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Trade and investment liberalisation and industrial per capita emissions in China: 1990 to 2007

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by

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Abstract

It was hypothesised that trade and investment liberalisation in China had a short term negative effect on the environment and a long term positive effect based on the assumption that externality can be internalised and that an environmental Kuznets curve (EKC) exists in China. To test this hypothesis, a modified version of Dean's (2002) simultaneous model using a sample as a whole, and a disaggregated sample based on above and below the turning point income of EKC was adopted. The results from the overall sample showed that for air pollutant (SO_2) and water pollutant (COD), the scale effects outweigh the technique effects, which is evidence for the pollution haven hypothesis. The split sample provided limited support for the EKC hypothesis because at the provincial level, a rising income via an increased level of international trade was associated with falling emissions due to the technique effect, so that rising income among the provinces tends to show a superior performance. The policy implication is that stricter environmental regulations are required for growing incomes because they may encourage better production techniques.

Key words: Government policy, environment and trade, air and water pollution, China

JEL codes: Q53, Q56, Q58

1. Introduction

There is a widespread belief that freer trade in countries with relatively lenient environmental standards will encourage 'dirty industries' that will pollute the environment (pollution haven hypothesis). The literature on the inverted-U hypothesis and Stolper-Samuelson theorem negate this belief in the long term but increased trade will harm the environment in the short term by encouraging the manufacture of pollution intensive goods. Increased trade raises income growth over time which motivates firms to shift to less pollution intensive production that reduces emissions significantly. The effect that trade liberalisation has on emission level is an issue of interest in which there is no clear theoretical background. Fundamentally the lower the environmental regulations the cheaper the environment is for a firm, which leads to increased specialisation in pollution intensive goods. This has been proven by the Heckscher-Ohlin (HO) trade model which states that a country with a relatively low factor price ratio (factors of production are in fixed supply) can be considered as an environmentally abundant country. If a country is well endowed with environmental resources then they export relatively environmentally intensive products. If we hold the assumption that externality can be internalised then the price paid for using the environment tends to rise up, with the result that firms would shift to less pollution intensive production techniques, as the Stolper-Samuelson theorem indicates (Antweiler et.al., 2001; Dean, 2002).

Literature on the inverted–U hypothesis argues (EKC) that income growth has three effects on the existing volume of polluting emissions. First, the greater the economic activity the greater will be the emissions as more inputs are used. This is known as the scale effect. Second, the higher the income of the people the more natural is their demand for a clean environment (normal good), and charges on effluent to ensure that this demand is met. Firms respond by shifting towards cleaner production processes, this is known as the technique effect. Finally, the share of pollution intensive goods in production falls, which is known as the composition effect. This argument forms the inverted-U hypothesis which shows that at lower income levels the effect of scale outweighs the effects of technique and composition, but as income reaches a critical level the effect of technique and composition outweighs the effects of scale. In the early stages of growth, environmental damage occurs because the policy response is weak but as incomes rise it tends to be stronger and pollution levels begin to fall (Grossman and Krueger, 1995). This policy response can result in environmental regulations and better infrastructure, both of which can be complementary objectives for reducing green house gas emissions.

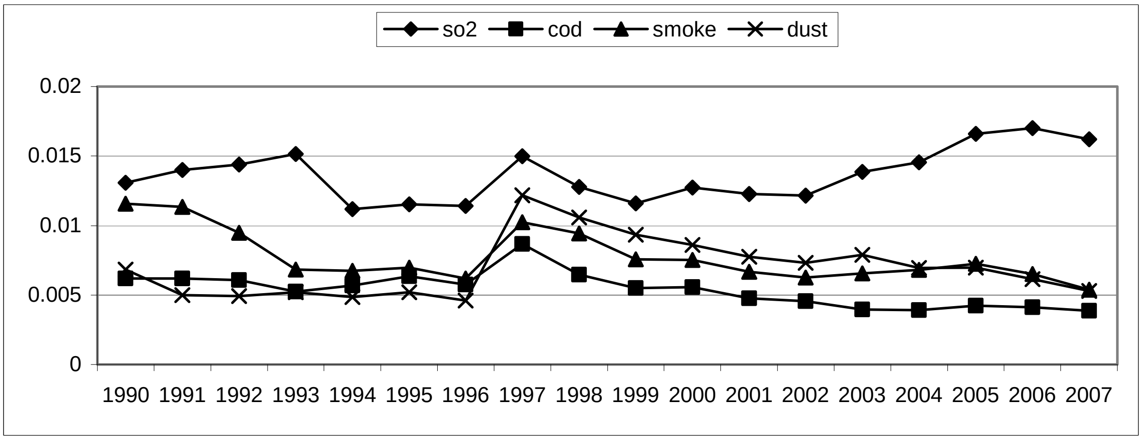
China, considered as a developing, lower average income economy, initiated reforms in 1978 and intensified trade and investment reforms in the mid-1990s. They have also introduced a number of environmental regulations since 1978 and have a current focus on emissions. The 1990s and 2000s have witnessed a rapid growth in the Chinese economy, reflected in reduced trade and investment barriers, increased trade, the rapid transmission of technology, and highly mobile capital and labour. China's transition process can be divided into two main phases. The first phase of gradualist, dual-track[1], decentralising reform (1979-1992) developed directly out of their rural successes where the focus was to protect core interests whilst moving power and resources away from central planners to local actors. By 1993 China had successfully moved from a command economy to a functioning market economy. The second reform phase (1993-present) established a firm macro-economic policy base which focussed on regulatory and administrative restructuring in key market sectors such as banking, taxation, corporate governance, as well as the external sector through membership in the WTO. Special economic zones were established along the coast to attract FDI, boost exports and import high technology products. Furthermore state-owned enterprises were allowed to operate and compete on free market principles and private enterprises were legalised and promoted. The average annual growth in GDP accelerated from 6% in the pre-1978 period to 9.8% in the post-1978 period, from 1979-2007. Population growth decelerated from 1.9% per year before 1978 to only 1.03% after 1978. As a result, per capita GDP doubled from 4.1% to 8.7% annually (Liu, 2009). The reforms raised two questions, one with regard to the success these attempted reforms and the other regarding its impact on the environment. The growing fear was that China might end up as a big polluter in the world.

