

Foreign Trade and Carbon Emission: Empirical Evidence from China

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Abstract: Foreign trade is considered a major driving force behind China's rapid economic growth. However, it is argued that China's development is relying excessively on environmental services. In this study, we aim to examine the linkage between foreign trade and carbon emission in China. We base our analysis on the Environmental Kuznets Curve (EKC) framework but we follow a different approach. Our analysis finds that foreign trade exerts a positive partial effect on per capita carbon emission. Our empirical results also support the EKC hypothesis by showing that as per capita income or TFP grows larger both carbon emission and its emission intensity first increase and then decline.

Keywords: foreign trade; environment; carbon emission; Environmental Kuznets Curve; sustainable development.

JEL Classifications: F41; O13; O53.

INTRODUCTION

Foreign trade has been widely regarded as one of the main driving forces behind China's remarkable economic growth in the past decades. However, concerns regarding the negative environmental consequences of the ever-growing foreign trade in China, especially during the past ten years, are escalating. It has been argued that China's process of economic development propelled by foreign trade has been relying too heavily on growing inputs provided by various environmental services. Excessive demands for such environmental resources are posing a serious threat to China's water, air, forests, and energy supplies and thus making the prospect of sustainable development highly questionable [1]. Bad consequences of the overuse of environmental resources include environmental deterioration and resource degradation. Total annual direct losses related to such environmental consequences were estimated to account for up to eight to ten percent of total annual income in China (see, for example, [2], [3], [4]). Other estimations show that, with limited scope of the costs accounted for, the environmental losses were about two to four percent of China's total income by the pollutant treatment cost approach and about three to six percent of China's total income by the environmental degradation cost approach (see, for example, [5]). The negative environmental consequences of economic development in China were considered largely due to the fact that economic performance relied too heavily on industrial investment but not enough on service sector development.

In order to achieve environmentally sustainable development, the "Eleventh Five-Year Plan" (2006–

2010) of the Chinese government aimed at reconstructing the Chinese economy to emphasize a greater role of the service sector. But this objective largely failed to materialize [6]. Further, the "Twelfth Five-Year Plan" (2011–2015) and the "Thirteenth Five-Year Plan" (2016–2020) strive to strengthen the key environmental objectives of the previous five-year plan by emphasizing the achievement of "green" development and improvement in living quality by means of deepening environmental protection and conservation through effective environmental management.

Among all environmental problems, greenhouse gas emission is a key issue associated with China's development. Accompanying China's rapid economic growth and opening up, the total greenhouse gas emission in China has been increasing at a rate of about ten percent annually over the past ten years or so. Several years ago, China overtook the United States to become the largest greenhouse gas emitter in the world. Historically, greenhouse gas emission (carbon dioxide emission, more specifically) has been positively related to economic development. Countries like the United Kingdom, the United States, Japan and South Korea all experienced a phase in which per capita carbon dioxide emission increased rapidly during their processes of initial industrialization and steady long run growth. For China, as mentioned above, total and per capita carbon dioxide emission increased year by year at a significant rate.

The issue of the relationship between foreign trade, pollution emission and the quality of the environment in

China has been addressed, to various degrees, by some previous studies. Some of these studies followed the framework of the Environmental Kuznets Curve (EKC). The EKC traces an inverted U-shaped relationship between environmental pollution and per capita income. In the EKC framework, increased income is accompanied by an increase in pollution in less developed economies but a decrease in pollution in more developed economies (see, for example, [7], [8]). Early EKC literature usually focused on the effect of economic performance on environmental quality (see, for example, [9], [10], [11]). The shortcoming of this literature was that it overlooked the fact that the linkage between income growth (or the income level) and environmental pollution may actually vary depending on the source of income growth. This is because growth in different industrial sectors may bear different pollution intensities (see, for example, [12], [13]).

