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What is Role of Different Type of Pollution in TFP Growth? – Empirical Research in China

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This paper using the provincial data 1996-2012 examines the effect of pollution on the economic growth. The result based on the fixed effect and 2SLS model indicate that, no mater what kind of pollutants, there exist nonlinear relationship between pollution and TFP. However, this type relationship is not consistent in different regions once we estimate the model in east, central and west region separately. More specifically, the CO_2 pollution has larger negative influence on the TFP in the more developed east regions. But the industrial effluents have larger negative effect in west regions.

1. Introduction

Natural environment and natural resources unambiguously constitute an important factor of the growth process. However, the limited resources and the limited ability of absorbing the waste are also become the block of economic growth. There are so many researches about the relationship of environment and economic growth emphasized environment could generate a positive long-run growth rate.

Some other researchers focused on the deterioration in the quality of the environment due to the increasing pollution, such as the air pollution and the greenhouse etc., pollution may affect growth throw two channels (Anderson, 1987) there are also huge literatures about the Environmental Kuznets Curve (EKC), is driven by the opportunity cost of the emissions damages to the environment which may be low at early stages of industrialization but will become higher when per capita income rises beyond a certain threshold level. At first, the catch up effect of environment means the less developed economics depend on the nature resources to catch up the developed countries by sacrificing the environment. If the emission damages becomes increasingly less tolerated, the pollution will restrict the economic growth. About the EKC there are numerous empirical relationships between the real per capita income and the pollution per unit of output (Azomahou et al.,2008) what is interesting is that the threshold level of EKC is different among developed and developing countries. In the developed countries this level would be aroused EKC (Selden, 1994, Grossman and Krueger, 1995, Stern and Common, 2001).

Some papers also conclude that the relationship of the environment and economic growth is not robust for a number of the pollutants (List et al., 2003). In order to check the different type of pollutants, this paper focus on air pollution and water pollution. The difference between them is that the air pollution is much more global, but the sewage is the local pollution. in other words, the CO_2 represent the high intensity of dispersion, but the sewage pollution denote the stable and less diffusion pollution.

In our papers we examine the effect of pollutions measured by the CO_2 and industrial sewage. Meanwhile, this paper construct a total factor productivity (TFP) index of the GDP, capital and labor. We then examine the relationship between the TFP growth and pollutions.

A recent study (Tzouvelekas et al., 2006) also tries to estimate the contribution of pollution to the growth of real per capita output. Chimeli and Braden (2005) try to derive a link between TFP and the environmental Kuznets curve. This paper will pay attention to the comparison of different type of pollutants and different regions.

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The organization of this paper as follow will divide into 4 parts. In the next we specify the theoretical model and the description of data. Then we proceed to discuss the empirical result and in the last section we provide some objective suggestion and remarks. Equations, figures, tables, and measurements.

2. Theoretical model

This paper will adopt the TPF index as the depend variable We construct a TFP growth index by subtracting from the output growth the weighted growth of physical capital and labor inputs, using the observed income shares of physical capital and labor as weights. The TFP index based on the observable data allows for the contribution of each input to differ across provinces and time and to be dictated by the data. We then examine the relationship between TFP growth and pollution

$$Y_{t} = F(X_{t}, E_{t}, t) \tag{1}$$

$$\overline{Y}_{it} = \overline{A}_{it} + \varepsilon_{L}\overline{L}_{it} + \varepsilon_{K}\overline{K}_{it} + \varepsilon_{E}\overline{E}_{it} \tag{2}$$

Y_t is the total output, X is the vector of the inputs like physical investment K, and labor force input L, E is the level of pollutions stock and t is a technology index measured by time trend, ε_L is the labor share of the productivity in the added-value sector. ε_K Physical capital share, which is equal to (1-ε_L).
The methodology to calculate TFP is Tornqvist index of TFP growth for country i in year t as follows:

$$\overline{TFP}_{it} = \overline{Y}_{it} - w_{Lit}\overline{L}_{it} - w_{Kit}\overline{K}_{it} \tag{3}$$

Rewriting the estimation function as following:

$$\overline{TFP}_{it} = W_{it}^{T}\beta + \theta(V_{it})\overline{E}_{it} + \mu_{it} \tag{4}$$