Although emissions increased in absolute terms, there were reductions in industrial emissions per capita, especially after 1997. Figure 1 shows the industrial per capita emissions during 1990-2007. The per capita reduction in SO_2, COD, and smoke and dust emissions began from around 1997 but per capita emissions of SO_2 began increasing from 2004 to 2006, and reducing from 2006. By 1996 China had effectively introduced a water pollution levy system

[1] Dual-track refers to the coexistence of a traditional plan and a market channel for the allocation of a given good.

across countries and cities by imposing levies on about 300,000 firms. In the absence of meeting the legal standard of discharge, firms must pay fees (Dean, 2002). Zhang and Fu (2008) wrote that industrial water emission (COD) has reduced over time. In the 1990s, six environmental laws and regulations were revised under which cleaner production and a discharge permit system was applied. Under this system, pollution sources were required to register with the local Environment Protection Body (EPBs) and apply for a discharge permit. These EPBs then allocated the allowable pollution loads to sources, issued discharge permits, and enforced permit conditions. By 2001, 430 sets of environmental standards were in place at the central government level and 1,020 sets of laws, regulations, ordinations and rules at the local level (Managi and Kaneko, 2006). Zhang and Fu (2008) argued that although the comprehensive regulatory framework is in place, the enforcement is weak.

Figure 1: Per capita emissions in China, 1990-2007



Source: Liu (2009). Data obtained from China Statistical Yearbook (various issues), and China Environment Yearbook (various issues).

This paper combines current anti-pollution policies in China with her increased levels of trade liberalisation, and uses quantitative analysis. The objective of this research is to study the links between trade, growth, and environmental pollution in the light of economic reforms (deregulation), and associated growth and increasing environmental regulations. In view of the foregoing, it was hypothesised that trade liberalisation in China had a short term negative effect on the environment and a long term positive effect based on the assumption that externality can be internalised and that an Environmental Kuznets curve (EKC) exists in China. To test this hypothesis, we adopted a modified version of Dean's (2002) simultaneous model using the whole sample and disaggregated sample based on the above and below the turning point income of EKC. The 1990 to 2007 period for our analysis reflects the intensive changes in economic reforms and environmental policies in China. This analysis is based on provincial panel data (30 provinces and 510 observations) and focuses more on provincial industrial emissions and provincial incomes. The next section links trade, growth and emissions in China by using the available literature survey. The third section outlines the method and economic estimation. The fourth section reports the results of provincial panel regression analysis on the overall sample and split samples above and below the estimated turning point income. The last section summarises the conclusions of this study.

2. Link between trade, growth and emissions in China

In the light of the conflicting results in the theoretical literature, trade and environmental issues remain largely empirical. In this section we present the current state of empirical research in China regarding the trade-growth-emissions nexus, and our own estimation of EKC and turning point income.

Empirical survey in China

Antweiler et.al. (2001) developed a theoretical model transposes the effects of income growth on emissions into scale, composition, and technique effects. The underlying argument is that pollution might increase through the scale effect because growth is associated with the use of more resources than are utilised. However, trade can lead to a reduction in emissions through the technique effect by promoting cleaner techniques in production processes. As income increases it is likely that the demand for cleaner goods increases, which might pressure firms to shift production and reduce pollution. This is widely known as the composition effect. The estimates indicate that trade liberalisation in developing countries does shift the composition of output towards dirty goods. However, when the composition effects are included in the calculations the authors find that trade liberalisation appears to have a positive effect on the environment.

As shown in Table 1, a few studies in China adopted modified version of Antweiler et.al. (2001) model (Dean, 2002; Chai, 2002; Shen, 2008; Dean and Lovely, 2008). Dean (2002) investigated the impact of trade on water pollution in China from 1987 to 1995 using a simultaneous-equations system which incorporates the multiple effects of trade liberalisation. China introduced water pollution levies on firms as early as 1981 and Dean's examination of pollution per capita at the provincial level showed that the intensity of the discharge fell dramatically in most provinces even though the absolute amount of wastewater discharged rose at the provincial level. Most of the provinces have worked to clean up their water as trade-induced income increases and the positive impact of technique effect have occurred. Chai (2002) found that China's experience with the trade liberalisation-environment nexus was consistent with international evidence. Shen (2008) used provincial data from 1993 to 2002 and the results showed that trade leads to more emissions in SO_2 and dust, and less in COD, arsenic, and cadmium.

In a recent working paper, Dean and Lovely (2008) calculated and tracked the pollution content of China's export and import bundles from 1995 to 2005 by studying the direct emissions of four pollutants for about 30 Chinese industries. Their findings showed that the pollution intensity of almost all sectors has fallen in terms of water pollution (measured by COD) and air pollution (measured by SO_2, smoke or dust) in 2004. Their study also revealed that China's major exporting industries are not highly polluting, and that over time the export bundle is shifting toward relatively cleaner sectors. In 1995, textiles and apparel accounted for the largest share of Chinese exports to the world but they fell by about a third over the following decade. Office and computing machinery and communications equipment however, were the fastest growing exports and in 2005 accounted for the largest export share. What is striking is that these growing sectors are cleaner than textiles and apparel, indeed by the available measures of air and water pollution they are among the cleanest manufacturing sectors. The most polluting sectors, such as paper and non-metallic minerals, have a very low and declining share in China's manufacturing exports. Contrary to popular expectations, linking industrial pollution intensities to detailed trade statistics shows that China's exports are less water polluting and generally less air polluting than Chinese import competing industries. Moreover, both Chinese exports and imports are becoming cleaner over time. Part of this trend reflects changes in the composition of the trade bundle, as noted above, but the evidence suggests that most of the fall in the pollution content of China's trade is due to changes in the intensity of industrial pollution rather than trade patterns.

Table 1: Summary of estimations on the impact of trade liberalisation on environment

Author	Emissions	Effects: Scale / Technique / Composition	Net effect
Shen (2008)	SO_2 and Dust	Scale effect dominates	Negative
	COD, Arsenic and Cadmium	Technique effect dominates	Positive
Dean and Lovely (2008)	SO_2, Smoke, Dust and COD	Technique and composition effects dominates	Positive
Dean (2002)	COD	Technique effect dominates	Positive
Chai (2002)	SO_2, Dust, COD	Scale effect dominates	Negative

Table 2 show the EKC turning point income for the corresponding emissions in China. The EKC hypothesis contends that pollution increases initially as a country develops its industry and then declines after reaching a certain level of economic progress. Pollution increases at the early phase of industrialisation due to the setting up of polluting industries. The turning point for pollution is the result of more wealthy and progressive communities putting institutional and non-institutional measures into place because they increasingly value a cleaner environment. When industrialisation is sufficiently advanced, less polluting service industries will gain prominence. During economic growth the inverted U-shaped curve develops, but beyond a certain income level the relationship between environmental pollution and income reverts to being a positive generating N-shape curve. To show the environmental impact in China, a number of studies estimated EKC (Llorca and Meunie, 2009; Diao et al., 2009; He, 2008; Shen, 2006; Groot et.al., 2004). Shen (2006) found evidence for an inverted-U curve for arsenic, cadmium, and COD. Evidence of an inverted-U curve was also found for SO_2 (He, 2008) and for wastewater, waste gas, soot and dust (Diao et al., 2009) and Llorca and Meunie (2009) obtained evidence of an N-shape curve for SO_2.

