Foreign trade and pollution: the case of South China water quality

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Abstract. With rapid economic growth, South China has to face the most serious water pollution. However, whether or not such kind of water pollution is mainly caused by foreign trade is questionable. And, how the trade mode will be changed by pollution and corresponding regulation is also uncertain. In this paper, a fully endogenous model, which integrate economic growth, energy use and pollution, is designed to interpret the interrelation among these key variables in South China. Through this model, a new possibility of water environment Kuznets curve change has been investigated. Attribute to mixed two stage feasible general least square estimation method, we conclude that foreign trade has strong influence on environment change rate and the turning point. It can make the virtuous circle of between economic growth and environment improvement come early or later in different circumstances. Export and import play different role in such process and have counter effects on environment.

1. Introduction

Since 1978, the reform and opening policy has brought a tremendous economic growth of the South China Area. Known as “World Factory”, this area has experienced international trade booming of about 30% growth annually. Unfortunately, the spring up of manufactures heavily polluted the air, water and soil and ecology system of this place. Environmental deterioration and resource exploitation hinder the economy from sustainable development. Nearly 40% cultivated land in the South China is heavily metal polluted and more than 10% is in fatal condition. Some people suffered ptomaine poisoning because of eating larminaria product of Guangzhou and Zhuhai City. The 18th Chinese Communist Party congress asserted that constructing eco-civilization is the long term strategy for people and pledged to enhance protection for environment and ecosystem. The central and local government are programming important trade transformation and upgrade in the South China region. However, can such trade policy direction helps the region to escape from heavy pollution? Will trade structure adjustments work in improving interrelationship between environment and economic growth of this pollution intensive export dependent region?

Environment Kuznets Curve explains relationship of the economic growth and environment. EKC hypothesis usually shows that pollution increases firstly and decreases afterwards, shaped as an
inverted U-shaped curve (Panayotou, 1993) [1]. This point is also given by Grossman and Krueger (1993) [2] in their study on economy and environment in NAFTA. In the beginning, pollution grows rapidly, which actually happened in most developed countries. As countries begin to pay more attention to ecosystem and health, Environment will improve gradually with economic growth. Selden and Song (1995) [3] introduced a time contiguous model and concluded that the capital distribution between economic growth and environment protection is important in EKC.

It is occasionally mentioned in literature that international trade, as important mobilization of factors and products, will also influence EKC dynamics. Some researchers regarded that liberalization of international trade is beneficial to environment because it promotes income so as to secure financial and technology support for environment (Egli and Steger, 2007) [4]. This is the channel of technology and preference. Cole (2004) [5] studied the interrelationship between international trade and environment. He saw liberalization of international trade as an instrument to help environmental resources global distributed optimally so as to facilitate production in the most efficient way. Suri and Chapman (1998) [6] found that liberalization of international trade is helpful to remove trade distortion produced by subsidy, custom and other trade barriers, which are proved to be deleterious to environment. Lopez (1994) [7] regarded the scale expansion will both increased return of environmental friendly technology, and increased marginal cost of pollution.

Opposite to viewpoints above, some researchers thought that liberalization of international trade is destructive to environment. The Pollution Heaven, a famous hypothesis, is supported widely by normative and positive studies. The Pollution Heaven hypothesis predicts that trade liberalization will cause production of pollution intensive goods to transfer to countries with relatively weak environmental policy of those strictly environmental regulated countries. Copeland and Taylor (1995) [8] developed a model with endogenous environmental policy. With assumptions that demand for better environment quality increases with income and that government implements environmental policy considering the preferences of residents, they predicted that South (developing countries) has a comparative advantage in producing pollution intensive good for trading. Liberalization of international trade transfers the pollution intensive industries from North (developed countries) to South.

However, some researchers considered that pollution intensive industry transfer from North to South is not inevitable. Antweiler et al (2001) [9] and Copeland and Taylor (1995) [8] introduced models for empirical test. With the assumption that pollution intensive industry is also capital intensive, North’s abundance of capital also makes them comparative advantageous to produce pollution intensive products. If the effect of stringent pollution control policy is less important than the effect of capital abundance, trade liberalization will make pollution intensive industry transfer from South to North even the former is more comparative advantageous in environment. Furthermore, Busse (2004) [10] regarded that labor cost, technology, political system, market scale and infrastructure also influence trade. Pollution intensive industry transfer mode doesn’t only depend on environment comparative advantage or factor endowment.

