Strategic Interaction in Spending on Environmental Protection: Spatial Evidence from Chinese Cities

In the last two decades, China has experienced rapid economic growth with annual increase in GDP of 8 to 9 percent (World Bank, 2007a). However, the economic growth is at the high cost of environment deterioration and resource depletion.

It is known that, the task of pollution control is assumed by most governments (Chinese government is no exception) as a consequence of fiscal decentralization reform implemented in eighty five countries over the last two decades (Feruglio and Anderson, 2008). Under the fiscal decentralization system, important expenditure responsibilities are assigned to local governments. Hence, it is important to understand the relationship between local government's behavior and environmental pollution (Zhang and Zheng, 2009). All governments play two leading roles in terms of environmental protection. One is to set environmental regulations, the other is to make environmental protection expenditures. In this study, we will focus only on government's expenditure behavior on environmental protection. When expenditure responsibilities are decentralized, it is expected that each government will not act by itself, it will incorporate to some extent the behavior of its neighboring government. Particularly, local government is expected to affect the spending behaviors of its neighboring governments via at least three channels (Manski, 1993). First, expenditure competition may occur if local governors compete with their neighbors in order to attract households or firms (Case et al, 1993; Revelli, 2003; Lundberg, 2006; Yu et al., 2012). Second, yardstick competition may occur if local governments' spending on environmental protection could promote local economic development and growth, which is assumed to be the major indicator used by its upper-level government to evaluate and promote (or reappoint) the local governors (Chen et al., 2005; Caldeira, 2011).Third, expenditure externality may occur if public spending (on infrastructure, environmental protection, healthcare, etc.) by one local government can create the benefits or detrimental effects on its neighboring jurisdictions (Case et al., 2005; Solé Ollé, 2003; Fréret, 2006, Yu et al., 2012). Besides these explanations of fiscal interactions proposed, Manski (1993) indeed suggests another explanation that fiscal interactions may result from a 'common intellectual trend' that drives fiscal choices in the same direction. In relation to public spending on environmental protection, the central or provincial government might offer common directives across city governments for increasing (or decreasing) certain kinds of expenditures. This form of spatial effect can occur in the context of China. In the empirical analysis as follows, these sources of fiscal interaction among city governments are to be disentangled by applying a spatial econometric technique.

Theoretically, there is no consensus on whether decentralized environmental policy-making induces a race to the bottom or a race to the top (Levinson, 1997). On the one hand, decentralized environmental policy-making of local governments may lead to local protectionism by enacting environmental standards that are too high in order to prevent undesirable facilities from locating within its jurisdiction (Markusen et al., 1995; Wilson, 1996; Glazer, 1999). On the other hand, local governments may set excessively lax environmental standards in order to attract and retain capital (Markusen et al., 1995; Wilson, 1996; Esty and Geradin, 1997).

Empirically, Fredriksson and Millimet (2002) find evidence that U.S. state regulators respond strategically to the regulatory standards of other jurisdictions, but they are unable to find evidence in supporting a race to the top or a race to the bottom hypothesis. Using state-level data to examine the impact of decentralized environmental policymaking in the U.S. under President Ronald Reagan, List and Gerking (2000) find that Regan's decentralization did not lead to a race to the bottom. This finding is consistent with the empirical work by Millimet (2003), but the latter finds evidence of a race to the top in pollution control expenditures.

The disagreement on the effect of environmental decentralization by these studies may be attributed to several factors such as different tax instruments used, different time of period covered, or ad hoc models specified. However, from the econometric perspective, the disagreement can be due to an omitted variable bias issue. It is known that taxation and expenditure decisions are simultaneously determined by local governments (in the U.S.), a region with high expenditures is by the same time a region with high tax rate. While these decentralization-related policy studies focus on either the tax competition side or the expenditure competition side when conducting empirical implementations, their failure to take both sides into consideration could suffer from possible omitted variable bias problem.