Table 2: EKC turning point income in China: literature survey

Authors	Turning point in yuan and EKC form	Regions/periods	Estimation
Llorca and Meunie (2009)	SO_2 (P 4596): N	28 provinces 1985-2003	Level, Cubic, Panel, Fixed-effect
Diao et al., (2009)	Wastewater (P 20132), Waste gas (P 20762), Soot (P 12659), Dust (P 10804): inverted-U	1 city: Jiaxing 1995-2005	Level, Square, Cubic, OLS
He (2008)	SO_2 (P 10226): Inverted-U and N	29 provinces 1992-2003	Level, Square, Cubic, Panel, Fixed-effect
Chen (2007)	SO_2 (P 13442), Dust (P 7359), Soot (P 7583): N	29 provinces 1992-2005	Log, Cubic, Panel, Fixed-effect
Shen (2006)	COD (P 6547), Arsenic (P 13879), Cadmium (P7500): inverted-U	31 provinces 1993-2002	Log, Square, 2SLS
Groot et al., (2004)	Waste gas: Inverted-U Solid waste: N	30 provinces 1982-1997	Level, Cubic Panel, Fixed-effect

Note: P = Peak point, All the turning points are in 1990 price.

As inconsistency in time, country, and methodology put a barrier against any meaningful comparison between cross-country studies, we presented evidence for an individual country by focusing China. As Vincent (1997) pointed out, the cross-country version of the EKC is misleading because cross-country regressions seem to be sensitive to slight alterations in the policy variables and small changes in the sample of the countries chosen. More could be learnt by examining the experiences of individual countries at varying levels of development, income, and patterns of consumption. Diao et.al. (2009) only used one city in their analysis and found a relatively high turning point income. The majority of the other studies seemed to be consistent in their application of methodology, time, and number of provinces. Emissions were measured in absolute levels, per capita terms, and per unit of gross regional product terms, covering a range of provinces in China[2]. Most of the studies used provincial level panel data for their analysis to examine fixed effects. The provincial turning point income (peak point) in the SO_2 series varied from 4,596 (Llorca and Meunie, 2009) to 10,226 (He, 2008). The turning point parameter estimates were dependent on the sample and type of emissions used in the respective studies (Table 2).[3] The provincial turning point income was

[2] Earlier studies focused Beijing (Wu et.al., 2002) using time series data. Groot et al. (2004) initiated using a sample of 30 provinces of China from 1982 to 1997.

[3] In a literature survey on cross-country studies (both developed and developing countries together) Stern (2004) finds that sulfer emissions (SO_2) and concentrations show the estimated income turning point range from $3137 to $22,675.

relatively low which could be predictable for China because it is developing and learning from the mistakes of their forefathers from across countries and is much more likely to quickly reach the turning point income.

Estimation of turning point income in China

We have also estimated the turning point income in China using the following quadratic and cubic functions of the levels of standard models:

Quadratic: $E_{it} = \alpha_i + \mu_t + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \varepsilon_{it}$ (1)

Cubic: $E_{it} = \alpha_i + \mu_t + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 Y^3 + \varepsilon_{it}$ (2)

i = 1, 2, …, n

t = 1, 2, …, n

where i indexes provinces and t indexes time; E_{it} is one of the four pollutants measured in per capita terms for province i at time t. Y is real GDP per capita for province i at time t; β is coefficient parameter; α_i are the cross section effects; μ_t are time effects; and ε_{it} is error term assumed to be stationary. The assumption is that although the extent of emissions per capita is likely to differ across countries\provinces at any particular income level, the income elasticity remains the same in all countries\provinces at a given income level. The 'turning point' income, where emissions are at a maximum, is given by:

Quadric function: $x^* = -\beta_1 / 2\beta_2$ (3)

Cubic function: $x_1^* = (-\beta_2 - \sqrt{\beta_2^2 - 3\beta_1\beta_3}) / 3\beta_3$ (4)

To obtain support for the EKC hypothesis we adopted a similar methodology (as indicated in equations 1 and 2) using provincial level panel data comprising 30 provinces\municipalities\autonomous regions for the period 1990 to 2007[4]. Quadric and cubic functions of income per capita (in constant 1990 prices) were applied. The quadric and cubic models in income levels provide a straightforward test for how the marginal propensity to emit varies with average income. Our study incorporates industrial emission variables such as industrial sulphur dioxide (SO_2), industrial smoke, industrial dust, and industrial chemical oxygen demand (COD) and provincial level real income which were obtained from various

[4] Chongqing became a municipality directly under the jurisdiction of central government in 1996. In order to keep consistency, the relevant data for Chongqing are added to those for province of Sichuan.

issues of the China Environmental Yearbook**.** Provincial income and consumer price index, and population, were obtained from the China Statistical Yearbook. The Hausman test compares the fixed versus random effects under the null hypothesis that the individual effects are uncorrelated and if correlated (null hypothesis is rejected), a random effect model produces biased estimators so a fixed effect model is preferred.[5]

Table 2 shows the estimation results of equations (1) and (2) for each of the four pollutants. The null hypothesis of the homogeneous province effect is strongly rejected in every pollutant, which indicates that OLS estimators are inefficient and may yield biased estimates (See F-test). Hausman tests of the null hypothesis that the fixed effect model and random effect model estimation do not differ substantially are rejected in every case, at the 1% or 5% significant level. This is indicative of the appropriateness of using the fixed effects model. The province-specification fixed effect accounts for the time-invariant factors unique to each province, such as resource endowment, while the time-specification fixed effect captures common shocks to all the provinces in each year, such as changes in environmental regulations, technological progress, or a shift in preferences.

For per capita SO_2, β_1 is positive and significant at the 10% level, and β_2 is negative and significant at the 1% level, which suggests an inverted-U shaped EKC. The adjusted R^2 values of the SO_2 model is 0.85, which suggests that the estimated function performs well in terms of goodness-of-fit statistics. Depending on the provincial and time fixed effects, per capita SO_2 start to decline when per capita GDP achieved 6,376 yuan. The cubic model predicted an increasing trend for per capita SO_2 emissions after the per capita GDP has attained a relatively high level of 24,346 yuan, especially in rich provinces such as Shanghai and Beijing. The turning points are evident in the estimated smoke per capita and dust per capita of approximately 6,306 yuan and 5,447 yuan respectively.

