Sulfur Dioxide Emission, Economic Growth and Energy Efficiency: A Panel-Data Analysis for China

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Background

- Rapid industrialization and urbanization have pulled millions of Chinese citizens out of poverty, while the demand for energy grows rapidly at the same time. China is now the world's largest energy consumer.

- As a result, ambient air quality in many Chinese cities exceeds both national standards and international guidelines. China has also turned out to be the biggest emitter of sulfur dioxide ,nitrogen oxides and carbon dioxide emission.

Motive

- The largest developing country has fallen into a dilemma and been asked to choose between a prosperous economy and a clean environment.

- Many previous closed small coal-powered plants reopened due to the slow down of economy； many previous switched from coal-to-gas power plants reuse the coal again .

- Thus the question of how to realize sustainable development has become prominent on the central policy agenda.

Research on growth-pollution

- The Environmental Kuznets Curve (EKC) Hypothesis is widely used when environmental researchers analyze the connection between economic growth and environmental degradation.

- Empirically, no substantial evidence was found in support of the EKC hypothesis . On the whole, the empirical evidence has been largely mixed.

Research on growth-pollution

Growth in energy consumption is not just a by-product of economic growth, it is a causal factor; Fossil-based energy has an economic advantage but gives rise to pollution concerns.

Research about Energy-growth

- The connection between energy consumption and economic growth is usually investigated on the direction of causality, such as no causality, bi-directional causality between economic growth and energy consumption, and uni-directional causality running from one to the other (Ozturk, 2010).
- The various types of causality mentioned above have been empirically tested using data from various countries, different variable selection and econometric methodologies. (Sari and Soytas (2004) in the case of Turkey, Ewing et al. (2007) for the USA, and Sari and Soytas (2007) for six developing countries)

Research about Energy-pollution

- Compared to the growing literature about energy-growth nexus, there are fewer studies focusing on the linkage between energy consumption and environmental quality.

- Most of the energy-pollution nexus analyses are based on causality testing between energy consumption and economic growth by adding the variable of pollution.

Research relating Energy-growth and Energy-pollution nexus

- Soytas et al. (2007) and Soytas and Sari (2008)

- Farhani and Rejeb (2012) employed a panel causality test to estimate the relationship among energy consumption, economic growth and emission for 15 Middle East and North Africa (MENA) countries.

- Menyah and Rufael (2010) examines the long-run and the causal relationship between economic growth, pollutant emissions and energy consumption for South Africa.

Research relating Energy-growth and Energy-pollution nexus

For the case of China

- The study of Zhang and Cheng (2009) showed uni-directional Granger causalities running from GDP to energy consumption; and from energy consumption to emission in the long run.

- Wang et.al (2011) found that there exists a bi-directional causality between energy consumption and emission for 28 provinces in China from 1995 to 2007.

Objective and Results

- This paper estimates the linkages among total sulfur dioxide emission, total GDP and energy efficiency in 27 provinces of China from 1995 to 2010.

- Both panel-based error correction model (ECM) and cross-sectional analytical approach are employed to investigate the short-run and long-run dynamic relationships.

- The results indicate that total real GDP has a diminishing positive impact on total sulfur dioxide emission and gains in energy efficiency have a significant diminishing negative effect on emissions.

Motives

- Why SO2?

  Sulfur dioxide emission has been extensively regulated since the end of last century in China.

- Why Total?

  emissions per capita in China would be significantly dragged down by its large population base. So the variables in terms of per capita sometimes may result in over-optimistic and misleading conclusions

Data

Table 1: Variable List

Definition	Label	Unit	Source
Total Volume of Sulphur Dioxide	SO_2	Ten thousand tons	China StatisticalYearbook (1995-2010)
Total Real GDP	GDP	In constant 1995, local currency 100 million Yuan	Each Province's Statistical Yearbook (1995-2010)
Total Consumption of Energy	Energy	Ten thousand tons of Standard Coal	Each Province's Statistical Yearbook (1995-2010)

Table 2: Summary Statistics of original data

Variable	Obs	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
SO_2	432	74.8736	50.2437	1.7343	232	0.8835	3.0904
GDP	432	5291.21	5294.35	167.8	33495.14	2.2817	9.4126
GDP/Energy	432	0.6066	0.26435	0.1619	1.2376	0.3772	2.3339

Econometric model

$$\Delta Ln(SO_2)_t = \alpha_1 + \alpha_2 \Delta Ln(GDP)_t + \alpha_3 \Delta Ln(GDP/Energy)_t + \lambda[Ln(SO_2)_{t-1} - \beta_0 - \beta_1 \Delta Ln(GDP)_{t-1} - \beta_2 \Delta Ln(GDP/Energy)_{t-1}] + \alpha_4 D_0 + \varepsilon_t$$