China serves as a good example to examine the government's environmental expenditure behavior in the context of fiscal decentralization for several reasons. First, it is recognized that local tax rate in China cannot be altered by local government. In other words, local governments cannot engage in tax competition, we need only examine the expenditure competition behavior of Chinese local governments. Second, despite of tremendous efforts made by the Chinese government to control pollution since two decades ago, environmental pollution in the form of water pollution and air pollution remain intensive and serious as mentioned above. Third, China has undergone a fiscal decentralization reform since 1994. Ever since, more important expenditure responsibilities (e.g., environmental expenditures) have been assigned to local governments.

Then, turning to the case of China, what is the Chinese government's environmental expenditure behavior under fiscal decentralization? Do Chinese city governments behave strategically on making environment protection spending decisions? Specifically, will the decentralization reform induce a race to the bottom or to the top of public spending on environmental protection? These questions are to be answered in this study. Using a cross-sectional data set of 249 Chinese cities in 2005, this study applies spatial econometric methods to examine the factors that determine public environmental protection spending in a decentralized economy. The empirical results reveal that city governments do behave strategically on making environment protection spending decisions. Precisely, a city government tends to cut its own spending as a response to the rise of environmental protection spending of its neighbors.

Using cross-sectional data of 249 Chinese cities, the empirical model of environmental protection expenditure can be specified in a classical linear model as,

$$y = \alpha\iota_n + X\beta + \epsilon,\ \epsilon \sim N(0,\ \sigma_\epsilon^2 I_n),\ n = 1, 2, \ldots, 249 \quad (1)$$

where ι_n is an n x 1 vector of ones associated with the constant term parameter α. y is n x 1 vector of the dependent variable denoting per capita city government's spending on environmental protection, X is a set of explanatory variables which are identified to influence city government's investment in pollution protection. ε is the error term across observations, β is the parameter to be estimated in this model.

Following the spatial econometric approach developed by Anselin (1988), the aforementioned model can be extended to account for spatial dependence in environmental protection spending of municipal cities. The spatial dependence can take several forms. One is the spatial lag model specifying the spatial correlation in the dependent variable, which more or less resembles the autoregressive (AR) model in time-series econometrics, the other is the spatial error model allowing for spatial autocorrelation in the error term, which hence is more or less like the moving average (MA) model in time-series econometrics. These two types of spatial correlation are commonly seen in the spatial econometric literature.

To account for spatial correlation in the dependent variable, that is, to specify a spatial lag model (SAR), the classical linear regression model in Equation (1) is adapted to be,

$$y = \alpha\iota_n + \lambda Wy + X\beta + \epsilon,\ \epsilon \sim N(0,\ \sigma_\epsilon^2 I_n),\ n = 1, 2, \ldots, 249 \quad (2)$$

where W is a non-stochastic $n \times n$ spatial weights matrix in which the element $m_{ij}$is equal to $1/d_{ij}$ with d_{ij}beingthe (greater-circle) distance between two cities i and j ($i \neq j$).[1] In making such specification, we assume that as the distance between cities i and j increases (decreases), m_{ij}decreases (increases), which poses less (more) spatial weight to the city pair (i, j). It can be seen that the weight matrix is defined as a priori by the economist and does not include parameters to be estimated.In this model, the parameters to be estimated are the usual regression parameters α, β, σ^2, and the spatial lag parameter λ, which measures the magnitude of interactive behavior across city governments.To estimate the model with a spatially lagged dependent variable, we apply the maximum likelihood estimation (MLE) method (Anselin, 1988).[2]

On the other hand, a model can incorporate a spatial dependence in the disturbances (SEM) can be specified as,

$$y = \alpha\iota_n + X\beta + \mu,\ \mu = \rho W\mu + \epsilon,\ \epsilon \sim N(0,\ \sigma_\epsilon^2 I_n) \quad (3).$$

Despite OLS estimation in the presence of spatial correlation among model disturbances yields unbiased coefficient estimator, estimates of standard errors will be inconsistent, which implies that t-statistics and F-statistics will be incorrect and misleading. Therefore, the spatial error model is also estimated using MLE.