[5] The fixed-effects model treats α_i and μ_t as regression parameters while the random-effects treats α_i and μ_t as components of random disturbance. In the situation where α_i and μ_t and the independent variables are correlated, then the random-effects equation cannot be estimated. Hausman (1978) test is widely used to test for inconsistency (correlation between the independent variables and the error components) in the random-effects estimates by testing slope parameters. In the circumstances where there are no statistical problems, the fixed-effects model can be estimated consistently (Stern, 2004).

Table 3: EKC estimates and turning point income for 30 provinces in China: 1990-2007

	SO_2		Smoke		Dust		COD	
	Squared	Cubic	Squared	Cubic	Squared	Cubic	Squared	Cubic
Constant	0.0124 *** (10.642)	0.0037 (1.1841)	0.0093*** (13.097)	0.0059*** (4.6384)	0.0086 *** (15.9609)	0.0050*** (3.8589)	0.0092 *** (30.88)	0.0106*** (17.0477)
Y (β_1)	5.93e-07* (1.8614)	3.97e-06*** (4.0044)	-2.43e-07 (-1.1499)	1.07e-06** (2.3588)	-4.78e-07*** (-3.1986)	8.74e-07* (1.9137)	-7.01e-07*** (-9.0635)	-1.25e-06*** (-5.125)
Y^2 (β_2)	-4.65e-11*** (-5.4694)	-2.97e-10*** (-5.7242)	-8.64e-12 (-1.2447)	-1.06e-10*** (-3.4481)	9.39e-13 (0.2373)	-9.95e-11*** (-3.2613)	9.26e-12*** (5.8005)	5.01e-11*** (2.6427)
Y^3 (β_3)	--	5.90e-15*** (5.5585)	--	2.29e-15*** (3.3404)	--	2.36e-15*** (3.3643)	--	-9.61e-16** (-2.1855)
Turning point (P)	6,376.34	9,212.43	--	6,306.99	--	5,447.89	--	--
Turning point (T)	--	24,346.89	--	24,454.15	--	22,659.45	37,900	--
Adj. R^2	0.8495	0.8591	0.7495	0.7526	0.6516	0.6597	0.8579	0.8588
F-statistic	64.40***	68.07***	34.59***	34.46***	21.99***	22.32***	68.83***	97.92***
Hausman	8.40**	10.55**	12.81***	13.52***	9.92***	12.31***	10.74**	12.13***
No. of Obs.	540	540	540	540	540	540	540	540
Shape-of curve	Inverted-U	N	--	N	Linear (Decreasing)	N	U	Inverted N

Notes: The values in parenthesis are the t-statistics for variables; *** indicates significant at 1% level, ** for 5%, and * for 10%; turning points refer to income per capita at 1990 constant price.

Source: Liu, 2009

Maximum pollution is reached at approximately 6,376 yuan per capita. All 30 provinces exceeded this threshold in the following order, the first 8 provinces achieved this from 1990 to 1995, the second 6 provinces from 1996 to 2000, the third 14 provinces from 2001 to 2005 and the last 2 provinces from 2006 to 2008.[6] The second threshold of average individual wealth (beyond which the slope of the curve is again positive) locates at around 24,364 yuan, and only Shanghai, Beijing and Shandong exceeded this in 1998, 2003, and 2006

6 The mean per capita GDP of 30 provinces during 1990-2007 was 4,409 yuan. The maximum per capita GDP was 28, 760 yuan recorded in Shanghai in 2007, while the minimum was 313 yuan recorded in the western province of Guizhou in 1990. Mean per capita emissions of SO2 and COD were relatively higher in coastal provinces.

respectively. The results also show that the poor central and western regions appear to have turning points at lower income levels than the richer coastal region (Liu, 2009).

3. The link between trade and emissions: Econometric framework

In view of the foregoing and to test the hypothesis that trade liberalisation in China had a short term negative effect on the environment and a long term positive effect based on the assumption that externality can be internalised and that an Environmental Kuznets curve (EKC) exists in China, a modified version of Dean's (2002) simultaneous model which treats income and emissions as a simultaneous problem, will be estimated. In addition the sample will also be split into above and below provincial per capita turning point income (Table 3).[7] Our estimate of an inverted-U curve turning point of 6,376 yuan is within the other existing estimates in the literature, such as 4,596 yuan from Llorca and Meunie (2009) and 10,226 yuan from He (2008). We chose an estimated provincial per capita turning point income in our analysis, based on inverted-U and 'N' curves in emissions such as SO_2, smoke, and dust. The chow test was used to establish whether there was any statistically significant difference in the coefficients obtained from the two sub-samples, based on above and below the turning point incomes.

Income model

If we assume that in a perfect competitive market with fully employed factors, a small open economy[8] produces two types of goods, dirty (X_1) and clean (X_2). All emissions are generated by production because there is no trans-border or consumption pollution. Production in each sector is a function of the restrictiveness of the trade regime (T), the stock of conventional factors of production, capital (K_j) and labour force (L_j), and the ability to generate environmental damage (E_j).

$$X_i = A(T)h_j[F(L_j, K_j), E_j] \qquad (5)$$

where $h(\cdot)$ is increasing and concave in $F(\cdot)$ and in E_j and is characterised by a constant returns to scale in $L_{j,}$ K_j, and E_j (j=1, 2). $F(\cdot)$ is an aggregator of the stock of conventional factors. Overall factor productivity (A) is assumed to be a function of the restrictiveness of the trade regime (T). Increased openness is assumed to lead to higher total factor

[7] The results and data in this paper are taken from Liu (2009).

[8] In order to make the theoretical model simpler, Dean (2002) adopted a small country assumption.

productivity ($A^{'} < 0$). The specification (5) assumes that the marginal rate of technical substitution between capital and labour is independent of the level of pollution. Dirty goods are defined as those which are relatively pollution intensive, therefore the production of X_1 uses a higher ratio of E_j than conventional factors at any given factor price ratio, other than the production of X_2.

