The Singapore Economic Review, (2021)

DOI: 10.1142/S0217590821500570

THE INFLUENCE OF GOVERNMENT'S EXPENDITURE IN THE ENVIRONMENTAL PROTECTION ON AIR POLLUTION IN TAIWAN

JR-TSUNG HUANG
Public Finance, National Chengchi University
No. 64, Section 2, ZhiNan Road
Wenshan, Taipei 11605, Taiwan
jthuang@nccu.edu.tw

Published Online

This study explores the influence of government's spending on environmental protection on air pollution in Taiwan. Using the panel data of 20 counties, county-level cities, and municipalities in Taiwan covering the period from 2013 to 2018 and the spatial econometric analysis due to considering the possible spatial dependence of air pollution represented by $PM_{2.5}$ concentration and SO_2 emissions, the primary finding is that government's spending in the environmental protection can statistically significantly improve air pollution regardless of where the financial source is. However, rather than the local fiscal expenditure on environmental protection, subsidies of the air pollution control from the central government can play more important roles to effectively improve air quality of the local area in Taiwan.

Keywords: Environmental protection; fiscal expenditure; air pollution; Taiwan.

1. Introduction

In recent years, improving the quality of life has become the focus of governments while they pursue goals of economic growth and technology improvement. According to the sustainable development goals proposed by the United Nations in 2015, it is mentioned that "make cities and human settlements inclusive, safe, resilient and sustainable" and that "ensure sustainable consumption and production patterns". Undoubtedly, these statements are related to issues regarding the environmental protection, including maintaining air quality and managing chemicals and wastes in a proper and environment-friendly way. Thus, it is obvious that air pollution, especially the two most common air pollution indicators — $PM_{2.5}$ concentrations and SO_2 emissions, already acquired worldwide attention.

As a matter of fact, inferior air quality can be hazardous to the health of human being. In 2014, World Health Organization pointed out that inferior air quality deteriorated cardiovascular function and that air pollution had already resulted in nearly 7 million deaths around the world in 2012. Therefore, how to effectively restraint harms made by air pollution is a critical issue that governments must pay attention. The damages arisen due to air pollution led many countries to carry on monitors and controls for the level of air pollution.

In Taiwan, both the trend of annual average $PM_{2.5}$ concentration and SO_2 emissions are declining under the active engagement in Taiwan's air pollution control by central and local governments.[1] According to the official information provided by Environmental Protection Administration, Taiwan, the concentrations of $PM_{2.5}$ among five regions in Taiwan during the period of 2013–2018 were no more than 30.[2] To be more specific, annual average $PM_{2.5}$ concentration in Southern Taiwan and Central Taiwan is comparatively high ranging from 20 to 30, while it is lowest in eastern area, which has the best air quality in Taiwan. In addition, there demonstrates a yearly declining trend of annual average $PM_{2.5}$ concentration among five regions during the same period. With regard to SO_2 emissions, Southern Taiwan is the area with the highest annual average SO_2 emissions during 2013–2018 and Northern Taiwan ranks third-highest one. Eastern Taiwan is the area with the lowest annual average SO_2 emissions during 2013–2018. Except for Eastern Taiwan, there exists a yearly declining trend of annual average SO_2 emissions among other four regions during the period 2013–2018. Therefore, regardless of which air quality indicator is adopted, Eastern Taiwan is still an area with best air quality in Taiwan.

The primary purpose of this paper is to understand the determinants of degree of air pollution in Taiwan, especially the roles of central and local governments' environmental expenditure in this regard. Furthermore, this study examines whether the impact of governments' spending on environmental protection on air pollution will be different if the budget is from different levels of government, which is from central and local governments. A panel data of 20 county-level administrative areas (county, hereafter) from 2013 to 2018 is adopted and several spatial econometric models are estimated due to considering the potential spatial dependence of air pollution, represented by $PM_{2.5}$ concentration and SO_2 emissions. The primary finding is that $PM_{2.5}$ concentration can be mitigated if local governments have more spending on environment protection. However, the magnitude of this negative impact is larger if the budget of this spending is from central government than from local government. However, SO_2 can be mitigated only if local governments have more spending on environment protection subsidized by the central government. Finally, air pollution has positively spatial dependence, suggesting that an increase in air pollution in one county will also increase air pollution in its neighboring counties.

The contributions of this research are shown as follows. First, it compares the difference between influences of the environmental protection spending from local government and of the air pollution control subsidies from the central government on the local air pollution. Second, this study takes $PM_{2.5}$ concentrations and SO_2 emissions as air pollution indicators

[1] The unit of annual average concentration of $PM_{2.5}$ is $\mu g/m^3$, while that of SO_2 is parts per billion (ppb).