A general form of spatial model has been termed SARMA (spatial autoregressive moving average) by Cliff and Ord (1981) which combines both the

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[1]The greater-circle distance is calculated based on the longitude and latitude of each city which can be obtained (as of February 3, 2011) fromhttp://www.gpsspg.com/maps.htm. Another commonly used weight matrix specification is the contiguity-based binary matrix in which each element m_{ij} of the matrix W is set to one if city i and j ($i \neq j$) share a common border, and zero otherwise.

[2] The log-likelihood function for each spatial model in this study can be found in LeSage and Pace (2009).

spatially lagged term as well as the spatially correlated error structure, it is specified as the following format,

$$y = \alpha\iota_n + \lambda Wy + X\beta + \epsilon,\ \epsilon = \rho W\epsilon + v,\ v \sim N(0, \sigma_v^2 I_n) \qquad (4)$$

where all variables and parameters are defined as above.[3] Similarly the SARMA model should be estimated by the MLE method.

In the empirical implementation, The Lagrange Multiplier (LM) tests and their robust versions can be used to choose among the SAR and SEM models, and the likelihood ratio (LR) tests can be used to choose between the SAR or SEM model and the general SARMA model (Anselin, 1988; LeSage and Pace, 2009)

The data set for this study consists of a cross-section of 249 Chinese cities in 2005.Table 1 lists the variables used in the empirical model. All variables, unless otherwise noted, are derived from *China City Statistical Yearbook 2006,*[4]which is published by National Statistical Bureau (2006). The dependent variable (EP) is per capita investment on environmental protection, which is classified as three categories (Figure A.1): investment in urban environment infrastructure facilities (IEIF), investment in treatment of industrial pollution sources (ITIP), and investment in environment components for new construction projects (IECC). The first category (IEIF) takes up the majority of total public investment in environmental protection. Specially, IEIF accounted for 50% or more of total public investment, the number even reached above 70% in 2005. As public investment in urban environment infrastructure facilities includes mainly the projects like natural gas supply, heating, drainage, landscaping, and urban sanitation, The IEIF is less closely related to environmental pollution treatment than the latter two categories of investment (ITIP and IECC).

With respect to the explanatory variables, REVENUE is an indicator to reflect a city's fiscal capacity which is measured by the city government's own revenue per capita. On one hand, Wagner's Law states that government activities increase as economies grow (Wagner, 1991). The Law implies that as economy develops, government would spend more on treating environmental pollutions. Thus, the influence of government's own revenue on expenditure in environmental protection is expected to be positive. In addition, the environment Kuznets curve (EKC) hypothesis posits an inverted-U relationship between environmental quality and economic development/growth. Similarly, we hypothesize that there exists an inverted parabolic relationship between governmental own revenue and environmental protection spending in this study. In the early stage of economic development/growth, environmental regulation is weak and ineffective, more efforts and revenue of local governments are required to protect environmental pollution. As fiscal revenue increases (due to economic growth) beyond some level, leading industries become cleaner, and environmental regulation becomes more effective, environmental improvements lead to fall in governmental own revenue in the later stage. Thus, the

[3] According to Anselin and Bera (1998), the spatial weight matrix used in the lag component in the SARMA model can be different from the matrix used in the error component. For simplicity, we assume these two weight matrices are identical.

variable REVENUE2 defined as REVENUE squared is expected to be negative. Urbanization rate (URBAN) is measured as the percentage of total population of a city living in urban area. It is known that China's high speed of economic development comes at a high cost of environmental degradation, while urbanization rate can be a good indicator to reflect a city's status of economic development, high urbanization rate implies that city has undergone an environmental degradation and implies further that more spending on environmental protection is demanded. Hence, the variable URBAN is expected to be positive. EDUCATION, measured as the percentage of total city's public expenditure allocated to education, is another variable considered to affect a city government's spending on environmental protection. Given the constant budget constraint of local governments, environmental protection expenditure and education expenditure are expected to be substitutes of each other. Consequently, the education variable is expected to be negative. SO2 indicates industrial sulfur dioxide emissions divided by total population in the city. More industrial emissions lead to more environmental pollutions, which calls for more environmental protection efforts. Thus, we expect the coefficient of SO2 to be positive. Natural condition in a city, such as green plants or sods has air-purifying effects by removing some common toxins (e.g., formaldehyde, benzene and carbon monoxide) from the air. It is expected that the city with better natural condition could spend less on environmental treatments. Further, a city observed to have more rainfalls is believed to have better air quality (partly due to its self-purification function) and more green plants. Therefore, it is justifiable to use the averaged amount of precipitation recorded during year 2005 as the proxy variable (RAIN) to reflect a city's natural condition. The data are taken from *Provincial Statistical Yearbook2009* for all China's cities.