To make things worse, the EKC framework has tended to miss out discussing the potential impact of foreign trade on pollution and the environmental quality. However, trade may actually contribute to explaining a manifested relationship between per capita income and environmental pollution (via various possible underlying mechanisms). Specifically, as the pollution haven hypothesis argues, differential stringency of environmental regulations between developed and underdeveloped countries (regions) may result in increased pollution-intensive production in the underdeveloped countries (regions) [14]. The factor endowment hypothesis, however, postulates that countries (regions) relatively abundant in factors used intensively in polluting industries will generate more pollution as trade barriers are lifted. However, despite the shortcomings of the EKC framework, the relevant literature has made three important contributions [13]. First, it raised important questions concerning how economic growth and foreign trade may affect the environment. Second, it has generated evidence suggesting the existence of an income effect that promotes the environmental quality. Third, there has been evidence that the income effect works because more stringent environmental regulations are associated with higher per capita incomes.

In this paper, we empirically study the relationship between foreign trade and carbon emission in China. We will build our analysis on the basic idea of the EKC framework but follow a different approach. Our analysis within this new approach will be carried out from a unique perspective of total factor productivity (TFP). This paper is thus structured as follows. In Section 2, we present the theoretical model, which forms the basic foundation for our subsequent empirical analysis. In Section 3, we design our empirical setup in preparation of our econometric analysis. In Section 4,

we present our estimation results and discuss related issues. Finally, Section 5 concludes this paper.

THE THEORETICAL MODEL

Globally, the past two decades have seen rising concern over the potentially unsustainable pattern of economic growth in many countries. Growth cannot be sustained if it is achieved at the cost of the deterioration of environmental quality or the depletion of natural resources. To study sustainable development, we first need to adopt a comprehensive measure of levels and changes of wealth. Obviously, this comprehensive measure of wealth should take account of levels and changes of natural capital and services provided by the environment.

We first follow [15] in providing a definition of sustainability. We assume time is continuous and the horizon is infinite. Let $\mathbf{C}(s)$ be a vector of economy-wide consumption flows at time s , where $\mathbf{C}(s)$ includes not only marketed consumption goods but also leisure, consumption services provided by nature, as well as various health services. Let $\mathbf{K}(s)$ be the vector of economy-wide stocks of various capital assets at time s . For simplicity, we assume that changes in productivity, population, etc., are exogenous, and for the moment, the size of population is constant. Let $U(\mathbf{C}(s))$ then be the economy-wide felicity at time s . Therefore, intergenerational well-being (at time t) can be expressed as

$$V(t) = \int_t^{\infty} [U(\mathbf{C}(s))e^{-\delta(s-t)}] ds \quad (1)$$

where $\delta > 0$ is the felicity discount rate. Familiarly, the intergenerational well-being is the (discounted) flow of the felicities of the current and future generations. An economic forecast at time t is the vectors $\{\mathbf{C}(s), \mathbf{K}(s)\}$ for $s > t$.

We can now state that economic development (growth) is sustained at time t is if $dV/dt \geq 0$. Needless to say, the intergenerational well-being V involves a forecast beyond time t into the future, whose values of stock of assets depend on the current stock of assets at time t . Thus, given $\mathbf{K}(t)$, $\mathbf{K}(s)$ and $\mathbf{C}(s)$ and therefore $U(\mathbf{C}(s))$ are determined for all future times $s > t$. We can then write

$$V(t) = V(\mathbf{K}(t), t) \quad (2)$$

where V also depends directly on t because this reflects the impact of time-varying factors that are taken to be exogenous and cannot be traced back to the evolution of capital stocks.

With such a definition of sustainability in mind, we can now move on to a model about foreign trade and its

effect on environmental quality. We follow [13] in presenting the simplest framework of the model. Assume the economy produces two goods, X and W, each produced with a constant returns to scale technology using two inputs, labor (L) and capital (K). The production of X generates pollution (a “dirty” good) but the production of W does not (a “clean” good). We further denote the price of good X by p and use good W as the numeraire. The production of good W is simply

$$w = H(K_w, L_w) \quad (3)$$

whereas the production of good X follows

$$x = z^\alpha [F(K_x, L_x)]^{1-\alpha} \quad (4)$$

where z stands for pollution emission. Production functions H and F both are increasing, concave and linearly homogeneous. If pollution is regulated so that the firms face a cost τ (pollution tax) for each unit of emission they release, then under the Cobb-Douglas production functional form, we should have

$$z/x = \alpha p / \tau \quad (5)$$

where z/x is obviously pollution per unit of output of good X (i.e. the emission intensity). We see that emission falls when the pollution tax τ rises, and rises when the price of good X, p , rises.