[2] This paper categorizes 20 counties/cities in Taiwan into five regions, Northern Taiwan, Central Taiwan, Southern Taiwan, Eastern Taiwan and outer islands according to National Spatial Plan issued by the Ministry of Interior, Taiwan. Northern Taiwan includes Taipei city, New Taipei city, Keelung city, Taoyuan city, Hsinchu city/county and Yilan county; Central Taiwan includes Miaoli county, Taichung city, Changhua county, Nantou county and Yunlin county; Southern Taiwan includes Chiayi city/county, Tainan city, Kaohsiung city and Pingtung county; Eastern Taiwan includes Hualian county, and Taitung county; Out islands include Penghu county.

August 19, 2021 12:04:14pm WSPC/172-SER 2150057 ISSN: 0217-5908 2ndReading

to examine the issue of air pollution. Third, this study explores the issue regarding whether these two air pollution indicators have a spatial dependence by employing the spatial econometric model. These contributions make this study different from previous studies. The rest of this paper is organized as follows. Section 2 reviews the existing literatures and Section 3 establishes empirical model and hypothesis followed by analyses and discussions in Section 4. Finally, conclusions and policy implications are provided in Section 5.

2. Literature Review

There are abundant literatures investigating whether air pollution will relatively decline when governments increase their expenditures of environmental protection, however their conclusions are not consistent due to different air pollution indicators and countries. López *et al.* (2011) analyzed 38 countries, which half are low and middle income, and proved that a rise in the proportion of public goods spending significantly lowers the concentration of SO_2 emissions, whereas it has no significant effect on lead. Halkos and Paizanos (2013) analyzed the effects of government spending on the emissions of SO_2, CO_2 and other pollutants on a sample of 77 countries from 1980 to 2000 and revealed that government spending has negative and significant effect on SO_2 emissions, whereas it affects CO_2 emissions hardly. Halkos and Paizanos (2014) further investigated the long-term effect of government's pollution protection spending on environment and revealed that the impact of government expenditure on CO_2 emissions is insignificant, whereas on SO_2 emissions, it is negative and significant.

In addition, López and Palacios (2014) further detected the reason why European environment gets better through the aspect of fiscal, trade and environmental policies and indicated that both increasing in the share of fiscal spending over GDP and shifting the emphasis toward spending on public goods instead of non-social subsidies can significantly reduce the concentrations of SO_2 emissions and O_3 emissions but not NO_2 emissions.[3] Islam and López (2014) explored how the composition of government expenditure by federal and state governments affects every kinds of air pollutants in America and found that redistributing expenditure from private subsidy to society and public goods by state and local governments can reduce the concentration of air pollution, but redistribution of federal government expenditure cannot.

There are several studies taking China as the research objective in this regard. He *et al.* (2017) empirically analyzed seven high contaminated cities in China including Beijing and Shijiazhuang and found that environmental protection expenditure does not have a significant effect on improving air pollution in long-term equilibrium, and even leads to deterioration slightly. Zhang *et al.* (2017) further investigated how every levels of governments affect environmental quality through fiscal expenditure. The result suggests that the total effects of increase in government expenditure on different kinds of pollutants are different such as the total effects are decreasing and inverted U-shaped for SO_2 emissions

[3] López and Palacios (2014) also indicated that environmental tax is found to lower the concentration of NO_2, but does not have effect on the emissions of O_2 and SO_2. In addition, trade openness is found to have direct impact on SO_2 emissions, but not on NO_2 emissions and O_3 emissions.

and soot, respectively. Huang (2018) adopted a spatial econometric model to empirically find that environmental protection spending of China's local governments has statistically negative impact on SO_2 emissions, suggesting that more environmental protection spending is likely to effectively lower the SO_2 emissions. An existence of spatial dependence of SO_2 emissions is also suggested.

The environmental Kuznets curve (EKC) hypothesis has been an important issue when it comes to the issue of economic development and environmental quality. Shafik (1994) claimed that the level of environmental pollution is higher as early stage of economic development. When income gets to a certain level, environmental quality would start to become better. This hypothesis has been supported by Grossman and Krueger (1993, 1995), Selden and Song (1994), Panayotou (1997), Vollebergh *et al.* (2009), Giovanis and Ozdamar (2016) and Sinha and Bhattacharya (2016, 2017).