Error Correction Model results

Table 5: Error Correction Model results

VARIABLES	$\Delta Ln(SO_2)$
ΔLn(GDP)	-0.642*
	(0.387)
ΔLn(GDP/Energy)	-0.667***
	(0.124)
ECM term, λ	-0.0675***
	(0.0167)
North Dummy	0.0189
	(0.0130)
Constant	0.121***
	(0.0460)
Observations	405
Number of Provinces	27

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The coefficients in ECM term

VARIABLES	$Ln(SO_2)$
Ln(GDP)	0.504***
	(0.0890)
Ln(GDP/energy)	-0.685***
	(0.234)
Constant	-0.464
	(0.901)
Observations	432
Number of provinces	27

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Figure 1: The relationship between SO_2 and GDP in Error Correction Mode

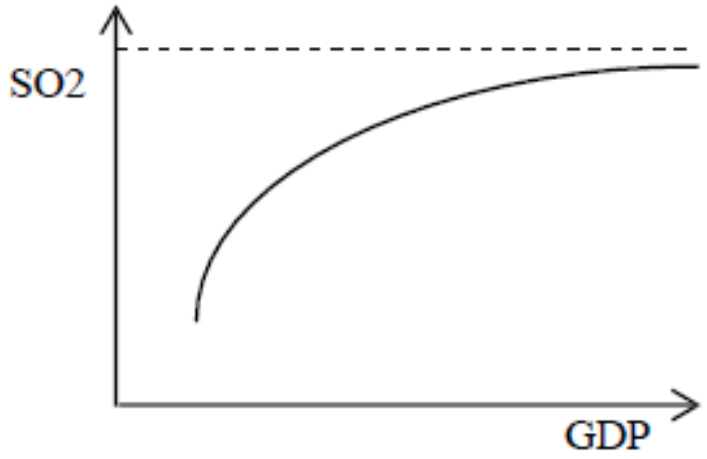
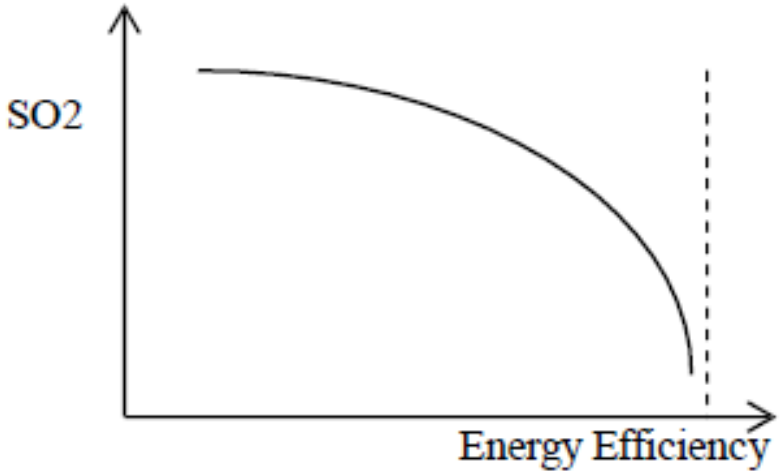


Figure 2: The relationship between SO_2 and Energy Efficiency in Error Correction Model



Cross-sectional Analysis

- In contrast to time-series and panel data, a cross-sectional analysis avoids all the non-stationarity problems. This allows us to do some regressions on variables themselves rather than on the first differences.

- Furthermore, since we have a lot of panels and relatively few years, a cross-sectional is feasible. If we divide the sample into early years and late years, calculate the early average and late average for each variable for the 27 provinces, and then we would have 54 observations in the aggregate.

