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Is International Trade an Influence Factor to the Pearl River Delta's Water EKC

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Abstract. Usually, international trade is thought as an influential factor to environment, but its effects on interrelationship of environment and economic growth is ignored. In order to investigate how international trade changes this relationship, the paper presents a model of endogenous Environment Kuznets Curve (EKC) model in which international trade is supposed to influence pollution through exportation and importation structure change. Income, environment and energy are grouped as endogenous variables. Simultaneous equations defining the dynamic interrelationship among these endogenous variables are estimated by feasible general least square estimation method (FGLS) and two stages least square estimation method (2SLS) with data from the Pearl River Delta region, China. The result shows that export and import structure has intense influence on the EKC turning point, environmental elasticity, maximum pollution value and curve slope. Structural export increase or import decrease is favorable to environment-economic dynamic relationship and shift EKC to better position.

Introduction

Environment Kuznets Curve describes the interrelationship of the economic growth and environment. Introduced by Panayotou (1993)[1], EKC hypothesis usually shows that pollution increases firstly and decreases afterwards, depicted as an inverted U-shaped curve. The hypothesis was also supported by Grossman and Krueger (1993) [2] in their study on the economic growth effects on environment in NAFTA. Some expectation results and real economic growth are congruous. In the early stage, demand for industrial production is far more important than for environment, leading to serious lack of attention to environmental regulation and protection. So, pollution grows rapidly in early stages, which can be observed in most industrializing countries. In the wake of economic growth and environmental deterioration, countries begin to pay more attention to ecosystem and health. Consumers direct their demand to more eco-friendly products and services and producers invest more in energy saving and emission control. Environment will improve gradually with economic growth.

There are four explanations to dynamics of the interrelationship between environment and economic growth, which were summarized by de Bruyn and Heintz (1998) [3] to consumer preference, distribution, technology and policy. All of these factors can provide channels through which international trade has essential influence. As to the first explanation, consumer preference, a typical producer always faces the dilemma that the scale expansion will bring not only increased return of environmental friendly technology, but also increased marginal cost of pollution (Lopez 1994; Lopez and Mitra 2000) [4, 5]. The dilemma is majorly brought by consumer preference. When a typical consumer is going to make purchase decision, he also needs to weigh the experience as well as the cost (McConnell 1997; Andreoni and Levinson 2001; Lieb 2004) [6-8]. That is one of the most important reasons to why EKC will come to some turning point and the point will shift with preference change. Since the economic development usually upgrades the consumer preference to higher level, both the demanders and the suppliers are willing to spend more on environment.

The second reason for EKC dynamics is the inter-period option in life cycle, i.e. distribution mention above. John and Pecchenino (1994) [9] regarded that a typical consumer prefers to consume more environment in early stage of industrialization and pay more for the pollution control and improvement in later stage, just as saving for deferred consumption. Selden and Song (1995) [10] reconsidered the question by introducing a time contiguous model and came to the conclusion that the capital distribution between economic growth and environment protection is an important reason to EKC turning point. When an economy plans to invest more in environment in the current period at the price of unconstrained consumption in order to decrease the huge cost for the future pollution control and ecosystem recovery, the turning point of EKC changes consequently.

The third reason explaining EKC dynamics is technology. Stocky (1998) [11] introduced a sectional contiguous function to illustrate the interrelationship between pollution and capital stock. He found that in early stage the pollution increases linearly with accumulation of capital. When arriving at the threshold level, the linear relationship will change non-linearly. Specifically, marginal pollution decreases with capital accumulation and environment will improve even though capital stock level is high enough. He also regarded that technology is a key factor influencing this process. When research and development is directed to environment friendly technology, the linear period, threshold and nonlinear stage all change, which means EKC change. Hartman (1995) [12] regarded that it is important to differentiate between material capital and human capital in their contributions to environment. Endogenous human capital accumulation changes structure of capital stock to a more advantageous form to environment, i.e. environment friendly capital constitution. Human capital is so called Zero-Pollution capital and technology investment in human capital is definitely favorable to environment. Therefore, EKC turning point change is the result of technology investment and progress change, e.g. more financial support to human resource in some area and some industry will promote environmental performance. This shifts EKC turning point to an earlier stage in economic growth. Ground on this point of view, Tahvonen and Salo (2001) [13] attributed the severe pollution in some developing countries to their immoderate investment in heavy energy exhausted industries and extensive growth mode.