Regarding other factors affecting air pollution, Bernauer and Koubi (2009) revealed that degree of democracy has independent and positive effect on air quality,[4] and that the strength of labor union is also found to conduce to reduce air quality, while the strength of green parties yields an opposite effect. Rosenblum *et al.* (2000) indicated that tertiary industrial sectors have the features of producing relatively low emissions. Gibson and Carnovale (2015) examined the influence of road user charge on driver behavior and air pollution and found that suspension of road pricing significantly increases the concentration of emissions of CO and PM_{10} in Milan by the range of 6–17%. Knorr *et al.* (2017) concluded that regions and periods with higher fire frequency result in high-risk $PM_{2.5}$ pollution. Giovanis (2018) suggested that traffic volume has a positive impact on air pollutants. In addition, Lalive *et al.* (2018) stated that the increase in rail service in Germany by 10% lowers the emissions of CO and NO_X by 1% and 2%, respectively, but will not influence emissions of SO_2 and O_3. Also, Giovanis (2018) pointed out that teleworking and reducing traffic volume are able to enhance air quality. Fu and Gu (2017) found that during the period of national holiday in 2012, the degree of air pollution increased by 15–20% due to the cancelation of freeway toll. Yang and Zhang (2018) concluded that sandstorm has significant effect on $PM_{2.5}$. In addition, Huang (2018) showed that trade factors have negative relationship with the SO_2 emissions, provinces with higher GDP of secondary industrial sectors per capita tend to discharge more SO_2 emissions, industrial pollution control invested by private sectors is conducive to reduce SO_2 emissions, the increase in population density leads to the decline of SO_2 emissions, and spatial autocorrelation coefficient is positive which proves that there have positive spatial dependence for the SO_2 emissions in China's provinces.

3. Methodology

Since this study mainly aims to analyze the influence of government expenditure regarding to environmental protection on the degree of air pollution, the dependent variable, the level

[4] Bernauer and Koubi (2009) indicated that among democracies, those with presidential systems are more conducive to air quality than with parliamentary systems.

of air pollution in county, is represented by two variables: Annual average concentrations of fine particulate matters ($PM_{2.5}$) and sulfur dioxide (SO_2). The higher the volumes they are, the higher the level of air pollution as well as the more severe air quality is. These two variables are collected from Air Quality Annual Report announced by Taiwan Environmental Protection Administration covering the period from 2013 to 2018 due to availability and measuring consistency. The empirical model and explanatory variables adopted in this study are illustrated as follows.

3.1. *Model specification*

For considering the potentially spatial dependence of air pollution, this study employs a spatial econometric model that can be categorized into three types, spatial Durbin model (SDM), spatial autoregressive (SAR) model and spatial error model (SEM). The SDM is developed by LeSage and Pace (2009), and it can be described as follows by using a simple two-way fixed-effect model:

$$y_{i,t} = \rho \sum_{j=1}^{N} w_{i,j} y_{j,t} + \alpha + \beta x_{i,t} + \theta \sum_{j=1}^{N} w_{i,j} x_{j,t} + \mu_i + \lambda_t + \varepsilon_{i,t}, \quad i \neq j, \tag{1}$$

where $y_{i,t}$ is the level of air pollution represented either by $PM_{2.5}$ concentration or SO_2 emissions of county i in year t, $i = 1, 2, \ldots, 20$ and $t = 2013, 2014, \ldots, 2018$. In addition, $w_{i,j}$ is an element in the ith row and jth column of a spatial weight matrix W and $w_{i,j}y_{j,t}$ represents the influences on dependent variables in a certain county arising dependent variables of other neighborhood.[5] ρ stands for SAR coefficient. θ and β are coefficients of explanatory variables. μ_i represents spatial-specific effect, while λ_t represents time-specific effect. Moreover, LeSage and Pace (2009) decomposed the impact of each explanatory variable on the dependent variable, the average total effect, into two parts: the average direct effect and the average indirect effect. For simplicity, estimation analysis focuses only on the average total effect.

This study first utilizes the Wald test proposed by Elhorst (2010) to test two null hypotheses H_0^1: $\theta = 0$ and H_0^2: $\rho\beta + \theta = 0$, and then to select the suitable spatial econometric model among SDM, SAR and SEM. If both H_0^1: $\theta = 0$ and H_0^2: $\rho\beta + \theta = 0$ are rejected, then the SDM is adopted. If H_0^1: $\theta = 0$ is rejected while H_0^2: $\rho\beta + \theta = 0$ cannot be rejected, then the SAR that eliminates $\theta \Sigma w_{i,j} x_{j,t}$ from Equation (1) is adopted. If H_0^2: $\rho\beta + \theta = 0$ is rejected while H_0^1: $\theta = 0$ cannot be rejected, then the SEM that eliminates $\rho \Sigma w_{i,j} y_{j,t}$ and $\theta \Sigma w_{i,j} x_{j,t}$ from Equation (1) and defines the error term as $\phi_{i,t} = \gamma \Sigma w_{i,j} \phi_{j,t} + \varepsilon_{i,t}$ is adopted.[6] However, if both null hypotheses cannot be rejected, then it is incapable of utilizing spatial econometric model to analyze. Then, the Hausman test proposed by Hausman (1978) is adopted to determine which of the fixed-effect or the random-effects model is more appropriate.