According to Race to Bottom hypothesis, posed by Dua and Esty (1997) [11], if South is abundant of environment, it has a comparative advantage in producing and export pollution intensive good to increase its balance of payment surplus and gross domestic product. Meanwhile, if North has abundant capital and technology, they may also have comparative advantage in similar industry (Westerlund, 2007) [12]. Therefore, South has incentive to loosen control on pollution so as to improve competitiveness. If both North and South do the same to secure their competitiveness and export, global environment will be damaged. In case that developed country doesn’t race to bottom because of its stringent legal system, vicious competition in environmental regulation will almost happen in developing countries.

Since the factor endowment and trade mode decided influences an economy in Race to Bottom and Pollution Heaven, arbitrary judgment on trade liberalization’s positive or negative effects on environment without considering economic development stage is less persuasive. Environment of an economy suffered from trade liberalization in relative low income stage may benefit from the same
trade mode in higher income stage. It is hard to say whether or not the opening policy which leads to some pollution currently is optimum when considering the future environmental benefits. Therefore, the key is the trade influence in the interrelationship of environment and economic growth rather than environment itself. Lots of literatures discussed that international trade will be beneficial or deleterious to environment, but few of them thoroughly investigated its effect on dynamics of EKC, the turning point, the deterioration or improvement speed, the elasticity and subsequent channel after crossing the pollution ceiling. Will structure and scale alteration of trade influence environment-economy dynamics? Will export of some products slow down the deterioration at a certain income level? Does pollution control have persistent effects on environment or just transitory? We will investigate the trade influence in EKC as well as answering these questions. In the next section, we introduce the model, variables and data. In section three, feasible general least square estimation method and two stages least square estimation method are adopted to estimate the simultaneous equation group. Section four is the result discussion and section five is conclusion.

2. Model, variables and data
Our models are endogenously constructed by three equations. The first one describes the relationship between the pollution $P$ and the income $Y$ and foreign trade. We set squared income $Y^2$ to capture the inverted U change of the relationship between pollution and income. Both export $X$ and import $M$ are considered. Also, we take technology progress $A$ into consideration.

$$P = b_{11}Y + b_{12}Y^2 + b_{13}X + b_{14}M + b_{15}A$$

The second equation describe the relationship between energy $E$ and income. We suppose that energy demand is decided by three factors. The first one is the income. Higher income suggests higher productions and higher energy use at given level of technology. The second one is the stock of capitals $K$, which includes two effects on energy demand. One effect is the scale effect, which regards that capital accumulation is accompanied by the enlargement of industry scale and needs more energy input. The other is the structural effects, which says capital accumulation is beneficial to energy saving due to its contribution to structure alteration from energy intensive industry to technology intensive industry. The third variable influencing the energy use is the technology. It includes the technology effects on the energy. Advancement of technology can improve the producing process and reduce the undesired energy loss.

$$E = b_{21}Y + b_{22}K + b_{23}A$$

The third equation capture the effects on income. This equations enable the model process the relationship among income, environment, energy and human resources fully endogenously. We consider all variables at per capita level. Thus the population variable can be removed from production function. Totally, we consider four factors for production, i.e. capital stock, environment, energy, technology and human resources $H$.

$$Y = b_{31}A + b_{32}K + b_{33}P + b_{34}E + b_{35}H$$

And corresponding production function could be Cobb-Douglas form like this:

$$Y = AK^\alpha E^\gamma H^\delta$$

$A$ is also the total factor productivity (TFP). And we suppose that the product has constant scale return, so we have:

$$\alpha + \beta + \gamma + \delta = 1$$

The last two equations describe the endogenous relationship between international trade and income. For simplicity, we suppose that import is affected only by income and the export is affected only by capital, so we have:

$$M = b_{41}Y$$

$$X = b_{51}K$$

All equations include constant variables and all endogenous and exogenous variables are selected by tests of Akaike information criterion (AIC) and Bayesian information criterion (BIC).