Therefore, output of both goods can be expressed as functions of factor endowments, prices and the environmental policy

$$w = w(p, \tau, K, L) \text{ and } x = x(p, \tau, K, L) \quad (6)$$

The value of national income, denoted G , for any given level of pollution emission z , can be written as

$$G(p, K, L, z) = \max\{px + w : (x, w) \in T(K, L, z)\} \quad (7)$$

where T is the feasible technology set. It can be shown that $\tau = \partial G / \partial z$. We further assume that there are N identical consumers in the economy. Each consumer maximize utility, taking pollution as given. The indirect utility function of one representative consumer can be written as

$$V(p, I, z) = v(I / \beta(p)) - h(z) \quad (8)$$

where $I \equiv G/N$ is the per capita income, β is a price index, and h is increasing and convex while v is increasing and concave.

To decide on the optimal pollution policy, the government chooses the pollution level so that utility of the typical consumer is maximized subject to production possibilities and private sector behavior. The government's problem is

$$\max_z V(I / \beta(p), z), \text{ s.t. } I = G(p, K, L, z) / N \quad (9)$$

where we note that the economy is assumed to be small in the world market and the government takes p as given, so that the first-order condition can be written as

$$V_I G_z / N + V_z = 0 \quad (10)$$

where actually $G_z = \tau$, by which the first-order condition above can be rearranged into the following

$$\begin{aligned} \tau &= G_z(p, K, L, z) = N \cdot (-V_z / V_I) \\ &= N \cdot \mathcal{G}(p, R(p, K, L, z), z) \end{aligned} \quad (11)$$

where we define $R \equiv I / \beta(p)$ as the real income of the representative consumer, and $\mathcal{G}(p, R, z)$ is the representative consumer's marginal damage from pollution. Equation (11) determines the efficient level of pollution z^* . To implement z^* , the government can either introduce the associated pollution tax τ^* or issue z^* marketable pollution quotas that would yield the equilibrium level of pollution tax τ^* .

THE EMPIRICAL SETUP AND THE DATA

The gist of the theoretical model presented in the previous section is that the economy has to face a tradeoff between goods production and environmental quality, given a certain level of technology (as described by the aggregate production function). It then naturally follows that, in order to achieve environmentally sustainable growth, on the one hand, technological progress in goods production is needed so as to generate per capita income growth, and on the other hand, technological progress in terms of emission abatement must exceed growth in aggregate income in order for pollution to fall and the environment to improve (see also [16], [17]).

Based on the spirit of the theoretical model, we are first interested in empirically testing the potential effect of openness to foreign trade on pollution emission. Our baseline regression specification, which follows the central idea of the EKC framework and employs a panel data structure, can be written as follows

$$\begin{aligned} \ln m_{it} &= \beta_{T1} \ln T_{it} + \beta_{T2} (\ln T_{it})^2 + \beta_{y1} \ln y_{it} + \beta_{y2} (\ln y_{it})^2 + \beta_{k1} \ln k_{it} + \beta_{k2} (\ln k_{it})^2 \\ &+ \beta_{h1} \ln h_{it} + \beta_{h2} (\ln h_{it})^2 + \beta_{L1} \ln L_{it} + \beta_{L2} (\ln L_{it})^2 + \tau_t + \varphi_i + \varepsilon_{it} \end{aligned} \quad (12)$$

where all the included variables enter the regression equation in logs, and i and t index the cross-sectional units (Chinese regions in the current case) and time periods, respectively. The dependent variable m_{it} denotes regional per capita pollution emission (carbon emission in the current analysis). The independent variables are (our measure of) regional trade openness T_{it} , regional per capita income (i.e. per capita GDP) y_{it} , regional per capita physical capital stock k_{it} , regional per capita human capital stock h_{it} , and regional population L_{it} . The squared terms of the relevant independent variables are also included in the equation in order to take account of potential nonlinear partial effects of these variables as predicted by the EKC framework. The terms τ_t , φ_i and ε_{it} are the time

varying intercept, the time constant regional heterogeneity, and the zero-mean idiosyncratic error term, respectively.