[5] The numbers in the W matrix will be row-standardized, that is, making the sum of the elements in each row equal to 1.
[6] Here, γ represents the coefficient of the spatial error. When γ is significant and not equal to 0, it shows the existence of spatial correlation among the error terms in the model, and the error term is no longer a white noise but is autocorrelated.

3.2. *Explanatory Variables*

The primary explanatory variable in this study is environmental protection expenditure from central government and from local government, respectively. The former is subsidies of air pollution control from the central government but conducted the local government (CGS) and the latter is the final accounting for the budget expenditure in environmental protection of local government (LGS). These two variables can help us distinguish the different impacts of environmental expenditure of air protection from local governments and from central governments on the air pollution. In addition, due to possible problems of endogeneity and the delay-effect of policy, both variables are 1-year lagged in the regression.[7] According to Huang (2018), more environmental protection spending of provincial government can effectively improve the quality of air. Therefore, the effects of CGS and LGS on $PM_{2.5}$ and SO_2 are expected to be negative in this study. Moreover, the effectiveness of CGS must be supervised by central government, and thus expected that the effect of CGS should surpass that of LGS.

In addition to CGS and LGS, other explanatory variables are selected primarily based on literatures mentioned above, including income, employment structure based on industry and several main pollutants. Due to the famous hypothesis of EKC, this study includes both annual real disposable income per capita (INCOM) and its square term (INCMSQ) as explanatory variables. According to EKC, the sign of the average total effect of INCM on the air pollution is expected to be positive, but it is expected to be negative for INCMSQ. Variables that stand for local employment structure are the percentage of employment in the industrial sector on total employment (SEC) and that of employment in the service sector on total employment (TRD). It is expected that SEC will make the air pollution more severe than TRD does. The density of firms with toxic chemicals (FIRM), fire frequency (FIRE) and traffic volume (PCU) all stand for pollution sources and are expected to damage the air quality in this study. Definitions, descriptive statistics, expected sign and data sources of dependent variables and explanatory variables are summarized in Table 1.

4. Empirical Results

Prior to the analysis of the estimation results, it is necessary to confirm that all variables meet the requirement of stationary. The commonly-used unit root test for variables of panel data in literatures is LLC test proposed by Levin *et al.* (2002) with the null hypothesis that variable has a unit root.[8] Table 1 also presents results of LLC unit root test for all variables and concludes that all variables reject the null hypothesis of unit root at 1% significance level, meaning that all variables are stationary and that spurious regression due to

[7] Due to that, values of CGS are zero for several counties in several years, such as Yunlin county from 2015 to 2017, Keelung city in 2013, New Taipei Municipality from 2014 to 2016, Tauyuan Municipality in 2016, and Chiayi city in 2013 and unable to be transformed into a logarithm form. Therefore, for consistency, the level values of all variables instead of their log values are adopted in this study and thus it is unable for us to provide the elasticity of the government expenditure which is much more meaningful.

[8] It is assumed that the panel regression is expressed as $\Delta y_{i,t} = a_{i,0} + \gamma_i y_{i,t-1} + a_{i,2}t + \sum_{j=1}^{P_i} \beta_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t}$, where $i = 1, 2, \ldots, n$, H_0: $\gamma_1 = \gamma_2 = \cdots = \gamma_n = \gamma = 0$, H_1: $\gamma_1 = \gamma_2 = \cdots = \gamma_n = \gamma < 0$.

Table 1. Definitions, Descriptive Statistics, Unit Root Test and Expected Sign of all Variables