The fourth reason to EKC dynamics is change of policy. Regime and policy plays an important role in interrelationship between environment and economic growth. Jones and Manuelli (2001) [14] introduced an overlapping-generation model. The result proved that if a typical behavior agent has the right and wisdom to select the appropriate environment tax rate, utility maximization rule in both current and the next generation will result in an optimal environment tax rate. Pollution deteriorates constantly before reaching some turning point and after that converges to a constant level. However, this conclusion didn't take the emerging policy change into consideration, e.g. emergency plan and an about face in consequent policy.

In the next section, a new endogenous model will be introduced to describe the process featured with above EKC dynamics.

Model, Variables and Data

Considering the complex interrelationship between environment and economic growth, we construct an endogenous model, see Figure S1. Economic growth relies on environment and energy input and has two channels through which to influence the environment. On one side, industry emissions aggravate the pollution, which is mainly scale effect. On the other side, economic development improve environment by structural change, technology progress, trade liberalization, foreign direct investment and environmental regulation. Energy production supports economic growth and influence the environment through emissions. However, it is also influenced by economic growth. After variables significance tests by Akaike information criterion and Bayesian information criterion for possible equations, we set simultaneous equation groups to

$$P=Y^2\times a_{11}+ Y\times a_{12}+XY\times a_{13}+ IY\times a_{14} \tag{1}$$

$E = Y\times a_{21} + K\times a_{22}$ (2)
$Y = P\times a_{31} + E\times a_{32} + K\times a_{33} + H\times a_{34}$ (3)

The first equation describes the relationship between pollution and income. Squared income is introduced to involve U or inverted U shape of EKC. However, there is no similar set for the export and import. We suppose that effects of both export and import is linear to pollution so that all structural effects are included by economic growth. The second equation is energy use. For simplicity, the energy demand is only related to production and capital stock. Total factor productivity is included in Y and influential to energy. The third equation is production function. We suppose that production needs four factors: environment, energy, capital and human resources. Human resources accumulation rate is constant and three other factors are determined endogenously. Detailed variables selection is explained as follow:

1 Income

Y is GDP per capita. Averaged indicator has higher relevance with individual preference and energy intensity. Square Y are introduced to simulate possible U shaped EKC. Cubic Y is dropped because there is no need to discuss the second turning point. Data are collected from the Pearl River Delta Statistic Yearbook 2004 till 2014, we use GDP per capita to describe average income in terms of comparable prices based on year 2000 so as to remove price fluctuation.

2 Environment quality

P is water quality grade with preference to biochemical oxygen demand (BOD). We segment water quality to 6 basic grades, according to national environmental quality standards for surface water GB3838-2002. However, between each neighbored grades from grade I to worse than grade V, water quality is sub segmented by BOD. We collect the water quality year report 2004 till 2014 from Geographic Information System in Guangdong Environmental Protection Department Data Center and BOD data are collected from water quality monitoring station. The final grade is from 1 to 20, smaller is better.

3 Import and export

We include two trade indicators. One is import ratio and the other, export ratio. In order to highlight the influence by trade structure, we use product of ratio and GDP. XY is the product of export ratio and GDP per capita and IY is the product of import ratio and GDP per capita. The ratio X is defined as the product of technology intensive export and environment friendly export proportion of total export, in which environment friendly sector is selected by average treated waste water discharge per unit output from 2004 to 2013. The ratio I is defined similarly, referring to import. Therefore, IY and XY includes technology progress and environment reservation in the international trade.

4 Other variables

We consider the following variables in equations. The first one is capital stock per capita K. It is calculated on the base of capital stock per capita in 2000. It needs two steps. First, the capital stock per capita of each city in the region in 2000 is calculated as base. However, it cannot be retrieved from database, so we estimate each city's aggregate investment from year 1990 to 2000, which is reckoned up by accumulating each city investment flow. Capital stock of each city in 2000 is estimated proportionally by their aggregate investments, taking capital stock of Guangdong province as total amount. Second, we adjust the data up to date by perpetual inventory method. So we can get capital stock in each city from 2003-2013. The second one is human resource H. We use educated years per capita to indicate human resource and this variable is the ratio of sum of educated years in all residents in population.

Estimation Results

The estimation includes four parts: the stationary test, model set, simultaneous equations coefficients estimation and robust test.

1 Stationarity Test

In order to investigate the stationarity, we apply Levin-Lin-Chu unit-root test on each variable and give the results in Table 1. All of original variables cannot reject unit-root hypothesis at 5%

critical level. After 1st order difference, various are stationary at the same critical level except Y^2, K and H. 2nd order difference result does not show substantial improvement. For this reason, we choose 1st order difference model for further estimation. Then, we apply error-correction-based panel cointegration tests by Westerlund (2007). The result shows that original model cannot pass the test, but after 1st order difference, variables in all three equations are cointegrated at 10% critical level. Ga of each equation is 0.0334, 0.0800 and 0.0812 respectively.

