China's fiscal decentralization and environmental quality: theory and an empirical study

Yu Hao[1,2,3,4,5,♠], Yu-Fu Chen[6,♠], Hua Liao [1,2,3,4,5] and Yi-Ming Wei [1,2,3,4,5]

[1] Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing, China
[2] School of Management and Economics, Beijing Institute of Technology, Beijing, China
[3] Collaborative Innovation Center of Electric Vehicles in Beijing, Beijing, China
[4] Sustainable Development Research Institute for Economy and Society of Beijing, Beijing, China
[5] Beijing Key Lab of Energy Economics and Environmental Management, Beijing, China
[6] Economic Studies, School of Business, University of Dundee, Dundee, United Kingdom

♠These authors contributed equally to this study and share first authorship.

Authors' emails. Yu Hao: haoyuking@gmail.com, haoyuking@bit.edu.cn ; Yu-Fu Chen: y.f.chen@dundee.ac.uk ; Hua Liao: liaohua55@163.com ; Yi-Ming Wei: wei@bit.edu.cn

ONLINE APPENDIX

Appendix A: Background information: China's fiscal decentralization

In general, the reform of fiscal decentralization so far could be divided into two stages. In the first stage, since the early 1980s, some experiments of fiscal decentralization were carried out. In 1985, the fiscal responsibility system (FRS) was formally implemented, under which the central government depended on the local governments to collect the total revenues and to provide resources to the central government. However, the FRS failed to effectively stimulate the local governments to raise the shared revenues. In this regard, in the second stage which started in 1994, the FRS was replaced by the Tax Sharing System (TSS), which explicitly defined and distinguished the central, shared, and local taxes between the central government and the provinces. Under the TSS, the ratio of central government fiscal revenues to total fiscal revenues rose significantly and remained relatively stable around 50 per cent. Accordingly, state taxation administrations and local taxation administrations were established to implement the system. The Chinese central government also makes transfer payments to localities to narrow regional differences.

It is noteworthy that there has been some important development regarding fiscal decentralization in the past few years. In the communique released after the third plenary session of the 18th CPC central committee, deepening the reform of the fiscal and tax system is stressed as an important measure. Concretely, the distribution of fiscal revenues between the central and local governments should be more equitable, and the budget system and tax structure should be further improved and revamped. Furthermore, as of 2018, to reduce tax cost and improve tax efficiency, the state administration of taxation and local administration of taxation merged at and below the provincial level. These latest reforms will have significant influences on China's economic growth and sustainable development, which could be an important research topic in the future.[1]

The original purpose of fiscal decentralization was to offer provincial governments more freedom and incentive to enlarge the country's financial resources by promoting economic growth and increasing enterprises' profits locally. Because the fiscal revenue sharing rules were quite different during the two stages of fiscal decentralization, the economic effects of fiscal decentralization varied remarkably in the two periods. More details about the fiscal decentralization in the two stages can be found in Lin and Liu (2000), Tsui and Wang (2004), and Sun *et al*. (2017).

Appendix B: Derivation of steady state consumption, capital and pollutant emissions

We start to investigate representative agent's utility function (6) including per capita consumption and pollutants. Therefore, the current-value Hamiltonian for the optimal control problem is

$$H = \ln(c_t) - \psi \frac{p_t^{1+\gamma} - 1}{1+\gamma} + \lambda_t^k\big((1-\tau)Ak_t - c_t\big) + \lambda_t^p(-\delta p_t + \delta_1 Ak_t - \beta_c(1-\phi)\,\tau Ak_t - \beta_l \phi\tau Ak_t), \quad (A1)$$

where λ_t^k is the dynamic multiplier for constraint for capital and λ_t^p for pollutants. The first order condition with respect to optimal consumption over time is

$$\frac{1}{c_t} = \lambda_t^k, \quad (A2)$$

and we have

$$\frac{1}{c_t}\frac{dc_t}{dt} = -\frac{1}{\lambda_t^k}\frac{d\lambda_t^k}{dt}. \quad (A3)$$

---

[1] As a reference, please see https://www.bna.com/insight-new-era-n73014481911/.