Variables	Definitions	Mean	S.D.	LLC Unit Root Test	Expected Sign
A. Dependent Variable					
$PM_{2.5i,t}$	Annual concentration of particles with a diameter of 2.5 μm or less of county i in year t (Unit: $\mu g/m^3$).	20.98	6.223	−12.218***	
$SO_{2i,t}$	Annual concentration of SO_2 of county i in year t (Unit: ppb).	2.737	0.767	−17.747***	
B. Explanatory Variables					
$CGS_{i,t-1}$	Lagged local governments' real air pollution control subsidies receiving from superior and matching grants of other agencies per capita (Unit: 1,000 NT dollars, base year = 2012).	0.076	0.066	−8.301***	−
$LGS_{i,t-1}$	Lagged real final accounting for local government agencies in environmental protection's budget expenditure per capita, excluding from subsidies from superior agencies and matching grants from other agencies (Unit: 1,000 NT dollars, base year = 2012).	1.631	0.423	−4.691***	−
$INCM_{i,t}$	Annual real disposable income per capita (Unit: Million NT dollars, base year = 2012).	0.293	0.044	−8.578***	+
$INCMSQ_{i,t}$	Square term of INCM.	0.088	0.028	−8.438***	−
$SEC_{i,t}$	Percentage of employment in the industrial sector (Unit: %).	34.174	9.595	−5.622***	+
$TRD_{i,t}$	Percentage of employment in the service sector (Unit: %).	58.090	10.670	−10.472***	+
$FIRM_{i,t}$	Density of firms which have been monitored for toxic chemicals (Unit: Number/km^2).	83.530	91.832	−41.711***	+
$FIRE_{i,t}$	Fire frequency (Unit: 1,000 times/year).	0.533	0.984	−6.194***	+
$PCU_{i,t}$	Average traffic volume passing through provincial highway per day (Unit: 1,000,000 PCU).	0.903	0.896	−14.532***	+

Notes: *, ** and *** indicate that the null hypothesis of unit root is rejected at 10%, 5% and 1% significance level, respectively.
Sources: Statistical Information Network of R.O.C, Annual Report, Pollution Control Expenditure Report of Environmental Protection Administration, Air Quality Annual Report of R.O.C. (Taiwan) and Traffic Volume Statistics Report of Directorate General of Highways.

Table 2. Correlation Coefficient Matrix and VIF Tests of Explanatory Variables

Variables	CGS	LGS	INCM	INCMSQ	SEC	TRD	FIRM	FIRE	PCU
CGS	1.000								
LGS	0.138	1.000							
INCM	−0.120	0.604	1.000						
INCMSQ	−0.123	0.616	0.995	1.000					
SEC	−0.425	−0.458	−0.073	−0.091	1.000				
TRD	0.118	0.766	0.538	0.526	−0.735	1.000			
FIRM	−0.202	0.287	0.459	0.472	0.055	0.291	1.000		
FIRE	−0.211	−0.009	0.140	0.133	0.148	−0.087	0.010	1.000	
PCU	−0.586	−0.097	0.024	0.004	0.369	−0.155	0.054	0.379	1.000
Mean VIF	3.73	3.74	2.93		2.56	2.64	3.29	4.22	4.09

non-stationary of variables can be avoidable. In addition, collinearity test of explanatory variables is also conducted by using two approaches that are commonly used in literatures to test collinearity: Pearson correlation coefficients and variance inflation factor (VIF). According to Table 2, the absolute correlation coefficients for a pair of variables are all less than 0.8, indicating no highly correlated relationship between any two variables. In addition, all the estimated VIF values are quite low, less than 5, meaning no collinearity among all explanatory variables.

The model selection tests, including Wald test and Hausman test, and estimation results for both $PM_{2.5}$ concentration and SO_2 emissions are all presented in Table 3. It is shown that the most suitable spatial econometric model for both $PM_{2.5}$ concentration and SO_2 emissions is SDM with random-effect due to that both H_0^1 and H_0^2 are rejected at 1% significance level by Wald test and that Hausman test cannot reject the null hypothesis that random-effect is better than fixed-effect.

4.1. *Estimation Results of $PM_{2.5}$ Concentration*

According to Table 3, both primary variables, subsidies of air pollution control from the central government but conducted the local government (CGS) and the final accounting for the budget expenditure in environmental protection of local government (LGS), have a negative and statistically significantly impacts on the concentration of $PM_{2.5}$. This finding is consistent with that in previous studies. In addition, the magnitude of the negative average total effect of CGS on the $PM_{2.5}$ concentration is larger than that of LGS on the concentration of $PM_{2.5}$, meaning that an increase in the CGS can improve air quality in terms of $PM_{2.5}$ concentration better than LGS can do. One dollar increase in CGS will decrease the overall $PM_{2.5}$ by about $0.046\,\mu\,g/m^3$, but the overall $PM_{2.5}$ will be decreased only by about $0.0062\,\mu\,g/m^3$ when one dollar increases in LGS.