Table 1 Stationarity of the Panel

	P	**Y2**	**Y**	**IY**	**XY**	**E**	**K**	**H**
t	-3.0835	2.9740	-0.6516	-0.2434	0.4063	-1.5767	5.3381	24.6327
t*	3.1135	4.9919	-0.0318	1.4019	1.4734	-0.0829	7.4388	27.6236
p	0.9991	1.0000	0.4873	0.9195	0.9297	0.4670	1.0000	1.0000
D1,t	-7.4040	-2.2712	-6.6362	-23.1677	-11.7804	-7.6981	-3.2056	10.4703
D1,t*	-2.4012	-0.1727	-4.9887	-20.7789	-7.1719	-4.3897	-1.2941	28.5688
D1,p	0.0082	0.4314	0.0000	0.0000	0.0000	0.0000	0.0978	1.0000
D2,t	-14.1898	-12.2261	-10.7677	-13.0170	-12.8126	-7.1027	-5.6408	7.5983
D2,t*	-8.9039	-9.8959	-8.2930	-4.7947	-5.9064	-3.1487	0.3223	52.7834
D2,p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.6264	1.0000

Note: Panel means is included and time trend not included. T is unadjusted and t* is adjusted. ADF regressions are made for 1 lag. LR variance are estimated by Bartlett kernel at 6.00 lags average.

2 Estimation and results

There are two effects in panel data analysis. One is individual effect and the other is time effect. Considering only 10 years of sample collected, we only include individual effects in the paper. Estimation is made in three stages. Firstly, we carry out F Test and Breusch LM Test to determine the availability of panel estimation or mixed regression only. And then Hausman Test is applied to decide whether individual fixed-effect model or random-effect model should be adopted. Thirdly, we shift our focus to residual. In the panel equation estimation, heteroscedasticiy auto-correlation can be often observed. So we will check inter-class heteroscedasticiy, inter-class correlation and intra-class correlation by adopting Wald Test, Frees Test and Wooldrigde method subsequently. The results are listed in Table 2.

Table 2 Model Set

Test		Pollution Eq	Energy Eq	Output Eq
Model Set	F	11.10***	93.59***	53.99***
	Breusch LM	124.74***	477.38***	364.47***
	Hausman	15.65*	0.54	8.08
	Panel/Mixed-reg.	Panel	Panel	Panel
	Fixed/Random	Fixed-effect	Random-effect	Random-effect
Residual Heteroscedasticity and Auto-correlation	Modified Wald	1356.22***	2450.34***	12201.88***
	Frees	2.222***	4.081***	3.955***
	Wooldrigde F	1.382	23.439***	31.554***
	Heteroscedasticity	Yes	Yes	Yes
	Inter-class	Yes	Yes	Yes
	intra-class	No	Yes	Yes
Inter-equation Correlation	Pollution Eq.	1.0000	--	--
	Energy Eq.	0.1455	1.0000	--
	Output Eq.	-0.3916	-0.3939	1.0000
	Conclusion	Residual LSDV is not significant. No inter-equation correlation		

Note: ***, ** and * denote 1%, 5% and 10% significance respectively.

Firstly, it can be seen from Table 2 that all equations can pass F and LM test significantly, so panel data estimation is better than mixed regression. Hausman test shows that only the pollution equation can adopt the individual fixed-effect model set at 10% significance, while other equations should be set as individual random-effect. Secondly, adjusted Wald test suggests that inter-class heteroscedasticiy does exist in all equations significantly and subsequent Frees test indicates that all equations have inter-class cross correlation. However, Wooldrigde test suggests that only pollution equation cannot reject the null hypothesis that there is no 1st stage inter-class auto-correlation. This equation is thereafter considered as inter-class independent and other two are highly inter-class auto-correlated. Thirdly, we regress the residuals of all three equations by least square dummy variable method (LSDV). The coefficient matrix suggests a weak correlation across equations. Adjusted R^2 is only 0.0295 and F test is not significant even at 10% critical level. Therefore, we conclude that pollution equation has heteroscedasticiy and inter-class auto-correlation, but no intra-class auto-correlation, and can be estimated perfectly by individual fixed-effect panel model estimation method. Both energy and output equation have heteroscedasticiy, inter-class and intra-class auto-correlation and individual random-effect panel estimation method is better than fixed-effect.