Income data are collected from the six province statistic yearbooks 2004 till 2015. They are Guangdong, Guangxi, Yunnan, Fujian, Guizhou and Hainan province. Real GDP per capita is chosen.
so as to remove price fluctuation impacts. Water quality score includes two parts, the integral part is defined by national environmental quality standards for surface water GB3838-2002, which sets water quality to six basic grades, i.e., 1-5 and 6. Grade 1 is the best quality and grade 6, which we set to 6, is the worst level. Considering the aquatic environment is closely related to biochemical oxygen demand (BOD), the decimal part of the water quality score is defined and sorted by BOD. The highest BOD of each grade of water quality in our sample is defined to grade number plus 0.9 and the lowest BOD is 0.0. Water quality data are collected from water quality year report 2004 till 2015 from Geographic Information System of Environmental Protection Department Data Centre and water quality monitoring station in six provinces.

As to import M and export X, we use their ratio to GDP per capita. Capital stock K is calculated by perpetual inventory method. The base year is 1990 and the accumulated part is calculated by investment of each year. All data are adjusted by price and the base year is also 1990. Human resource H is defined by educated years per capita and calculated by the ratio of sum of educated years in population. All of above data are collected from statistic books from 1990-2015 of each province.

3. Estimation results

3.1. Model set

Three steps are applied to set this endogenous model. Firstly, Breusch LM Test is applied to determine whether or not panel estimation should be used. Secondly, we use Hausman Test to choose between individual fixed-effect model and random-effect model. Thirdly, inter-class heteroscedasticity, inter-class correlation and intra-class correlation are tested by Wald Test and Frees Test. The results of BLM support that panel data estimation is better than mixed regression. Hausman Test supports the model to adopt individual fixed-effect estimation. Adjusted Wald test and Frees Test suggest that inter-class heteroscedasticity and cross correlation exist in all equations significantly.

3.2. Simultaneous equations estimation

We combine two stage least square estimation method (2SLS) and feasible general least square estimation method (FGLS) to 2SFGLS to estimate the coefficients. 2SLS is used to avoid bias and inconsistency of estimators. FGLS can avoid heteroscedasticity and auto-correlation. Ordinary panel regression results are also reported for comparison. The results are listed in Table 1 and Table 2.

| Table 1. Simultaneous Equations Estimation for Pollution, Energy and Foreign Trade |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|
|                                 | Y              | Y^2            | X              | M              | K              | A              | Con             | WaldX^2         |
| **P**                          | 2.3300         | -0.1050        | -1.2332        | 1.9990         | --             | -1.9422        | 1.8773          | 115.60          |
| **2SFGLS**                     | 10.38***       | -4.20***       | -4.05***       | 10.00***       | --             | -3.03***       | 1.8773          | **            |
| **P**                          | 2.8563         | -0.1295        | -1.4835        | 1.5974         | --             | -1.4490        | 2.0403          | 90.90***        |
| Ordinal                        | 11.98***       | -8.01***       | -2.45***       | 1.08           | --             | -1.30          | --              |                |
| **E**                          | 0.4376         | --             | --             | --             | 2.8778         | 2.7735         | 0.2889          | 87.72***        |
| **2SFGLS**                     | 10.22***       | --             | --             | --             | 4.89***        | 1.18           | --              | **            |
| **E**                          | 0.9990         | --             | --             | --             | 3.1556         | 2.4330         | 0.6440          | 62.88***        |
| Ordinal                        | 4.54***        | --             | --             | --             | 6.43***        | 1.05           | --              |                |
| **M**                          | 0.1173         | --             | --             | --             | --             | --             | --              |                |
| **2SFGLS**                     | 4.48***        | --             | --             | --             | --             | --             | --              |                |
| **M**                          | 0.1240         | --             | --             | --             | --             | --             | --              |                |
| Ordinal                        | 2.01**         | --             | --             | --             | --             | --             | --              |                |
| **X**                          | --             | --             | --             | --             | --             | --             | 0.0145          | --              |
| **2SFGLS**                     | --             | --             | --             | --             | --             | --             | 3.44***         | --              |
| **X**                          | --             | --             | --             | --             | --             | --             | 0.0090          | --              |
| Ordinal                        | --             | --             | --             | --             | --             | --             | 2.00**          | --              |

aAs to FGLS +2SLS, data below coefficients are Z statistics and to Non-FGLS, t statistics. WaldX^2 shows the joint significance. ***, ** and * denotes 1%, 5% and 10% critical level.
EKC more like A, i.e. 1st order derivatives is relatively larger on the left of the turning point and preference is an important explanation to the EKC. However, preference change tends to reshape the effected by international trade is different from the change by consumer preference. Consumer pollution degree will need more time before the turning point and less time after it. This EKC change point and speed up environmental improvement after it. In another word, reaching the same EKC such kind of import, it will slow down their pace on pollution deterioration before the EKC turning right. When a region strengthens technology intensive and less pollution intensive export or control decline at the identical income level. Just as illustrated above, plainer on the left and steeper on the right.