As mentioned earlier, it is because the effectiveness of CGS must be supervised by central government. The other possible reason is that CGS is purely for air pollution control, but LGS is for entire environmental protection, air pollution control is only part of

Table 3. Estimation Results of Panel SDM with Random-Effect

	Dependent Variable: $PM_{2.5}$		Dependent Variable: SO_2	
Explanatory Variables	Average Total Effect	S.E.	Average Total Effect	S.E.
$CGS_{i,t-1}$	−45.957	(19.804)**	−5.682	(2.098)***
$LGS_{i,t-1}$	−6.198	(3.330)*	−0.304	(0.340)
$INCM_{i,t}$	201.205	(198.923)	38.078	(22.450)
$INCMSQ_{i,t}$	−516.976	(306.519)*	−78.264	(34.798)**
$SEC_{i,t}$	0.263	(0.347)	0.038	(0.039)
$TRD_{i,t}$	−0.432	(0.417)	0.022	(0.048)
$FIRM_{i,t}$	0.086	(0.019)***	0.003	(0.002)*
$FIRE_{i,t}$	1.086	(0.512)**	0.014	(0.051)
$PCU_{i,t}$	2.374	(3.519)	0.387	(0.399)
Constant	12.193		−2.755	
P	0.519***		0.311***	
σ_e^2	1.215 ***		0.025***	
Log likelihood	−225.313		4.661	
Wald spatial lag test	46.1***		26.95***	
Wald spatial error test	46.64***		22.62***	
Hausman test	0.16		5.92	
Observations	120		120	

Notes: *, ** and *** indicate at 10%, 5% and 1% significance level, respectively.

it. It is worth noting that this conclusion does mean that the central government can provide a better public good, such as high quality of air in this study, than the local government in Taiwan because both CGS and LGS are conducted by the local government to protect air quality, but they are from different financial resources. The former is subsidized by the central government, the latter is the budget of local government.

As to the hypothesis of EKC, only the square term of the annual real disposable income per capita (INCMSQ) has a significant and negative influence on $PM_{2.5}$ concentration of meaning that the inverted U-shaped relationship between income and $PM_{2.5}$ concentration does not exist in this study. Both density of firms with toxic chemicals (FIRM) and fire frequency (FIRE) have a positive and statistically significant influence on the concentration of $PM_{2.5}$. However, there are no evidences to support any impacts of employment structure and traffic on $PM_{2.5}$ concentration in this study. Finally, the coefficient of spatial autocorrelation ρ is 0.519 and statistically significant at 1% significance level, implying that a county's $PM_{2.5}$ concentration is positively affected by its neighboring counties.

4.2. *Estimation Results of SO_2 Emissions*

As to the SO_2 emission, according to Table 3, the finding of impacts of two primary variables, CGS and LGS, on the SO_2 emission is different from that of $PM_{2.5}$ concentration. It is shown that CGS has a negative and statistically significantly impact on SO_2

August 19, 2021 12:04:19pm WSPC/172-SER 2150057 ISSN: 0217-5908 2ndReading

emissions, whereas LGS does not have a statistically significant influence on SO_2 emissions. That is to say, CGS is more effective to improve the quality of air than LGS in Taiwan and 1 dollar increase in CGS will decrease the overall SO_2 by about 0.0057 ppb.

In addition, the hypothesis of EKC is supported in the case of SO_2 emissions. The average total effect of INCM on the SO_2 emissions is statistically significant and positive, but it is statistically significant and negative for INCMSQ. It implies that the relationship between income and SO_2 emissions is inverted U-shaped. The density of firms with toxic chemicals (FIRM) also has a statistically significant and positive influence on SO_2 emissions. However, there are no evidences to support any impacts of employment structure, fire frequency and traffic on the SO_2 emissions in this study. Finally, similar to $PM_{2.5}$ concentration, there exists a significant spatial correlation of SO_2 emissions among counties in Taiwan. The coefficient of spatial autocorrelation ρ is 0.311 and statistically significant at 1% significance level, implying that a county's SO_2 emission is positively affected by its neighboring counties.

4.3. *The robustness of the results*

To conduct the robustness test, this study excludes the outer islands from the samples to estimate the empirical model and provides the primary results in Table 4. It is same as in

Table 4. Primary Results of Panel SDM with Random-Effect W/O Outer Islands

Dependent Variable: $PM_{2.5}$		Dependent Variable: SO_2	
Explanatory Variables	Average Total Effect (S.E.)	Explanatory Variables	Average Total Effect (S.E.)
$CGS_{i,t-1}$	−37.609**	$CGS_{i,t-1}$	−5.456**
	(18.743)		(2.162)
$LGS_{i,t-1}$	−4.053	$LGS_{i,t-1}$	−0.103
	(3.182)		(0.350)
$INCM_{i,t}$	−155.864	$INCM_{i,t}$	19.499
	(198.923)		(22.450)
$INCMSQ_{i,t}$	47.242	$INCMSQ_{i,t}$	−50.044
	(347.260)		(34.798)
$TRD_{i,t}$	−0.707	$FIRM_{i,t}$	0.002
	(0.400)		(0.002)
ρ	0.495***	ρ	0.311***
σ_e^2	1.103***	σ_e^2	0.024***
Log likelihood	−208.119	Log likelihood	6.817
Wald spatial lag test	43.44***	Wald spatial lag test	27.43***
Wald spatial error test	47.68***	Wald spatial error test	23.98***
Hausman test	1.22	Hausman test	2.13
Observations	114	Observations	114

Notes: *, ** and *** indicate at 10%, 5% and 1% significance level, respectively.