Our sample includes 28 provincial-level regions (provinces for short) in the mainland of China over the period of 1997–2013. Exact annual data on provincial carbon emission (defined $M \equiv mL$) are hard to obtain directly. However, an effective measure of annual provincial carbon emission can be constructed in the following way

$$M_{it} = \sum_j \frac{E_{jit}}{E_{it}} \cdot \frac{M_{jit}}{E_{jit}} \cdot E_{it} = \sum_j S_{jit} \cdot F_{jit} \cdot E_{it} \quad (13)$$

where M_{it} , as defined above already, is total provincial carbon emission (of province i in period t), E_{it} is total provincial energy consumption, M_{jit} is provincial carbon emission from the consumption of the j -th type of energy, and E_{jit} is provincial consumption of the j -th type of energy. Therefore, S_{jit} denotes the share of provincial consumption of the j -th type of energy in total provincial energy consumption, and F_{jit} denotes the emission intensity (coefficient) of the j -th type of energy regarding carbon emission. In this current study, owing to data availability, we choose three types of energy, namely, petroleum, coal, and natural gas for constructing our measure of provincial carbon emission based on the formula above. Relevant data needed for the construction can be found in various official publications of the National Bureau of Statistics of China. Once data on M_{it} are obtained, it is then straightforward to obtain data on regional per capita carbon emission m_{it} .

The trade openness variable T_{it} is constructed as the share of provincial foreign trade (exports and imports) in provincial income, where relevant data are also available from official publications of the National Bureau of Statistics of China. (This trade openness measure can be adjusted to take account of a broader sense of openness. See, for example, [18]). Likewise, data on provincial population L_{it} and provincial (real) per capita income y_{it} can also be easily obtained or calculated from relevant official publications of the National Bureau of Statistics of China. Further, data on provincial per capita physical and human capital stocks, k_{it} and h_{it} , can be constructed by following the method of [19].

Beside the regression specification in (12), another similar but alternative regression specification we are also interested in working on can be expressed as follows

$$\ln m_{it} = \beta_{T1} \ln T_{it} + \beta_{T2} (\ln T_{it})^2 + \beta_{A1} \ln A_{it} + \beta_{A2} (\ln A_{it})^2 + \beta_{k1} \ln k_{it} + \beta_{k2} (\ln k_{it})^2 + \beta_{h1} \ln h_{it} + \beta_{h2} (\ln h_{it})^2 + \beta_{L1} \ln L_{it} + \beta_{L2} (\ln L_{it})^2 + \tau_t + \varphi_i + \varepsilon_{it} \quad (14)$$

where we can easily notice that we have replaced per capita income y_{it} in (12) with the level of TFP (denoted A_{it}) here in (14). One advantage of (14) over (12) is that the former, by construction, would apparently involve less multicollinearity among its independent variables.

We are now left with the issue of how to obtain data on TFP. To keep things tractable, we apply a regression method to obtain the relevant levels of TFP as a residual to the aggregate production function. We adopt a Cobb-Douglas aggregate production function of the form

$$Y = AK^\alpha H^{1-\alpha} \quad (15)$$

where Y is output, A is TFP, K is physical capital stock, and H is our measure of human capital stock so that $h \equiv H/L$ is per capita human capital stock. Assuming growth of TFP is governed by the following dynamics

$$\dot{A}/A = \lambda(\ln A^* - \ln A) \quad (16)$$

where A^* denotes the balanced-growth-path TFP, which is in turn determined by

$$A_{it}^* = C_i T_{it}^\pi h_{it}^\omega W_t \quad (17)$$

where i indexes the region and t indexes time. C_i encompasses a host of time-constant, region-specific factors, T_{it} refers to trade openness, and W_t denotes the world frontier TFP, which grows exogenously over time. Combing (15), (16) and (17), with a bit of rearrangement, finally leads to