When cities in the South China tend to export more region. It can be observed that the contour line moves to the far end of the income growth with the increase in import or decrease in the export. When cities in the South China tend to export more intensive pollution goods for earning foreign exchange, or import less, the situation is worse for their industry history of the South China since opening and reform. One of the most beautiful city of

Table 2. Simultaneous Equations Estimation for Income²

|       | P   | E   | H   | K   | A   | Con | WaldX² |
|-------|-----|-----|-----|-----|-----|-----|--------|
| Y     | 0.3340 | 0.2886 | 2.0008 | 0.2098 | 0.1190 | 1.0004 | 109.34*** |
| 2SFGLS | 6.77*** | 3.87*** | 10.98*** | 10.44*** | 3.56*** |        |        |
| Y     | 0.1445 | 0.4545 | 2.2020 | 0.1299 | 0.0998 | 1.0080 | 109.93*** |
| Ordinary | 1.05 | 2.13*** | 7.66*** | 2.01** | 6.77*** |        |        |

aAs to FGLS +2SLS, data below coefficients are Z statistics and to Non-FGLS, t statistics. WaldX2 shows the joint significance. ***, ** and * denotes 1%, 5% and 10% critical level.

4. Discussion

We focus on the impact on environment by the international trade. We find that smaller export ratio X or larger import ratio X will both shift the turning point of EKC to the right, i.e. higher income level and worse water quality. And either smaller export or larger import will make the EKC slope smaller, i.e. plainer on the left of the turning point and steeper on the right.

First, we find that with the increase in export ratio or decrease in import ratio, EKC slope will decline at the identical income level. Just as illustrated above, plainer on the left and steeper on the right. When a region strengthens technology intensive and less pollution intensive export or control such kind of import, it will slow down their pace on pollution deterioration before the EKC turning point and speed up environmental improvement after it. In another word, reaching the same EKC pollution degree will need more time before the turning point and less time after it. This EKC change effected by international trade is different from the change by consumer preference. Consumer preference is an important explanation to the EKC. However, preference change tends to reshape the EKC more like A, i.e. 1st order derivatives is relatively larger on the left of the turning point and smaller on the right, because in the earlier stage of economic growth, preference alteration favours the low-end manufacturers of cost competition. With the upgrade of the economy, consumers demand more on comfort, experience and environment, thus, environment will deteriorate faster in early stage as well as improve faster in later stage and the EKC looks like more convex.

Quite different from the effects of preference, effect from international trade makes the left part of EKC plainer for this region. With the economic growth, a region may apply such strict environmental regulations to manufacture that only environmental or pollution free industry can survive in competition domestically. Pollution intensive industries need to cut down their output as well as emissions, just as many enterprises need to do in the near future in some cities of the South China, according to their thirteenth five-year development planning. At the same time, increasing cost doesn’t allow labour intensive industry to remain. Therefore, pollution intensive and less technology intensive production transports to lower growth stage region or country. With the process, scale effects are somewhat offset by structural effects and the move to the pollution peak slows down. After the turning point, technology advancement has more and more positive influences on environment and works with which, trade structural change even has more effects on pollution control.

Change of export and import not only changes the slope of EKC, but also the turning point of this region. It can be observed that the contour line moves to the far end of the income growth with the increase in import or decrease in the export. When cities in the South China tend to export more intensive pollution goods for earning foreign exchange, or import less, the situation is worse for their environment. This is just what they had done since 1978.