For shadow prices we have the following relationships for capital and pollutants via envelope theorems:

$$\frac{d\lambda_t^k}{dt} = -\lambda_t^k(1-\tau)A - \lambda_t^p(\delta_1 A_t - \beta_c(1-\phi)\,\tau A - \beta_l\phi\tau A) + \rho\lambda_t^k, \tag{A4}$$

$$\frac{d\lambda_t^p}{dt} = \psi p_t^\gamma + (\rho+\delta)\lambda_t^p. \tag{A5}$$

From equation (A4), we observe that higher pollutants lead to higher value of λ_t^k and hence a lower level of consumption.

Combined with equation (A3), we have

$$\frac{1}{c_t}\frac{dc_t}{dt} = (1-\tau)A + \frac{\lambda_t^p}{\lambda_t^k}(\delta_1 A - \beta_c(1-\phi)\alpha\,\tau A - \beta_l\phi\tau A) - \rho. \tag{A6}$$

We need to solve for the steady state and obtain the values for λ^p, λ^k, k, p at steady state as the analytical forms of solutions for such dynamic system are hard to obtain. Note that the shadow price of pollutants, λ_t^p, are supposed to be negative as pollutants are a bad, not a good.

In steady state, we have $\frac{d\lambda^p}{dt} = 0$ and

$$\lambda^p = -\frac{\psi p_t^\gamma}{\rho+\delta} < 0. \tag{A7}$$

For λ^p at steady state of equation (A4), we have

$$-\lambda^k (1-\tau)A - \lambda^p (\delta_1 A - \beta_c(1-\phi)\,\tau A - \beta_l \phi\tau A) + \rho\lambda^k = 0. \tag{A8}$$

For the steady state value of pollutants, we have $\frac{dp}{dt} = 0$ for equation (5) in the main text and we have

$$\delta p = (\delta_1 - \beta_c(1-\phi)\,\tau - \beta_l\phi\tau)Ak. \tag{A9}$$

Similarly, we have the following equation for steady-state consumption $\frac{dk}{dt} = 0$ for equation (4) in the main text,

$$(1-\tau)Ak - c = (1-\tau)Ak - \frac{1}{\lambda^k} = 0. \tag{A10}$$

There are four unknown variables λ^p, λ^k, k, p in four equations (A7)-(A10). Substituting equations (A7), (A9), (A10) and (A2) into (A8) gives the steady-state value for k,

$$k = \frac{1}{A(\delta_1 - \beta_c(1-\phi)\,\tau - \beta_l\phi\tau)}\left(\frac{\delta^\gamma(\rho+\delta)\left(1-\frac{\rho}{A(1-\tau)}\right)}{\psi}\right)^{\frac{1}{\gamma+1}}. \tag{A11}$$

With equation (A11), we have the following steady state values for c and p respectively:

$$c = \frac{(1-\tau)}{(\delta_1 - \beta_c(1-\phi)\,\tau - \beta_l\phi\tau)}\left(\frac{\delta^\gamma(\rho+\delta)\left(1-\frac{\rho}{A(1-\tau)}\right)}{\psi}\right)^{\frac{1}{\gamma+1}}, \tag{A12}$$

$$p = \frac{(1-\tau)}{\delta}\left(\frac{\delta^\gamma(\rho+\delta)\left(1-\frac{\rho}{A(1-\tau)}\right)}{\psi}\right)^{\frac{1}{\gamma+1}}. \tag{A13}$$

Equations (A11)-(A13) are equations (7)-(9) in the main text.

Appendix C: The characteristics of the key variables at the steady state

The following conciliations could be drawn from the steady-state values of consumption, capital and pollutants that are determined by equations (7)-(9).