$V_{it} = \{E_{it}, \Omega_{it}\}$, where Ω_{it} can be any other variables included in the coefficient function.
Then, we will use the function (5) to estimate the effect of the different types of pollutants. Besides this basic model, this paper will add the non-linear environmental variables to estimate the threshold effect which may be consistent to the EKC. In order to exclude the effect of other variables on the TFP, this paper also add the industrial structure, urbanization rate, human capital and openness of the market as the control variables. Then, taking the Kuznets effect into account, we also put the quadratic item of the pollution variables into the estimation model. The estimation model could be re-written as following:

$$\ln TFP = \alpha_0 + \alpha_1 E + \alpha_2 E^2 + \alpha_3 \ln urbanization + \alpha_4 \ln openness + \alpha_5 \ln Humancapital + \varepsilon \tag{5}$$

In the function (6), E denotes the environmental variable. Of course, there may exist the endogenous problem. Such as, the development of TFP will also have effect on the environmental pollutant emission. We will further address this endogenity problem by using instrument variables in the next part.

3. Description of the data

All of the data are collected from China statistic yearbook, China labor statistic yearbook and China energy yearbook from 1996-2012 it is a panel date coved 30 provinces (combining Chongqing and Sichuan)
TFP: using the total provincial GDP deduct the labor share and the physical capital share in the added-value sector. And we adapt the provincial labor compensation to calculate it.
E: This paper adapts the CO_2 per GDP and the industrial effluent per GDP as the indictor of the environmental variable respectively.
Urbanization: According to many references, we measure it by the percentage of the non-agriculture population.
Openness: The import and export share of total output is the indictor of degree of the openness.
Human capital: Actually there are many indictors could measure the Human capital, what this paper used is the attainment rate of the high school.
As the Table 1 shown, the average emission of CO_2 is 4.8% per GDP and the industrial effluent is about 15%. Theses statistics described the pollution intensity in China. It seems industrial effluent is much serious than the CO_2 pollution, despite it is difficult to determine which source of pollutant has great serous destroy intensity.
Table 2 illustrate the correlation coefficient relationship of these variables.

Table 1: Description of main variables

Variable	Obs	Mean	Std. Dev	Min	Max
LTFP	493	0.797	0.352	0.191	1.98
Non-A(%)	493	0.324	0.123	0.135	0.658
CO_2/GDP(%*%)	493	0.487	0.35	0	2.50
S/GDP(%*%)	493	1.5	1.09	0.047	5.89
CO_2/L(%)	493	0.006	0.012	0	0.105
S/L(%)	493	0.014	0.018	0.001	0.119
HC(%)	493	8.35	6.68	0.8	53.59

Note: NO-A representing the percentage of non-agriculture population measures the urbanization intensity. CO_2/GDP, S/GDP represent the CO_2 emission of per GDP and industrial sewage per GDP respectively; CO_2/L, S/L represent the CO_2 emission per worker and industrial sewage per worker respectively. HC is the human capital measured by percentage of high level education workers.

Table 2: Correlation and coefficients matrix

Variables	LTFP	NO-A	CO_2/GDP	S/GDP	CO_2/L	S/L	HC
LTFP	1						
Non-A	0.692***	1					
CO_2/GDP	-0.459***	-0.181***	1				
S/GDP	-0.594***	-0.408***	0.29***	1			
CO_2/L	0.118**	0.353***	0.353***	-0.148*	1		
S/L	0.029	0.348***	0.259***	0.135**	0.776***	1	
HC	0.699***	0.673***	-0.231***	-0.498*	0.297***	0.2***	1

In the first column, relationship between TFP and the CO_2 per GDP, industrial effluent per GDP are both significant negative. Besides that, the relationship Between TFP and human capital, urbanization et al are significant positive. The empirical result explain that, increasing pollutant, will decrees the productivity. Oppositely, increasing investment of human capital and improving the step of urbanization will facilitate the growth of productivity. However, this paper also calculates the correlation coefficient between the TFP and the pollutant using the CO_2/population and sewage /population, the result in Table 2 shows that there exists significant positive effect between them. These correlation coefficients are not suitable to our expectation. In order to investigate the difference, we will use different pollution indictor to run the regression.