Assuming that this country is producing dirty goods using their abundant resources, in which they have a comparative advantage, the cost of environmental damage is internalised via emissions taxes (τ). And some level of trade restrictions on the importation of X_2 exists. The unit cost functions for each good can be used to derive changes in relative factor prices as a function of change in the relative prices of goods,

$$(\hat{\tau} - \hat{w}) = (1/|\theta|)(\widehat{p_1} - \widehat{p_2}) \qquad (6)$$

where ^ is the proportional change in a variable, ω is the wage paid to conventional factors, p_j are the domestic prices of goods j; θ_{ij} is the share of input i (i=F, E) in unit cost of output j, and $|\theta| = |\theta_{E1} - \theta_{E2}| > 0$. Note that $(\widehat{p_1} - \widehat{p_2}) = (\widehat{p_1^*} - \widehat{p_2^*} - \hat{T})$ (where * indicates world prices). Equation (6) captures changes in the derived demand for inputs as a function of changes in the relative prices of goods.

With a constant return to scale, Dean (2002), the changes in the composition of output is as follows:

$$\widehat{X_1} - \widehat{X_2} = (1/|\lambda|)(\hat{E} - \hat{F}) + \sigma_s |\theta| (\hat{\tau} - \hat{w}) \qquad (7)$$

where σ_s is the elasticity of substitution along the production possibility frontier; λ_{ij} is the share of total i used in producing j, and $|\lambda| = |\lambda_{E1} - \lambda_{E2}| > 0$.

Nominal income growth can be showed:

$$\widehat{Y_N} = \alpha_1 \widehat{p_1} + \alpha_2 \widehat{p_2} + \alpha_1 \widehat{X_1} + \alpha_2 \widehat{X_2} = \alpha_E \hat{\tau} + \alpha_F \hat{w} + \alpha_E \hat{E} + \alpha_F \hat{F} \qquad (8)$$

where α_j is the share of sector j (j=1,2) in total output; α_i is the share of input i (i=E,F) in total output.

Using the equations (6) and (8), real income growth is then:

$$\widehat{Y} = \alpha_E \widehat{E} + \alpha_F \widehat{F} + \widehat{A} \tag{9}$$

The technological change is Hicks-neutral, which means that changes in technology do not affect the optimal choice of other factors and it is identical across sectors. Assuming the world's stock of knowledge (N) grows at a rate ω, that $N_t = N_0 e^{\omega t}$, and a country's ability to access that knowledge is inhibited by its trade restrictions (T). Therefore, the world's knowledge accumulation occurs at rate $\beta(T)\omega$ ($0 < \beta < 1$, and $\beta' < 1$), and local knowledge is given at rate δ for simplicity. Then 'equation (9)' may be written as:

$$\widehat{Y} = \alpha_E \widehat{E} + \alpha_F \widehat{F} + \beta(T)\omega + \delta \tag{10}$$

Emissions model

Following the standard labour supply model where workers utility is a function of both goods consumption and leisure, for the supply of environmental damage (E), let utility be a positive function of goods consumption and environment damage, $U=U(C_1,C_2,E)$ where C_j is the consumption of good j, and E is environmental damage. Given that consumers value goods and that their production generates some level of pollution, utility maximisation yields consumer demand for a level of clean environment and, a level of environmental damage they are willing to tolerate. Consumers will tolerate higher levels of E only if firms pay a higher price. Assuming that a clean environment is a normal good, an increase in income raises demand for a clean environment which reduces the supply of E.

A variable supply of environmental damage (E) can be written as $E = \gamma(\tau, p_1, p_2, Y_N)$. By differentiating and writing in proportional change, we have

$$\widehat{E} = \varepsilon_\tau \hat{\tau} + \varepsilon_{E1} \widehat{p_1} + \varepsilon_{E2} \widehat{p_2} + \varepsilon_Y \widehat{Y_N} \tag{11}$$

Where ε_τ, ε_{E1}, ε_{E2} are own price elasticity and ε_Y is income elasticity.

Assuming that consumer demand for a clean environment (supply of E) is homogeneous with degree zero in income and prices, which means if we scale income and price by the same proportion, the value of E does not change. By substituting for changes in commodity prices from equation (6), equation (11) can be written as:

$$\widehat{E} = \varepsilon_{\tau w}(\hat{\tau} - \widehat{w}) + \varepsilon_Y \widehat{Y} \tag{12}$$

where $\varepsilon_{\tau w}$ is a reduced-form environment supply elasticity with respect to changes in relative factor prices, assuming that commodity prices adjust to a change in factor prices. Dean (2002) states that if the supply curve does not bend backward then $\varepsilon_{\tau w} > 0$, and since a clean environment is a normal good, then ε_Y <1. Thus, a rise in income reduces the amount of environmental damage individuals are willing to allow at any price τ.

Substituting (6) to (12) yields emissions growth as a function of change in relative price of goods and growth in real income:

$$\widehat{E} = (\varepsilon_{\tau w}/|\theta|)(\widehat{p_1^*} - \widehat{p_2^*} - \widehat{T}) + \varepsilon_Y \widehat{Y} \tag{13}$$

Together, equations (10) and (13) form a simple simultaneous system describing income growth and emissions growth as functions of the restrictiveness of the trade regime. In this system, trade liberalisation affects the growth of emissions in two ways. First, recall that changes in the domestic terms of trade are $(\widehat{p_1} - \widehat{p_2}) = (\widehat{p_1^*} - \widehat{p_2^*} - \widehat{T})$, thus a reduction in trade restrictions will raise the relative price of dirty goods (Equation 13), leading to increased specialisation in these goods and then an increase in emissions. This is the direct effect of freer trade on the composition of output (composition effect), which is captured by the first term in (Equation 13). Second, lower levels of restrictions will raise income growth (Equation 10). This increase in income will reduce the growth of emissions since it reduces the willingness of individuals to supply the environment as a factor of production at any changing level of emissions. This is the indirect effect of freer trade, via its effect on income growth (technique effect), which is captured by the second term in (Equation 13).

Following the specification by Dean (2002), the simultaneous equations model can be given as following:

$$\Delta \ln Y_{it} = \beta_0 + \beta_1 \Delta \ln \overset{+}{E}_{it} + \beta_2 \Delta \ln \overset{+}{L}_{it} + \beta_3 \Delta \ln \overset{+}{I}_{it-1} + \beta_4 \Delta \overset{+}{T}_{it} + \beta_5 \text{Trend} + \beta_6 \overset{+}{WTO} + \varphi_{it} \tag{14}$$

$$\Delta \ln E_{it} = \alpha_0 + \alpha_1 \Delta \ln \overset{\pm}{Y}_{it} + \alpha_2 \Delta \overset{\pm}{T}_{it} + \alpha_3 \Delta \ln \overset{\pm}{TOT}_{it} + \alpha_4 \text{Trend} + \mu_{it} \tag{15}$$

where Δ indicates first difference. Y refers to industrial output. E denotes the emissions. L and I denote the labour force and capital stock in industrial sector, respectively. All the above variables are in natural logarithm difference form. ΔT Measures change of trade openness, i.e. exports plus imports to GDP in percentage (the ratio is less than one in most provinces and percentage is used instead of log). $\Delta \ln TOT$ denotes change in the terms of trade. Trend denotes a linear time trend. WTO is a dummy variable showing the date of joining World Trade Organisation. μ, and φ are error terms, and $_i$, and $_t$ denote province index and time index.

