emissions. On the other hand, there is unidirectional causality running from income to SO<sub>2</sub> emissions. This suggests that SO<sub>2</sub> emissions are significantly affected by changes in income, while income is not affected by

changes in  $\text{SO}_2$  emissions. Together, these findings provide evidence that all independent variables can be used to forecast future  $\text{SO}_2$  emissions and justify the use of our model in Eq. (1).

## **5. Concluding Remarks**

Although corruption can have an effect on the environment in China, no study has directly addressed this issue empirically. In this short article, therefore, we take into a corruption variable into account in a dynamic panel model when estimating the income-energy- $\text{SO}_2$  emissions nexus. Our results show that anti-corruption cases seem to have a beneficial effect on reducing  $\text{SO}_2$  emissions in China. Other findings shows that income growth tends to lower  $\text{SO}_2$  emissions, while energy consumption increases  $\text{SO}_2$  emissions.

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**Table 1**

Results of cross-sectional dependence (CD) test.

	$\ln(so)_2$	$\ln y$	$\ln y^2$	$\ln ec$	$\ln cor$
CD statistic	29.73**	74.27**	74.14**	72.79**	29.72**
<i>p</i> -value	0.00	0.00	0.00	0.00	0.00

*Notes:* \*\* denotes rejection of the null hypothesis at the 1% level.

**Table 2**

Results of panel unit root tests.

Variable	CADF		CIPS	
	Level	First difference	Level	First difference
$\ln(so)_2$	-2.42	-2.96**	-2.89	-3.98**
$\ln y$	-1.70	-2.81**	-1.53	-3.38**
$\ln y^2$	-1.24	-2.80**	-1.21	-3.36**
$\ln ec$	-2.48	-3.01**	-2.63	-4.25**
$\ln cor$	-2.14	-3.17**	-3.11**	-3.84**

*Notes:* CADF and CIPS represent cross-sectionally augmented Dickey-Fuller and cross-sectionally Im-Pesaran-Shin tests, respectively. \*\* denotes rejection of null hypothesis at the 1% level.

**Table 3**

Results of panel cointegration tests.

Test	Statistics
Panel PP statistic	-8.23**
Group PP statistic	-14.73**
Panel ADF statistic	-6.09**
Group ADF statistic	-5.77**
Kao test statistic	-2.29**

*Notes:* \*\* denotes rejection of the null hypothesis of no cointegration at the 1% level.

**Table 4**

Results of long-run estimates

Variable	FMOLS		DOLS		Fixed effects	
	Coefficient	<i>p</i> -value	Coefficient	<i>p</i> -value	Coefficient	<i>p</i> -value
lny	2.09**	0.00	2.15**	0.00	2.06**	0.00
lny <sup>2</sup>	-0.28**	0.00	-0.28**	0.00	-0.26**	0.00
lnec	0.80**	0.00	0.72**	0.00	0.80**	0.00
ln $\text{cor}$	-0.17**	0.00	-0.03	0.00	-0.13**	0.00
$R^2$	0.88		0.96		0.87	

*Notes:* \*\* denotes significance at the 1% level.

**Table 5**

Results of bootstrap panel Granger causality test.

Hypothesis	Fisher statistics	<i>p</i> -value	Conclusion
$\ln y \rightarrow \ln(so)_2$	119.09**	0.00	One-way causality from $\ln y$ to $\ln(so)_2$
$\ln(so)_2 \rightarrow \ln y$	42.44	0.93	
$\ln y^2 \rightarrow \ln(so)_2$	113.56**	0.00	One-way causality from $\ln y^2$ to $\ln(so)_2$
$\ln(so)_2 \rightarrow \ln y^2$	43.75	0.89	
$\ln ec \rightarrow \ln(so)_2$	151.22***	0.00	Two-way causality between $\ln ec$ and $\ln(so)_2$
$\ln(so)_2 \rightarrow \ln ec$	129.77***	0.00	
$\ln cor \rightarrow \ln(so)_2$	158.06***	0.00	Two-way causality from $\ln cor$ and $\ln(so)_2$
$\ln(so)_2 \rightarrow \ln cor$	83.47**	0.02	
$\ln ec \rightarrow \ln y$	74.67*	0.07	Two-way causality between $\ln ec$ and $\ln y$
$\ln y \rightarrow \ln ec$	150.30***	0.00	
$\ln ec \rightarrow \ln y^2$	76.33**	0.05	Two-way causality between $\ln ec$ and $\ln y^2$
$\ln y^2 \rightarrow \ln ec$	132.19***	0.00	
$\ln cor \rightarrow \ln y$	66.83	0.19	One-way causality from $\ln y$ to $\ln cor$
$\ln y \rightarrow \ln cor$	84.72***	0.01	
$\ln cor \rightarrow \ln y^2$	66.81	0.19	One-way causality from $\ln y^2$ to $\ln cor$
$\ln y^2 \rightarrow \ln cor$	92.69***	0.00	
$\ln ec \rightarrow \ln cor$	94.19***	0.00	One-way causality from $\ln ec$ to $\ln cor$
$\ln cor \rightarrow \ln ec$	66.27	0.21	

Notes: \*\*\*, \*\* and \* denote significance at the 1%, 5% and 10% levels, respectively.

Please note:

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The Editor