In specifying the model, city-specific characteristics not capturedby the explanatory variables as mentioned above may affect city's public spending behavior of environmental protection in that city. Without accounting for these characteristics couldlead to potential omitted variable bias. To deal with this issue, provincial dummy variables are included in the model. Doing so allows us to remove the common directives set uniformly by the upper governments across city governments for increasing (or decreasing) certain kinds of expenditures. i.e, adding provincial dummy variables allows us to remove the third sources of fiscal interactions as mentioned above while focusing on other possible sources.

As mentioned before, the results based on OLS (Eq. 1) are inconsistent if spatial effects exist in the model. To test the existence of spatial dependence, we apply Moran's (1950) *I* test on the residuals from the OLS model.[5] The test statistic of 2.543 (p = 0.011) indicates that there is significant spatial dependence in the data, suggesting a spatial econometric model, a spatial lag model (Eq. 2) or a spatial error model (Eq. 3), should be used.

The Lagrange multiplier (LM-Lag) test is applied to test for spatially lagged dependence. Likewise, the LM-Error test is applied to test for spatial error dependence. The LM-Error test reveals evidence of spatially correlated error

[5] The OLS results are reported in Table A.1 in the Appendix.

dependence at 10% level of significance, while the LM-lag test does not reveal spatially lagged dependence. However, these two tests fail to separate one form of spatial dependence from another if only one or both types of dependence exist. Hence, we resort to two robust versions of these two LM tests. It is shown that either test statistic is found to be greater than its corresponding critical values ($p < 0.05$ for Robust LM-Lag, $p < 0.10$ for Robust LM-Error). This result suggests that a general model with spatial error and spatial lag terms, the SARMA model, should be used. In addition, we find that the log-likelihood for the SAR, SEM, and SARMA models are, respectively, -1623.60, -1607.28, and -1535.51, the LR test result for the SARMA versus SAR (176.18, with 1 degree of freedom [df], $p < 0.01$), or SEM (143.54, 1 df, $p < 0.01$) confirms that the SARMA model is the best candidate to explain the data.

We find that the spatial lag parameter (λ) and the spatial error coefficient (ρ) are, respectively, -0.253 and 0.627, and both are statistically significant at 1%. The finding implies that, within the current environmental management system, Chinese city governments are engaging in strategic interactions in spending on environmental protection. Further, spatial interactions across city governments appear in the form of both spatially lagged dependent variables and spatially correlated disturbances. In other words, while we find that city governments appear to act similarly following a common natural shock (e.g., acid rain or sandstorm), or a policy shock (e.g., the to-be-enacted Taihu Management Plan [‘*Tai Lake GuanliTiaoli*’ in Chinese],[6] or even due to other unobserved omitted variables, the result reveals that a city government tends to cut its own spending as a response to the rise of environmental protection spending of its neighbors.

With respect to the explanatory variables, city government’s own revenue (REVENUE) and its squared term are respectively positive and negative, and both terms are statistically significant. This result indicates an inverted-U relationship hypothesis between fiscal capacity and environmental protection spending.[7] In other words, per capita spending on environmental protection increases first as per capita government revenue rises, and then falls after reaching a certain turning point. SO2 is found to affect environmental protection spending positively. This result implies that more industrial SO_2 emissions cause more devastation to the environment, which calls for more spending on protecting the environment. URBAN is found to be statistically significant at 5% level with a positive coefficient sign. This result is consistent with our expectation. From the demand-side perspective, China’s rapid economic growth and fast urbanization progress are accompanied by degrading environmental quality, and require the government to invest more on protecting the environment. From the supply-side perspective, fast urbanization progress could promote economic growth of a city which further raises the city’s fiscal revenue. The city government, thus, is more capable of paying for environment abatement. The share of education expenditure

[6]The Plan requires that provinces of Jiangsu, Zhejiang, and Shanghai to take actions to clean up massive water pollution in the basin area. Tai Lake is located in the junction of Shanghai, Jiangsu and Zhejiang province. It is the third largest freshwater lake in China after Poyang and Dongting Lakes with a total area of 36,900 km^2. The Taihu Lake Basin contains myriads of lakes and rivers with a total river course length of more than 120 km (Chen, 2005).