Furthermore, a new estimation method is applied to the simultaneous equations by combining two stage least square estimation method (2SLS) and feasible general least square estimation method (FGLS). 2SLS is adopted to estimate each single equation so as to avoid bias and inconsistency of estimators. FGLS is used after 2SLS so as to avoid heteroscedasticity and auto-correlation. We also give the non-FGLS results for comparison. For the convenience of subsequent comparison and control, we readjust some measuring unit in equations. The results are listed in Table 3.

Table 3 Simultaneous Equations Estimation

	Y²	**XY**	**IY**	**K**	**Con**	**Wald χ^2**
P	-0.1390	-1.6267	1.8164	--	1.0451	138.40
FGLS+2SLS	-9.20***	-5.03***	8.00***			***
P	-0.1295	-1.4835	1.5974	--	1.1685	86.43***
Non-FGLS	-6.17***	-1.45	2.54**			
E	--	--	--	3.4546	0.3570	67.54***
FGLS+2SLS				14.51***		
E	--	--	--	2.5580	0.6433	63.10***
Non-FGLS				7.61***		
	P	**E**				
Y	0.3344	0.3114	--	0.3233	1.2245	104.33***
FGLS+2SLS	6.77***	3.16***		13.18***		
Y	0.1517	0.7923	--	0.1409	1.0010	89.01***
Non-FGLS	2.07**	5.55***		2.80***		

As to FGLS +2SLS, data below coefficients are Z statistics and to Non-FGLS, t statistics. Wald χ^2 shows the joint significance. ***, ** and * denotes 1%, 5% and 10% critical level. Con of each equation under is 1.0451, 0.3570 and 1.2245

Also, we add two control variables to pollution equation to check estimation robustness. One is regulation and the other is foreign direct investment. The estimation result is listed in Table 4.

Table 4 Robust Estimation

Equation	**P**					
	Y	Y2	XY	IY	Regulation	FDI
Eq. 1	2.6820	-0.1390	-1.6267	1.8164	--	--
	14.51***	-9.20***	-5.03***	8.00***		
Eq. 2	2.8411	-0.1150	-1.7267	1.9883	-5.5562	--
	7.34***	-6.55***	-9.15***	7.12***	-6.48***	
Eq. 3	2.0345	-0.2269	-1.1415	1.4637	--	2.8003
	13.44***	-6.66***	-10.34***	12.49***		-9.11***
Eq. 4	2.2263	-0.1990	-1.6547	1.3030	-7.1342	2.6569
	7.75***	-10.70***	-10.00***	8.45***	-6.57***	1.01

All estimations are made by FGLS +2SLS, and data below coefficients are Z statistics. ***denotes critical level.

From the results in Table 4, we find that all the variables are significant from Eq. 1 to Eq. 4, except the FDI in Eq. 4. First, regression result of Eq. 1 shows the same coefficients in Table 3, which means that all income, squared income, export and import have effects on environment. The coefficient of export is negative, which means the export is advantageous to environment improvement. Opposite to that, the imports shows disadvantageous effects on environment. Compared with Eq. 2 to Eq. 4, we find that this result is robust even when environment regulation and foreign direct investment is considered. Most of literatures regarded that export of China, featured with labor and environment intensive use and low technology level, increased the pollution of this country. However, we find the other side of the coin. The export sector of China is more competitive than those which only produce for domestic consumption and investment. The advantage of competition is derived from the traditional manufacture skills and experiences, but not the low cost brought by uncontained pollution. On the other side, the import mainly involved with machines and equipment, which are deployed in the scaled industry to increase the productivity. This is the bane of the pollution increase.

We also find that the FDI is not significant when considering environment regulation. There is no direct relationship between the effects of regulation and FDI. However, this can be explained by the strength of regulations. The powerful crowding out effects of regulation will dwarf many effects by other factors, e.g. when the impacts of FDI are relatively weak and unstable, the environment regulation will drive away all the effects by FDI.

Discussion

We will focus on dynamic interrelationship between growth and water pollution in the Pearl River Delta water EKC.

1 Dynamic interrelationship between growth and water pollution

First, estimation results show that the interrelationship of economic growth and water pollution is inverted-U-shaped EKC and will possibly reach an undesirable pollution level even though consider Y^2 only, which can reflect situations of most cities in the Pearl River Delta. We find that water pollution will increase with economic growth before it reaches the possible highest point, which is 37, measured by our water quality index. Obviously, this value is well above ceiling set, which means that water quality will deteriorate much more than we see currently. The turning point of EKC that makes the pollution arrive at the peak is 161814 CNY per capita, 26099 USD at foreign exchange rate of 6.2, is also well above the level by most research done. However, this point can be only reached on the premise that a region has no export of technology intensive and environmental goods but the import of such goods account for the full GDP. That is almost impossible in reality. However, when developing region exports too many pollution intensive goods in early stage of growth, they will experience a long time severe environmental deterioration.