Table 3 that the most suitable spatial econometric model for both $PM_{2.5}$ concentration and SO_2 emissions is SDM with random-effect. The significance and sign of estimated average total effect of variables that are not shown in Table 4 are the same as those of their counterparts in Table 3. According to Table 4, it is shown that CGS has a negative and statistically significantly impact on both $PM_{2.5}$ and SO_2 emissions, whereas LGS does not have a statistically significant influence on both $PM_{2.5}$ and SO_2 emissions. It implies that the primary conclusion that an increase in the CGS can improve air quality in terms of $PM_{2.5}$ concentration and SO_2 emissions better than LGS can do is quite robustness regardless the outer islands is included in or excluded from the samples.

In addition, this study further includes the annual volume of diesel vehicles per km^2 area (ADV) in the empirical models to test the robustness of findings from Table 3.[9] The estimated results of adding ADV show that the significance and sign of CGS and LGS are the same as those in Table 3 even though ADV does not have a statistically significant impact on neither $PM_{2.5}$ concentration nor SO_2 emissions. It further confirms that the primary findings from Table 3 are quite robust.[10]

5. Concluding Remarks

The primary purpose of this study is to explore the influence of environmental protection expenditure of government on air pollution in Taiwan and to find any different impacts if this expenditure is sourced from different levels of government, say central and local government. This study uses $PM_{2.5}$ concentration and SO_2 emissions as the indicator of air pollution and adopts a panel data of 20 counties in Taiwan covering the period from 2013 to 2018. After estimating a panel SDM with random-effects, suggested by several model selection test, for $PM_{2.5}$ concentration and SO_2 emissions, respectively, due to considering a potential spatial dependence of $PM_{2.5}$ concentration and SO_2 emissions, the primary finding of this study is that the environmental protection expenditure of local government can statistically and significantly mitigate the air pollution in Taiwan. The magnitude of this negative influence of local government's environmental protection expenditure on the $PM_{2.5}$ concentration is larger if this expenditure is subsidized by the central government than from local government's budget. In addition, only the environmental protection expenditure subsidized by the central government can statistically and significantly reduce SO_2 emissions in Taiwan.

In addition, the hypothesis of EKC is supported only in the case of SO_2 emissions. The density of firms with toxic chemicals (FIRM) can worsen the quality of air regardless of which indicator of air pollution is adopted. The fire frequency (FIRE) has a positive and statistically significant influence on $PM_{2.5}$ concentration. Finally, it is shown that air pollution has a positive spatial correlation regardless of which indicator of air pollution is adopted, meaning that a county's air pollution is positively affected by its neighboring counties.

[9] Since the correlation coefficient between PCU and the annual volume of diesel vehicles is larger than 0.8, this study uses ADV instead of the annual volume of diesel vehicles in the empirical models.
[10] The estimated results including ADV in the models are available upon requests.

In order to improve the quality of air in Taiwan, according to primary findings, this study suggests that Taiwan's central government should pay more attention to the issue regarding air pollution and provides more subsidies of air pollution control to local government no matter the air is polluted by $PM_{2.5}$ concentration or SO_2 emissions. Although the influence of the budget expenditure in environmental protection of local government is less that of subsidies of air pollution control from the central government, if local government can spend more budget in environmental protection, it can also improve the quality of air, especially if the air is polluted by $PM_{2.5}$ concentration. In addition, once air pollution is improved in one county, that of the neighboring counties can be also improved due to the feature of spatial dependence of air pollution. It is also suggested that local government should decrease the density of firms with toxic chemicals and the fire frequency in its county. Finally, according to the EKC supported by this study, especially SO_2 emissions, increasing residents' income is another way for local government to improve the quality of air in the county.

Acknowledgments

The author gratefully acknowledges financial support provided for this research by the Ministry of Science and Technology, Taiwan (MOST-108-2410-H-004-024-MY2). The author would also like to thank Mr. He-Shun Hsu, Ms. Ruo-Lin Wang, Ms. Pei-Yun Miao and Ms. Chia-Ling Hu for their assistance in data collection and analysis during the preparation of this paper. All views and errors are solely those of the author.

References

Bernauer, T and V Koubi (2009). Effects of political institutions on air quality. *Ecological Economics*, 68, 1355–1365.

Elhorst, JP (2010). Matlab software for spatial panels. *International Regional Science Review*, 37(3), 389–405.