(EDUCATION), which is considered as one major component of public expenditure, is found to be statistically insignificant. The precipitation variable RAIN is positive and carries the unexpected sign, which could be partially due to the reverse causality problem between rainfall and environmental protection not taken into account in the SARMA model.

One main issue that may plague the estimations in the SARMA model is that the variable Wy is endogenous and also some explanatory fiscal variables can be endogenous. To check whether the results obtained from the SARMA regression are robust to possible endogeneity bias, Kelejian and Prucha (1998) suggest an instrumental variable method, a three-step procedure known as a generalized spatial two-stage least squares (GS2SLS) procedure.The GS2SLS procedure proceeds as follows.

In the first step the regression model in Eq. (4) is estimated by two-stage least squares (2SLS) using a set of instrument variables H (X, WX, W^2X). That is, regressing Wy on X, WX, W^2X and using the fitted values Wy as instruments for Wy. In the second step, estimating the autoregressive parameter ρ by GMM using the residuals obtained in the first step. In the last step, using the estimates of ρ to perform a spatial Cochrane-Orcutt transformation of the data and obtain efficient estimates of β and λ.

The diagnostic tests suggests that the chosen instruments are relevant (at 5% level p = 0.020) and exogenous (at 10% level, p = 0.092), and the variables in interest (REVENUE, SO2, URBAN, RAIN, EUDCATION) are indeed endogenous (at 10% level, p = 0.065).We find that the spatial lag and error parameters are statistically significant, indicating that both types of spatial dependence coexist in the model. In particular, based on the GS2SLS approach, we find that the spatial lag remains statistically significant with similar coefficient size to that in the SARmodel (without accounting for endogeneity). This empirical finding confirms our earlier finding that cities engage in strategic interaction in deciding their spending on environmental protection. Specifically, a positive spillover effect emerges from environmental protection across cities. Turning to other explanatory variables, in general we find that the empirical results from the SARregression are consistent with the GS2SLS specification, except that we find education share is positively associated with per capita environmental protection expenditure. This result fails to support the 'crowding-out' effect of fiscal expenditures, and is beyond our expectation. A tentative explanation could be that, under a constant budget constraint, the city government is likely to increase both expenditures while cutting back other types of public expenditures.

The second issue is related to the specification of spatial weighting matrix. In a further robustness check, we investigate whether the results of the spatial interaction between cities are not an artifact of the statistical procedure (in which the neighborhood variable picks up the effect of any random set of cities), we build an intentionally absurd weighting matrix using a randomly generated spatial weighting matrix following Ladd (1992), Case et al. (1993), and Yu et al. (2012). Particularly,

we ordered the cities alphabetically, and then each city's neighbors were defined to be the two other cities that follow the city in the alphabetical ordering The Moran test (based on residuals from the OLS model) reveals that there is no evidence of spatial dependence, and the spatially lagged parameter (based on estimating the SAR model) using the new spatial weighting matrix is not statistically significant at the 10% level. Hence, our spatial results are not an artifact of the statistical procedure.
Our finding shows that fiscal capacity matters for city governments in making decisions on environmental protection spending under a constant budget constraint. As a city's fiscal revenue increases, the ability of the city government to spend on environmental protection increases, but with a decreasing rate. It is observed that poor cities are in a worse position than rich cities in fiscal abilities, and the poor cities, some of which are severely harmed by water or air pollution,[8] are also the cities that shoulder an excessively heavy fiscal burden. From the national point of view in reducing overall pollutions, fiscal responsibilities could be better centralized.