$$\begin{aligned} \Delta \ln y_{it} = & \alpha \Delta \ln k_{it} + (1-\alpha) \Delta \ln h_{it} \\ & - \rho \ln y_{it} + \rho \alpha \ln k_{it} + \rho(1-\alpha+\omega) \ln h_{it} \\ & + \varphi \ln T_{it} + \xi_i + \eta_t + u_{it} \end{aligned} \quad (18)$$

where $\rho \equiv (1 - e^{-\lambda \Delta t})$ and sign Δ in (18) pertains to the difference between the levels associated with the two time points t_2 and t_1 ($\Delta t = t_2 - t_1$). Therefore, by applying a nonlinear least squares regression based on (18), we can estimate the value of the structural parameter α in the aggregate production function. Once the value of α is determined, TFP can then be calculated as a residual based on the production function in (15). Our regression turns out to show that the estimated value of α is about 0.55. We are thus able to obtain the relevant levels of TFP as a residual to the production function by adopting this value $\alpha = 0.55$ and inserting it back into (15).

RESULTS AND DISCUSSIONS

We use an annual data setup in our regression analysis, where each period t in (12) and (14) pertains to one

calendar year, so that we have 17 calendar years in our sample period 1997–2013. Therefore, we use 16 year dummy variables, plus a common intercept, to account for the time intercept τ_t in (12) and (14). Our regression results are summarized in Table 1 and Table 2, where each table is based on (12) and (14) respectively. Of all the regressions in Tables 1 and 2, our preferred estimation is the fixed effects (FE) estimator as this estimator controls for the time-constant

province heterogeneity. Other estimations, namely, the GLS random effects (GLS RE), the ML random effects (ML RE) as well as the plain OLS estimators, are also run only for the sake of comparison. To save space, the estimated time intercepts (i.e. the estimated coefficients on the time dummy variables, as well as the common intercept) are not reported in the tables.

Table 1. Estimation Results Based on Equation (12)

Sample: annual data, 28 Chinese provinces, 1997–2013				
Dependent variable: $\ln m_{it}$				
Variable	FE	GLS RE	ML RE	OLS
$\ln T_{it}$	0.227 (0.002)	0.035 (0.619)	0.157 (0.030)	-0.598 (0.000)
$(\ln T_{it})^2$	0.052 (0.005)	0.019 (0.246)	0.039 (0.022)	-0.118 (0.000)
$\ln y_{it}$	1.879 (0.000)	1.471 (0.000)	1.688 (0.000)	-0.876 (0.053)
$(\ln y_{it})^2$	-0.082 (0.008)	-0.051 (0.093)	-0.067 (0.021)	0.115 (0.001)
$\ln k_{it}$	0.588 (0.071)	0.681 (0.043)	0.633 (0.045)	1.636 (0.000)
$(\ln k_{it})^2$	-0.018 (0.437)	-0.025 (0.304)	-0.022 (0.323)	-0.098 (0.002)
$\ln h_{it}$	-0.185 (0.032)	-0.198 (0.008)	-0.202 (0.009)	-0.158 (0.021)
$(\ln h_{it})^2$	-0.101 (0.134)	-0.059 (0.395)	-0.083 (0.206)	0.001 (0.093)
$\ln L_{it}$	-0.050 (0.000)	-0.266 (0.000)	-0.923 (0.000)	-0.586 (0.008)
$(\ln L_{it})^2$	0.582 (0.000)	0.331 (0.000)	0.417 (0.000)	0.107 (0.004)

P-values are in parentheses. To save space, the estimated time intercepts are not reported in the table.