In the presence of simultaneity, it is recommended to use two-stage least squares (2SLS) and instrumental variables on the expectation that this will create estimators that are consistent and efficient (Gujarati, 2003). In most linear simultaneous equations, it is common to use all the exogenous variables in the system as instruments for all the endogenous variables (Shen, 2006). The instruments in our equations are changes in capital stock and number of workers, change of ratio of trade to GDP, WTO dummy (China entered into WTO in 2001) and change in terms of trade. Since the growth in emissions and income across provinces are likely to differ based on variations in the types of industries concentrated in them, the fixed effects were estimated. The cross-section weights method was used in both equations to correct for specific province heteroskedasticity.

The expected signs are reported on the top of all the explanatory variables in equations (14) and (15). In equation (14) the change in output $\Delta \ln Y$ is a function of change in capital ($\Delta \ln I$), change in labour ($\Delta \ln L$), change in emission ($\Delta \ln E$), and change in trade openness (ΔT). Both signs of capital change ($\Delta \ln I$) and labour change ($\Delta \ln L$) are expected to be positive because as more factors are placed into production, so more output is expected. The pollution emissions growth variable ($\Delta \ln E$) is expected to be positively associated with output growth ($\Delta \ln Y$), based on the assumption that a greater use of environmental resources in increasing production is likely to be associated with an increase in emissions. The ratio of total trade to GDP is used as a proxy for trade openness (ΔT) and is intended to reflect the range of trade and investment reforms. The trade openness (ΔT) variable is expected to be positively associated with output growth ($\Delta \ln Y$) on the assumption that any increase in openness will raise productivity and thereby income.

The association between income growth ($\Delta \ln Y$) and emissions in equation (15) is ambiguous and can be either positive or negative because income growth is expected to capture both scale and technique effects. More output requires more factor input and results in more pollution (scale effect), but as incomes rise, people increase their demand for a cleaner environment and then impose higher penalties and shift towards clean production processes to reduce emissions (technique effect). The sign is positive if the scale effect dominates the technique effect but if the technique effect outweighs the scale effect then a negative sign is expected. Any changes in the price of exports relative to imports ($\Delta \ln TOT$) are used to capture the influence of comparative advantage in emissions growth, and the signs are ambiguous. The sign will be negative if China has a comparative advantage in the production of less polluting industries, or vice versa. The changes in trade to GDP (ΔT) reflect trade reform in relative prices and are expected to be either a positive or a negative sign. The sign will be negative if a reduction in the level of trade restrictiveness causes an increase in emissions (reflecting a static comparative advantage in pollution intensive goods in China) and vice versa. The WTO variable is expected to be positively associated with output growth, based on the assumption that joining the WTO will enhance trade and investment and thereby increase the existing level of output.

The sample comprised 30 provinces, municipalities, and autonomous regions from 1990-2007. Emissions (water, air and other) were measured in Tons and were obtained at the industry level (manufacturing, mining and utilities) from various issues of the China Statistical Yearbook and China Environment Yearbook. Income (Y) was measured as the value of industrial output (manufacturing, mining and utilities) and was obtained from the Chinese Statistical Yearbook. The labour force was measured by the number of workers and works in the industrial sector at the end of the year. Capital stock (constant 1990 prices) at the provincial level was used in the computation of Perpetual Inventory Method (PIM) incorporating a 5% capital depreciation rate. All variables were constructed at the industry level (manufacturing, mining and utilities) and were in constant 1990 prices. Data for the world terms of trade are from the World Bank, World Development Indicator. The ratio of total trade to GDP[9] was used to proxy trade restrictiveness, and the value of total trade was exports plus imports, obtained from the China Statistical Yearbook (1990-2007).

4. Results

We used the 2SLS method and estimated the fixed effect. The analysis was from 1990 to 2007 using provincial panel data (30 provinces and 510 observations) and focussed more on provincial industrial emissions and income. First differencing was used to overcome a high correlation between the independent variables. Equations (14) and (15) formed a system in which income and emissions growth were determined simultaneously (see tables 4 and 5). Based on inverted-U curves for emissions such as SO_2, smoke, and dust, we chose above and below provincial per capita turning point income in our sub samples. The split sample was expected to support the EKC hypothesis because at the provincial level, rising income via increased levels of international trade are associated with falling emissions, so that a rising income among the provinces tends to show a superior performance in reducing emissions.

In our overall sample (ALL), the domestic terms of trade (TOT) showed a strong positive relationship with the growth of SO_2 (air pollutant) and COD (water pollutant). A 1% increase in the terms of trade ($\Delta \ln TOT$) caused SO_2 emissions to rise by 2.57%, and COD emissions by 3.22%. A 1% increase in trade openness (ΔT) also raised the COD emissions by 0.21% (Equation 15). $\Delta \ln TOT$ and ΔT were expected to capture the competitiveness and direct effect of the trade liberalisation package, but the results suggest that China may have a comparative advantage in SO_2 and COD pollution-intensive goods in the light of supporting pollution haven hypothesis. However a 1% increase in the terms of trade ($\Delta \ln TOT$) reduced smoke and dust emissions by 3.48% and 0.33% respectively, which indicated a comparative disadvantage in smoke and dust (equation 15).

[9] Shen (2008) adopted the provincial income computed in expenditure method arguing that this was relatively better measure. We adopt the same at the constant 1990 prices.