4. Empirical result

The estimation results in Table 3 demonstrate that there is the nonlinear relationship between the CO_2 and TFP. Fixed effects model relax the assumption of equality of constant terms, while random effects model further assume that individual effects might be randomly generated. The use of different panel data techniques is important to extract as much information as possible from the data. It is also an important way to test the robustness of the estimation results. Hausman statistic of 9.71 and 27 in the model 1 and 3 indicate that the fixed-effect model (model 1 and 3) are preferred. Therefore, this paper will make use of fixed effect model (FE) to estimate the coefficient of independent variables and control variables. These coefficients in model 1 and model 3 consistently explained that the total factor productivity is increasing as the increase of emission of CO_2 firstly, and then the increasing of CO_2 will frustrate in growth of TFP. Taking the heterostatisicity and serial correlation, this paper made wald test and wooldridge test (wld test) and adopt the FGLS estimation methodology to get much more precise result. In the column (2) and column (4), we can also conclude that, increasing CO_2 would have nonlinear effect on the growth of TFP. The coefficients of the two estimation models are similar. What is more, the human capital and urbanization and the openness degree are all have significant positive effect on the TFP growth as the estimation result represent.

Firstly, In order to provide the robust result of the relationship between environmental pollution and the TFP, this paper also focuses on the industrial effluent. The regression result in Table 4 shows the impact of industrial sewage on the TFP. Considering the heteroscedasticity and autocorrelation problems, we also use the FGLS methodology to estimate the coefficients. The result in Table 4 of the FGLS model 2 and 4 are robust. There is the inverse U shape between the industrial effluent and TFP, and the coefficients of effluents and CO_2 are similar.

Table 3: Basic result based on the CO_2 emission

Independent Variables	LTFP----dependant variable			
	Model 1 (FE)	Model 2 (FGLS)	Model 3 (FE)	Model 4 (FGLS)
CO_2/GDP	-1.449*** (-13.92)	-0.375*** (-4.59)	-0.308*** (-3.43)	-0.349*** (-5.18)
(CO_2/GDP)^2	0.408***(8.86)	0.113**(3.03)	0.066** (1.82)	0.11*** (3.45)
Ln(Non-A)			0.348*** (6.44)	0.249*** (6.41)
Ln(HC)			0.030*** (16.46)	0.015*** (8.51)
Ln(Sec-industry)			0.184*** (2.72)	0.262*** (3.93)
Ln(IE)			-0.0013(-0.08)	0.036*** (4.81)
AR(1)				
$\bar{R}^2$	0.375	0.274	0.695	0.323
Hausman Test	9.71**	46.12***	27.***	
Wald test	144***	26.75***	2768**	
Wld test	209.5***		111.4***	
Obs	493	493	493	493

Note: (1) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$(2) Wald test and Wald test are used to test heteroscedasticity and autocorrelation problems, FGLS in model 2 and model 4 are used to solve these problems. (3) IE explained the openness of this country.

Table 4: Basic result based on the discharge of industrial sewage

Independent Variables	LTFP----dependant variable			
	Model 1 (RE)	Model 2 (FGLS)	Model 3 (FE)	Model 4 (FGLS)
Sewage/GDP	-0.341*** (-19.38)	-0.29*** (-11.65)	-0.180*** (-7.96)	-0.195*** (-7.84)
Sewage/GDP)^2	0.406*** (10.25)	0.035*** (7.8)	0.02** (4.98)	0.024*** (5.58)
Ln (Non-A)			0.202** (3.78)	0.192*** (4.95)
Ln (HC)			0.022*** (10.78)	0.012*** (6.65)
Ln (Sec-industry)			0.009 (0.15)	0.150*** (2.61)
Ln (IE)			0.028* (1.74)	0.037*** (4.77)
$\bar{R}^2$	0.6554	0.182	0.735	0.384
Hausman	1.02		15.19**	
wald	---	193***	1215***	409***
Wld test	191.9***		137.2***	
Obs	493	493	493	493

Note (1) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$(2) Wald test and Wld test are used to test heteroscedasticity and autocorrelation problems, FGLS in model 2 and model 4 are used to solve these problems.

That is to say, the CO_2 and the effluent both have the similar effect on the TFP growth. The similarity not only reflects on the U shape pattern, but also on the magnitude of the coefficients of the pollutant variables. In a word, no matter the pollutant is global or local, the influence of the pollutants on the TFP is robust.