- The higher the tax rate τ on pollutant reduction, the lower the equilibrium pollutants p, if the ratio of ρ/A is not big and substantially smaller than 1; the more consumers hate pollutants with larger values of ψ or γ, the lower the level for p.
- The impact of the environmental tax τ cones in two forms: higher tax on output reduces consumption directly via the tax, but higher tax also raises consumption via the factor of $1/(\delta_1 - \beta_c(1-\phi)\,\tau - \beta_l\phi\tau)$ as consumers are happier with higher utility via lower level of emissions and levels of pollutants. As $\beta_l > \beta_c$, it is obvious that consumption is higher when all tax money goes into local government expenditures with ϕ near 1 or more taxes should be allocated to provincial the government.
- There would be minimum of equilibrium pollutants according to equation (9) and possible minimum of consumption with some choice of environmental tax τ. Equations (8) and (9) give the relationship of $\frac{c}{p} = \frac{\delta}{(\delta_1-\beta_c(1-\phi)\,\tau-\beta_l\phi\tau)}$, which gives the steady-state ratio of consumption to pollutants with the value of tax rate and the degree of fiscal decentralization. This implies that the government needs to choose the amounts (c, p) with different values of tax rate and ϕ. A
- In an economy with $\beta = \beta_c = \beta_l$ and $\beta < \delta_1$, the steady-state consumption is higher with null tax rates.
- With the above properties, one can draw the conclusion that the effect of reduction by the provincial government depends on $\beta_l\phi\tau$ and the relationship between per capita pollutant emissions and fiscal decentralization is shaped like an inverted-U.

- The nature of technology in production with pollutants as by-products also plays a role in the economy, namely via δ_1. Better clean technology with smaller δ_1 will reduce the need to spend more money in reducing pollutants and hence raise consumption.
- Higher depreciation rate δ of pollutants leads to lower equilibrium pollutants and higher consumption, as consumers care less about pollutants that would naturally dissipate in environment; and consumers would have higher consumption.

Appendix D: The proof of proposition 1

Equation (9) directly shows that expenditure spent by governments reduces pollutants. The relationship of consumption-pollutant ratio $\frac{c}{p} = \frac{\delta}{(\delta_1 - \beta_c(1-\phi)\,\tau - \beta_l \phi \tau)}$ shows that for given consumption, fiscal decentralization reduces the relative pollution level, which then implies an inverted-U relationship between pollutant and fiscal decentralization.

Appendix E: Some additional explanations of the three propositions

It is noteworthy that taxation for pollution emissions, consumers' dislike of pollution, and the incentive of the representative provincial government to improve environmental quality collectively help to curb pollution. When the level of fiscal decentralization is relatively low, the rapid increase in pollutant emissions caused by economic growth dominates the dynamics of emissions, therefore the pollution level rises along with fiscal decentralization. However, after the fiscal decentralization reaches a certain level and the average income is considerably high (also note that fiscal decentralization promotes per capita GDP at the steady state as proposition 2 suggests), the higher public demand for better environment and more environmental investment arranged by local government would jointly cause pollutant emissions to decrease as the level of fiscal decentralization continues growing.

For proposition 2, the greater efficiency of the representative provincial government in reducing pollution means that for a given steady-state level of pollutant emissions, lower taxation on reducing pollution is needed with greater fiscal decentralization that may lead to a higher steady-state consumption level.

Essentially proposition 3 describes the process through which normal good c and inferior good (pollutant emissions) p reach their steady-state levels on the basis of the representative consumer's utility maximization. If pollutant emissions are excluded from the utility function, the pollutant level would be much higher following some model setups that reflect some specific situations of economic development and pollution emissions. Under certain circumstances, per capita emissions may even continue to grow, which would potentially lead to environmental disasters. In this regard, one can refer to the "Green Solow Model (GSM)" developed by Brock and Taylor (2010) to see the possible situations (some combinations of key parameters) under which pollution level would consistently increase over time.

Appendix F: Research framework

To present the research idea of this study intuitively, the two components of total effect of fiscal decentralization on environment – the direct and indirect impacts – are shown in figure A1 below. Essentially, the total impact of fiscal decentralization on environmental quality can be distinguished into direct and indirect effects. The reason for the existence of direct effects is that fiscal decentralization enables sub-national governments to have some degree of freedom in distributing fiscal resources, and it has been proved that government expenditure amount and structure can affect the environment (e.g., Halkos and Paizanos, 2013; Zhang *et al*., 2017). The amount of the direct effect is therefore, $\frac{\partial p}{\partial(fisdec)}$, which is obtained from the estimation results of equation (11). The indirect effect exists because fiscal decentralization may have influences on economic growth (e.g., Jin *et al*., 2005; Jin and Zou, 2005; Chu and Zheng, 2013) and there is a potential EKC relationship between environmental quality and economic development (e.g., Auffhammer and Carson, 2008; Du *et al*., 2012). In this regard, the level of indirect effect is generated through the impacts of these two influences (i.e., $\frac{\partial p}{\partial y} \cdot \frac{\partial y}{\partial(fisdec)}$) of which the first item $\frac{\partial p}{\partial y}$ is obtained from equation (11) while the second term ($\frac{\partial y}{\partial(fisdec)}$) is gauged from equation (10).