In Table 1, the FE estimation generates significant estimated coefficients on most of the explanatory variables (terms). Statistic significance discussed here in this analysis is at the usual 5% level unless otherwise stated. Particularly, the estimated coefficient on $\ln T_{it}$ is about 0.23, which is significantly positive. The estimated coefficient on the squared term of $\ln T_{it}$ is about 0.05, which is also positive and significant. These two estimates show that ceteris paribus, that is, once provincial per capita income, provincial population, and provincial per capita physical capital and human capital stocks (as well as the individual province heterogeneity) are controlled for, provincial openness to foreign trade exerts a positive partial effect on provincial per capita carbon emission. The actual mechanism for this partial effect, however, is unclear. Our conjecture is that, as the theoretical model above has suggested, regional openness to foreign trade may affect regional carbon emission by affecting regional input of natural

resources and/or regional industry mix (the relative shares of the output and inputs across different sectors), a change in either of which is in turn associated with a change in regional TFP.

The estimated coefficient on $\ln y_{it}$ is 1.879, which is significantly positive, while that on its squared term, $(\ln Y_{it})^2$, is -0.082 , which is significantly negative. Therefore, the partial effect of $\ln y_{it}$ on the dependent variable $\ln m_{it}$ is estimated to be $1.879 - 0.164 \ln y_{it}$. This is equivalent to saying that the partial effect of $\ln y_{it}$ on the logarithm of the emission intensity, $\ln(m_{it}/y_{it})$, is $0.879 - 0.164 \ln Y_{it}$. With regional population controlled for in the regression, this result supports the EKC hypothesis by showing that as (per capita) income grows larger, pollution (carbon) emission (and emission intensity) first increases and then declines.

The estimated coefficients on $\ln k_{it}$ and $(\ln k_{it})^2$ are both insignificant, meaning that once all the other explanatory variables are controlled for, physical capital is not shown to have a significant partial effect on carbon emission. The estimated coefficient on $\ln h_{it}$ is -0.185 , which is significantly negative, while that on its squared term, $(\ln h_{it})^2$, is insignificant (insignificantly negative). Therefore, the partial effect of $\ln h_{it}$ on the dependent variable $\ln m_{it}$ is estimated to be negative, which indicates that, ceteris paribus, a higher level of regional per capita human capital is associated with a lower level of regional per capita carbon emission.

The estimated coefficient on $\ln L_{it}$, which is -0.050 , and the one on its squared term, $(\ln L_{it})^2$, which is 0.582 , are both significant. Therefore, the partial effect of $\ln L_{it}$ on $\ln m_{it}$ is $-0.050 + 1.164 \ln L_{it}$. According to our modeling earlier, when the partial effects of all the other explanatory variables are netted out, a change in regional population must be associated with a change in either regional TFP or/and the level of regional resource input, both of which may in turn have an impact on regional carbon emission.

Table 2. Estimation Results Based on Equation (14)

Sample: annual data, 28 Chinese provinces, 1997–2013				
Dependent variable: $\ln m_{it}$				
Variable	FE	GLS RE	ML RE	OLS
$\ln T_{it}$	0.302 (0.000)	0.121 (0.112)	0.164 (0.040)	-0.409 (0.000)
$(\ln T_{it})^2$	0.045 (0.004)	0.038 (0.035)	0.044 (0.013)	-0.091 (0.000)
$\ln A_{it}$	2.229 (0.000)	1.290 (0.000)	1.405 (0.000)	-0.748 (0.069)
$(\ln A_{it})^2$	-0.097 (0.004)	-0.074 (0.026)	-0.089 (0.013)	0.099 (0.002)
$\ln k_{it}$	0.770 (0.020)	0.494 (0.028)	0.506 (0.105)	1.487 (0.000)
$(\ln k_{it})^2$	-0.032 (0.187)	-0.018 (0.434)	-0.019 (0.412)	-0.120 (0.001)
$\ln h_{it}$	-0.238 (0.023)	-0.157 (0.014)	-0.193 (0.010)	-0.204 (0.031)
$(\ln h_{it})^2$	-0.054 (0.440)	0.006 (0.524)	-0.003 (0.604)	0.043 (0.423)
$\ln L_{it}$	-0.497 (0.000)	-0.396 (0.000)	-0.361 (0.000)	-1.083 (0.015)
$(\ln L_{it})^2$	0.684 (0.000)	0.353 (0.000)	0.458 (0.000)	0.101 (0.002)

P-values are in parentheses. To save space, the estimated time intercepts are not reported in the table.