Next, we proceed to investigate the robustness of our findings. We first check for possible endogeneity of the pollution variable. We instrument it by past values of input quantities. There is possible causality issue between environmental pollution and TFP growth. The growth of TFP relies on the natural resources initially which will lead to the serious pollution. And as the developed of economic, the serious environmental deterioration will block the economic healthy growth. The causality direction can run in both ways, which may leads to the endogeneity problem. Following previous studies (Demurger,2001), A two stage-state least squares(2SLS) procedure will be applied to solve the endogeneity issue. We instrument the transport-related variables with their own one-year lagged values and other exogenous variables in the function (7). As shown in the Table 5, LM-statistic of each estimation model is significant at 1% level, indicating that the instrument variable is acceptable.

The subsequent interpretation and the further analysis will based on the fixed effect model and 2SLS regression result, reporting in Table 5. The estimate result of model 1 and 2 of Table 5 shows that, whether we control other variables or not, the impact of CO_2 pollutant on the TFP growth is inverse U shape .increasing emission of CO_2 will has different influence direction on the TFP growth. Initially, the CO_2 emission will facilitate growth of economic. And then it will have negative effect. Based on the description in Table 2, the mean value of CO_2 per GDP is 0.487, we can find that, at the mean value of current CO_2 emission, the coefficient is -0.599. That is to say, increasing 1 unit of CO_2 emission will decrease the growth of TFP 5.99%. Adapting the some method to get the coefficient of industrial effluent of model 4, it is approximate -0.24

illustrating that 1 unit addition discharge of industrial sewage will reduce the TFP about 0.24%, holding other variables constant.

Table 5: 2SLS estimation results

Independent Variables	LTFP----dependant variable			
	Model1 FE (2SLS)	Model 2 FE (2SLS)	Model 3 FE (2SLS)	Model 4 FE (2SLS)
CO_2/GDP	-1.835*** (-9.64)	-0.379** (-2.08)		
(CO_2/GDP)^2	0.572*** (7.7)	0.091 (1.24)		
Sewage/GDP			-0.358*** (-15.76)	-0.191*** (-6.01)
Sewage/GDP)^2			0.0445*** (8.19)	0.02*** (3.45)
Ln (Non-A)		0.365*** (5.03)		0.206*** (3.33)
Ln (HC)		0.0277*** (10.63)		0.019*** (9.47)
Ln (Sec-industry)		0.2077** (2.44)		0.007 (0.09)
Ln (IE)		-0.003 (-0.14)		-0.035** (-2.05)
$\bar{R}^2$	0.3314	0.683	0.63	0.721
LM	23.34***	19.75***	23.13***	95***
Obs	462	462	462	462

Note (1) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (2) The instrument variables are lag1 and lag 2 CO_2/GDP and its quadratic item.

Table 6: Effect of discharge of CO2 in different regions (2SLS)

Independent Variables	(East regions) lnTFP	(Center regions) lnTFP	(West regions) lnTFP
CO_2/GDP	-1.739*	-0.108	0.0983
	(-2.46)	(-0.57)	(0.15)
(CO_2/GDP)^2	1.836**	0.0225	-0.277
	(2.67)	(0.31)	(-1.06)
Ln (Non-A)	0.431***	0.277***	0.389
	(5.41)	(3.39)	(1.59)
Ln (HC)	0.0241***	0.0176***	0.0136*
	(5.87)	(4.13)	(1.97)
Ln(Sec-industry)	-0.0621	0.472***	1.016***
	(-0.47)	(5.71)	(5.34)
Ln (IE)	0.0544*	-0.0688*	0.0250
	(2.35)	(-2.43)	(0.53)
N	176	160	128
R^2	0.761	0.673	0.741

Note: (1) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The result in Table 5 of different pollutants illuminate that the pollution have negative effect on the TFP growth currently. That is to say, the emission of CO_2 and discharge of industrial effluent are both over the turn point, which has positive effect on the growth of economic.