Table 4: Estimated results for equation (14)

$$\Delta \ln Y_{it} = \beta_0 + \beta_1 \Delta \ln \overset{+}{E}_{it} + \beta_2 \Delta \ln \overset{+}{L}_{it} + \beta_3 \Delta \ln \overset{+}{I}_{it-1} + \beta_4 \Delta \overset{+}{T}_{it} + \beta_5 \text{Trend} + \beta_6 \overset{+}{WTO} + \varphi_{it} \qquad (14)$$

	Y			Y			Y			Y		
	All	<6376	>6376	All	<6376	>6376	All	<6376	>6376	All	<6376	>6376
$\Delta \ln SO_2$	-17.16*** (-10.02)	2.23*** (7.24)	2.55*** (5.55)									
ΔlnSmoke				19.42*** (10.02)	0.88*** (7.24)	1.00*** (5.55)						
ΔlnDust							-1.42*** (-10.02)	10.67*** (7.24)	12.21*** (5.55)			
ΔlnCOD										-5.21*** (-10.02)	263.9*** (7.24)	302.1*** (5.55)
Cons.	0.01 (0.50)	-0.36*** (-5.40)	0.48*** (5.23)	1.84*** (10.42)	-0.03 (-1.20)	0.10** (2.33)	0.18*** (9.75)	2.99*** (6.99)	3.49*** (5.58)	0.04** (2.18)	8.25*** (7.15)	9.51*** (5.56)
ΔlnL	1.41*** (10.21)	0.30*** (3.69)	0.33** (2.32)	4.63*** (10.34)	0.26*** (3.24)	0.28** (2.01)	-0.77*** (-6.66)	6.62*** (7.32)	7.56*** (5.57)	0.56*** (5.64)	31.66*** (7.26)	36.2*** (5.56)
ΔlnK	0.09*** (9.11)	0.01** (2.46)	0.02*** (3.28)	-0.06*** (-8.89)	0.01*** (2.73)	-0.01 (-0.85)	0.03*** (6.56)	-0.11*** (-7.24)	-0.11 (-0.40)	0.03*** (5.89)	-0.81*** (-7.28)	0.92*** (5.55)
ΔT	1.72*** (9.63)	0.04 (0.26)	0.11*** (5.40)	2.68*** (9.89)	-0.20 (-1.36)	0.15** (2.17)	0.06*** (6.52)	-0.04 (-0.27)	0.03*** (4.87)	0.53*** (6.68)	16.9*** (7.24)	19.2*** (5.56)
Time Trend	0.01*** (4.52)	0.05*** (7.01)	0.06*** (6.70)	0.15*** (9.61)	0.02*** (5.78)	0.03*** (6.30)	0.008*** (3.37)	0.40*** (7.26)	0.47*** (5.75)	0.03*** (7.71)	3.43*** (7.24)	3.93*** (5.57)
WTO Dummy	1.09*** (10.42)	-0.37*** (-5.78)	0.44*** (5.08)	1.16*** (10.41)	0.09** (2.56)	0.13*** (3.10)	0.16*** (6.93)	2.93*** (7.14)	3.37*** (5.54)	0.55*** (10.41)	37.5*** (7.23)	42.9*** (5.55)
R^2	0.33	0.20	0.28	0.32	0.20	0.28	0.326	0.20	0.28	0.326	0.20	0.28
F-test	38.22***	9.79***	13.63***	38.22***	9.79***	13.63***	38.22***	9.79***	13.63***	38.22***	9.79***	13.63***
Obs.	510	264	246	510	264	246	510	264	246	510	264	246

Notes: t-statistics in parentheses; ***Significant at the 1% level; **significant at the 5% level; *significant at the 10% level; Includes fixed effects for provinces. Standard errors corrected for groupwise heteroscedasticity and first-order autocorrelation.

Source: Liu, 2009

Table 5: Estimated results for equation (15)

$$\Delta \ln E_{it} = \alpha_0 + \alpha_1 \Delta \ln \overset{\pm}{Y}_{it} + \alpha_2 \Delta \overset{\pm}{T}_{it} + \alpha_3 \Delta \ln \overset{\pm}{TOT}_{it} + \alpha_4 \text{Trend} + \mu_{it} \quad (15)$$

	SO_2			Smoke			Dust			COD		
	All	<6376	>6376	All	<6376	>6376	All	<6376	>6376	All	<6376	>6376
Cons.	-0.173** (-2.69)	-0.24 (-1.55)	-0.24* (-1.79)	0.126 (1.33)	0.20 (0.92)	-0.31 (-1.55)	0.050 (0.41)	-0.57* (-1.86)	-0.60** (-2.59)	-0.23*** (-3.45)	0.03 (0.20)	-0.42*** (-2.93)
ΔlnY	1.21** (2.36)	0.09 (0.79)	-0.25*** (-2.69)	-1.70** (-2.26)	0.12 (0.77)	-0.20* (-1.67)	-0.71* (-1.66)	-0.01 (-0.04)	0.11 (0.69)	1.34** (2.57)	0.06 (0.54)	-0.27*** (-2.69)
ΔlnTOT	2.57** (2.25)	4.43 (1.24)	7.95** (2.44)	-3.48** (-2.07)	-7.55 (-1.48)	8.78* (1.79)	-0.33* (-1.78)	13.4* (1.87)	18.86*** (3.33)	3.22*** (2.76)	-0.72 (-0.21)	9.17*** (2.63)
ΔT	0.005 (0.05)	-0.06 (-0.23)	0.28* (1.88)	-0.006 (-0.04)	-0.28 (-0.71)	0.49** (2.18)	0.035 (0.21)	0.51 (0.91)	0.72*** (2.77)	0.21** (2.29)	0.22 (0.81)	0.43*** (2.70)
Time Trend	0.004** (2.19)	0.003 (0.42)	-0.02*** (-2.88)	0.005 (1.61)	0.03*** (3.11)	-0.04*** (-2.97)	0.005 (1.29)	0.0002 (1.58)	-0.05*** (-3.47)	0.001 (0.64)	-0.0003 (-0.05)	-0.02* (-1.90)
R^2	0.034	0.039	0.072	0.017	0.052	0.061	0.027	0.050	0.072	0.020	0.035	0.068
F-test	4.15***	1.85	3.29***	2.04*	2.50**	2.75**	3.31**	2.43**	3.28***	2.44**	1.69	3.06**
Obs.	510	264	246	510	264	246	510	264	246	510	264	246

Notes: t-statistics in parentheses; ***Significant at the 1% level; **significant at the 5% level; *significant at the 10% level; Includes fixed effects for provinces. Standard errors corrected for groupwise heteroscedasticity and first-order autocorrelation.