Second, the result supports the adjustment to trade structure as a balanced development choice and the way of scale firstly and structure secondly is not optimal. Slope of EKC only measures the change rate of environment without considering effects other than income, e.g. international trade. Tangent plain in space measures the aggregate change rate of two factors, one is scale effect by growth and the other is structure effect by trade. Path on the surface perpendicular to the contour illustrates the nearest way to the pollution peak, supposing that this pollution level is inflexible. So, we regard that the usual way adopted by developing regions, which is scale firstly and structure secondly, is a bad choice because there will be a longer period of their suffering from pollution. Unfortunately, this is just the industry history of the South China since opening and reform. One of the most beautiful city of
scenery in the South China, even in South China, Zhaoqing City, is polluted severely with their ceramic and stone material factories. Many cities in the region is going to make amendments in their next development strategies. Simultaneous progress of economy and international trade mode is better for its smaller cost, e.g. on health, species diversity, etc. Considering that some damage by pollution is irreversible after all, balanced development is more advantageous.

Third, we find the influence in the South China environment by import and export are flexible and different in marginal percentage. We give the marginal growth rate of pollution regarding export and import ratio in Figure 1. It looks like somewhat linear, but both are convex curves essentially. Positive slope curve illustrates the elasticity of water quality to import ratio and negative slope curve is for elasticity to export ratio, given that human resource level $H$ and capital stock $K$ fixed at 2004 level.

![Figure 1. Environmental Elasticity to Trade](image)

Just as we mentioned above, export ratio of technology intensive and pollution free good is beneficial to environmental improvement as shown by the negative slope line in Figure 1. With the increase in the export, pollution decreases and the marginal percentage of the decrease rise along with the export ratio growth. Although we mentioned a relative close economy will perform better in EKC turning point, this result shows that the marginal return in environment is increasing along with such beneficial export growing. On the other side, import ratio of technology intensive and pollution free good hinder environment from improving and the elasticity is also increasing with ratio raise. It suggests that influence on environment by such trade mode is increasing with higher proportion of trade to GDP, including both export and import. There are three reasons can explain this result. First, higher trade dependence often corresponds to advanced stage of economic growth and technology effects in this stage is usually stronger than early stages. Second, rise of trade ratio also brings greater structural change to industry and the favoured region has less possibility in becoming Pollution Heaven. Third, scale enlargement has decreased marginal pollution, and demand for better environment is increasing. We compare the influences among three groups, the South China, non-Pearl-River-Delta region in Guangdong province and the Changjiang River Delta. The estimation result shows that the elasticity of environment to export and import in each group is 0.029 and -0.045, 0.005 and -0.013, 0.020 and -0.037 respectively on average at 5% critical level, corresponding to their openness in such industry. So our perspective to the environmental change due to trade adjustments is more optimistic in the South China than the region of control group.

In our data, the South China has higher export ratio as well as higher import ratio than other region in the same province, so the aggregate water pollution elasticity to trade structure is not so far away as the elasticity to either export or import alone from other regions in Guangdong province. That is why a high trade dependence region can seldom find the trade scale enlargement improves environment significantly. Balanced trade in technology intensive and environmental good has less effects on pollution because the structural effect is offset and only technology effect remains.
5. Conclusions
In most discussion about EKC, international trade is only considered as a subordinate factor influencing the relationship between income and environment. The model in this paper reconsiders the mixed effect of income and trade and offers some important influences made by trade. From the estimation, we conclude that interrelationship between the South China economic growth and water pollution is inverted-U-shaped EKC. The pollution will possibly reach an undesirable level far beyond the point that the region ever experienced. Less opening economy may be beneficial to environment and opening modes also influence the environmental performance in this region. As to environmental performance, the South China suffered more from international trade than North China, which is less opening or structural different. The economic growth of the South China hasn’t passed the turning point and the temporary pollution change is not the evidence of long run water quality improvement. The most interesting implication is that balanced trade growth may not result in EKC change. If openness is neutral to environment, balanced pollution intensive trade also has no significant influence on EKC. It suggests that China needs to direct trade to environmental friendly export or pollution intensive import. Will it be a Race to Top rather than Race to Bottom when all countries do the same thing? And will it be a good choice for developing countries in trade liberalization negotiations? It should be answered with more caution after investigation.

Acknowledgements
This work is financially supported by the National Natural Science Foundation of China (71203037), the Foundation for Distinguished Young Talents in Higher Education of Guangdong (2012WYM-0049) and the Natural Science Foundation of Guangdong Province (2015A030313499).

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