In Table 2, the FE estimation also generates significant estimated coefficients on most of the explanatory terms. Owing to the space constraint, we omit providing a discussion of the results from the other estimations in Tables 1 and 2. Particularly, the estimated coefficients on $\ln T_{it}$ and its squared term $(\ln T_{it})^2$ are 0.302 and 0.045 respectively, both of which are significantly positive. These two estimates show that once provincial TFP, provincial population, and provincial per capita physical capital and human capital stocks (as well as the individual province heterogeneity) are controlled for, provincial openness to foreign trade exerts a positive partial effect on provincial per capita carbon emission. The underlying mechanism for this positive partial

effect is unclear. However, a possible reason is that, as our theoretical modeling earlier has suggested, regional openness to foreign trade may affect regional carbon emission by affecting regional input of natural resources, a change in which is in turn associated with a change in regional output (given the level of regional TFP and the levels of other production inputs).

The estimated coefficient on $\ln A_{it}$ is 2.229 , which is significantly positive, while that on its squared term, $(\ln A_{it})^2$, is -0.097 , which is significantly negative. Therefore, the partial effect of $\ln A_{it}$ on the dependent variable $\ln m_{it}$ is estimated to be $2.229 - 0.194 \ln A_{it}$.

With the other explanatory variables controlled for in the regression, this result also supports the EKC hypothesis by showing that as TFP, hence (per capita) income, grows larger, pollution (carbon) emission (and emission intensity) first increases and then declines.

The estimated coefficient on $\ln k_{it}$ is significantly positive (which is 0.770) but that on $(\ln k_{it})^2$ is insignificant. The estimated coefficient on $\ln h_{it}$ is -0.238 , which is significantly negative, while that on its squared term, $(\ln h_{it})^2$, is insignificant (insignificantly negative). Therefore, the partial effect of $\ln h_{it}$ on the dependent variable $\ln m_{it}$ is estimated to be negative, which again indicates that, ceteris paribus, a higher level of regional per capita human capital is associated with a lower level of regional per capita carbon emission.

The estimated coefficient on $\ln L_{it}$, which is -0.497 , and the one on its squared term, $(\ln L_{it})^2$, which is 0.684, are both very statistically significant and practically large. The partial effect of $\ln L_{it}$ on $\ln m_{it}$ is thus $-0.497 + 1.368 \ln L_{it}$. Again, according to our modeling earlier, when the partial effects of all the other explanatory variables are netted out, a change in regional population should be associated with a change in the level of regional resource input, which may in turn have an impact on regional carbon emission.

CONCLUDING REMARKS

Foreign trade has been widely accepted as one of the major driving forces behind China's spectacular economic growth in the past few decades. However, it is also argued that China's economic development has been relying too heavily on growing environmental inputs. Excessive exploitation of various environmental services poses serious threats to China's ecosystem and natural resources, which makes the prospect of environmentally sustainable development highly questionable. Among the environmental problems, greenhouse gas emission is a big issue associated with China's economic development. In this study, we aim to empirically examine the linkage between foreign trade and carbon emission in China. We base our empirical analysis on the core idea of the EKC framework but we follow a different approach based on the concept of TFP.

We find that once per capita income, population, and per capita physical capital and human capital stocks are controlled for, openness to foreign trade exerts a positive partial effect on per capita carbon emission. We realize that openness to foreign trade may affect carbon emission by affecting the input of natural

resources and/or industry mix, a change in either of which may be associated with a change in TFP. We also find that our results support the EKC hypothesis by showing that as (per capita) income or TFP grows larger carbon emission and its emission intensity both first increase and then decline. The major policy implication of this study is that although foreign trade is an engine for economic growth, it may also be a contributor to carbon emission and hence a deteriorating environment. Therefore, when designing development strategies, the negative environmental impacts of foreign trade should be fully accounted for in order to achieve environmentally sustainable development.

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