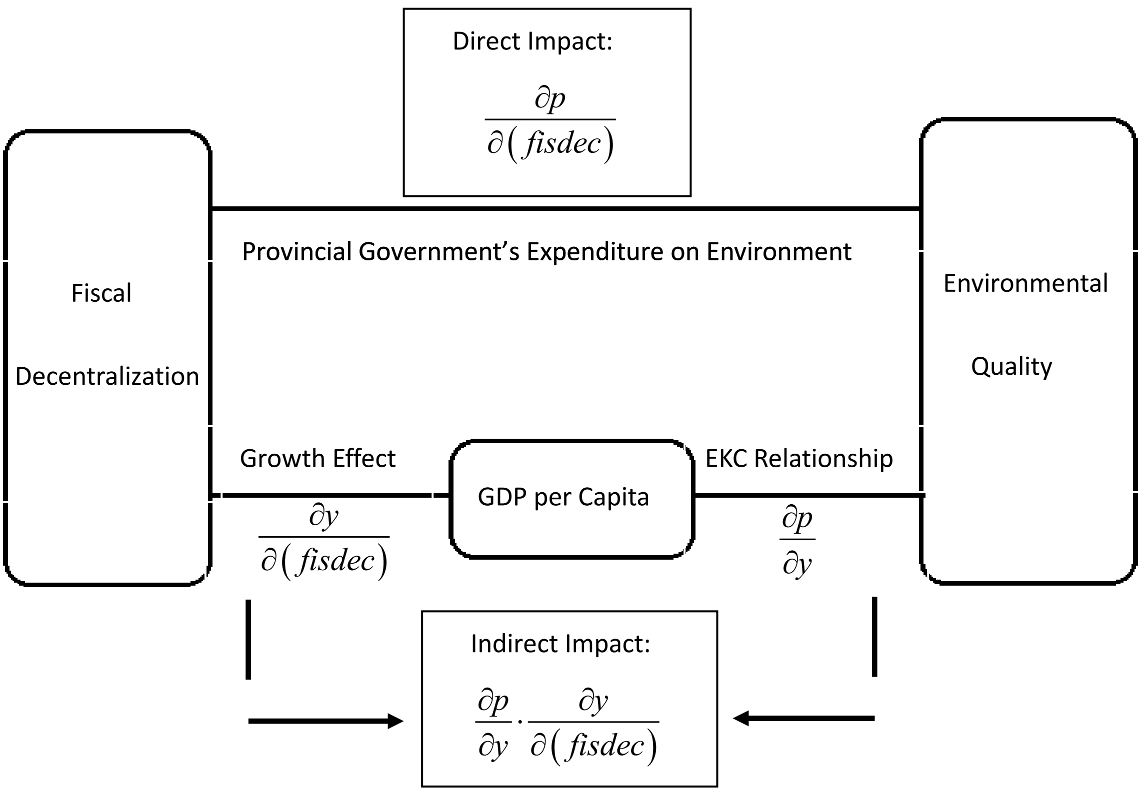

Figure A1. Sketch of research framework.

Appendix *G*: The impact of fiscal decentralization on SO_2

Following a similar procedure, the impact of fiscal decentralization on SO_2 is also calculated, and the result is shown in figure A2.