Furthermore, our finding on the spatial autoregressive parameter supports the view of fiscal centralization. The empirical result shows that cities are influenced by their neighbors. Particularly, cities respond to increased environmental protection spending in neighboring cities by increasing their own spending. As a result, it can be expected that city governments tend to free-ride in spending on environmental protection. While our study fails to find a 'race-to-bottom' in environmental protection spending, studies by scholars such as Fredriksson and Millimet (2002), Woods (2006), and Konisky (2007) find both evidence supportive of the race to the bottom and race to the top in environmental regulatory decisions. If the race to the bottom-type dynamics were observed to affect the spending behavior of Chinese cities, services of environmental protection and treatment for the whole society would be expected to be severely underprovided. In this regard, fiscal responsibilities could also be better centralized.

Stepping further, we actually are able to analyze in more details why it is true that underprovision or inefficiency of environmental protection service could occur by running a simple regression in the following. Using industrial SO_2 emissions as a proxy variable for local natural environmental condition, we examine the issue whether a city's environmental condition has any effect on public health spending of its neighboring cities. The empirical model is specified as,

$$MEDICAL_i = \beta_0 + \beta_1 W{*}SO2_i + \mu_i \qquad (5)$$

where $MEDICAL_i$ denotes public medical expenditures of city *i in 2005*, $SO2_i$ stands for SO_2 emissions in city *i in 2005*. *W* is the distance-based spatial weight matrix constructed based on the longitude and latitude of each city. μ_i is the disturbance term. β is the coefficient to be estimated. The positive and statistically significant coefficient for *WW* implies that the pollution of neighbors generates substantial loss for a city in terms of medical bills. In other words, if the environmental qualities of the neighboring cities are relatively higher, the health spending of the city can be

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[8] *2009 Annual Report on Urban Environmental Management and Comprehensive Control of China* (Ministry of Environmental Protection of the People's Republic of China), retrieved on March 15, 2011.

lower, vice versa. Thus, this result further implies that environmental investment of a city can impose a positive externality on its neighboring cities through affecting its neighbor's health expenditure.

Economic theory states that, in the presence of no externalities, marginal revenue of the investment has to equate marginal cost associated with the investment at the optimal level of local government's environmental investment, i.e., MR = MC. However, in a decentralized economic system, we find that a local government's spending on environment protection can affect the health spending of its neighboring governments, yet the local government does not take this effect into account. When positive externality appears, the socially optimal level of investment should be set at a level where $MC_{social} = MR_{local} + MR_{neighbor}$. It is easily seen that $MC_{social} = MR_{local} + 3.21 > MR_{local} = MC_{local}$, implying that local governments will spend on environmental protection at a level that is less than socially optimal.

Chinese central government has been calling for actions on abating environmental pollution, however, environmental protection expenditure (as a share of GDP) remains so low within the range of 1-1.5% in the last decade. This study attempts to unravel such phenomenon in the context of fiscal decentralization where more fiscal responsibilities like environmental protection expenditure are borne by local governments.

Using a cross-sectional data set of 249 Chinese cities in 2005 in the spatial econometric framework, we reach the following major conclusion: a city government tends to cut its own environmental protection spending as a response to the rise of environmental protection spending of its neighbors. This finding implies that a city government's decision making on environmental protection spending causes positive externalities on its neighboring cities.

Our main finding has important implications for policy makers in making fiscal arrangements across jurisdictions. The positive spillovers under a decentralized decision making process imply that the externalities have to be internalized in order to reduce efficiency loss. In other words, one possible way to provide a socially optimal spending level of environmental protection is have the positive externalities internalized by an upper-tier government, or internalized by an independent agency like Tennessee Valley Authority in the United States which is operated by a federally owned corporation. In China, such agency would be like Tai Lake Management Agency, or Yangtze River Water Resources Committee.

This study is a first attempt to introduce spatial econometric techniques to explore empirically the Chinese local government's expenditure behavior in environmental protection. Though the findings and implications originated from this empirical study are shown to be important, The aforementioned two issues merit additional research in the future, when data are available, to explore the true spatial effects across local governments' spending on environmental protection before informing appropriate public policy.