Second, we find that relatively closed economy or less opening economy may be beneficial to environment and different opening modes also influence the environmental performance in investigated region. In order to compare, we suppose that a country have no trade, e.g. a closed economy, thus the max value of water pollution is only 14, when income arrive at 99886 CNY or 16111 USD per capita. This conclusion suggests that a closed economy will reach EKC turning point earlier than an unconstrained opening economy. It is true in many countries' early stage development. When they boom export, they also suffer from tremendous industrial transfer, which is mostly pollution intensive and with less technology. In order to enhance export department competitive strength, the government tends to loose environmental control for reducing cost. Therefore, a relatively closed economy can usually protect environment better than an opening economy and less expose to the risk of Race to Bottom and Pollution Heaven. Data show that water pollution index in a closed economy in our model is less than 2/5 of full opening economy possibly, supposing that the latter only export pollution intensive product and this output is the whole GDP. We test the model result by estimate the same equation group again, using data of other regions in Guangdong province out of Pearl River Delta. The result shows that there is less pollution as well as influence of international trade. The averaged water quality in those region is only 69% of the Pearl River Delta at 5% critical level.

However, if opening mode is an inverse one, i.e. no pollution intensive import and such kind of export scale equals to GDP, the region may reach the best result. According to this model estimation, the EKC turning point in such kind of region is 3, measured by water quality index, and the corresponding income per capita is 37959 CNY or 6122 USD. This turning point is about 10 thousand USD less than the worst situation, 16111 USD. It is also an explanation to why countries are empirically experiencing quite different turning point. For comparison, we estimate the model using data from neighbor province Fujian. This region has lower ratio of import and higher export than the Pearl River Delta. And the estimated turning point average is very close to the predicted value, which is 78% of the Pearl River Delta level.

Third, the result suggests that the economic growth of the Pearl River Delta hasn't pass the turning point. Turning point we estimated ranges from 6122 to 16111. It is only slightly different from the research work of Selden and Song (1994) in which they think sulfur dioxide, carbon monoxide and suspended particles concentration will reach its highpoint from 7114 to 13383 US dollars according to panel analysis on developed countries data. Quite different from most of domestic literatures, we don't think real pollution turning point in the Pearl River Delta as well as China is close to the floor of the income level range, even considering their late-development advantage in environmental protection. So, it is suspicious when some region in developing countries show their improvement of environment and declared that they had crossed the mountain top and come to the pollution decline channel. We regard that situations are not so optimistic to them. When export demand for the Pearl River Delta slows down and structurally changed and the government implies more stringent environmental regulations on producers, environment will improve slightly temporarily. The long run trend is still in deterioration before reaching turning point. According to the model, as to Pearl River Delta, GDP per capita changed from 20280 CNY in 2000 to 73961 CNY in 2013 in comparable prices of year 2000. Water quality deteriorated from 8 to 13 along with economic growth. Supposing that import and export ratio and structure remains, water environment will keep deteriorating until GDP arrives at 97040 CNY or 15651 USD. The worst water quality is 14. So the Pearl River Delta is still on the left of the turning point, but not too far. If we take consideration that the Pearl River Delta will possibly dwindle their labor intensive industries because of essential loss of export competition power, the result may be complex and unpredictable.

Conclusions

We find that the trade structure and scale has significant influences over EKC, including turning point, elasticity, maximum value and shape. When technology intensive and environmental export ratio increase or import ratio decrease, the turning point of the Pearl River Delta will shift to the left, the lower income level. The maximum pollution also declines. Quite different from the effects of preference, effect from international trade makes the left part of EKC plainer rather than steeper for the region. It suggests that such kind of trade mode protects this region from rapid and severe pollution deterioration. Furthermore, adjustment to trade structure as a balanced development choice is recommended to policy maker and the way of scale firstly and structure secondly is not optimal. The shortest path to the pollution peak is the simultaneous trade adjustment on scale and structure. The pollution absolute elasticity to export and import both increase with the trade ratio rise. Highly export dependent city of such kind benefits more environmental improvement from trade and highly import dependent city suffers loss in ecosystem. As to the Pearl River Delta region, when not crossed the mountaintop of pollution in EKC, proper trade policy guide can reduce environmental loss.

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