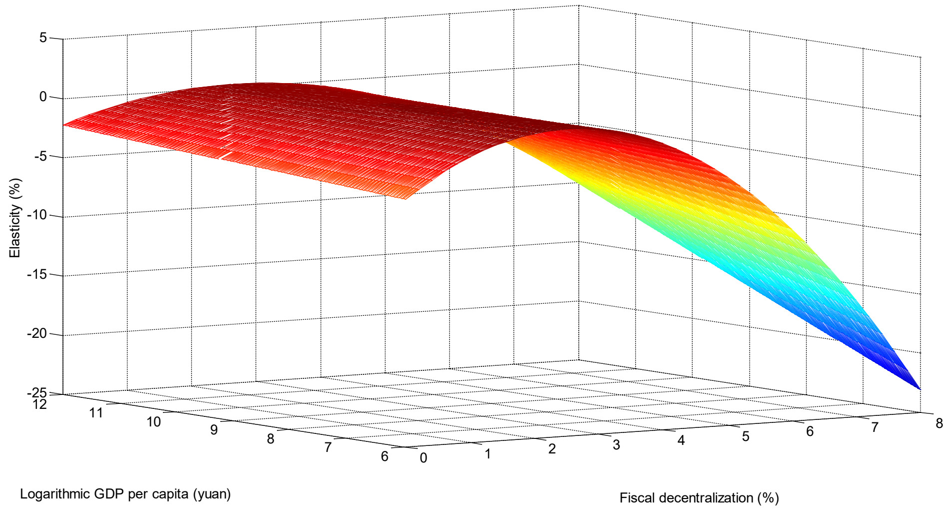

Figure A2. The impact of fiscal decentralization on SO_2 emissions per capita.

Notes: For SO_2, the direct impact of fiscal decentralization is -3.198+2.992fisdec-0.588fisdec^2, while the indirect impact of fiscal decentralization is (-1.844+2.070fisdec-0.429fisdec^2) • (1.506-0.170lny). fisdec and lny represent the level of fiscal decentralization and logarithmic per capita GDP.

Generally speaking, the shape of figure A2 is quite similar to that of figure 1. As for SO_2, the total effect of the increase in fiscal decentralization on per capita SO_2 emissions is first to increase and subsequently to decrease. The inverted-U shaped direct effect dominates the indirect effect, and the influence of GPD per capita on the total effect is trivial.

Again, the relationship between fiscal decentralization and SO_2 emissions shown in figure 2 is partly determined by some important characteristics of SO_2. For SO_2, China's economy has already entered the second stage of development because SO_2 has long been considered a harmful pollutant. However, given the tremendous differences in economic development across various regions, China as a whole is likely to remain in the transition period and the steady state of the balanced growth path has not yet been reached. As a result, similar to the situation for CO_2, the total effect of fiscal decentralization on SO_2 would be at first increasing and then decreasing as the turning point is reached.

As a result, the estimation results indicate that for both pollutants of CO_2 and SO_2, the indirect effects of fiscal decentralization are nonlinear, and the nexus of environmental quality and fiscal decentralization is in essence "inverted-U" shaped as shown in figures 1 and 2. These results also have important implications for energy and environmental policies in China. As discussed previously, the direct effects function through the influences of fiscal decentralization on industrial development. As China is still in the process of industrialization, higher fiscal decentralization would at first promote more energy- and pollution-intensive industries that could rapidly boost local GDP such as steel industry, nonferrous metal industry and chemical industry. Such industrial policy would trigger huge energy consumption and lead to considerable pollution, therefore environmental quality deteriorates as the level of fiscal decentralization rises. As local government has greater fiscal decentralization and the process of industrialization deepens, more fiscal resources may be used to support the tertiary industry that is relatively more environmentally friendly (Zhou *et al*., 2018). At this stage, the environmental pollution would decrease along with fiscal decentralization. In this regard, to limit the unfavorable direct effects of fiscal decentralization for the provinces and regions where the fiscal decentralization rate is relatively low, stricter energy and environmental regulations should be conducted to avoid the excessive development of energy- and pollution-intensive industries. Another interesting finding is that the level of fiscal decentralization that maximizes the GDP per capita is different from the level corresponding to which the pollutant emissions are highest. Specifically, according to the first-difference GMM results shown in table 2, when the level of fiscal decentralization is 3.6 the GDP per capita reaches its maximum. Comparatively, as intuitively shown in figures 1 and 2, the levels of fiscal decentralization corresponding to the highest pollutant emissions are approximately 2.2 for CO_2 and 2.5 for SO_2. As a result, the fiscal policymakers should keep a balance between economic growth and environmental protection when choosing an appropriate level of fiscal decentralization.