At last, this paper tests the impact of pollution across regions in Table 6 and Table 7. One of the important characteristics of the China economy is unequal across regions, such as, the developed eastern region, the developing central region, and the lagging western region. To identify the impact of infrastructure on regional economic growth, we classify all provinces into three regions based on their geographic location. These are Eastern China (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan), Central China (Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan), and Western China (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu,Qinghai, Ningxia, and Xinjiang). The result in Table 7 shows that the emission of CO_2 has significant negative effect on the east region, and it also follows the inverse U Shape. However, these influence patterns are not significant in all other regions. The possible explanation is that source of CO_2 mainly coming from the vehicle exhaust concentrate on the developed east region. And in the central region, there is also negative effect of CO_2 emission on the TFP despite it is not statistically significant. Once we take industrial effluent into account, as the Table 8 shown, it is a different story, the nonlinear relationship is significant in the west region comparing with the other two regions. The reason may be that despite the developed regions may generate much more industrial effluents, simultaneously, the regulation is stricter and purification treatment system is much more advanced. The negative effect is diluted comparing with this in the west regions. In another word, there exist significant inverse U shape effect pattern of industrial effluents in the west region, and the effect size is also much larger. Those demonstrates that the industrial effluent has much more serious negative effect on TFP growth in west regions.

Table 7: Effect of the discharge of industrial sewage in different regions

Independent Variables	(East regions) lnTFP	(Central regions) lnTFP	(West region) lnTFP
Sewage/GDP	-0.141**	-0.062	-0.387***
	(-3.137)	(-1.609)	(-7.684)
(Sewage/GDP)^2	0.004	0.001	0.051***
	(0.389)	(0.183)	(5.764)
Ln(Non-A)	0.326***	0.131	-0.048
	(4.648)	(1.576)	(-0.476)
Ln(HC)	0.019***	0.015***	0.001
	(7.93)	(4.118)	(0.172)
Ln(Sec-industry)	-0.411**	0.377***	0.721***
	(-3.26)	(4.093)	(4.026)
Ln(IE)	0.006	-0.092**	-0.101***
	(0.314)	(-3.140)	(-3.570)
N	176	160	128
R^2	0.787	0.693	0.828

Note: (1) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5. Conclusion

This paper investigates the impact of pollution on the TFP growth. We find that generally, CO_2 and industrial effluent both have significant nonlinear effect on the TFP growth. At the same time, these two type pollutants have negative effect on the TFP growth under current emission of them. However, the difference pollutants present different effect in different regions. In the much more developed regions of china, the CO_2 has much more significant negative contribution of TFP growth, on the contrary, the industrial sewage seems has much more negatively impact on the lagging west regions.

The results above suggest that government policies on the pollutions should be different among regions and different pollutant types. In spite these two types of pollutants both restrict the TFP growth, the intensity of different regions and different pollutant are not the same. The urgent problem in the much more developed regions is how to efficiently control and govern the car exhaust. However, in the west regions, the prior issue is how to take measure to improve the purification system to abate the effluent pollution.

Reference

Anderson C.L., 1987, The production process: Inputs and wastes, Journal of Environmental Economics & Management, 14, 1-12. https://doi.org/10.1016/0095-0696(87)90001-5

Azomahou T., Laisney F., Van P.N., 2008, Economic development and CO_2 emissions: a nonparametric panel approach, Journal of Public Economics ,90, 1347-1363. https://doi.org/10.1016/j.jpubeco.2005.09.005

Chimeli A.B., Braden J.B., 2005, Total factor productivity and the environmental Kuznets curve, Journal of Environmental Economics & Management,49, 366-380. https://doi.org/10.1016/j.jeem.2004.06.003

Demurger S.,2001, Infrastructure development and economic growth: an explanation for regional disparities in China? Journal of comparative economy, 29, 95–117. https://doi.org/10.1006/jcec.2000.1693

Grossman G.M., Krueger A.B., 1995, Economic growth and the environment, Quarterly Journal of Economics, 110, 353-377. DIO:10.2307/2118443

List J.A., Millimet, D.L., Stengos T., 2003, The environmental Kuznets curve: Real progress or misspecified models? The Review of Economics and Statistics, 85, 1038-1047. https://www.jstor.org/stable/3211824

Selden T.M., Song D., 1994, Environmental quality and development: Is there a Kuznets curve for air pollution emission? Journal of Environmental Economics & Management, 27, 147-162. https://doi.org/10.1006/jeem.1994.1031

Stern D.I, Common M.S., 2001, Is there an Environmental Kuznets curve for sulfur? Journal of Environmental Economics & Management, 41, 162-178. https://doi.org/10.1006/jeem.2000.1132

Tzouvelekas E., Vouvaki D, Xepapadeas A., 2006,Total factor productivity and the environment: a case for green growth accounting, Mimeo, University of Crete. https://dx.doi.org/10.2139/ssrn.981133