Fu, S and Y Gu (2017). Highway toll and air pollution: Evidence from Chinese cities. *Journal of Environmental Economics and Management*, 83, 32–49.

Gibson, M and M Carnovale (2015). The effects of road pricing on driver behavior and air pollution. *Journal of Urban Economics*, 89, 62–73.

Giovanis, E (2018). The relationship between teleworking, traffic and air pollution. *Atmospheric Pollution Research*, 9, 1–14.

Giovanis, E and O Ozdamar (2016). Structural equation modeling and the causal effect of permanent income on life satisfaction: The case of air pollution valuation in Switzerland. *Journal of Economic Surveys*, 30(3), 430–459.

Grossman, GM and AB Krueger (1993). Environmental impact of a North American free trade agreement. In *The Mexico-U.S. Free Trade Agreement*, PM Garber (ed.), pp. 13–56. Cambridge, MA: The MIT Press.

Grossman, GM and AB Krueger (1995). Economic growth and the environment. *The Quarterly Journal of Economics*, 110(2), 353–377.

Halkos, GE and EA Paizanos (2013). The effect of government expenditure on the environment. *Ecological Economics*, 91, 48–56.

August 19, 2021 12:04:19pm WSPC/172-SER 2150057 ISSN: 0217-5908 2ndReading

Halkos, GE and EA Paizanos (2014). Exploring the effect of economic growth and government expenditure on the environment. MPRA Paper No. 56084.

Hausman, JA (1978). Specification tests in econometrics. *Econometrica*, 46(6), 1251–1271.

He, L, M Wu, D Wang and Z Zhong (2017). A study of the influence of regional environmental expenditure on air quality in China: The effectiveness of environmental policy. *Environmental Science and Pollution Research*, 25(8), 7454–7468.

Huang, JT (2018). Sulfur dioxide (SO_2) emissions and government spending on environmental protection in China — Evidence from spatial econometric analysis. *Journal of Cleaner Production*, 175, 431–441.

Islam, A and RE López (2014). Government spending and air pollution in the US. *International Review of Environmental and Resource Economics*, 8, 139–189.

Knorr, W, F Dentener, JF Lamarque, L Jiang and A Arneth (2017). Wildfire air pollution hazard during the 21st century. *Atmospheric Chemistry and Physics*, 17, 9223–9236.

Lalive, R, S Luechinger and A Schmutzler (2018). Does expanding regional train service reduce air pollution?. *Journal of Environmental Economics and Management*, 92, 744–764.

LeSage, JP and RK Pace (2009). *Introduction to Spatial Econometrics*. London: CRC Press Taylor and Francis Group.

Levin, A, CF Lin and CSJ Chu (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, 108, 1–24.

López, RE and A Palacios (2014). Why has Europe become environmentally cleaner? Decomposing the roles of fiscal, trade and environmental policies. *Environmental and Resource Economics*, 58, 91–108.

López, RE, G Galinato and A Islam (2011). Fiscal spending and the environment: Theory and empirics. *Journal of Environmental Economics and Management*, 62, 180–198.

Panayotou, T (1997). Demystifying the environmental Kuznets curve: Turning a black box into a policy tool. *Environment and Development Economics*, 2(4), 465–484.

Rosenblum, J, A Horvath and C Hendrickson (2000). Environmental implications of service industries. *Environmental Science & Technology*, 34(22), 4669–4676.

Selden, TM and D Song (1994). Environmental quality and development: Is there a Kuznets curve for air pollution emissions?. *Journal of Environmental Economics and Management*, 27, 147–162.

Shafik, N (1994). Economic development and the environmental quality: An econometric analysis. *Oxford Economic Papers*, 46, 757–773.

Sinha, A and J Bhattacharya (2016). Environmental Kuznets curve estimation for NO_2 emission: A case of Indian cities. *Ecological Indicators*, 67, 1–11.

Sinha, A and J Bhattacharya (2017). Estimation of environmental Kuznets curve estimation for SO_2 emission: A case of Indian cities. *Ecological Indicators*, 72, 881–894.

Vollebergh, HRJ, B Melenberg and E Dijkgraaf (2009). Identifying reduced-form relations with panel data: The case of pollution and income. *Journal of Environmental Economics and Management*, 58(1), 27–42.

Yang, J and B Zhang (2018). Air pollution and healthcare expenditure: Implication for the benefit of air pollution control in China. *Environment International*, 120, 443–455.

Zhang, Q, S Zhang, Z Ding and Y Hao (2017). Does government expenditure affect environmental quality? Empirical evidence using Chinese city-level data. *Journal of Cleaner Production*, 161, 143–152.