Appendix H: Robustness analysis

Because several different measures of fiscal decentralization have been used by researchers, it is necessary to determine whether the estimation results vary when other measures of fiscal decentralization are utilized. Therefore, the empirical study was also conducted using fiscal decentralization on the basis of fiscal revenue data, and the estimation results are roughly similar to the estimation results shown in tables 2-4.[2] Notably, Propositions 1-3 of the theoretical model are also supported by the alternative fiscal decentralization, and the total effects of fiscal decentralization on pollutant emissions for CO_2 and SO_2 are similar to those

[2] The alternative fiscal decentralization is defined as the ratio of per capita provincial fiscal revenue to the per capita national fiscal revenue (the sum of all provincial and central governments' fiscal revenues). This alternative fiscal decentralization based on fiscal revenue is highly correlated with the benchmark fiscal decentralization indicator on expenditure (the coefficient of correlation of the two fiscal decentralization indicators is 0.91). Due to space limitations, the estimation results using the alternative measures of fiscal decentralization are not given here but are available upon request.

shown in figures 1 and 2.

To determine whether any of the explanatory variables other than income have an effect on pollutant emissions when income increases, the interactive terms between per capita GDP and each of the other explanatory variables (e.g., lny*fisdec, lny*tradeopen, lny*popden, and lny*secondind) are also added in equation (11). The estimation results indicate that all of the interactive terms are insignificant, suggesting that there is probably no obvious interaction effects between income and other explanatory variables. Because none of the interactive terms are significant, these results are not reported in tables 3 and 4.

Moreover, to test the reasonability of using the ratio of per capita provincial fiscal expenditure to per capita national fiscal expenditure (fisdec) as the measurement of fiscal decentralization level, a falsification test is conducted by replacing the fisdec with ‘GDP ratio indicator’, which is constructed by the ratio of per capita provincial GDP to per capita national GDP. The estimation results indicate that the coefficients of ‘GDP ratio indicator’, its square and cube by first-difference GMM and orthogonal-difference GMM turn out to be basically insignificant. Additionally, when ‘GDP ratio indicator’ rather than fiscal decentralization level is utilized, many other control variables become insignificant, especially for CO_2 emissions. Therefore, the falsification test results also to some extent verify the reasonability and validity of using fisdec to measure the level of fiscal decentralization in China.[3]

[3] We are very grateful to an anonymous reviewer who suggested doing such a falsification test. Due to space limitations, the estimation results of the falsification test are not reported here but are available upon request.

References

Auffhammer M and Carson RT (2008) Forecasting the path of China's CO_2 emissions using province-level information. *Journal of Environmental Economics and Management* **55**(3), 229–247.

Brock WA and Taylor MS (2010) The green Solow model. *Journal of Economic Growth* **15**(2), 127–153.

Chu J and Zheng XP (2013) Chinas fiscal decentralization and regional economic growth. *Japanese Economic Review* **64**(4), 537–549.

Du L, Wei C and Cai S (2012) Economic development and carbon dioxide emissions in China: provincial panel data analysis. *China Economic Review* **23**(2), 371–384.

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

Jin H, Qian Y and Weingast BR (2005) Regional decentralization and fiscal incentives: federalism, Chinese style. *Journal of Public Economics* **89**, 1719–1742.

Jin J and Zou HF (2005) Fiscal decentralization, revenue and expenditure assignments, and growth in China. *Journal of Asian Economics* **16**(6), 1047–1064.

Lin JY and Liu Z (2000) Fiscal decentralization and economic growth in China. *Economic Development and Cultural Change* **49**(1), 1–21.

Sun Z, Chang CP and Hao Y (2017) Fiscal decentralization and China's provincial economic growth: a panel data analysis for China's tax sharing system. *Quality & Quantity* **51**(5), 2267–2289.

Tsui K and Wang Y (2004) Between separate stoves and a single menu: fiscal decentralization in China. *The China Quarterly* **177**, 71-90.

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

Zhou C, Wang S and Feng K (2018) Examining the socioeconomic determinants of CO_2 emissions in China: a historical and prospective analysis. *Resources, Conservation and Recycling* **130**, 1–11.