Econometric model

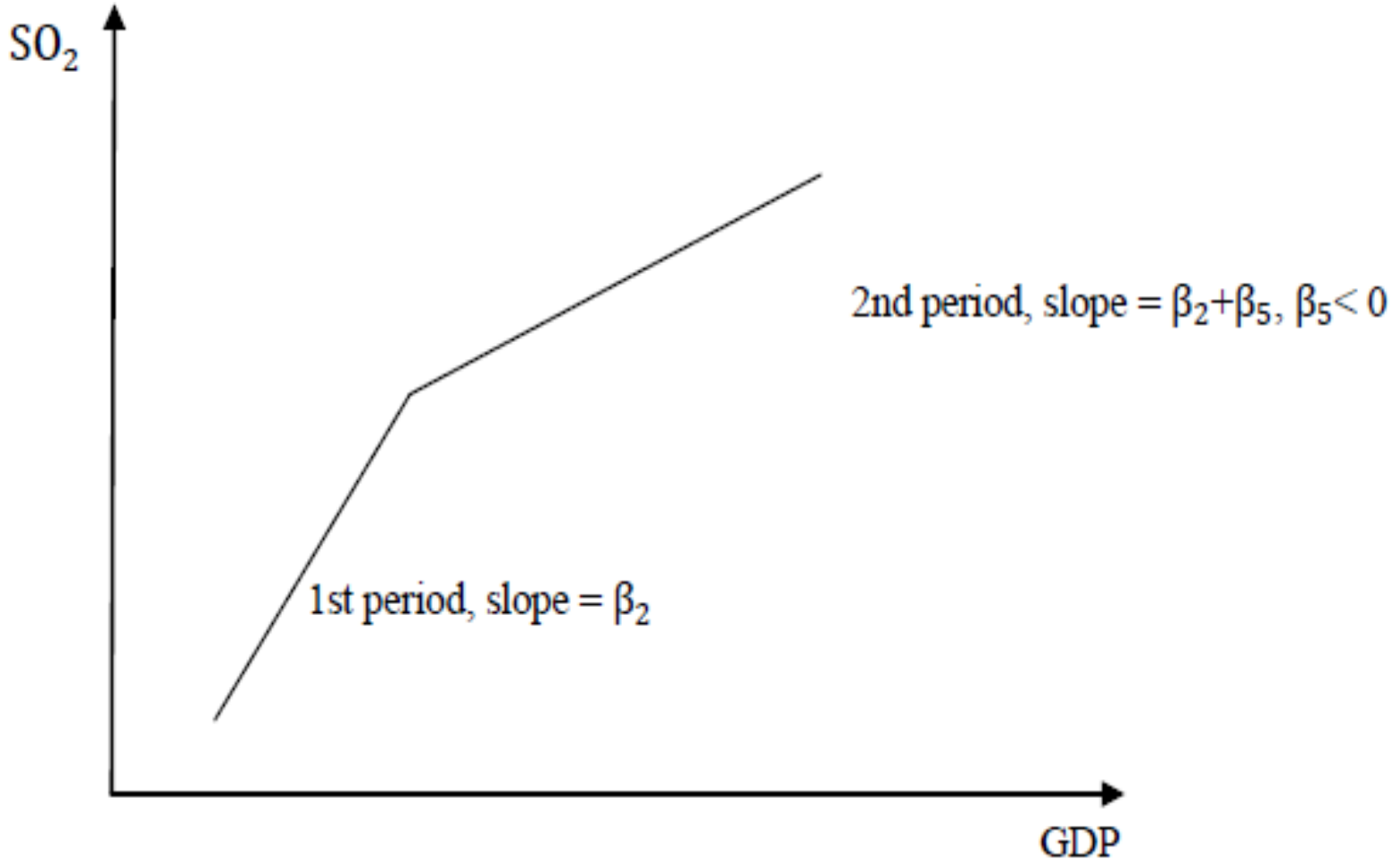
$$\Delta Ln(SO_2)_{it} = \beta_1 + \beta_2 Ln(GDP)_{it} + \beta_3 Ln(GDP/Energy)_{it} + \beta_4 D_1 + \beta_5 D_1 * Ln(GDP)it + \beta 6\ D1 * Ln(GDP/Energy)it + \varepsilon it$$

Cross-sectional results

VARIABLES	Equation (3) Ln(SO_2)	Equation (4) Ln(SO_2)
Ln(GDP)	1.067***	1.095***
	(0.129)	(0.137)
Ln(GDP/Energy)	-1.431***	-1.346***
	(0.208)	(0.254)
Late Period Dummy	-0.355**	0.190
	(0.134)	(2.294)
Dummy*Ln(GDP)		-0.0553**
		(0.025)
Dummy*Ln(GDP/Energy)		-0.160
		(0.257)
Constant	-5.306***	-5.463***
	(1.154)	(1.181)
Observations	54	54
R-squared	0.704	0.709

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Figure 3: The relationship between SO2 and GDP in cross-sectional analysis



Conclusion

- Total real GDP has a diminishing positive impact on total sulfur dioxide emission and energy efficiency has a diminishing negative effect on total emission.
- It is not necessary to expect a turning point in our ECM case; a long-tail shape may exist because we focus on total real GDP rather than GDP per capita, this would be consistent with a turning point in a model using per capita data.
- By encouraging research and development of environmental technology, the policy makers could save energy resource and cut pollution while still striving to maintain its momentum in the economy.

Decomposing the Environmental Effects of Trade Liberalization: The Case of Consumption-Generated Pollution

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Thank you!

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