Source: Liu, 2009

Trade liberalisation will indirectly affect the growth of emissions via its effect on income growth (the scale effect increases emissions while the technique effect decreases emissions). This indirect impact can be captured by multiplying the coefficient of ΔT in equation (14) and the coefficient of the $\Delta \ln Y$ in equation (15). In equation 15, there is an expected association between ΔT and $\Delta \ln E$, although the association is insignificant for SO_2, smoke and dust, but is significant for COD. In equation 14, a 1% rise in the ΔT leads to an increase in Y by 0.53% for COD. This increase in Y, via freer trade, causes COD emissions to increase by 0.71% (1.34*0.53). Hence, the indirect effect of trade liberalisation through rising income worsens COD emissions but confirms the pollution haven hypothesis. The net impact is that a 1% increase in international trade causes a net increase in COD emissions of 0.92% (see Table 6: direct impact of 0.21% plus indirect impact of 0.71%). Both the scale and technique effects confirm the pollution haven hypothesis. Because ΔT was not significant for SO_2 and dust in equation (15), we did not interpret them. Our assumption is that ΔT is a relatively better indicator than $\Delta \ln TOT$, which reflects the 'openness' associated with the ongoing package of trade liberalisation.

Turning to the estimated results of the income growth equation (see equation 14), most of the estimated coefficients were highly significant and consistent with the expected signs. Traditional factors such as growth in the labour force and physical capital contributed positively to the growth in industrial output (except capital growth for smoke emissions).

Table 6: The net trade liberalization impact on environment

Pollutants	Direct impact	Indirect impact	Net impact
Overall sample			
COD	0.21	(0.53*1.34) = 0.71	0.92
Split sample			
SO_2	0.28	(-0.25*0.11)= -0.03	0.25
Smoke	0.49	(-0.20*0.15)= -0.03	0.46
COD	0.43	(-0.27*19.2)= -5.18	-4.75

Note: Direct impact measured by the coefficients of openness (ΔT) in Equation 15. Indirect impact measured by the coefficient of income growth ($\Delta \ln Y$) in Equation 15, multiplying the coefficient of openness (ΔT) in Equation 14. Net impact is equals to direct impact plus indirect impact.

A further insight may be achieved by disaggregating the sample into provinces where the per capita turning point income exceeded the above estimated turning point income and provinces where it was less. The Chow test was used to establish whether there is any statistically significant difference in the coefficients obtained for the two sub-samples.[10] The results clearly showed that there is a significant difference between the two sub-samples. Support for this view was found when provinces with rising incomes were examined separately, the overall fit of the equations improved and the variable coefficients of

[10] For this purpose, a null hypothesis that there is no difference between the sub-samples and an alternative hypothesis that there is difference between sub-samples were formed. The null hypothesis is rejected if calculated F statistics (calculated using residual errors of the total sample and sub-samples), is above the critical value at 1%, 5% or 10% level. The calculated F statistics for SO_2, smoke, dust, and COD in equation 14 are 1.96, 1.89, 1.75 and 2.01 respectively. The calculated F statistics for SO2, smoke, dust and COD in equation 15 are 3.01, 3.83, 2.31 and 2.31 respectively.

‘openness’ ($\Delta \ln TOT$ and ΔT) for emissions became significant, which confirmed the comparative advantage of pollution-intensive goods. As a direct effect, a 1% increase in trade openness (ΔT) increased SO_2, smoke, and COD emissions by 0.28%, 0.49% and 0.43% respectively (Table 5). As an indirect effect, a 1% increase in ΔT reduced SO_2, Smoke, and COD emissions by 0.03, 0.03 and 5.18 respectively. As a result, the net impact of COD becomes negative by 4.75%, which indicated that the technique effect outweighed the scale effect (Table 6). For SO_2, and smoke indirect impact showed a negative sign which indicated that the indirect effect of trade liberalisation through rising incomes reduced the SO_2 and smoke, and confirmed the rising technique effect in relation to the scale effect.

5. Conclusion

Our own estimation of EKC in China showed that the turning point provincial income was 6,376 yuan per capita at constant 1990 prices, which was consistent with other studies (Llorca and Meunie, 2009; He, 2008). Maximum pollution was reached at around 6,376 yuan per capita and all 30 provinces exceeded this threshold in the following order; the first 8 provinces from 1990 to 1995, the second 6 provinces from 1996 to 2000, the third 14 provinces from 2001 to 2005, and the last 2 provinces from 2006 to 2008. China’s provincial income turning point is relatively low compared to cross country studies. As Vincent (1997) argued, the cross-country version of the EKC was misleading, which may be due to varying income and consumption patterns across countries. China is currently in the process of development and likely to reach the turning point income more rapidly than developed countries. This argument is consistent with Stern (2004) who showed that developing countries are adopting developed country standards with a short time lag, and are sometimes performing better than developed countries. A true relationship between development and the environment may be country specific and require further intensive research using more rigorous time-series panel data methods.

In order to test the hypothesis that trade related income has a greater impact on the activities that motivate for a cleaner environment in the long term, we estimated the EKC model and a modified version of Dean’s simultaneous model using Chinese provincial data from 1990 to 2007. It was expected that the modified version of Dean’s simultaneous model would capture the impact of trade ‘openness’ on growth through direct effect, via changes in trade openness and indirect effect via income growth. Our results from the overall sample showed that the scale effects of air pollutant (SO_2) and water pollutant (COD) outweighed the technique effect, which provided evidence for the pollution haven hypothesis. This was confirmed for COD which showed that both direct and indirect impacts were positive and resulted in an increase in net emission due to an increase in trade (Table 6). We did not get support for our hypothesis in the overall sample.

The overall sample was split into the above and below the estimated turning point income in the modified version of Dean's model to obtain further evidence for our hypothesis. At the provincial level rising income per capita was associated with rising direct impact and falling indirect impact for SO2, smoke, and COD, so that provinces with a higher per capita income tended to show a relatively better technique impact in emissions. The indirect impact was higher for COD than the direct impact which generated a negative net impact that revealed an overall reduction in emissions. One can note the similarity between our results and those of Dean (2002). Dean studied COD emissions and concluded that a 1% decline in trade restrictiveness (Black Market Premium was used as a proxy) generates an increase of 0.08% in the growth rate of income (direct effect) and reduces in the growth rate of emissions by negative 0.03%.

This sort of analysis rarely gives conclusive results, but the results from the split sample (above turning point per capita income) offer support for the hypothesis that a rising income is associated with lowering COD emissions (net impact) and tendency towards a SO_2 and smoke (indirect impact). We believe that the split sample provided limited support for the EKC hypothesis, at the provincial level rising incomes via increased levels of international trade were associated with falling emissions due to the technique effect, so that rising incomes among the provinces tended to show a superior performance. The policy implication is that stricter environmental regulations need to be associated with growing income because they may lead to better production techniques. In this sense we were successful in combining the environmental regulations in China with their increased levels of trade liberalisation using quantitative analysis. However, the statistical association is weak and the explanatory power of the equation is low in our split sample. The models need to be developed further to capture more of the impact that changes in trade policy might make on income and emissions.

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